Columbia River System Operations
Environmental Impact Statement

Appendix E
Fish, Aquatic Macroinvertebrates, and Aquatic Habitat

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CHAPTER 1 - METHODS AND MODELS

1.1 INTRODUCTION

This appendix describes the methods and models used to determine effects of alternatives considered on fish and aquatic resources in the Columbia River System Operations (CRSO) Environmental Impact Statement (EIS).

1.1.1 Methods

A variety of methods were employed to evaluate effects of alternatives on fish and aquatic resources. These include regionally approved models, application of accepted relationships, use of surrogate species, and qualitative evaluations. Effects analyses were broken into three broad groups – anadromous fish, resident fish, and aquatic macroinvertebrates.

1.1.1.1 Anadromous Fish

A total of 18 anadromous species or Evolutionarily Significant Units (ESUs) were evaluated as part of the EIS. Tools used in the analysis of effects of alternatives on these species included models, surrogate comparisons, and qualitative analysis. Models were used to quantifiy effects to four species (Table 1-1). These models include the COMPASS model for juvenile downstream migration and survival, National Oceanic and Atmospheric Administration (NOAA) Life Cycle models for adult upstream migration and survival, Comparative Survival Study (CSS) models for both juvenile downstream and adult upstream migration and survival, and a total dissolved gas (TDG) model for evaluating effects of gas supersaturation. Each of these models will be discussed below in the models section.

Anadromous species that did not have suitable models to predict effects of alternatives were evaluated using both qualitative analyses and surrogate extrapolation. Surrogate methodology uses the outputs from modeled species to provide insights into the effects of alternatives on other species with similar life histories and habitats. Where an appropriate model or surrogate was not available, a qualitative evaluation of hydrology and water quality data was used to evaluate changes to the environmental factors important to the life stages of fish species, as illustrated by the Concept Evaluation Models (CEMs). Table 1-1 shows the methods used for evaluating each of the anadromous species analyzed within this EIS.

Table 1-1. Primary evaluation methods used to evaluate each anadromous species

Species/ESU/DPS	Analysis Methods
Upper Columbia River Spring-Run Chinook Salmon	COMPASS, NWFSC Life Cycle Model (Wenatchee Population), TDG Tool, CEM, Qualitative
Upper Columbia River Steelhead	COMPASS, TDG Tool, CEM, Qualitative
Upper Columbia River Coho Salmon	UC Spring Chinook surrogate, CEM, Qualitative
Columbia River Sockeye Salmon	UC Spring Chinook surrogate, CEM, Qualitative
Upper Columbia Summer/Fall Chinook Salmon	CEM, Qualitative

Species/ESU/DPS	Analysis Methods
Middle Columbia Spring-Run Chinook salmon	UC Spring Chinook surrogate, CEM, Qualitative
Middle Columbia Steelhead	UC Spring Chinook surrogate, CEM, Qualitative
Snake River Spring/Summer Chinook Salmon	COMPASS, CSS cohort model, NWFSC Life Cycle Model (Upper Salmon, South Fork Salmon, and Middle Fork Salmon MPGs), CSS Life Cycle Model (Grande Ronde/Imnaha MPG) TDG Tool, CEM, Qualitative
Snake River Steelhead	COMPASS, CSS cohort model, CSS Life Cycle Model (Grand Ronde/Imnaha MPG), TDG Tool, CEM, Qualitative
Snake River Coho Salmon	Snake River Spring Chinook Salmon Surrogate, CEM, Qualitative
Snake River Sockeye Salmon	Snake River Spring Chinook Surrogate, CEM, Qualitative
Snake River Fall Chinook Salmon	CEM, Qualitative
Lower Columbia Spring Chinook Salmon	Snake River Spring/Summer-Run Chinook Salmon Surrogate, CEM, Qualitative
Lower Columbia Steelhead	Snake River Steelhead Surrogate, CEM, Qualitative
Lower Columbia River Coho Salmon	Snake River Spring Run Chinook Salmon Surrogate, CEM, Qualitative
Chum Salmon	Snake River Spring Run Chinook Salmon Surrogate, CEM, Qualitative
Pacific Eulachon	CEM, Qualitative
Green Sturgeon	CEM, Qualitative
Pacific Lamprey	CEM, Qualitative
American Shad	Qualitative

1.1.1.2 Resident Fish

All resident fish were evaluated during workshops to qualitatively assess changes to the important relationships described by the CEMs and considered local knowledge of how fish species interact with their environment and one another at the fish community level. Effects to resident fish were analyzed by eight subbasin teams using predicted metrics, such as water flow, elevation, temperature, and DO. Where possible, relationships between these metrics and biological metrics were used to quantify expected changes to habitat elements, such as productivity, the number of resident fish that are swept downstream past the dams due to flows (i.e., entrainment), and habitat losses based upon existing literature or local information. Where quantitative data could not be generated, qualitative analyses were completed using existing literature and expert knowledge from local managers.

1.1.1.3 Macroinvertebrates

Consistent data regarding macro-invertebrate habitats and populations in the Columbia River Basin are lacking. To analyze the effects of Multiple Objective Alternatives (MOs) to these resources, the teams used existing literature to compare expected outcomes from the MOs using the hydrology and water quality modeling outputs, similar to resident fish analyses.

1.1.1.4 Workshops

Multiple full-day effects analysis workshops were held from January through June 2019 (Table 1-2). Participants included fish experts from the three co-lead agencies and many cooperating agencies.

Table 1-2. Full List of CRSO EIS Fish Team Meetings Supported by Triangle Associates

Meeting Title	Meeting Date	Meeting Location	Number of Meetings
Anadromous Fish Team Bi-Weekly Calls	June 29, 2018–June 14, 2019	Webinars	23
Resident Fish Team Bi-Weekly Calls	June 27, 2018–July 10, 2019	Webinars	20
Upper River Anadromous Species Effects Analysis (No Action Alternative)	January 24, 2019	Boise, ID	1
Lower River Anadromous Species Effects Analysis (No Action Alternative)	January 29, 2019	Ridgefield, WA	1
Lamprey Effects Analysis (No Action Alternative)	January 30, 2019	Portland, OR	1
Eulachon & Sturgeon Effects Analysis (MO1/MO4)	March 28, 2019	Portland, OR	1
Coho & Chum Effects Analysis (MO1/MO4)	March 29, 2019	Portland, OR	1
Lamprey Effects Analysis (MO1/MO4)	April 2, 2029	Walla Walla, WA	1
Upper River Anadromous Species Effects Analysis (MO1/MO4)	April 3 – 4, 2019	Walla Walla, WA	2
Eulachon & Sturgeon Effects Analysis (MO2/MO3)	April 22, 2019	Ridgefield, WA	1
Coho & Chum Effects Analysis (MO2/MO3)	April 23, 2019	Portland, OR	1
Lamprey Effects Analysis (MO2/MO3)	May 21, 2019	Boise, ID	1
Upper River Anadromous Species Effects Analysis (MO2/MO3)	May 22 – 23, 2019	Boise, ID	2
Resident Subgroup Lead Meetings	August 23, 2018 October 19, 2018 December 11, 2018	Walla Walla, WA Webinar Portland, OR	3
Kootenai Resident Subgroup Effects Analysis (No Action Alternative)	January 16, 2019	Bonners Ferry, ID	1
Upper Columbia River (Canada to Chief Joseph) Resident Subgroup Effects Analysis (No Action Alternative)	January 31, 2019	Spokane, WA	1
Middle Columbia (McNary to Bonneville) Resident Subgroup Effects Analysis (No Action Alternative)	February 14, 2019	Portland, OR	1
Pend Oreille Resident Subgroup Effects Analysis (No Action Alternative)	February 28, 2019	Coeur d'Alene, ID	1
Kootenai Resident Subgroup Effects Analysis (No Action Alternative) Follow-Up Webinars	March 13, 2019 March 28, 2019 April 30, 2019	Webinars	3
Upper Columbia River (Chief Joseph to McNary) Resident Subgroup Effects Analysis (No Action Alternative)	March 14, 2019	Wenatchee, WA	1

Meeting Title	Meeting Date	Meeting Location	Number of Meetings
Lower Columbia River (Below McNary) Resident Subgroup Effects Analysis (MO1/MO4)	April 8, 2019	Portland, OR	1
Snake River Resident Subgroup Effects Analysis (MO1/MO4)	April 9, 2019	Walla Walla, WA	1
Upper Columbia River (Canada to Chief Joseph) Resident Subgroup Effects Analysis (MO1/MO4)	April 10, 2019	Spokane, WA	1
Pend Oreille Resident Subgroup Effects Analysis (MO1/MO4)	April 11, 2019	Spokane, WA	1
Upper Columbia River (Chief Joseph to McNary) Resident Subgroup Effects Analysis (MO1/MO4)	April 18, 2019	Webinar	1
Snake River Resident Subgroup Effects Analysis (MO2/MO3)	May 16, 2019	Walla Walla, WA	1
Clark Fork Resident Subgroup Effects Analysis (MO1/MO2/MO3/MO4)	May 30-31, 2019	Kalispell, MT	2
Upper Columbia River (Canada to Chief Joseph) Resident Subgroup Effects Analysis (MO2/MO3)	June 5, 2019	Spokane, WA	1
Anadromous Fish Modeling Meeting	July 18, 2018	Webinar	1
Anadromous Fish Modeling Meeting	August 28-29, 2018	Seattle, WA	1
Anadromous Fish Modeling Meeting	September 27, 2018	Seattle, WA	1
Anadromous Fish Modeling Meeting	October 25-26, 2018	Walla Walla, WA	1
Anadromous Fish Modeling Meeting	December 17-18, 2018	Seattle, WA	1
Anadromous Fish Modeling Meeting	March 19, 2019	Portland, OR	1
Anadromous Fish Modeling Meeting	April 29, 2019	Portland, OR	1
Anadromous Fish Modeling Meeting	May 29, 2019	Portland, OR	1
Clark Fork NEPA Mitigation Meeting	May 31, 2019	Webinar	1
Mitigation Planning Call	June 4, 2019	Webinar	1
UC CAN-CHJ NEPA Mitigation Meeting	June 5, 2019	Webinar	1
Lower Columbia River NEPA Mitigation Meeting	June 11, 2019	Webinar	1
Lamprey NEPA Mitigation Meeting	June 11, 2019	Webinar	1
Upper Columbia River NEPA Mitigation Meeting	June 17, 2019	Webinar	1
Pend Oreille Kootenai NEPA Mitigation Meeting	June 17, 2019	Webinar	1
Snake River NEPA Mitigation Meeting	June 20, 2019	Webinar	1
NEPA Compliance Team Call with Fish Technical Team	November 6, 2018	Webinar	1

1.1.1.5 Powerhouse Surface Passage

All four MOs contained measures to improve downstream fish passage by installing or using existing Powerhouse Surface Passage Structures at one or more Federal Columbia River Power System (FCRPS) projects. To evaluate the effects of these structures on fish populations, modelers need an estimate of the effectiveness of these structures in diverting migrating fish that historically passed through powerhouses to new surface passage routes.

A number of studies have looked at surface passage throughout the FCRPS under a wide variety of environmental and operational conditions (Johnson et. al. 2007, Krcma et al. 1982, Ploskey et. al. 2007, Ploskey et al. 2012, Ploskey et al. 2012a, and Swan et. al. 1997). These studies reported varied results. The sluiceways at Bonneville, The Dalles, and Ice Harbor are most similar in concept to the potential designs for the EIS alternatives. Recommendations from this section were based on results from these three sites.

BONNEVILLE SLUICEWAY

Bonneville Dam has three separate passage routes: Spillway, Powerhouse 1, and Powerhouse 2. Juvenile fish passage facilities at Powerhouse 1 consist of chain gates and an ice and trash sluiceway with a flow capacity near 2000 cfs. Powerhouse 1 was equipped with a juvenile bypass system consisting of turbine intake screens, vertical barrier screens, gatewell orifices, a bypass channel, and an outfall. However, the juvenile bypass system was removed in 2002 due to low survival through that route. Powerhouse 1 has relatively high turbine survival. During the juvenile fish passage season, powerhouse 1 is operated as a second priority to Powerhouse 2. Powerhouse 2 has a corner collector and juvenile fish bypass system. These have relatively high passage efficiency and survival. Historical sluiceway passage values (Johnson et. al. 2007, Krcma et al. 1982, Ploskey et. al. 2007, Ploskey et al. 2012, Ploskey et al. 2012a) are summarized in Table 1-3.

THE DALLES - SLUICEWAY

The Dalles Dam sluiceway is located along the entire length of the 22-turbine-unit powerhouse, which is oriented parallel to the river channel centerline. Surface flow passes through weir-type chain gates into a channel that has a hydraulic capacity of 5,000 cfs. Historical passage efficiency values (Krcma et al. 1982, Ploskey et. al. 2007, Ploskey et al. 2012, Ploskey et al. 2012a, and Swan et. al. 1997) are over 50% (Table 1 3).

ICE HARBOR SLUICEWAY

The Ice Harbor Dam sluiceway was evaluated in 1995 prior to installation of a juvenile bypass system in the sluiceway channel. Combinations of wide surface-overflow entrances (6.1 m wide, 1.8 m deep, and 2.3 ms-1 entrance velocity) and deeper, slotted, entrances (up to 1.8 m wide, 12.2 m deep, and up to 1.2 ms-1 entrance velocity) were studied. The wide, surface overflow entrances had the highest passage rates based on hydroacoustics and radiotelemetry, where a total of 57% of the radio-tagged Chinook salmon used sluice gate 2B, which was a surface-skimming flow (Swan et al. 1996).

Table 1-3. Historical fish passage efficiency Relative to Powerhouse passage at Bonneville, The Dalles, and Ice Harbor

Project	Spring Hydro-Acoustic	Summer Hydro-Acoustic	CH1 Active Tag	Steelhead Active Tag	CH0 Active Tag
Bonneville	35% (33-37)	46% (29-71)	41% (24-77)	49% (29-65)	42% (13-77)
The Dalles	–	–	51% (25-67)	56% (46-63)	28% (18-51)
Ice Harbor	–	–	57%	–	–

The literature on surface passage efficiency for sluiceways at FCRPS projects shows a wide range of factors to regulate surface passage structure efficiency. They inform us of the potential efficiency of similar surface passage structures. For example, we assume values reported for Ice Harbor and The Dalles sluiceway are slightly inflated when compared to Bonneville because without powerhouse surface passage at these projects there would be greater opportunity for fish approaching the powerhouse to reject that route and pass via the spillway. This uncertainty still exists at Bonneville but, due to its configuration, the likelihood of rejecting the powerhouse is substantially reduced.

ASSUMPTIONS

The proposed powerhouse surface passage structures would incorporate higher design discharges than most of the structures reviewed, relative to powerhouse capacity. These structures would also be designed to maximize the potential for fish discovery with hydraulics that reduce or eliminate rejection. Therefore, an assumed 30% efficiency for powerhouse surface passage structures is likely too conservative when compared to available literature, and would lead to a low estimate for alternatives effects on fish species. In addition, the assumed efficiencies of these routes varies by species. ***Consequently, the team chose Powerhouse Surface Passage efficiencies for sub-yearling and yearling Chinook, and Steelhead at 30, 40, and 50% respectively for purposes of the CRSO EIS effects analysis***.

1.1.1.6 IFP Turbines

Improved Fish Passage (IFP) turbines are proposed or planned for installation at three projects: Ice Harbor, McNary, and John Day. In order to effectively model the impact of these new turbines, modelers need an estimate of the degree of improvement in the turbine environment and resulting fish survival. Because each dam and even each turbine has a different potential for survival, relative survival improvements need to be calculated for units receiving new turbines. A turbine performance evaluation was conducted by the USACE, Walla Walla District to estimate this relative improvement.

Turbine mortality is split into direct and indirect mortality. Direct turbine mortality includes injuries that occur during turbine passage, while indirect turbine mortality can include effects like predation that occur as a result of disorientation or poor egress following turbine passage. The primary sources of direct turbine mortality come from mechanical, shear or pressure related injuries.

Physical hydraulic models were used to evaluate the potential for mechanical and sheer related injuries, while potential for pressure related injuries was evaluated using sensor fish or computation fluid dynamic (CFD) models.

PHYSICAL MODELS

Based on ERDC physical modeling, mechanical and sheer related injuries would be reduced by **45 and 66 percent** for the new adjustable and fixed blade IFP turbines respectively (Table 1-4).

PRESSURE MODELS

For pressure related injuries the upper one percent operating condition was chosen for comparisons since this is generally associated with the highest calculated fish passage mortality from pressure related injuries.

The Ice Harbor existing, new fixed and new adjustable IFP turbines were analyzed using CFD models. These models were used to determine a calculated barotrauma mortality for the upper operating point for each of these turbines. The improvement over existing turbines, in reduced calculated barotrauma mortality, was estimated at **69 and 77 percent** for new adjustable and fixed blade IFP turbines resepectively.

Assumptions:

1) A portion of the pressure mortality is already accounted for in the strike mortality. For the sake of this analysis an assumption of 50% of fish that would be exposed to mortal low pressures would also be exposed to strike or shear mortality.

2) Improvements seen in Ice Harbor testing/modeling would be similar for John Day and therefore the same percentage improvement in direct mortality will be seen.

To get a final estimate of improvements in direct turbine survival the team needs to combine the estimates of mortality from turbine physical models and estimates of barotrauma mortality from CFD models. Because many of the fish that pass close enough to blades to be struck will also potentially experience low pressures, the two estimates are not simply additive.

Indirect mortality following turbine passage within the tailrace is harder to assess. With reductions in injury through the turbine runner and improvements to the flow within the draft tube environment, it is anticipated that the modification at Ice Harbor will reduce indirect mortality as well as direct mortality. While direct mortality can be assessed numerically as noted above, it is difficult to separate out the indirect mortality that is occurring for the existing or new turbine units. Consequently, these estimates are for direct mortality only.

Table 1-4. Calculated Combined Fish Passage Mortality Improvement from Existing Ice Harbor Turbines to New Ice Harbor IFP Turbines

IFP Runner	Reduction in Strike Mortality (%)	Reduction in Barotrama Mortality (%)	Combined Reduction in Mortality (%)
Fixed Blade	66%	77%	68.1%
Adjustable Blade	45%	69%	49.0%

Because it has not been determined how many units will be fixed or adjustable for future powerhouse replacement, a conservative value of 50 percent, closer to the lower of the two estimated improvements was selected (i.e. turbines with 80 percent survival would see improvements to 90 percent or a reduction in mortality of 50 percent). This approach would be assumed for Ice Harbor and McNary in the No Action Alternative, and for John Day in all other alternatives.

1.2 MODELS

1.2.1 COMPASS Model

The Comparative Passage or COMPASS model produces juvenile survival metrics for Upper Columbia and Snake River ESUs of spring Chinook salmon and steelhead. The COMPASS model was developed to predict the effects of alternative operations of Snake and Columbia River dams on juvenile salmon survival, travel time, and ocean arrival time. Survival is estimated in two steps - direct effects of the hydrosystem and latent effects which occur outside the hydrosystem. Although the COMPASS model can be used for a variety purposes, including in-season monitoring of survival and travel time, the primary function of the model is to compare hydrosystem survival across management scenarios. The three main operations that vary among management scenarios are flow, proportion of river flow passed through the spillway, and transportation. For additional information regarding the COMPASS model see Zabel et al. 2008 and the COMPASS model documentation from 2019.

COMPASS results were generated for all alternatives using COMPASS version 2-8-7b with June 2018 survival and traveltime calibrations for either Snake River or upper Columbia River ESUs of spring Chinook salmon and steelhead. Population indices at Lower Granite Dam were estimated for each year in the 80-year water record with temperature and flow data for the NAA scenario; these yearly indices were used as the initial release distributions in the COMPASS model.

1.2.1.1 COMPASS Changes

There were several ways in which scenario runs for the CRSO EIS alternatives differed from the "default" configuration of the COMPASS model. These include the way SARs were generated, use and documentation of Upper Columbia spring Chinook modules, water temperature inputs, the inclusion of additional powerhouse surface passage routes and Improved Fish Passage turbines, alterations for breaching scenarios, and assumptions regarding hatchery stocks.

1.2.1.2 Smolt to Adult Returns

The COMPASS model documentation makes references in several places to estimation of post-Bonneville survival. These features are essentially smolt-to-adult return rate (SAR) models. These SAR models are still present and functional in COMPASS, so the team has left references to these models in the documentation. However, it is important to note that, for the CRSO COMPASS runs, only the within-hydrosystem portion of the COMPASS model was used. The SAR models used for CRSO scenario analysis are not part of the COMPASS model and are not documented within the COMPASS documentation; instead, please refer to documentation of the life cycle model for all post-Bonneville portions of our CRSO scenario runs.

1.2.1.3 Upper Columbia Analyses

Because there is no current documentation and diagnostics for the calibrated COMPASS models for upper Columbia River (UC) stocks of spring Chinook and steelhead similar to what is presented for Snake River stocks in Appendices 1 and 2 of the COMPASS documentation, COMPASS calibration for these species are discussed here. PIT tag data of upper Columbia River origin fish were used to generate CJS estimates of survival to calibrate to, in a process essentially identical to that done for Snake River stocks. Only spring-run UC Chinook salmon data was used; any summer-run UC Chinook were excluded from the calibration data. All UC origin steelhead detected at Rock Island Dam or McNary Dam were used.

Models were calibrated to two reaches; Rock Island Dam to McNary Dam and McNary Dam to Bonneville Dam. Similar to the process for Snake River stocks, the McNary to Bonneville reach was calibrated first, and then that calibrated model was used for McNary Pool in the process of calibrating the Rock Island Dam to McNary Dam reach. There is one major difference compared to how Snake River stocks were calibrated: in the McNary to Bonneville reach, data from UC-origin fish alone was insufficient to produce satisfactory reservoir survival model fits. Data from UC origin fish was added to Snake River origin fish to calibrate survival in the McNary to Bonneville reach. The migration rate model calibration for that reach still used UC-origin data exclusively.

The resulting best-fit models for UC stocks of Chinook and steelhead were comparable to models for Snake River stocks in the McNary to Bonneville reach and simpler than Snake River models in the Rock Island to McNary reach. The reservoir survival models for both species of UC stocks have travel time and temperature as predictors for the McNary to Bonneville reach and travel time alone as a predictor for the Rock Island to McNary reach. The migration rate models for both species of UC stocks have flow and spill as major predictors in both calibration reaches, and tend to be less sensitive to temperature than Snake River stocks but more sensitive to spill.

1.2.1.4 Water Temperature

The COMPASS model documentation makes reference in a few places to water temperature models that use flow relationships to predict water temperature within the hydrosystem. This

water temperature model was not used for CRSO scenario runs; instead, the team used water temperature predicted by the ACOE and transmitted to us as part of the overall H&H dataset.

1.2.1.5 Powerhouse Surface Passage

In COMPASS, each passage route has a passage efficieny assigned to it. Powerhouse surface passage efficiency is defined as the portion of powerhouse fish that pass via the surface passage route. For alternatives that included powerhouse surface passage structures the team assumed different surface passage efficiencies of 0.4 for yearling Chinook and 0.5 for steelhead. Existing sluiceways at The Dalles and Bonneville have surface passace efficiencies that were derived from previous studies. See discussion in Methods section of this appendix for more detail.

1.2.1.6 IFP Turbines

For modeling purposes the team assumed the installation of IFP turbines at Ice Harbor, McNary and John Day dams would reduce turbine induced injury and mortality by 50% (Table 1-5). See discussion in Methods section of this appendix for more detail.

Table 1-5. Estimated turbine mortality for juvenile Chinook in Ice Harbor, McNary, and John Day Reservoirs

Project/Species Combination	Before IFP Turbine installation	After IFP Turbine installation
ICE Chinook	0.0570	0.0285
ICE Steelhead	0.1290	0.0645
MCN Chinook	0.1283	0.0642
MCN Steelhead	0.2110	0.1055
JDA Chinook	0.1125	0.0563
JDA Steelhead	0.1833	0.0916

1.2.1.7 MO3 Alterations

The COMPASS model was substantially reconfigured for CRSO alternative MO3 – the dam breaching alternative. Model parameters and diagnostics are included in the documentation for models upstream of Lower Granite Dam. There are two sets of such models: one model from the Snake River Trap to Lower Granite Dam, and a second model from the Imnaha River and Grande Ronde River traps to Lower Granite Dam. Since all model statistics for the CRSO scenario runs are from Lower Granite Dam to Bonneville Dam, these models from above Lower Granite Dam are not used in normal scenario runs. The exception is alternative MO3.

In the MO3 alternative, all four dams on the Snake River are breached. For this alternative, a modified version of COMPASS was created. This version of COMPASS removes all Snake River dam-related models and allows all former pools within the Snake River to flow freely, without impoundment. Fish were released from the same location in MO3 runs as in other alternatives (just above the site of Lower Granite Dam). However, instead of the normal models, survival and travel time models that were fit to the segment of the Snake River between the Imnaha

River trap and the Snake River trap were used. Survival and travel time models fitted to data from the free-flowing portion of the middle Snake River above Lower Granite Pool will be used for the breached lower Snake River in alternative MO3. Three different COMPASS runs, using three different model calibrations were used to evaluate dam breaching (MO3). These runs were evaluated for wild and hatchery fish combined and for wild fish only in the event that the Snake River Compensation hatcheries would be closed after breaching The same release distributions were used, but were adjusted earlier or later based on the predicted difference in mean travel time in Lower Granite Pool under the NAA alternative versus under each MO3 calibration.

MO3-SNK uses COMPASS calibrated to the historical migration and reservoir survival between Lower Granite and McNary. Under this calibration the model uses the same reservoir migration and survival model used for the other alternatives. This model is fitted based on PIT tag data between Lower Granite and McNary dams from 1998-2017. Therefore, all fish used for this model's calibration were experiencing an impounded river. The dam breach in alternative MO3 will change the river environment to conditions well outside the range of the calibration dataset with water velocities 5-8 times faster under MO3 than in the calibration data. The model responds to this change in water velocity and there are no numerical issues with using the model in MO3. However, it is unknown if the behavioral patterns fitted by the model will hold or if they will change at higher velocities.

MO3-SAL uses COMPASS calibrated to historical migration and survival patterns above the Snake River smolt trap for fish tagged at the Salmon River Trap and assumes that this population represents the whole. The model used for the MO3-SAL run is fitted to PIT tag data from fish tagged at the Salmon River smolt trap near Whitebird, ID. Thus, only fish from populations in the Salmon River basin are included in the calibration for this model. Since the results are being compared here to other alternatives run with a calibration fitted to data from all Snake River salmon populations, there is a possibility that inherent differences between Salmon River origin fish and other Snake River fish may influence the relative results. Raw data used for calibration shows that daily survival and migration rates appeared very similar to those from basin-wide datasets originating at the Snake River smolt trap and Lower Granite and appears to validate the assumption.

While the timing and location are different between the calibration and prospective reaches under MO3-SAL the team assumes behavior remains the same. The model used for the MO3-SAL run is fitted to PIT tag data in the reach from the Salmon River smolt trap near Whitebird, ID to the Snake River smolt trap at Lewiston, ID. This reach is upstream of the reach where the model was applied prospectively in MO3. There is a possibility that physiological or behavioral differences would occur in actuality that the model does not capture. However, the fitted model form and migration and survival model slopes fitted to the Salmon Trap data are very similar to those seen in the impounded lower Snake River, this assumption is probably not having a large effect.

The final run for breaching, MO3-GRNIMN, uses a COMPASS calibration fitted to PIT tag data from fish tagged at the lower Grande Ronde River and Imnaha River smolt traps. Therefore, only fish from populations in eastern Oregon are included in the calibration for this model. Since the results are being compared here to other alternatives run with a calibration fitted to data from all Snake River salmon populations, there is a possibility that inherent differences between eastern Oregon fish and other Snake River fish may influence the relative results. Raw data used for calibration were examined and showed that daily survival rates were lower on average than those from basin-wide datasets and Salmon River fish. Additionally, the Grande Ronde and Imnaha survival rates displayed a steeper drop in survival later in the migration season than in data from other populations. This pattern in the data influenced the slopes fitted in survival model calibration. Consequently, the MO3-GRNIMN model likely estimates lower survival than models calibrated to all Snake River populations.

While the timing and location are different between calibration and prospective reaches, the team assumed that behavior remains the same. Prior to late April, Grande Ronde and Imnaha trap fish display very slow migration rates with no detectable relationship between migration rate and water velocity. Fish from the Salmon River or from basin-wide samples at Lower Granite Dam and the Snake River trap do not display this pattern in migration rate. It is possible that many of the fish tagged in April at the Grande Ronde and Imnaha traps are not yet smolted and are still rearing, which would explain their slow migration rates. It is questionable whether these fish will continue to migrate slowly through the rest of the Snake River. If these fish become more smolted as they move downstream, the model may underpredict their migration rates in lower reaches of the Snake River.

It appears that both assumptions for the MO3-GRNIMN calibration are being violated to some extent. However, after detailed examination of the calibration process, no errors were found in calibration. While it seems unlikely that the Grande Ronde and Imnaha dataset is representative of the Snake River as a whole, it is an important component of the basin-wide population, and it is valuable to include this calbiration for comparison to the other models and as a measure of the uncertainty associated with the MO3 alternative.

1.2.1.8 Hatchery Production

It was assumed hatcheries that compensate for the Snake River projects would be closed after the dams were removed. As a result, wild fish would dominate the anadrmomous smolt populations. To evaluate the effects to modeling an additional model run was conducted for MO3-SAL using only wild fish. MO3-SAL was selected because the calibration is already dominated by approximately 75% wild fish and the initial runs showed values in the mid-range of the other two model calibrations. This run uses dam routing equations fitted to only wild fish and used the same reservoir survival and traveltime models, which are fitted to a dataset containing approximately 75% wild fish and 25% hatchery fish; thus, reservoir survival and traveltime predominately reflects wild fish in both the hatchery-wild and wild only runs, though there is some hatchery influence.

1.2.1.9 Measures not Modeled

Modification of the Juvenile Bypass Facility at Lower Granite Dam and gatewell modifications at Bonneville powerhouse number 2 were not modeled due to model limitations.

1.2.1.10 Statistics and Data Fields

These analyses generated summary statistics and raw data for Snake River spring summer Chinook and steelhead and upper Columbia River spring Chinook and steelhead for each alternative. While descriptions of summary statistics and raw data fields are presented here, all data and results are discussed in the section for data – Data and Results. Descriptions of summary statistics are shown in Tables 1-6 and 1-7, with descriptions of raw data fields in Tables 1-8 and 1-9, and descriptions of dam passage fields are shown in Table 1-10.

Table 1-6. Description of summary statistics reported from the COMPASS model for Snake River spring-summer Chinook and steelhead for each alternative

Statistic	Description
Mean Survival	80-year average in-river survival (LGR Forebay to BON Tailrace)
95% CI Survival	95% confidence interval of mean in-river survival
Mean Arrival at BON	Mean Julian day of fish arriving at Bonneville Dam (in-river migrants only)
Proportion Destined for Transport	Proportion of fish that would have been transported if in-river survival were 100%
Mean Gas Exposure	Average dissolved gas level experienced by fish across LGR Pool to Bonneville Pool
Proportion Powerhouse Passsage	The proportion of all dam passage events (from LGR to BON) that were via the turbines or bypass routes (sluiceways are treated as a spill route)
Mean Traveltime (LGR-MCN)	80-year average travel time in days from LGR Forebay to MCN Tailrace
Mean Traveltime (MCN-BON)	80-year average travel time in days from MCN Tailrace to BON Tailrace
Mean Migration Rate (LGR-MCN)	80-year average migration rate in miles per day from LGR Forebay to MCN Tailrace
Mean Migration Rate (MCN-BON)	80-year average migration rate in miles per day from MCN Tailrace to BON Tailrace
Mean Temp Experience (Snake)	Average temperature experienced by in-river migrant fish across LGR Pool to IHA Tailrace
Mean Temp Experience (Columbia)	Average temperature experienced by in-river migrant fish across MCN Pool to BON Pool
Mean Flow Experience (Snake)	Average flow experienced by in-river migrant fish across LGR Pool to IHA Tailrace
Mean Flow Experience (Columbia)	Average flow experienced by in-river migrant fish across MCN Pool to BON Pool
Mean Gas Experience (Snake)	Average dissolved gas experienced by in-river migrant fish across LGR Pool to IHA Tailrace
Mean Gas Experience (Columbia)	Average dissolved gas experienced by in-river migrant fish across MCN Pool to BON Pool

Statistic	Description
Avg. Num Bypasses	Average passage history of dam passages through a bypass system across the 8 FCRPS Dams (includes partial passage information of inriver morts and transported fish)
Avg. Num Turbine Passages	Average passage history of dam passages via turbines across the 8 FCRPS Dams (includes partial passage information of inriver morts and transported fish)
Avg. Num Spill Passages	“Spill Passages" Average passage history of dam passages through a spillway or sluiceway across the 8 FCRPS Dams (includes partial passage information of inriver morts and transported fish)

668 **Table 1-7. Description of summary statistics reported from the COMPASS model for Snake**
669 **River spring-summer Chinook and steelhead for each alternative**

Statistic	Description
Mean Survival	80-year average in-river survival (Rock Island Pool to BON Tailrace)
Mean Survival (MCN to BON)	80-year average in-river survival (McNary Pool to BON Tailrace)
SD survival (year-to-year)	Standard deviation in in-river survival among the 80 water years
Mean Arrival at BON	Mean Julian day of fish arriving at Bonneville Dam (in-river migrants only)
Proportion Destined for Transport	Proportion of fish that would have been transported if in-river survival were 100%
Mean Gas Exposure	Average dissolved gas level experienced by fish across Rock Island Pool to Bonneville Pool
Proportion Powerhouse Passsage	The proportion of all dam passage events (from RIS to BON) that were via the turbines or bypass routes (sluiceways are treated as a spill route)
Mean Travel time (WEL-MCN) (Days)	80-year average travel time in days from Rock Island Pool to the head of McNary Pool
Mean Traveltime (MCN-BON) (Days)	80-year average travel time in days from MCN Tailrace to BON Tailrace
Mean Migration Rate (WEL-MCN) (mi/day)	80-year average migration rate in miles per day from Rock Island Pool to the head of McNary Pool
Mean Migration Rate (MCN-BON) (mi/day)	80-year average migration rate in miles per day from MCN Tailrace to BON Tailrace
Mean Temp Experience (WEL-Hanford)	Average temperature experienced by in-river migrant fish across Rock Island Pool to the Hanford Reach
Mean Temp Experience (Lower Columbia)	Average temperature experienced by in-river migrant fish across MCN Pool to BON Pool
Mean Flow Experience (WEL-Hanford)	Average flow experienced by in-river migrant fish across Rock Island Pool to the Hanford Reach
Mean Flow Experience (Lower Columbia)	Average flow experienced by in-river migrant fish across MCN Pool to BON Pool
Mean Gas Experience (WEL-Hanford)	Average dissolved gas experienced by in-river migrant fish across Rock Island Pool to the Hanford Reach
Mean Gas Experience (Lower Columbia)	Average dissolved gas experienced by in-river migrant fish across MCN Pool to BON Pool
Avg. Num Bypasses	Average passage history of dam passages through a bypass system across 3 Mid-Columbia dams (RIS, WAN, and PRD) and 4 Lower Columbia dams (includes partial passage information of inriver morts)

Statistic	Description
Avg. Num Turbine Passages	Average passage history of dam passages via turbines across 3 Mid-Columbia dams (RIS, WAN, and PRD) and 4 Lower Columbia dams (includes partial passage information of inriver morts)
Avg. Num Spill Passages	Average passage history of dam passages through spillways and sluiceways across 3 Mid-Columbia dams (RIS, WAN, and PRD) and 4 Lower Columbia dams (includes partial passage information of inriver morts)

670 **Table 1-8. Description of raw data fields reported from the COMPASS model for Snake River**
671 **spring-summer Chinook and steelhead for each alternative**

Field	Description
Year	Year of the 80-year water record
Species	Species used for run
InRivSurvSNK	In-River Survival from Lower Granite Tailrace to the confluence with the Columbia River
InRivSurvLCol	In-River Survival from McNary Pool to Bonneville Dam
InRivSurv	In-River Survival from Lower Granite Dam to Bonneville Dam
ProportionTransported	Proportion of fish destined to be transported if reservoir survival were 100%
MedDayLGR	Median julian day of fish passage at LGR (in-river migrants only)
MedDayConfl	Median day of fish passage at confluence of Snake and Columbia
MedDayBONinriv	Median day of fish passage at Bonneville tailrace (in-river migrants only)
MedDayBONtrans	Median day of fish passage at Bonneville tailrace (transported fish only)
meanTravelTime	Mean fish travel time (days) from Lower Granite Dam to Bonneville Dam
meanMigRate	mean fish migration rate (mi/day)
meanTemp	Mean fish temperature experience- weighted average of temperature by fish passage
meanFlow	Mean fish flow experience- weighted average of flow by fish passage
meanFSpill	Mean fish spill experience- weighted average of spill by fish passage
meanGas	Mean fish gas experience- weighted average of gas by fish passage
SNKTravelTime	Mean fish travel time (days) from Lower Granite Dam to the confluence with the Columbia
SNKMigRate	Mean fish migration rate (mi/day) in the Snake
SNKTemp	Mean fish temperature experience in the Snake
SNKFlow	Mean fish flow experience in the Snake
SNKFSpill	Mean fish spill experience in the Snake
SNKGas	Mean fish gas experience in the Snake
LCTravelTime	Mean fish travel time (days) from McNary Pool to Bonneville Dam
LCMigRate	Mean fish migration rate (mi/day) in the Columbia
LCTemp	Mean fish temperature experience in the Columbia
LCFlow	Mean fish flow experience in the Columbia
LCFSpill	Mean fish spill experience in the Columbia
LCGas	Mean fish gas experience in the Columbia
BonFlow	Mean spring flow in Bonnevile Pool
propBONinriv	Proportion of fish surviving to Bonnevile which were in-river migrants
propBONtrans	Proportion of fish surviving to Bonnevile which were transported

Field	Description
InRivSurv_q975	Upper 97.5% quantile of In-River Survival from Monte Carlo scenario analysis
InRivSurv_q025	Lower 2.5% quantile of In-River Survival from Monte Carlo scenario analysis

672 **Table 1-9. Description of raw data fields reported from the COMPASS model for Upper**
673 **Columbia River spring Chinook and steelhead for each alternative**

Field	Description
Year	Year of the 80-year water record
Species	Species used for run
InRivSurvUC	In-River Survival from Rock Island Pool to the head of McNary Pool
InRivSurvLCol	In-River Survival from McNary Pool to Bonneville Dam
InRivSurv	In-River Survival from Rock Island Pool to Bonneville Dam
MedDayRIS	Median julian day of fish passage at Rock Island Dam
MedDayConfl	Median day of fish passage at confluence of Snake and Columbia
MedDayBON	Median day of fish passage at Bonneville tailrace
meanTravelTime	Mean fish travel time (days) from Rock Island Pool to Bonneville Dam
meanMigRate	mean fish migration rate (mi/day)
meanTemp	Mean fish temperature experience- weighted average of temperature by fish passage
meanFlow	Mean fish flow experience- weighted average of flow by fish passage
meanFSpill	Mean fish spill experience- weighted average of spill by fish passage
meanGas	Mean fish gas experience- weighted average of gas by fish passage
UCTravelTime	Mean fish travel time (days) from Rock Island Pool to the head of McNary Pool
UCMigRate	Mean fish migration rate (mi/day) from Rock Island Pool to the head of McNary Pool
UCTemp	Mean fish temperature experience from Rock Island Pool to the head of McNary Pool
UCFlow	Mean fish flow experience from Rock Island Pool to the head of McNary Pool
UCFSpill	Mean fish spill experience from Rock Island Pool to the head of McNary Pool
UCGas	Mean fish gas experience from Rock Island Pool to the head of McNary Pool
LCTravelTime	Mean fish travel time (days) from McNary Pool to Bonneville Dam
LCMigRate	Mean fish migration rate (mi/day) from McNary Pool to Bonneville Dam
LCTemp	Mean fish temperature experience from McNary Pool to Bonneville Dam
LCFlow	Mean fish flow experience from McNary Pool to Bonneville Dam
LCFSpill	Mean fish spill experience from McNary Pool to Bonneville Dam
LCGas	Mean fish gas experience from McNary Pool to Bonneville Dam
BonFlow	Mean spring flow in Bonnevile Pool

674 **Table 1-10. Description of passage data fields reported from the COMPASS model for Snake**
675 **and Upper Columbia River spring Chinook and steelhead for each alternative**

Field	Description
Year	Year in the 80-year set
Species	Species used for the run
PropSpill_XXX	Proportion of fish that passed via normal spillbay at dam XXX
PropRSW_XXX	Proportion of fish that passed via RSW spillbay at dam XXX

Field	Description
PropSluice_XXX	Proportion of fish that passed via sluiceway at dam XXX (at Bonneville the corner collector is a sluiceway route)
PropBypass_XXX	Proportion of fish that passed via bypass at dam XXX
PropTurbin_XXX	Proportion of fish that passed via turbines at dam XXX
ProbXBypass	Given a fish survived to Bonneville tailrace, the probability it would have been bypassed X times
PropXTurbine	Given a fish survived to Bonneville tailrace, the probability it would have passed via turbines X times
PropXSpillway	Given a fish survived to Bonneville tailrace, the probability it would have passed via spill (normal spillbay or RSW) X times

1.3 NWFSC LIFE CYCLE MODEL

Northwest Fisheries Science Center (NWFSC) Life Cycle Modeling (LCM) uses COMPASS hydrosystem passage inputs to produce estimates of adult return metrics for one population (Wenatchee) of Upper Columbia Spring Chinook salmon, and for three population groups (South Fork Salmon, East Fork Salmon, and Upper Salmon) of Snake River Spring Chinook salmon (Table 1-11).

Table 1-11. Chinook populations used in the NOAA LCM analysis are listed below by basin

Chinook Population Group	Basins	Fish Populations
Snake River spring-summer Chinook	Middle Fork Salmon River	Bear Valley Creek
Snake River spring-summer Chinook	Middle Fork Salmon River	Big Creek
Snake River spring-summer Chinook	Middle Fork Salmon River	Camas Creek
Snake River spring-summer Chinook	Middle Fork Salmon River	Loon Creek
Snake River spring-summer Chinook	Middle Fork Salmon River	Marsh Creek
Snake River spring-summer Chinook	Middle Fork Salmon River	Sulphur Creek
Snake River spring-summer Chinook	South Fork Salmon River	Secesh River
Snake River spring-summer Chinook	South Fork Salmon River	South Fork Salmon River
Snake River spring-summer Chinook	South Fork Salmon River	East Fork South Fork
Snake River spring-summer Chinook	Upper Salmon River	Salmon R. Upper Main
Snake River spring-summer Chinook	Upper Salmon River	Yankee Fork
Snake River spring-summer Chinook	Upper Salmon River	East Fork
Snake River spring-summer Chinook	Upper Salmon River	Pahsimeroi
Snake River spring-summer Chinook	Upper Salmon River	Salmon R. Lower Main
Snake River spring-summer Chinook	Upper Salmon River	Lemhi (above Redfish)
Snake River spring-summer Chinook	Upper Salmon River	N. Fork Salmon
Snake River spring-summer Chinook	Upper Salmon River	Catherine Creek
Snake River spring-summer Chinook	Upper Salmon River	Valley Creek
Upper Columbia River Spring Chinook	Wenatchee	Wenatchee

The set of NWFSC life cycle models developed in support of the 2018 FCRPS Biological Opinion range in complexity as far as the number of distinct life stages, and dynamic relationships with river and ocean environment, habitat factors, predators, and climate variability and change

(NOAA Technical memo, Zabel and Jordan (Eds.); in press). The models used to estimate SAR and adult abundance for the 2019 CRSO-EIS used a Multivariate Autoregressive State Space (MARSS) modeling framework (Crozier and Zabel in press, Jorgensen in press). The MARSS method to fit survival relationships with environmental factors, and accurately simulate natural variability is described in Burke et al. (in press), and Holmes et al. 2012. The five life stages defined by the model included fall spawning and early rearing, later tributary rearing including downstream migration through the Snake and Columbia river, early ocean entry, additional years in the ocean, and pre-spawn survival as adults. Early life stages are modeled in the COMPASS model, while later life stages are modeled here. Jack returns are included in SAR estimates (Figure 1-1).

Data inputs used to develop this model for Upper Columbia, and three Salmon River major population groups include run reconstruction based estimates of wild spawner abundance, age structure, hatchery fraction and harvest rate, as well as stage specific survival estimates from juveniles PIT tagged as parr. Survival from the smolt to adult stage for both groups was estimated from pit-tag detections at Bonneville Dam. Upstream survival is also based on pit-tag detections from Bonneville Dam to Lower Granite Dam 2004-2016, and includes harvest in the mainstem rivers (Crozier et al. 2016). Survival from Lower Granite Dam to the spawning grounds (i.e., pre-spawn mortality) was treated as a constant (0.9), based on data summarized by Bowerman et al. (2016).

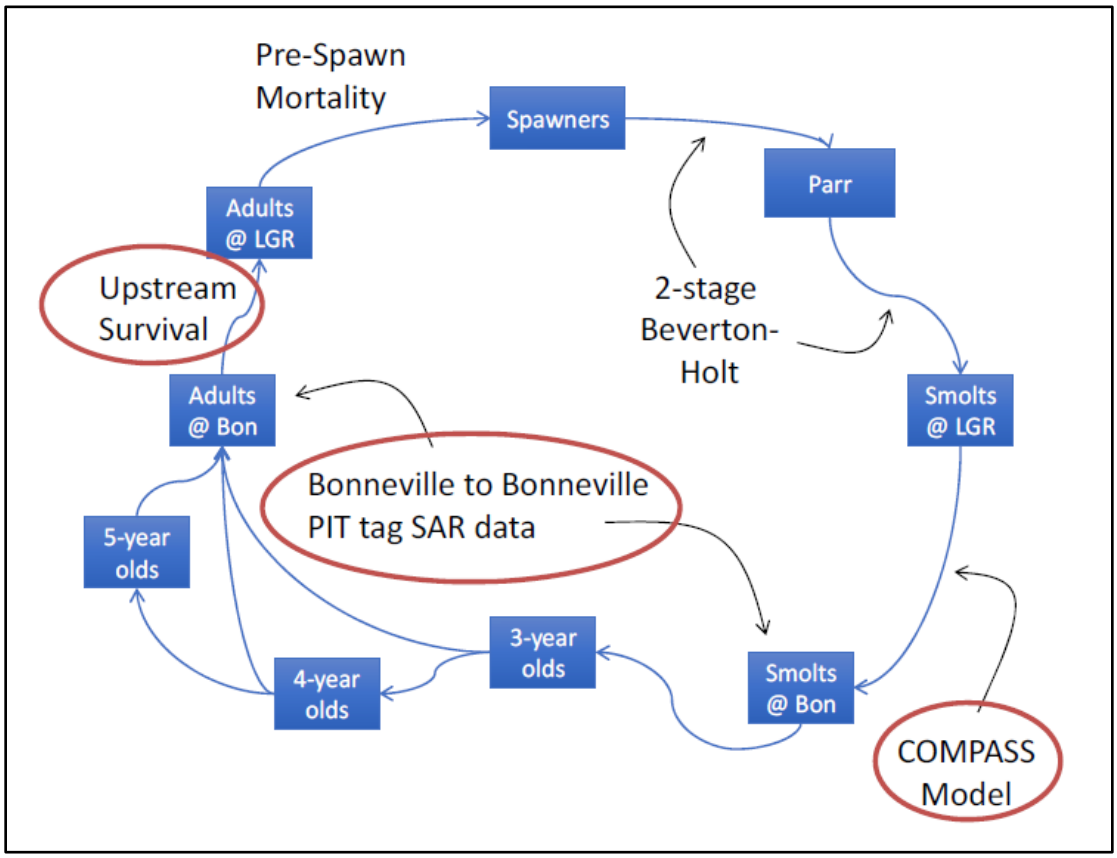

Figure 1-1. Flow for NOAA life cycle modeling

1.3.1 Smolt to adult return

The approach used to estimate survival from arrival at Lower Granite Dam to adult return at Bonneville and Lower Granite Dams is described in Burke et al. (in press). Survival and travel time output from the COMPASS model representing alternative scenarios of hydrosystem management was integrated into the model of wild adult abundance (Faulkner et al. in press). Data from both hatchery and wild origin juveniles was used to calibrate functional relationships with dam operations and river conditions in COMPASS. COMPASS implementation notes in this technical appendix describe the steps taken to address structural and operational measures included under each CRSO alternative.

Post-Bonneville survival through the lower Columbia estuary and 1-3 years of ocean survival are simulated with ocean indicators determined to have strong correlation with SAR. These include the winter sea surface temperature, the summer sea surface temperature along the Washington and Oregon coast, and the coastal upwelling index. The MARSS approach was used to simulate ocean conditions while capturing realistic correlation structure among covariates.

Ocean entry timing has previously been found to have a significant effect on SAR (Scheuerell et al. 2009). On average, a delay in the date of ocean entry could result reduced survival, particularly later in the season. PIT-based SAR data from smolts detected at Bonneville Dam has shown a different annual level of effect of the date of ocean entry, so yearly effects were simulated in the model with a combination of a linear random effects term and a quadratic fixed effects term that allowed date of entry to have a different level of effect, comparable to the observed data. Transported fish were assumed to have high survival in the barges (0.98), but tend to have lower post-Bonneville return rates compared to in-river migrants, particularly early in the season. The transport to in-river ratio (TIR) has a strong seasonal component, and SAR rates of transported fish were modeled separately from in-river fish.

An additional sensitivity analysis was carried out to assess the effect of latent mortality on adult ocean survival. Four values of latent mortality reduction were evaluated - 0, 10, 25 and 50%. To determine the effect of reducing latent mortality by any assumed value modelers multiply abundance or SAR estimates by that value and add it to the modeled value for an estimate of whatthe team would expect if latent mortality were reduced by that amount. These estimates were to abundance and SAR estimates for MO1, MO3, and MO4. A potential latent mortality benefit was not considered in MO2 because this alternative was not expected to mitigate latent mortality.

1.4 CSS MODELS

Comparative Survival Study (CSS) models were used to produce both juvenile and adult metrics for the Snake River Spring/Summer Chinook and steelhead ESUs. A suite of models were utilized to analyze the CRSO operations alternatives. The CSS ‘cohort’ models were applied to analyze expected juvenile survival, juvenile Fish Travel Time (FTT), ocean survival, SARs, and Transport:In-river Ratios (TIRs) for yearling Chinook salmon and steelhead from the Snake River Basin. The CSS Life Cycle Model was also applied to analyze expected Smolt-to-Adult Return

rates (SARs) and adult spawning ground abundances for six tributary populations of Chinook salmon in the Grand Ronde Basin (McCann 2017, chapter 2 http://www.fpc.org/documents/CSS/2017%20CSS%20Annual%20Report%20ver1-1.pdf). The 80-year water record and predicted flow and spill data sets for each CRSO alternative, provided by BPA, were utilized in these analyses.

1.4.1 CSS Cohort model

Full documentation of the CSS cohort model, used to generate juvenile fish travel time, juvenile fish survival, and TIR relative to CRSO Alternatives, is provided in the CSS memo ("Documentation of Experimental Spill Management: Models, Hypotheses, Study Design, and response to ISAB" http://www.fpc.org/documents/memos/30-17.pdf). Chapter 3 describes retrospective analysis of observed PIT tag data for development of the model. The objective of these efforts was to identify the best fitting, most parsimonious, and biologically supportable models to describe the relationships between demographic response metrics and sets of independent variables. Chapter 6 of the documentation shows an example of prospective modeling using simulated hydrosystem inputs under non-CRSO spill scenarios.

For the Cohort models, the input variables include water transit time, proportion of river spilled (PITPH), date of juvenile release at Lower Granite Dam, and ocean conditions. CSS cohort model predictions of juvenile fish travel time and juvenile survival have been validated by comparing to actual estimates from monitoring data. Operations data at each project across the 80-year water record were used as inputs for the models. For each cohort and water year, 10,000 random simulations were generated using the parameters described in the models presented. CSS model analyses have identified water transit time and spill, and the presence of removable spillway weir and temporary spillway weirs for steelhead, as the most important variables affecting smolt to adult return rates for Snake River salmon and steelhead.

1.4.2 CSS Life Cycle Model

The Life Cycle model applied to the Grande Ronde/Imnaha major population group of Snake River Spring Chinook is able to integrate decades of data on tributary adult spawners, tributary smolts, in-river survival estimates, ocean survival estimates, smolt-to-adult return estimates, and harvest estimates within a single framework. The predicted abundances and smolt-to-adult return rates (SARs) capture temporal trends in variability, as well as sensitivity to environmental drivers. Details on how SARs were estimated in the Life Cycle Model are provided in McCann et al. (2017, pg 30-33).

- The SARs presented in results include jacks.
- Harvest is treated as a random draw from historical harvests.
- Ocean indices are simulated.
- Transported fish were not included in the cohort-specific SARs.

- Comparisons of the SARs of transported smolts relative to the SARs of wild origin in-river smolts (i.e., the TIR ratio) are presented as a separate metric from the CSS cohort model.
- Summary statistics for SARs and return abundances were calculated slightly differently from the methods in McCann et al. (2017). In this analysis, the two metrics were averages over a random 10 year period in the 80 year simulations for each simulated outcome. This is in contrast to always taking the average of the last 10 years in McCann et al. (2017). All metrics are averages of 1000 simulations.

1.4.2.1 CRSO Implementation Notes

The CSS analyses of CRSO alternatives included three levels of assumed passage efficiencies for proposed Powerhouse Surface Passage (PSP) structures, measures included in several of the CRSO alternatives (10%, 20% and 30%).

Improved Fish Passage turbines are included as a measure in several of the CRSO alternatives. But CSS did not model the effects of these turbines.

The CSS modeling did not include any transportation from McNary Dam for MO2. MO2 includes a measure that specifies that no powerhouse screens will be installed at McNary Dam, however at the same time McNary Dam is included as an additional fish transportation site. Without screen installation, the proportion of juvenile fish available for transportation at McNary will be reduced. Fish that would have been routed to the collection system will pass through the powerhouse turbines.

1.4.2.2 PITPH documentation

PITPH is a metric that describes the expected number of powerhouse encounters during the downstream migration. For smolts originating upstream of Lower Granite Dam, if there is zero spill through the FCRPS, the PITPH would be 8. If there is 100% spill and no powerhouse operation PITPH would be 0.

In the dam breach scenario, in which the four lower Snake River Dams are removed, the maximum PITPH that could be experienced by downstream migrants will range from 0 to 4. Water transit time, which measures the average time for water to pass through each reservoir, would also be reduced in the Snake River under a dam breach scenario. http://www.fpc.org/documents/CSS/2015%20CSS%20Annual%20Report.pdf pg. 465-485. Tables 1-12 and 1-13 show the mean PITPH for Snake River spring-summer Chinook and Steelhead with different assumed Powerhouse Surface Passage (PHSP) collection efficiencies.

Table 1-12. Mean Seasonal average PITPH (95% confidence interval) for spring-summer Chinook over the 80-year water record for each alternative

Alternative	No PHSP	PHSP – 10% Efficiency	PHSP – 20% Efficiency	PHSP – 30% Efficiency
NAA	2.15 (2.06-2.23)	N/A	N/A	N/A
MO1	1.85 (1.72-1.97)	1.81 (1.69-1.94)	1.78 (1.65-1.90)	1.74 (1.62-1.87)

Alternative	No PHSP	PHSP – 10% Efficiency	PHSP – 20% Efficiency	PHSP – 30% Efficiency
MO2	3.90 (3.82-3.98)	3.76 (3.68-3.84)	3.62 (3.54-3.70)	3.48 (3.41-3.56)
MO3	0.62 (0.57-0.67)	0.60 (0.55-0.65)	0.58 (0.53-0.63)	0.56 (0.51-0.61)
MO4	0.45 (0.40-0.50)	0.41 (0.37-0.46)	0.38 (0.33-0.42)	0.34 (0.30-0.38)

Note: PHSP refers to the addition of Powerhouse Surface Passage structures with assumed 10, 20, and 30% collection efficiencies.

Table 1-13. Mean Seasonal average PITPH (95% confidence interval) for spring-summer steelhead over the 80-year water record for each alternative

Alternative	No PHSP	PHSP – 10% Efficiency	PHSP – 20% Efficiency	PHSP – 30% Efficiency
NAA	1.96 (1.85-2.06)	NA	NA	NA
MO1	1.69 (1.56-1.83)	1.68 (1.54-1.81)	1.66 (1.53-1.79)	1.64 (1.51-1.77)
MO2	3.65 (3.55-3.75)	3.52 (3.43-3.62)	3.39 (3.30-3.48)	3.26 (3.18-3.35)
MO3	0.47 (0.42-0.52)	0.47 (0.42-0.52)	0.46 (0.41-0.51)	0.46 (0.41-0.51)
MO4	0.36 (0.31-0.42)	0.34 (0.29-0.39)	0.31 (0.26-0.36)	0.28 (0.24-0.32)

Note: PHSP refers to the addition of Powerhouse Surface Passage structures with assumed 10, 20, and 30% collection efficiencies.

ESTIMATES OF DETECTION PROBABILITY VERSUS PROPORTION SPILL

During development of the PITPH variable for The Dalles Dam and Bonneville Dam, the Ice and Trash Sluiceway (ITS) were combined with the turbine passage route in estimates of total powerhouse passage. The rationale for this decision was: 1) smolts enter the ITS in a similar manner as smolts entering bypass systems at the other dams, 2) smolts exiting the ITS follow a similar route in the tailrace as smolts that pass through the turbines, 3) smolts that use the ITS have similar tailrace egress times as smolts that pass through the turbines, and these tailrace egress times are approximately double those of smolts that pass via the spillway, and 4) smolts that exit the ITS pass near or through zones of high predator (northern pikeminnow and smallmouth bass) density in the tailrace, and this predator exposure is expected to be similar to smolts that pass through the turbines. Smolts that exit the corner collector at Bonneville Dam enter into the same area as smolts that pass through the spillways, unlike the ITS, where smolts enter areas directly adjacent to the turbine outfalls. For these reasons, the team believes that it is appropriate to combine the ITS route with the turbine route for quantifying total powerhouse passage.

Estimates of average proportion utilized in the 2019 CRSO analyses are provided in Table 1-14 below. These estimates reflect the modifications to the MO2 data set provided by the federal agencies on May 23, 2019. For the CSS life-cycle model, estimates of proportion transported were a function of the estimated cumulative PITPH at the three transportation projects (LGR, LGS, and LMN) and the specified start date for transportation at LGR and LGS. The NAA has transportation beginning on May 1, MO1 calls for transportation to begin on April 15th, and transportation would be initiated on April 25th for MO2 and MO4. No transportation will occur under MO3, which includes the measure of dam breach for the four lower Snake Dams.

Table 1-14. Mean estimates of proportion transported (95% confidence interval) for Chinook over the 80-year water record for each CRSO EIS Alternative used in the CSS life-cycle modeling

EIS Alternative	No PSP	PSP – 10% Efficiency	PSP – 20% Efficiency	PSP – 30% Efficiency
NAA	0.192 (0.176-0.208)	–	–	–
MO1	0.265 (0.243-0.288)	–	–	–
MO2	0.338 (0.314-0.363)	–	–	–
MO3[A]	–	–	–	–
MO4[B]	0.075 (0.071-0.079	0.073 (0.069-0.076)	0.071 (0.068-0.074)	0.069 (1.066-0.071)

Notes: [A] With breach, no transportation is provided under M03.

[B] M04 is the only alternative that proposes PSP at transportation sites. Therefore, this is the only alternative that had different estimates for proportion transported across the assumed 10%, 20% and 30% efficiencies.

1.5 TDG MODEL

The University of Washington TDG model uses outputs from the COMPASS model and the Corps water quality modeling to estimate juvenile survival and reach average exposure to TDG, average juvenile fish migration depth, and exposure timing.

1.5.1 Background and Introduction

Because high TDG levels can affect the health and survival of salmon (Weitkamp et al. 2008) the assessment of the gas exposure effects on fish is critical for assessing effects of the alternatives on salmon restoration efforts. This section describes a model to assess the relative impacts of hydrosystem operations on TDG generation and its effects on juvenile fish passing through the hydrosystem.

The TDG model uses the COMPASS smolt passage model (Zabel et al. 2008) to simulate the fish movement and TDG exposure based on flow, spill and TDG provided from models developed by other groups involved in the CRSO analysis. The model characterizes the effect TDG on juvenile fish passage with two metrics:

1) Mortality due to gas bubble disease

2) Reach Average TDG Exposure

The sections below describe the history of the model development, its conceptual framework, quantitative details, calibration and limitations, a brief user guide, example application and interpretation.

1.5.2 Model Development

The TDG model is essentially a standalone submodel of COMPASS. The TDG submodel system can generate TDG using inputs of flow and spill or it can accept TDG and hydraulic information from other models. For the CRSO analysis of TDG effects, two metrics are computed for each alternative: mortality from TDG exposure and average reach exposure. For the CRSO analysis,

this model uses COMPASS results generated by NOAA using water quality inputs provided by the Corps water quality modeling group. In addition, a web-based TDG model is available so users can explore the model characteristics.

1.5.3 Conceptual Model

For each reach, TDG exposure of fish depends on travel time through the reservoirs and the TDG concentration while migrating through each of the reservoirs. Travel time depends on the water velocity and fish migration rate. The effective exposure is denoted as dissolved gas supersaturation (DGS). TDG in a reservoir depends on spill and the level of dissolved gas in the upstream reservoir (Figure 1-2). TDG levels are provided through the water quality modeling process for two locations in each reservoir: a high value at the tailrace of the upstream dam and a low value for the forebay of the downstream dam. Each metric is computed using the upstream and dowstream set of TDG values. The survival and exposure metrics are then averaged to obtain the nominal metric value. The tailrace value represents an upper-bound for the reservoir gas level and the forebay values represents a lower-bound for the reservoir gas level. The metrics generated by these two bounds represent high and low exposure and mortality calculated for each reach and over the entire hydrosystem. Note, the model only calculates the effects of TDG on mortality, other mortality processes are not included.

The model was developed from principles of dose-dependent mortality and empirical relationships for the effects of spill and flow on TDG levels and fish migration velocity. The mortality rate equation was developed from laboratory studies that determined the mortality rate of juvenile Chinook salmon exposed to constant levels of supersaturation (Dawley and Ebel 1975, Dawley et al. 1976). Depth of migrating fish was developed from field studies conducted at Snake and Columbia River dams (Stevens et al. 1980, Li et al. 2015a, Li et al. 2015b, Li et al. 2018).

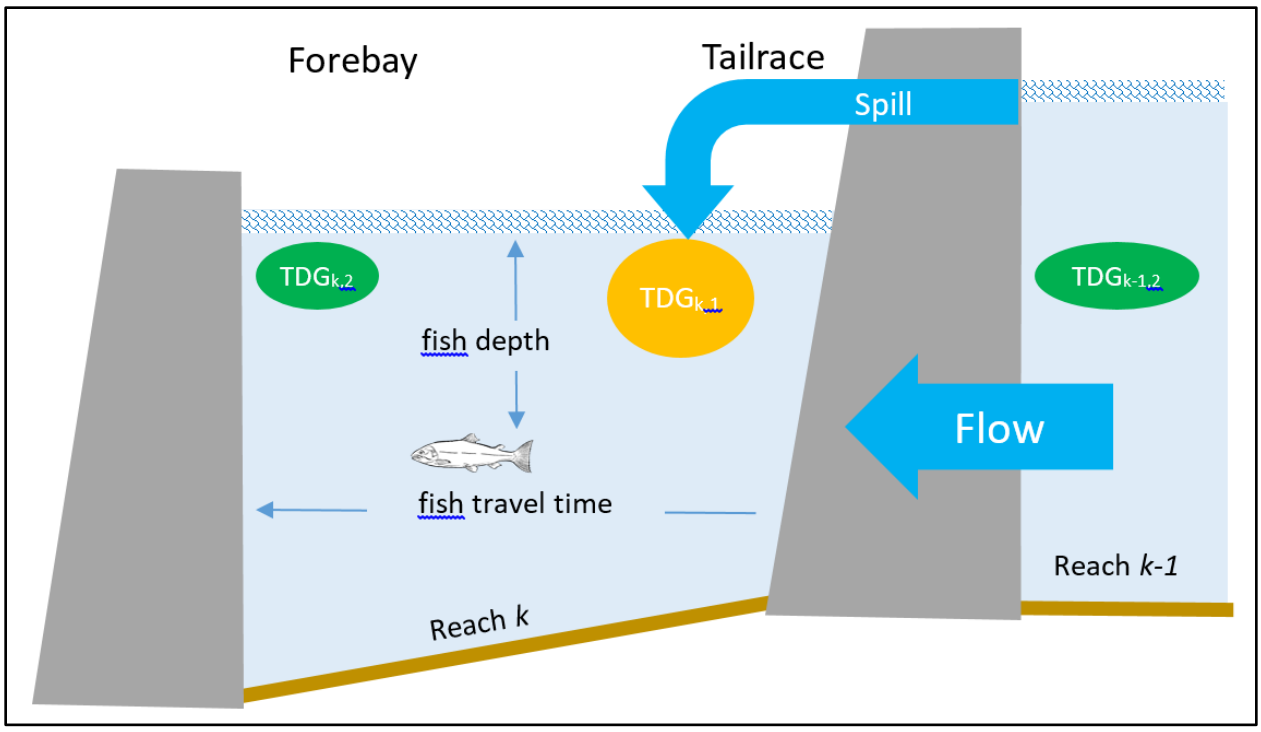

Figure 1-2. Conceptual model of factors determining TDG exposure and mortality of fish passing through a reservoir.

Reservoir TDG levels are supplied for the upstream (tailrace) and downstream (forebay) sections. Exposure indexes are calculated for each TDG level and then averaged. The upstream level $TGD_{k,1}$ depends on the amount of spill, powerhouse flow and the forebay levels in the upstream dam $TDG_{k-1,2}$. Direct GBD mortality depends on reservoir TDG levels, fish depth and fish travel time.

1.5.4 Quantification

This TDG modeling system provides a full hydrosystem representation of the effects of TDG on fish passage through reservoirs. The model represents a first order approximation of exposure and biological response. In terms of its spatial coverage it is the best system available. In the TDG model, fish movement components are calibrated for the entire hydrosystem (Zabel and Anderson 1997, Zabel et al. 1998) and the model integrates with the fish passage and hydraulic models being used in the CRSO process. Finally, the TDG mortality equation is based on first principles of dose-response kinetics calibrated from laboratory studies.

The exposure metrics are detailed separately below. The development, calibration and validation of COMPASS is beyond the scope of this document, but the migration rate, location, passage tracking, and environmental conditions are essential to this analysis. To compute the TDG exposure metrics, detailed book-keeping of fish exposure to water properties is computed at 21 locations.

Programming languages used: COMPASS output processing is done with PERL for file manipulation and data extraction, and R for analysis, quantification and graphics display. Essential inputs include:

1) TDG data provided by the Corps on a daily basis over the 80-year hydrologic record, COMPASS migration rate inputs and fish releases for each hydrologic year, and assumptions on the modal depth of swimming for each species.

The output metrics are calculated from daily information on fish residence time in reservoirs and their associated TDG information.

1.5.4.1 Reach Average Exposure to TDG

Reach Average Exposure (RAE) is computed directly on COMPASS outputs where the number of fish passing and TDG level on each day are used to compute the reach exposure in reach k (REk). Next, a weighted average reach exposure is computed using the lengths of the reaches. For each hydrosystem operation alternative a single RAE metric is computed each year and species.

Equation 1. Reach Average Exposure Computations

$$RE_{k,i} = \sum_{j}^{J} TDG_{j,k,i} \cdot \frac{N_{j,k}}{TotalFish_k}$$

$$RAE_i = \frac{\sum_k RE_{k,i} \cdot \text{length}(reach_k)}{\sum_k \text{length}(reach_k)}$$

$$RAE = \left(RAE_1 + RAE_2\right)/2$$

where:

j = first day of passage and J = last day of passage;

k = reach index (LGR = 0, LGS = 1 … BON = 7);

i = TDG location with i = 1 upper reservoir location (tailrace), i = 2 lower reservoir location (forebay);

$TDG_{j,k,i}$ = total dissolved gas supersaturation level (above 100%) on day j in reservoir k and location I;

and

$N_{j,k}$ = Number of fish in passing through reach k on day j.

The number of fish passing each reach is calculated from the COMPASS model using arrival time distributions of smolts at Lower Granite Dam. Each hydrologic year has a unique arrival time distribution that is fixed across the alternative operation scenarios.

1.5.4.2 Mortality Due to GBD

The computation of GBD bubble disease mortality involves assumptions and parameters from other studies. The following is excerpted from the CRiSP1.6 Theory and Calibration manual available March 07 2019 at http://cbr.washington.edu/sites/default/files/manuals/crisp16_tc.pdf. CRiSP was the predecessor to COMPASS and the functionality of this sub-model is retained in COMPASS. The methods are modified slightly from the original text to reflect current COMPASS model status. The computations presented below are embedded in the COMPASS code.

There is uncertainty as to the significance of GBD-induced mortality at low levels of supersaturation (<110%). Above that, the rate increases significantly. The transition between low levels of generally sublethal effects to the higher level lethal effects involves a shift in the bubble-related mechanisms that lead to death. Specifically, at levels of supersaturation below the threshold fish are more susceptible to death related to infection and stress while above the threshold fish experience death from large intravascular bubbles (White et al. 1991).

The level of total dissolved gas is generated by spill at the dams and then dissipated as the water moves downstream (Fig. 1). In the TDG model, the effects of lethal levels of TDG are considered. The difference in TDG exposure resulting from downstream gas dissipation in a reservoir is approached by averaging the exposures computed separately using the TDG from the tailrace of a reservoir's upstream dam and TDG from the forebay of a reservoir's downstream dam.

Assessing the effect of gas mortality involves six steps:

1) Define gas mortality rate for TDG level of a fish of a standardized length for a given depth.
2) Adjust the TDG to the depth of the fish.
3) Adjust the mortality rate for fish length.
4) Define the depth of the fish in the reservoir.
5) Integrate the mortality rates across fish depth distribution.
6) Calculate the reservoir survival resulting from gas bubble mortality.

1. DEFINE GAS MORTALITY RATE FOR TDG LEVEL OF A FISH OF A STANDARDIZED LENGTH FOR A GIVEN DEPTH.

The mortality rate for a specific level of TDG was determined for juvenile Chinook salmon and steelhead using data which tracked the mortality of fish over time using tanks with different

depths (Dawley and Ebel 1975, Dawley et al. 1976). The lethal effect of TDG were greater in the 0.25 m tanks than the 2.5 m tanks. However, the mortality in the two configurations were similar exhibiting a linear slow rate of mortality at low TDG levels and a transition to higher mortality rate once the TDG had exceeded a critical level TGDc.

The model characterizes this transition in mortality rate with a piecewise linear function that expresses the rate of mortality M' as a function of the extra gas supersaturation using a Heaviside function *H*() (Figure 1-3). This allows the model to assume a moderate linear increase in mortality (slope = *a*) at low levels of gas supersaturation and when the lethal threshold of saturation TDG_C is reached, the Heaviside function turns on and the mortality curve increases linearly with a higher rate (slope = *a* + *b*). Using Dawley and Ebel (1975), the empirical gas mortality rate equation is:

Equation 2. Defining Gas Mortality Rate for TDG level, length, and depth.

$$M\left(TDG,z\right)=a\cdot\left(TDG-m\cdot z\right)\cdot H\left(TDG-m\cdot z\right)+b\cdot\left(TDG-m\cdot z-TDG_c\right)\cdot H\left(TDG-m\cdot z-TDG_c\right)$$

where

M = base gas bubble mortality rate for standard fish,

TDG = level of gas supersaturation at the surface,

TDG_C = critical threshold at which the mortality switches to a higher rate,

m = decrease in TDG with fish depth z,

a = species-specific gas mortality rate coefficient with units of TDG-1 day-1 determining the initial rate of increase of mortality per %-increase in TDG,

b = species-specific gas mortality rate coefficient with units of TDG-1 day-1, determining the increase of mortality per %-increase in TDG above TDGc, and

H() = Heaviside function, also known as the unit step function; equal to zero when its argument is negative and one when its argument is positive.

Table 1-15. Mortality rate coefficients

Parameter	Spring Chinook	Steelhead
a	0.000021	0.000594
b	0.005980	0.004820
TDG_C	10.9	12.7

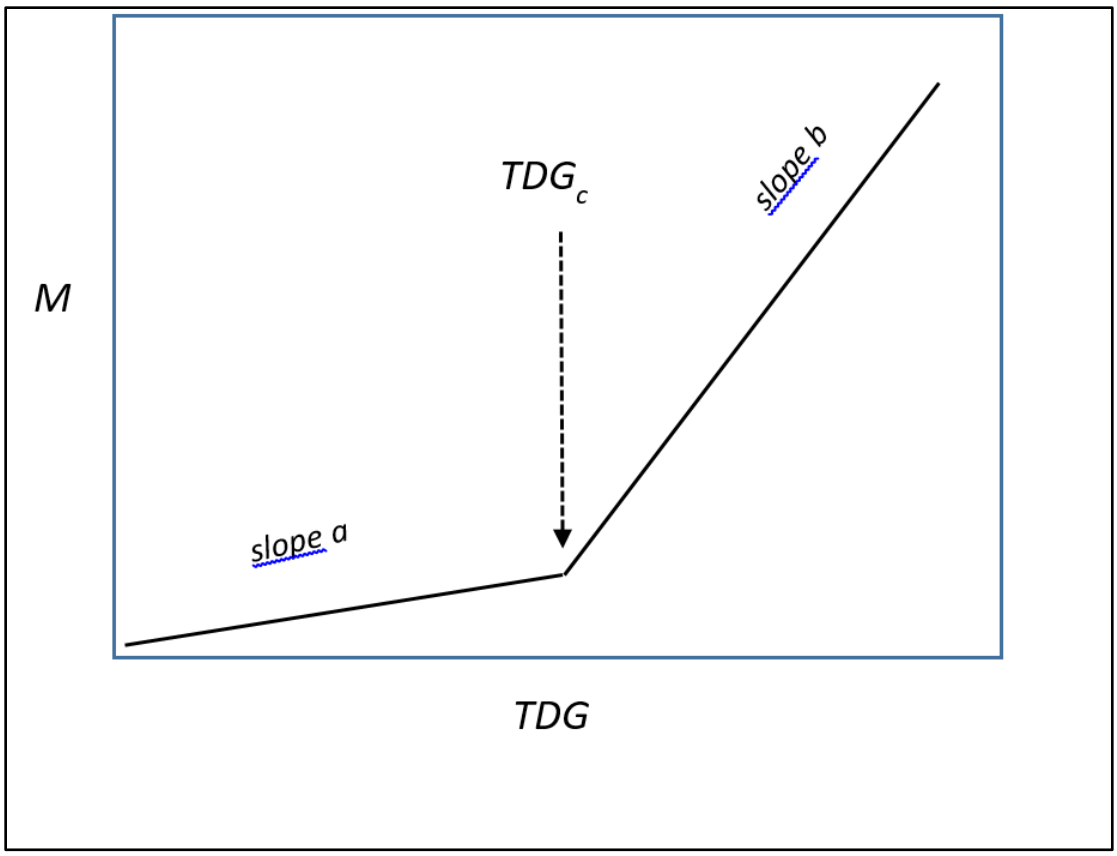

Figure 1-3. Dissolved gas mortality rate equation for total dissolved gas level TDG

Using Dawley survival data for fish exposed under 40 days; the parameters *a* and *b* were fit using linear regression (Table 1-15). The underlying data for the analysis is given in (Tables 1-16 and 17).

The mortality rate also appears to exhibit an exposure duration threshold that suggests that TDG compensatory mechanisms are functional for a period of time and then begin to break down. As a result, fish exposed to for up to 2 months or more in the Dawley experiments were susceptible to mortality at a higher rate than fish exposed for a short period of time. The model used data for fish exposed for 40 days or less, on the order of time that the fish are exposed in the river system. This subset of the mortality data was used to determine the TDG mortality coefficients.

Table 1-16. Chinook mortality rates

%TDG	Days (t)	0.25m Survival (S)	0.25m Mortality rate (M)	2.5m Survival (S)	2.5m Mortality rate (M)
105	20	0.99	0.0005	1	0
105	40	0.98	0.00051	1	0
105	60	0.97	0.00051	0.99	0.00017
105	80	0.9	0.0013	0.97	0.00038
105	100	0.88	0.0013	0.97	0.0003

%TDG	Days (t)	0.25m Survival (S)	0.25m Mortality rate (M)	2.5m Survival (S)	2.5m Mortality rate (M)
105	120	0.87	0.0012	0.96	0.00034
115	10	0.95	0.0051	–	–
115	20	0.84	0.0087	1	0
115	30	0.72	0.011		
115	40	0.62	0.012	1	0
115	50	0.49	0.014	–	–
115	60	0.22	0.025	0.97	0.00051
115	70	0.12	0.03	–	–
115	80	0.08	0.032	0.88	0.0016
115	100	0.05	0.03	0.83	0.0019
115	120	–	–	0.78	0.0021
120	10	0.77	0.026	–	–
120	20	0.57	0.028	1	0
120	30	0.32	0.038	–	–
120	40	0.22	0.038	1	0
120	50	0.1	0.046	–	–
120	60	0.03	0.058	0.95	0.00085
120	70	0.02	0.056	–	–
120	80	0.01	0.058	0.71	0.0043
120	100	–	–	0.64	0.0045
120	120	–	–	0.58	0.0045
127	10	–	–	0.97	0.003
127	20	–	–	0.88	0.0064
127	30	–	–	0.7	0.012
127	40	–	–	0.52	0.016
127	60	–	–	0.38	0.016
127	80	–	–	0.1	0.029
127	100	–	–	0.07	0.027

1019 Notes: *0.25m = shallow tank experiments; **2.5m = deep tank experiments.
1020 Source: (Dawley and Ebel 1975, Dawley et al. 1976)

1021 **Table 1-17. Steelhead mortality rates based on survival data and mortality rates**

%TDG	Days (t)	0.25m Survival (S)	0.25m Mortality Rate (M)	2.5m Survival (S)	2.5m Mortality Rate (M)
105	1	1	0	1	0
105	2	1	0	1	0
105	3	–	–	1	0
105	4	–	–	1	0
105	5	0.96	0.0082	1	0
105	6	–	–	1	0
105	7	0.95	0.0073		
110	1	1	0	1	0

%TDG	Days (t)	0.25m Survival (S)	0.25m Mortality Rate (M)	2.5m Survival (S)	2.5m Mortality Rate (M)
110	2	1	0	1	0
110	7	0.97	0.0044	0.99	0.0014
115	1	1	0	1	0
115	2	0.95	0.026		
115	3	0.7	0.12	1	0
115	4	0.58	0.14	–	–
115	5	0.48	0.15	–	–
115	6	0.41	0.15		–
115	7	0.37	0.14	0.97	0.0044
120	0.8	0.76	0.34	–	–
120	1	0.67	0.4	–	–
120	1.2	0.42	0.72	–	–
120	1.9	0.060	1.5	–	–
120	2	–	–	0.99	0.005
120	3	–	–	0.96	0.014
120	7	–	–	0.94	0.0088
127	2	–	–	0.92	0.042
127	3	–	–	0.87	0.046
127	4	–	–	0.82	0.05
127	5	–	–	0.8	0.045
127	6	–	–	0.77	0.044
127	7	–	–	0.75	0.041

Notes: *0.25m = shallow tank experiments; **2.5m = deep tank experiments.
Source: (Dawley and Ebel 1975, Dawley et al. 1976)

2. TDG DEPTH CORRECTION FACTOR M

Fidler and Miller (1994) and Dawley and Ebel (1975) demonstrated that the critical supersaturation threshold increases at greater depth. The experiments indicated that mortality curves in shallow tanks at 112% saturation were equivalent to mortality curves in a deep tank with 122% supersaturation. Based on the mechanisms controlling partial pressures of gas bubbles, the partial pressure increases approximately 10% per meter below the surface (Richards 1965). Fidler and Miller (1994) noticed a linear change in the threshold depth for gas bubble trauma symptoms giving the correction factor. The slope of this linear relationship is 73.89 mmHg m^{-1}, and given the relationship of TDG to pressure (0.1316 %/ mmHg), this is equivalent to m = 9.72 m^{-1} or m = 2.96 ft^{-1}.

3. SIZE-MORTALITY RATE RELATIONSHIP

The Dawley and Ebel (1975) study demonstrated that large fish had higher levels of mortality. The experiments exposed fall chinook of various sizes to 112% supersaturation in shallow tanks and determined the cumulative mortality curves varied with size (Dawley and Ebel 1975,

Fig. 10). These data were then used to infer the effect of fish length on TDG mortality in reservoirs.

The resulting mean mortality rates are plotted against fish length (Fig. 1-4). The slope of the line relating mean mortality rate to length is 0.00126. The regression was not confined to go through zero because Dawley and Ebel (1975) and Jensen et al. (1986) both report that there is a sensitivity threshold for size. The cumulative mortality over time for the different fish sizes is illustrated in Fig. 1-5.

The ability of a fish to establish gas equilibrium should be related to its volume to surface area ratio, which is proportional to fish length. Thus, on physical principles of gas exchange, a length relationship should affect TDG mortality. For a first order estimate of the length relationship to mortality rate is:

Equation 3: First order estimate of Fish Length relationship to mortality rate

$$M(L) = \alpha + \beta * L$$

Where:

M (L) = effective gas bubble mortality rate as a function of fish length,

L = fish length in mm,

 = 0.0012 mm-1, length coefficient for TDG mortality rate (regression of all data from the 112% shallow tank experiments (Dawley et al. 1976), and

 = intercept mortality rate in which the effects of fish depth and TDG exposure are inferred

The mortality rate is corrected for fish length from the laboratory studies to the field example using:

Equation 4: Mortality Rate Corrected by Fish Length

$$M(L) = M(L_e) \cdot (L + c) / (L_e + c)$$

where

L = length of fish in environment, and

L_e = length of fish in TDG mortality experiments.

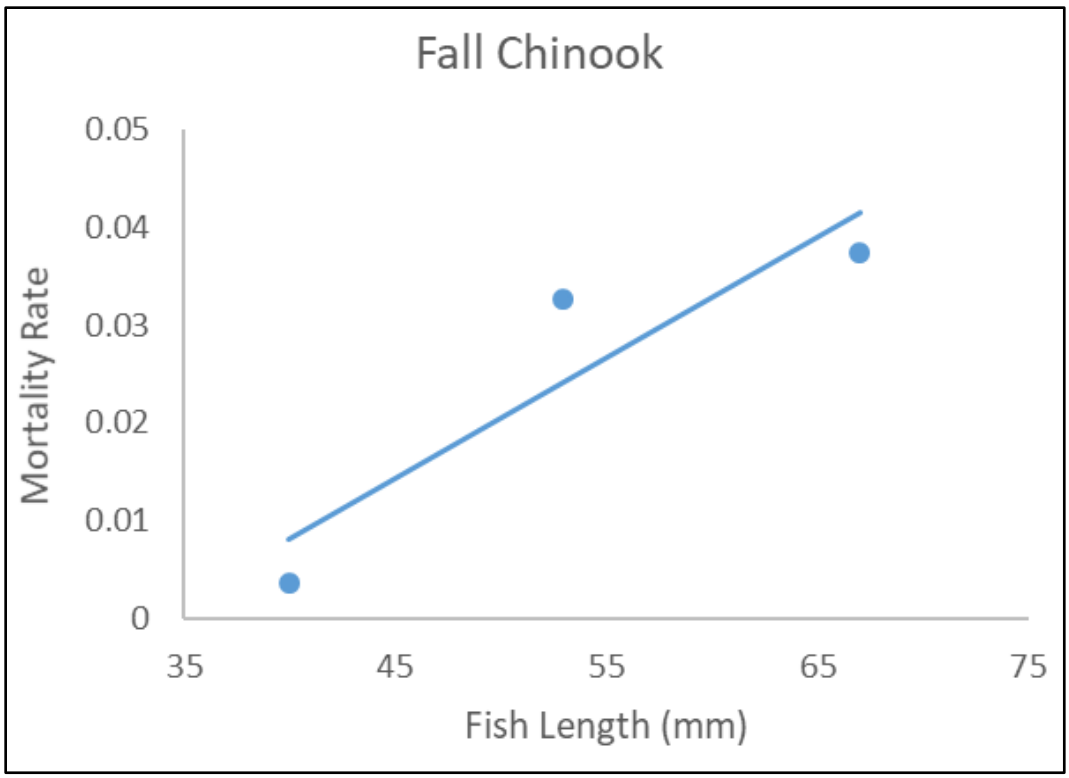

Figure 1-4. Relationship of mortality rate with fish length

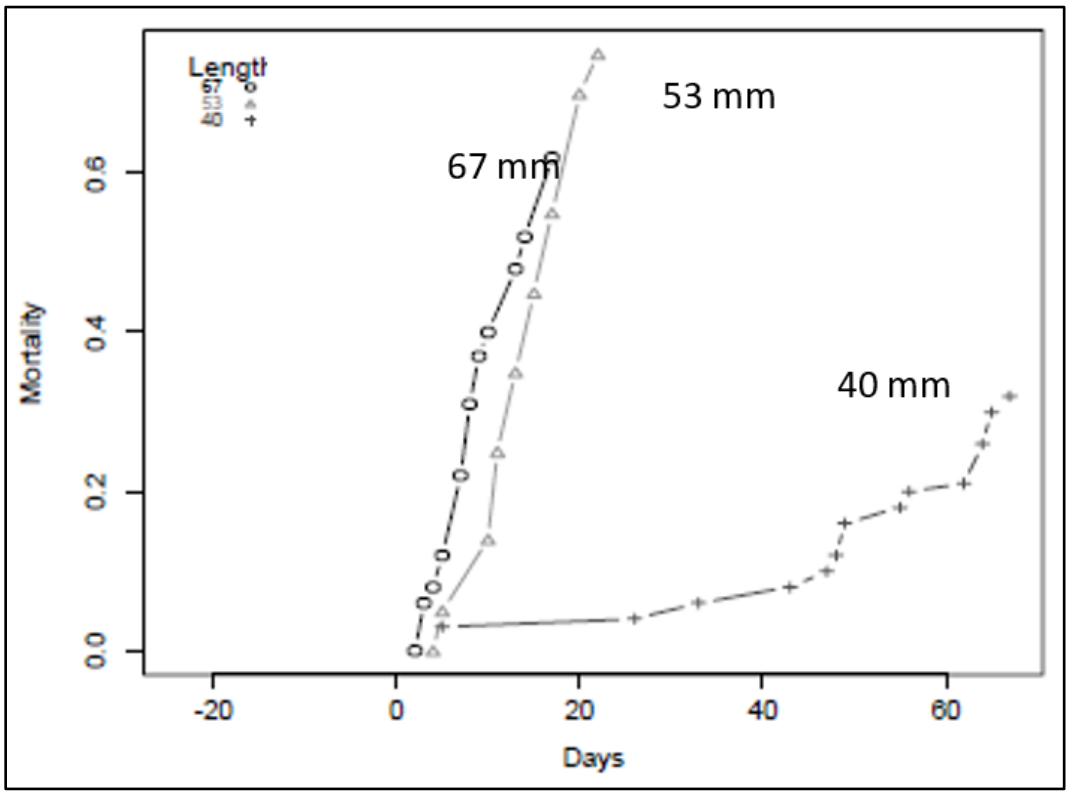

Figure 1-5. Cumulative mortality vs. exposure time to TDG supersaturation (112%) for different fish lengths

4. FISH VERTICAL DISTRIBUTION

Fish from a given species will distribute vertically (Figure 1-5). A number of distribution functions have been hypothesized (Zabel 1994). For simplicity the team uses an isosceles triangular distribution to define the fish density with depth (Fig. 1-5):

Equation 5: Computing Fish Vertical Distribution

$$Dist(z) = H(z_D - z) \cdot \left(m_0 \cdot z \cdot H(z) + \left(m_1 - m_0 \right) \cdot \left(z - z_0 \right) \cdot H(z - z_m) - m_1 \cdot \left(z - z_b \right) \cdot H(z - z_b) \right)$$

where

z = fish depth,
z_D = depth of the reservoir,
z_b = maximum depth of fish distribution,
z_m = mode of fish distribution,
m_0 = slope of distribution function above mode, and
m_1 = slope of distribution function below mode.

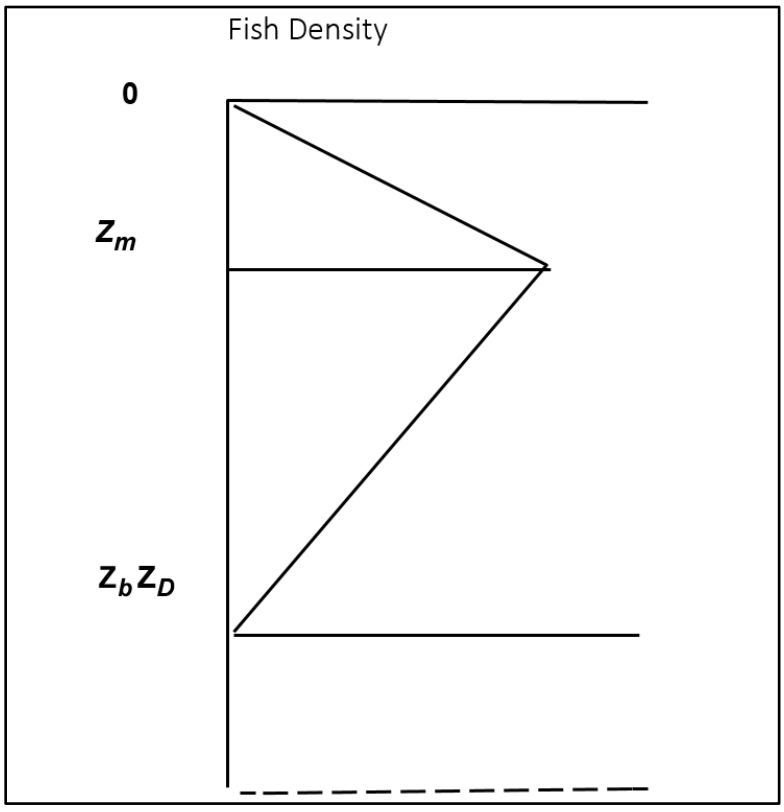

Figure 1-6. Illustration of fish depth distribution of fish

The gas bubble disease rate depends on fish depth which is characterized by a mode depth and bottom depth. Fish depths vary continuously over day and night, fish age, and position in the

river. For the current model, depth parameters are required for each species which are derived from the literature (Table 1-18).

Table 1-18. Fish vertical distributions and references

Species	Location	Time	Mode depth (m or ft)	Reference
Spring Chinook	Forebay	Day	39 ft 5 ft 2.6 -12.2 m	(Ebel and Raymond 1976, Johnson et al. 1985, Li et al. 2015a, Li et al. 2015b, Li et al. 2018)
Spring Chinook	Reservoir	Day	12-24 ft 27-36 ft	(Smith 1974, Dauble et al. 1989)
Spring Chinook	Reservoir	Night	0-12 ft 27-36 ft	(Smith 1974, Dauble et al. 1989)
Spring Chinook	McNary Pool	–	1.5 – 3.2 m	(Beeman and Maule 2006)
Steelhead	Forebay	Day	13 ft 4 ft 2.6 – 12.2 m	(Ebel and Raymond 1976, Johnson et al. 1985, Li et al. 2015a, Li et al. 2015b, Li et al. 2018)
Steelhead	Forebay	Night	–	–
Steelhead	Reservoir	Day	0-12 ft	(Smith 1974)
Steelhead	Reservoir	Night	12-24 ft	(Smith 1974)
Steelhead	McNary Pool		2 -2.3 m	(Beeman and Maule 2006)

Note: CRSO analysis selected values: Mode = 7 ft. Maximum = 50 ft. for all rows

5. AVERAGE MORTALITY RATE THROUGH RESERVOIR

A reservoir average mortality rate per day is created by calculating the depth weighted average as

Equation 6: Average mortality per day (Depth Weighted Average)

$$M_{j,k,i} = \int_0^{z_D} Dist(z) \cdot M\left(TDG_{j,k,i}, z, L\right)_{j,k,i} dz$$

With:

$$M_{j,k} = \left(M_{j,k,1} + M_{j,k,2}\right) / 2$$

Where:

$M_{j,k,}$= average gas bubble mortality for day j in reservoir k,

$M_{j,k,i,}$ = average gas bubble mortality for day j in reservoir k using TDG from reach location I,

$TDG_{j,k,i}$ = surface total dissolved gas supersaturation level on day j in reach k and reservoir location I,

L = fish length in environment, and

z = fish depth in reservoir.

6. RESERVOIR SURVIVAL ASSOCIATED WITH GB

The reservoir survival resulting from gas bubble disease only is defined is:

Equation 7: Survival with Gas Bubble Disease

$$S_{j,k} = \exp\left(-M_{i,k} \cdot t_{j,k}\right)$$

Where:

$S_{j,k}$ = survival without predation in reservoir k on day j,

$M_{j,k}$ = TDG mortality rate at a specific level of supersaturation in reservoir k on day j, and

$t_{j,k}$ = exposure time in reservoir k on day j.

Evaluation

The TDG metrics characterize the impacts to fish at different levels of specificity. The reach average involves a model of physical production of TDG and a biological model of the travel time of fish through reservoirs. The TDG production model (RESSIM) was developed by the Corps group and the fish travel time model was developed by the University of Washington (Zabel 1994) and consequently refined and further calibrated by NOAA (Zabel et al. 2008). The fish mortality metric applies the TDG exposure metrics to model the direct mortality due to the exposure. This metric has additional levels of uncertainty because the rate of mortality requires dissolved gas supersaturation (DGS), which depends on fish depth. These metrics provide a numerical ranking of the impacts of alternative hydrosystem operations on exposure of juvenile migrants. The relationships of the metrics to actual direct and latent mortality resulting from TDG exposure have not been determined.

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CHAPTER 2 - CONCEPTUAL ECOLOGICAL MODELS

2.1 INTRODUCTION

2.1.1 Conceptual Ecological Models

Conceptual ecological models (CEMs) are non-quantitative planning tools that identify the major drivers and stressors on natural systems and sensitive populations. The ecological effects of these stressors and the best predictive attributes or metrics of these ecological responses are used to evaluate effects of potential actions in the system. CEMs can be used with any ecological restoration and conservation program and can become a communication, planning, and assessment tool for decision making and alternative evaluation. A set of CEMs has been developed for listed and sensitive fish species within the Columbia River basin as a tool for conducting qualitative evaluations of the effects of alternatives on these fish species. CEMs were created for species that were either listed under the Endangered Species Act or were identified as species of concern within the watershed. These include:

Anadromous Species

Spring/Summer-Run Chinook

Fall-Run Chinook

Steelhead

Sockeye

Coho

Chum

Pacific Lamprey

Eulachon

Green Sturgeon

Resident Species

Bull Trout

Kootenai River White Sturgeon

Burbot

Redband Rainbow Trout

Westslope Cutthroat Trout

White Sturgeon

Each CEM was built from extensive literature reviews that document the processes that drive the relationships between critical life stages and the habitat elements for each fish and show

how controlling factors ultimately influence these critical life history stages. Line thickness in the CEM shows the strength of the relationship, while line color shows the current understanding of the relationship. Reference sections for each species are also included.

How to Read a CEM: Become familiar with the CEM from the bottom up, and then follow the arrows from the top down. The bottom row of boxes (in gold) indicate the life stages that an individual of the species must successfully complete in order to move on to the next stage and ultimately complete its life history and contribute to the population. The next row (green boxes) above these life history boxes are biological processes that affect that indiviual's ability to complete the life history outcome of the boxes below them. The third row up (pink boxes) represent habitat elements that influence the life history elements. Habitat elements can be either an element necessary to a life stage, or one that affects the success of that life stage either adversely or beneficially. Finally, the blue boxes in the top row indicate the controlling factors, or drivers, that determine or affect the habitat elements. Arrows in the model are the links showing the flow of influence from drivers to habitat elements to critical processes, and finally to life stage success. Three different line thicknesses are used to indicate high, medium, or low magnitude of effect or influence, and the color of the line indicates the level of understanding, or scientific certainty, of that particular link. Note that links can also flow between boxes in the same row if, for example, one driver influences another. For a simple example, in the Spring/Summer Chinook salmon CEM below, the controlling factor "Hydrosystem Structures and Operations" influence the habitat element "Physical Barriers" that can impede "Habitat Access" and "Upstream Migration" processes necessary for an adult to complete "Return Migration" and "Spawning".

It is important to note that the CEMs include all controlling factors (both human-caused and natural) that affect the species to give a sense of the "big picture" of effects; the scope of the EIS analyses, however, is focused on only those controlling factors that are determined by the configuration and operation of the CRS. CEMs were developed on a general scale at the species level. While it would be very difficult and time-consuming to develop these at a more local or regional scale, they serve as a good starting point for developing relationships of environmental factors that can be controlled by the CRS and may change under the various alternatives and how that may affect fish at the ESU/DPS or the fish community level. This is the basis of the qualitative analyses used in this EIS.

The remainder of this section are the CEMs that were developed in this process, followed by the references used to inform the process.

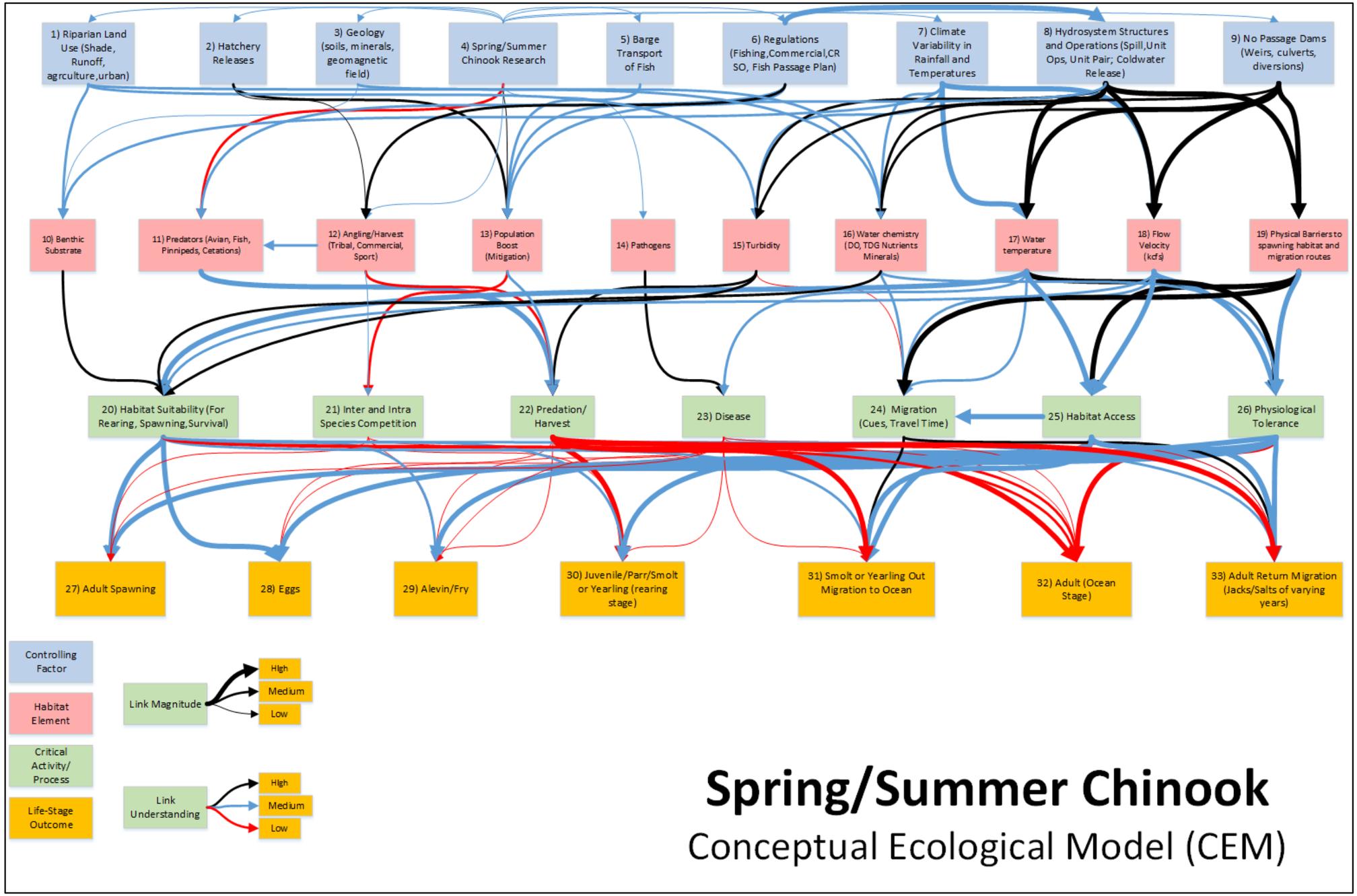

Figure 2-1. General Conceptual Ecological Model for Spring/Summer Chinook Salmon.

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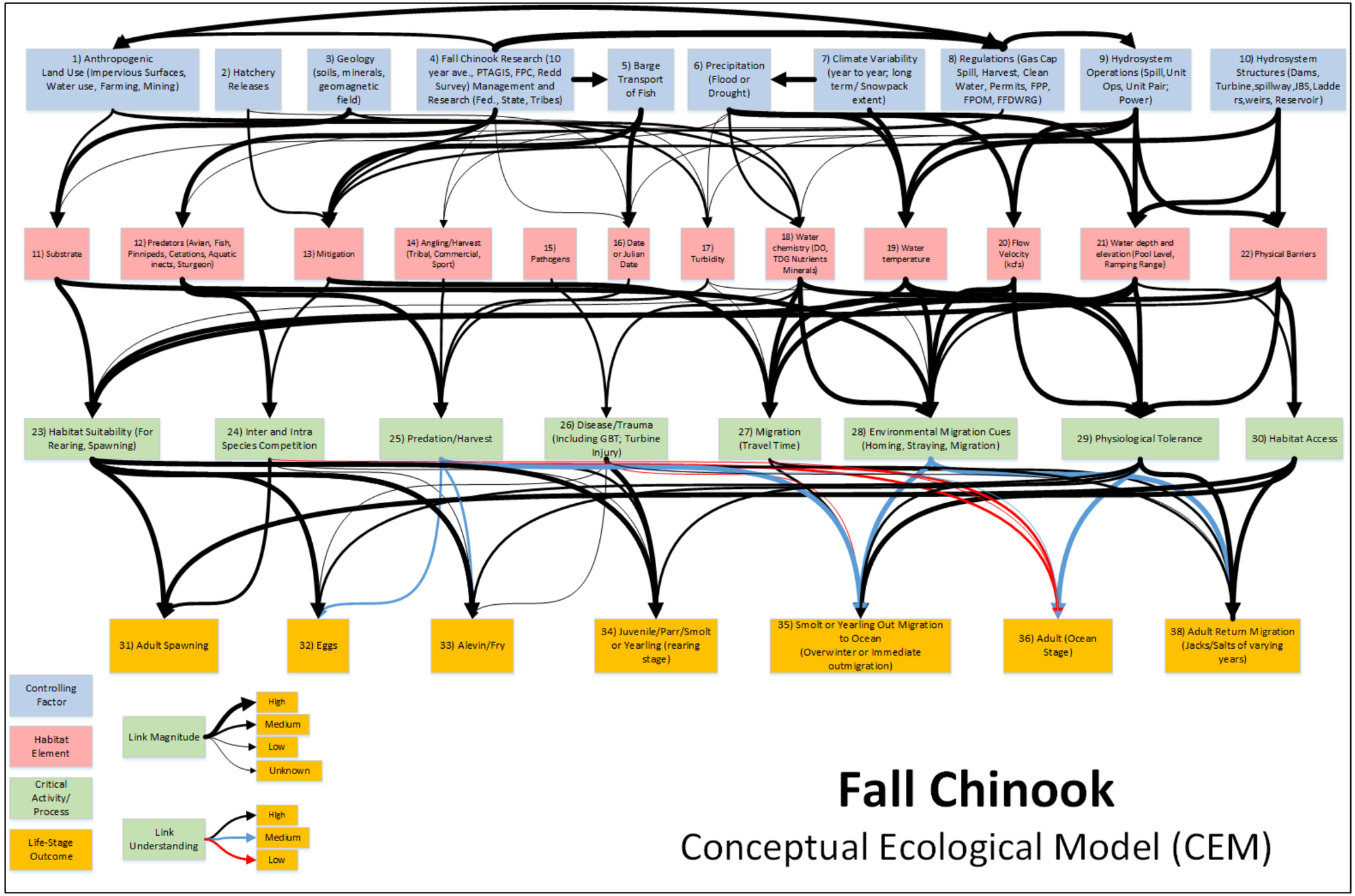

Figure 2-2. General Conceptual Ecological Model for Fall Chinook Salmon

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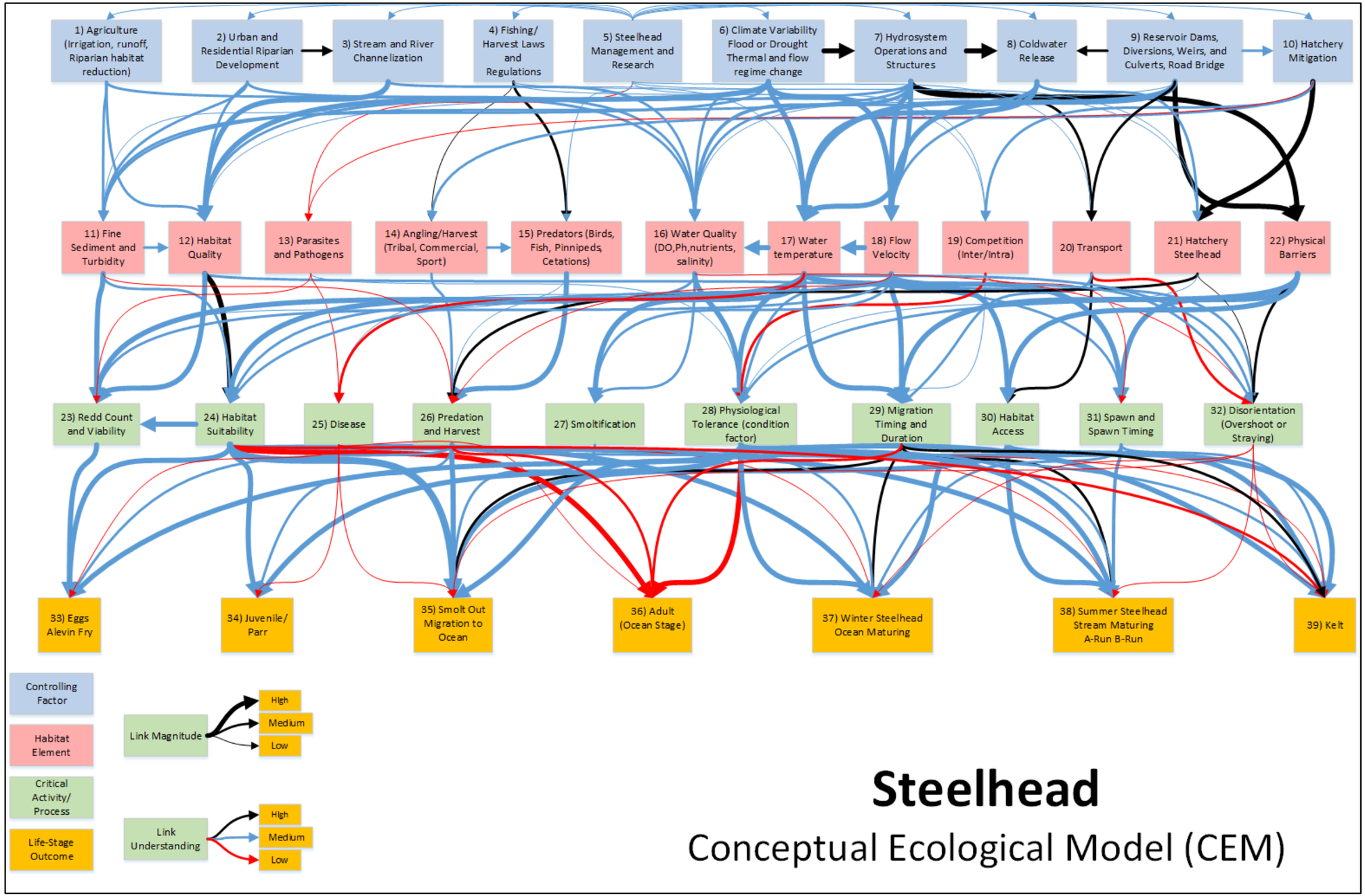

Figure 2-3. General Conceptual Ecological Model for Steelhead

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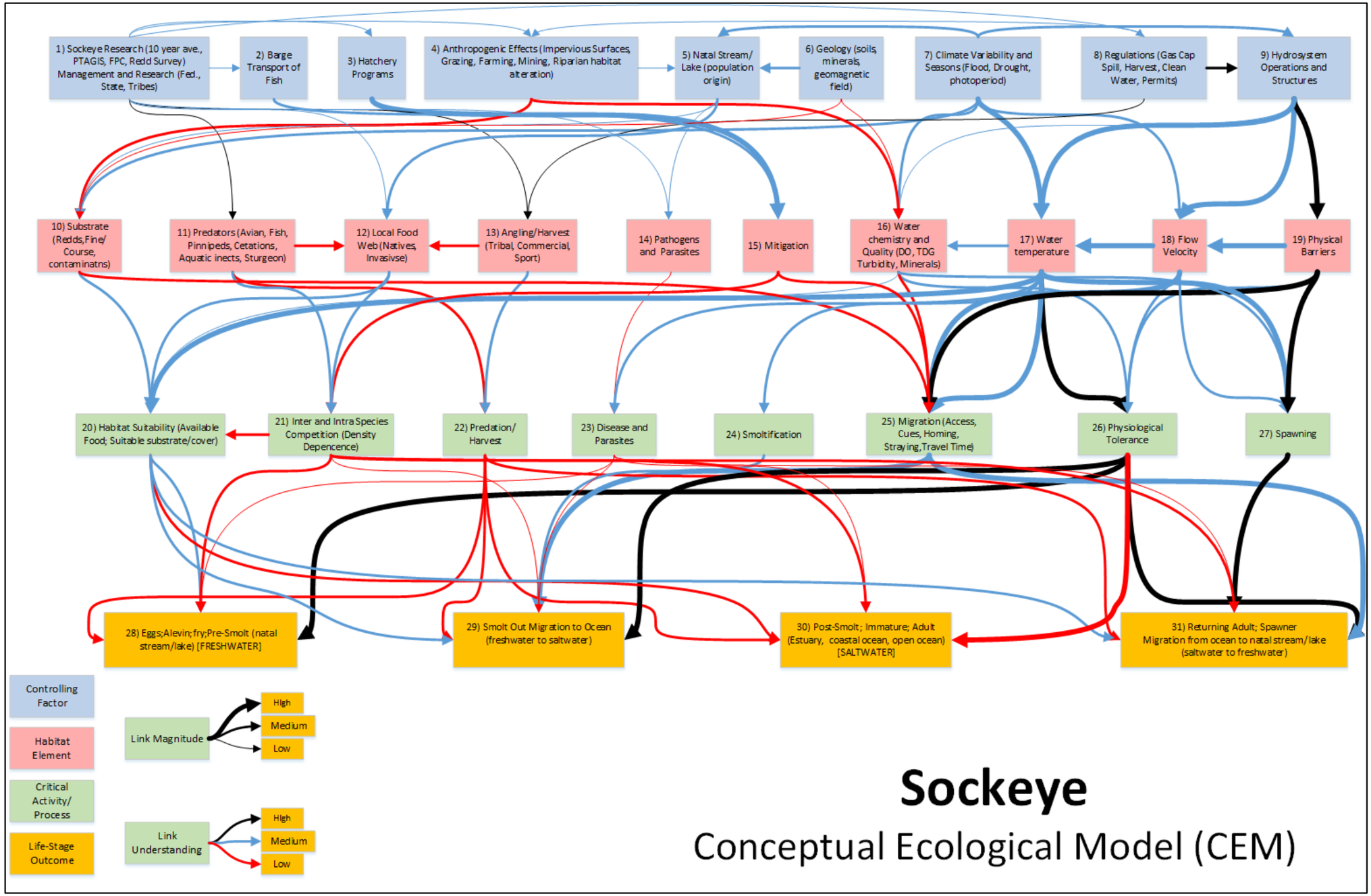

Figure 2-4. General Conceptual Ecological Model for Sockeye Salmon

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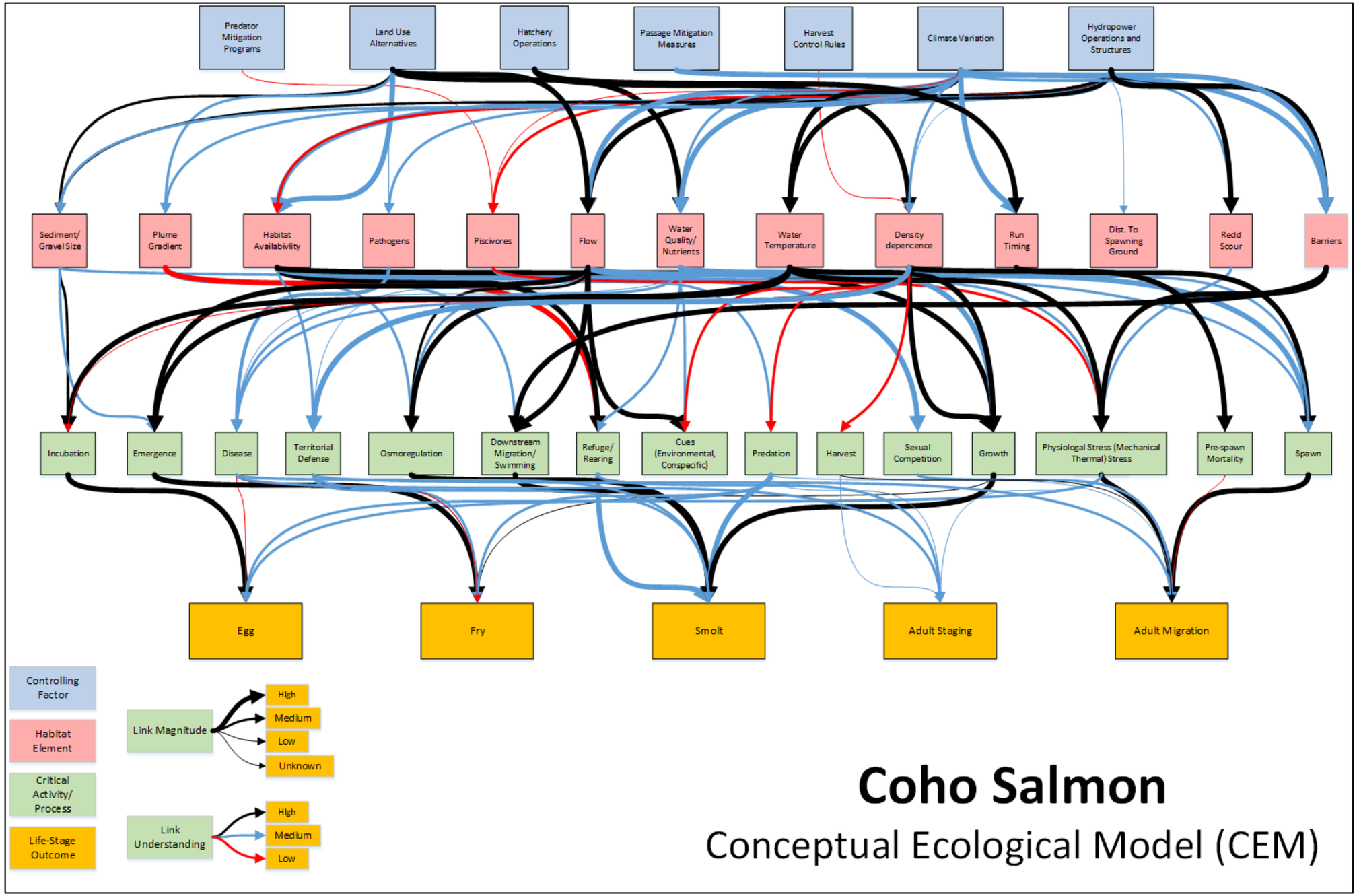

Figure 2-5. General Conceptual Ecological Model for Coho Salmon

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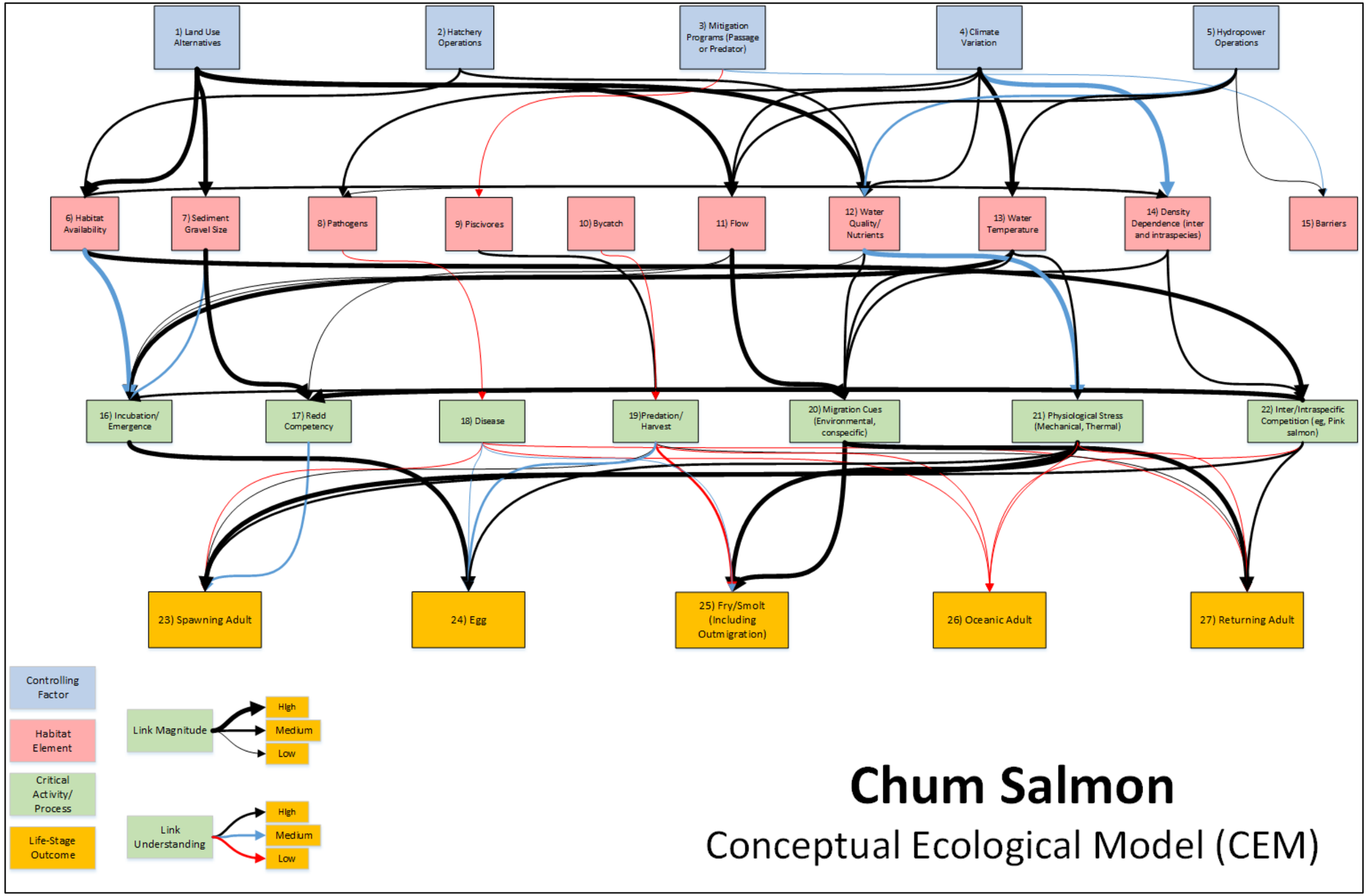

Figure 2-6. General Conceptual Ecological Model for Chum Salmon

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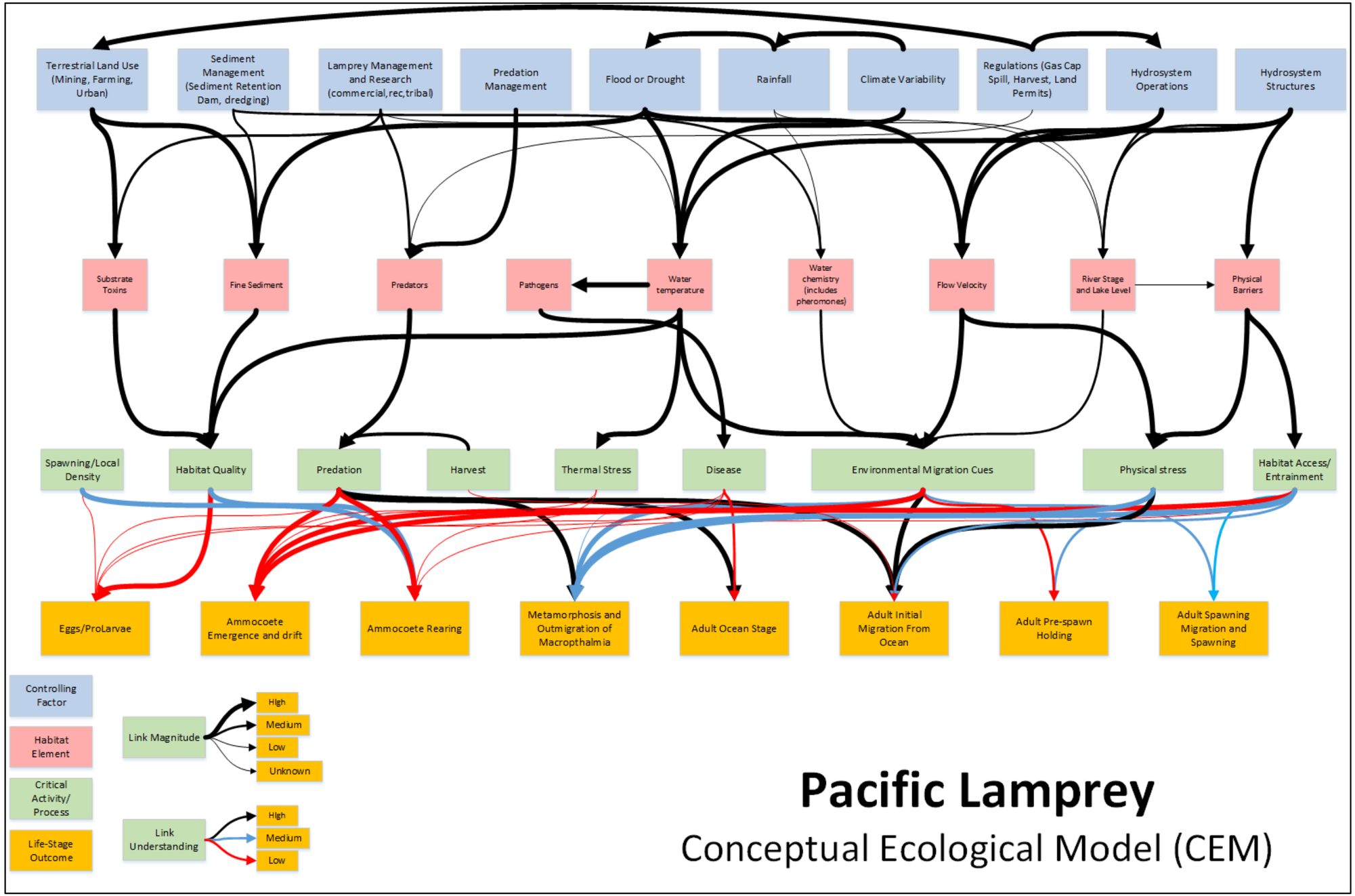

Figure 2-7. General Conceptual Ecological Model for Pacific Lamprey.

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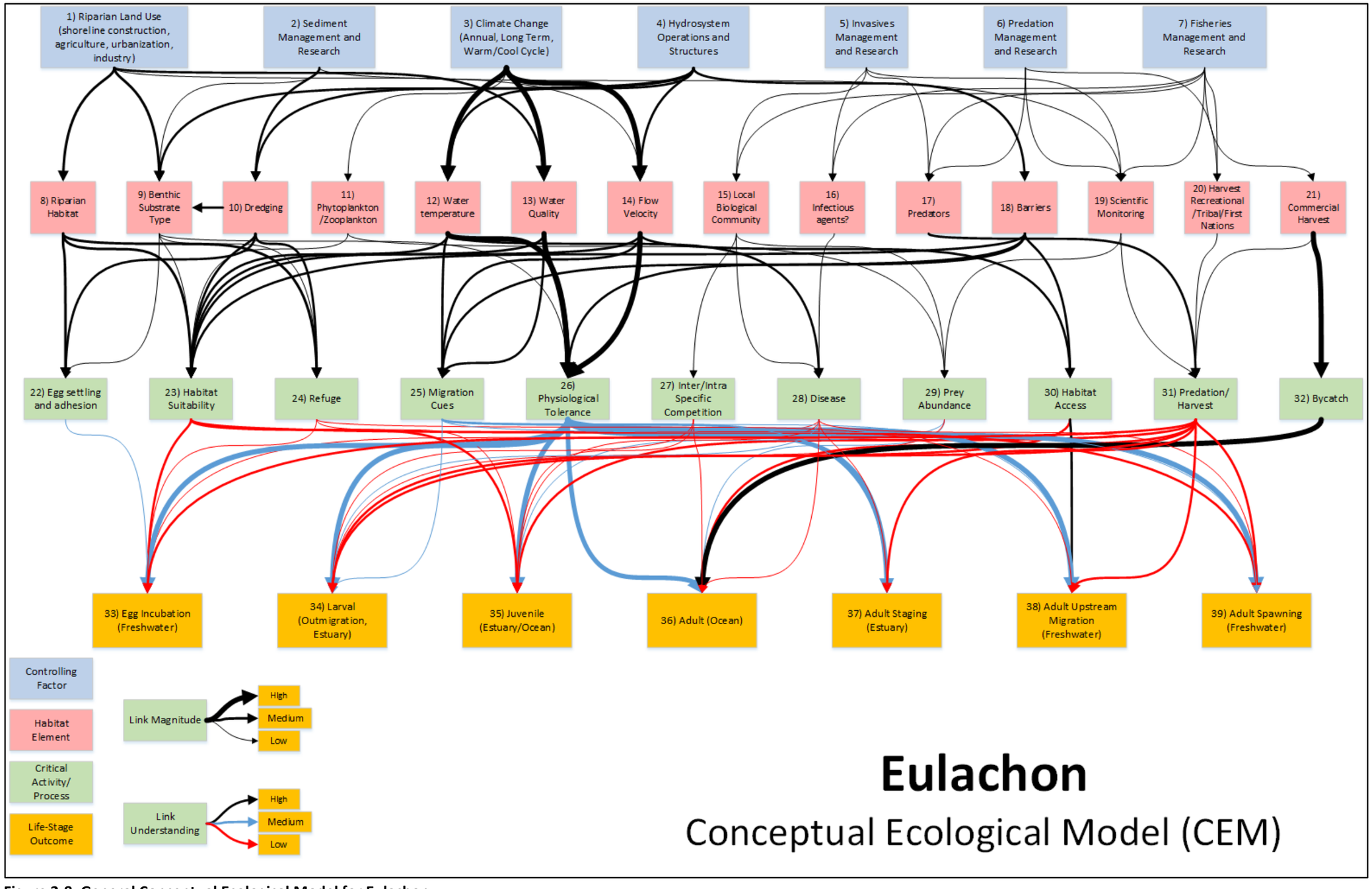

Figure 2-8. General Conceptual Ecological Model for Eulachon.

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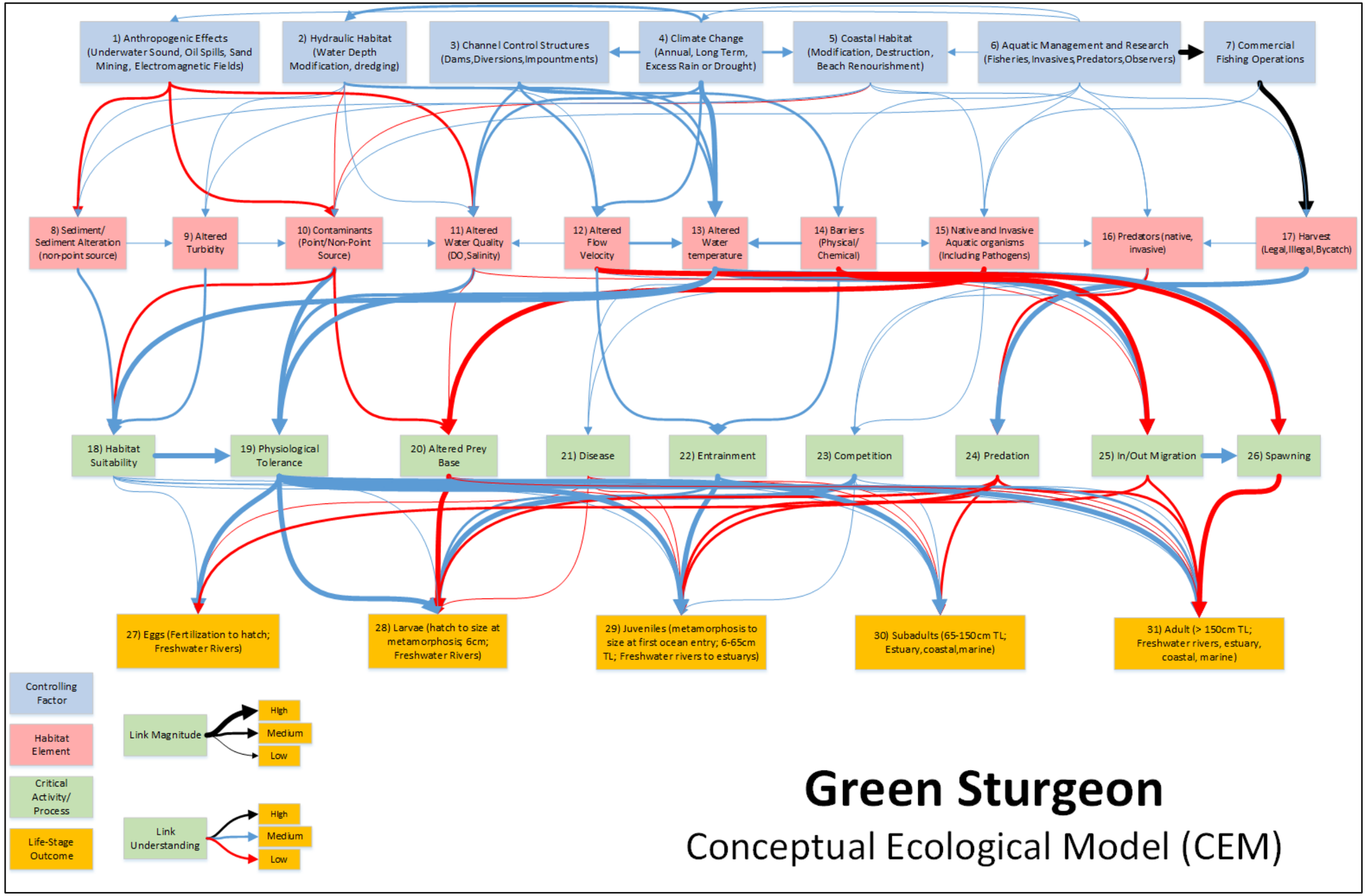

Figure 2-9. General Conceptual Ecological Model for Green Sturgeon

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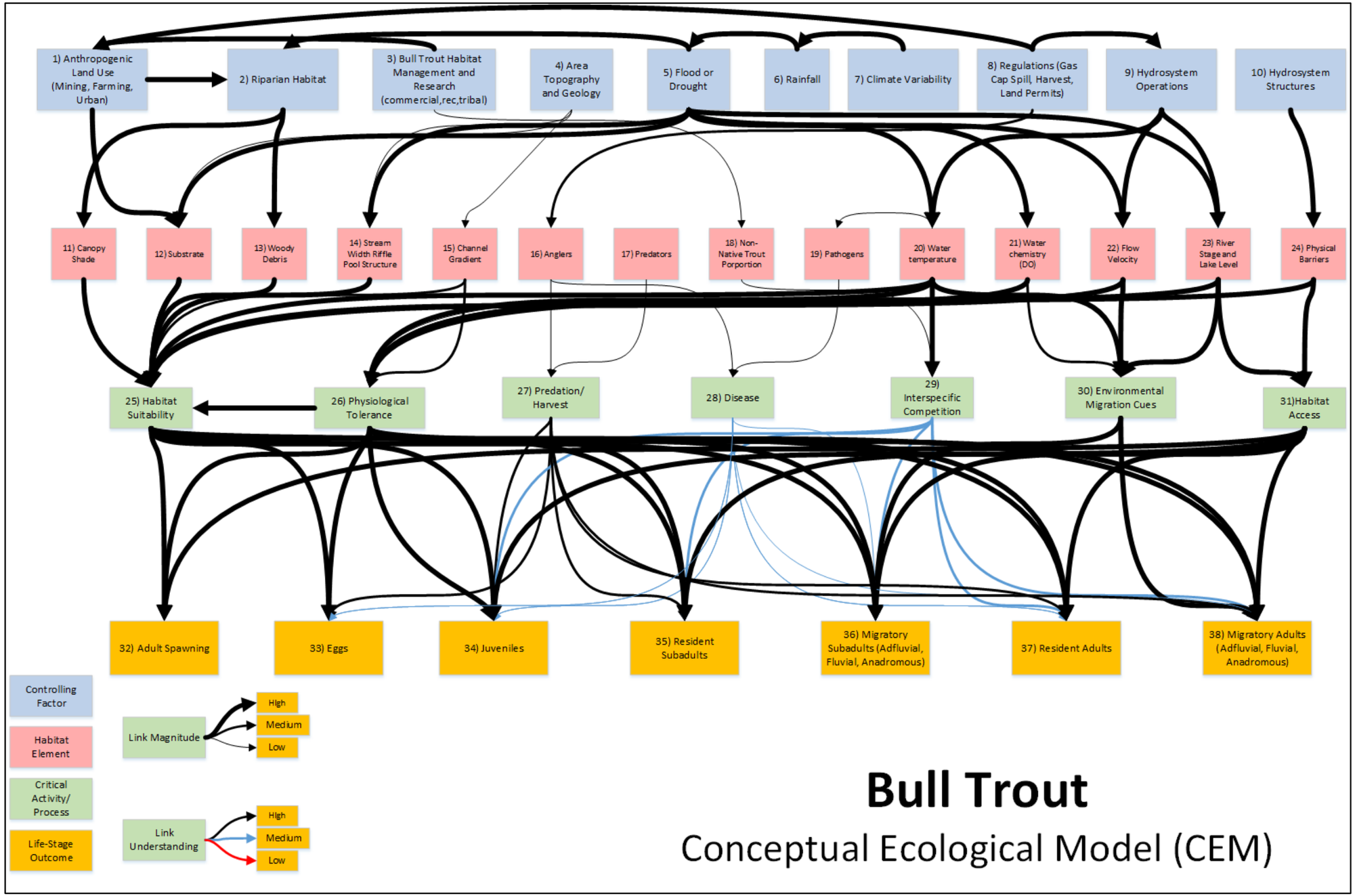

Figure 2-10. General Conceptual Ecological Model for Bull Trout.

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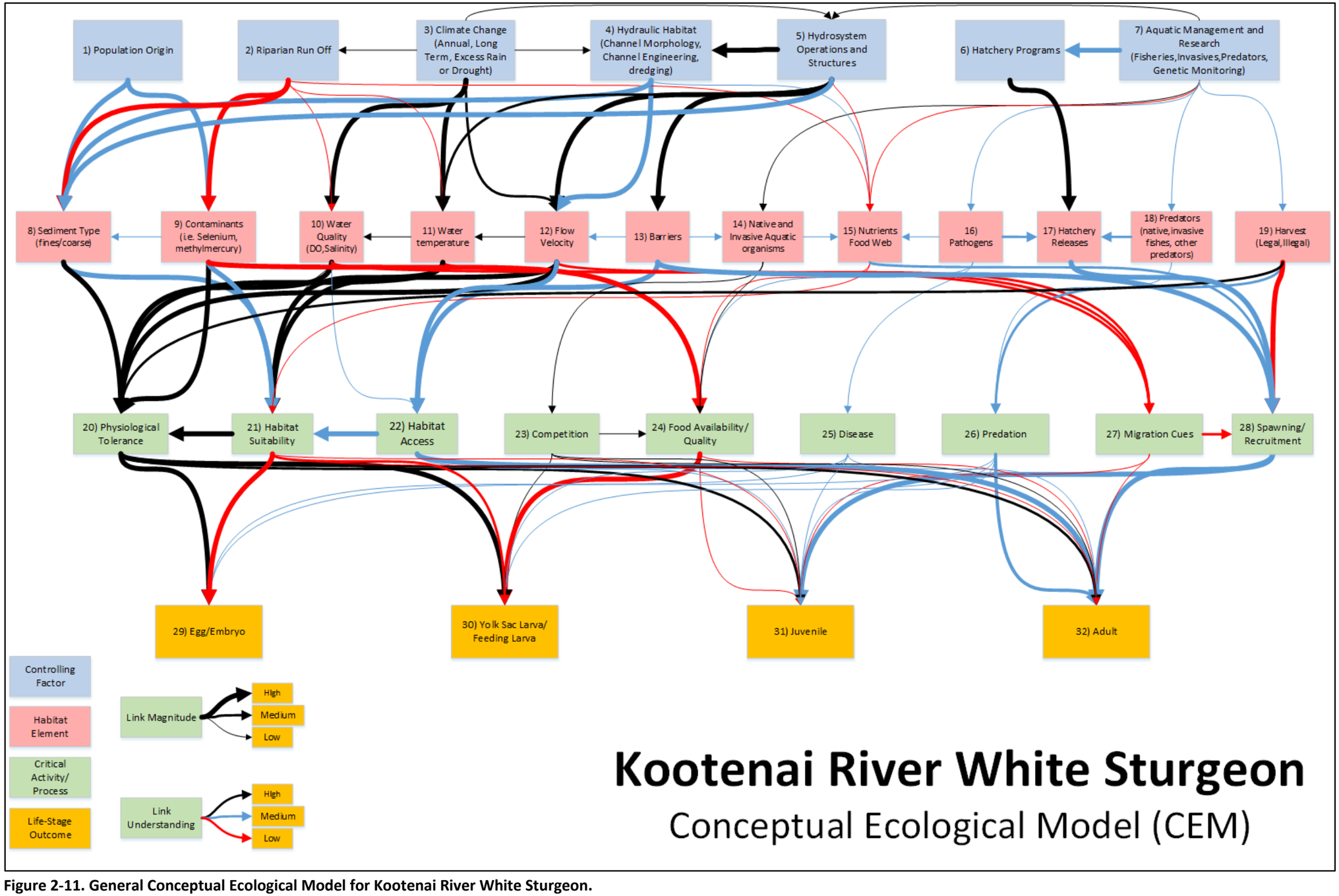

Figure 2-11. General Conceptual Ecological Model for Kootenai River White Sturgeon.

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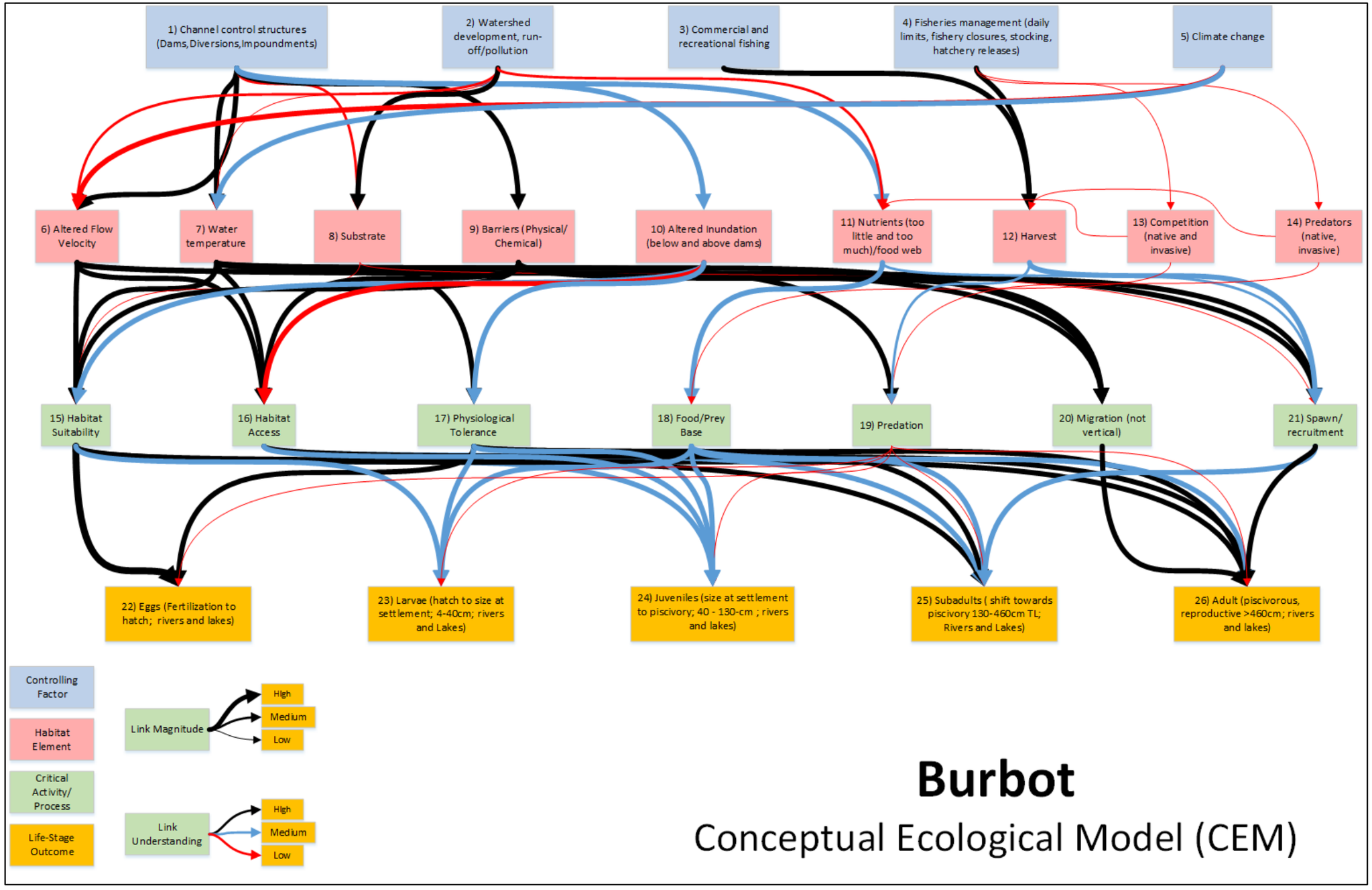

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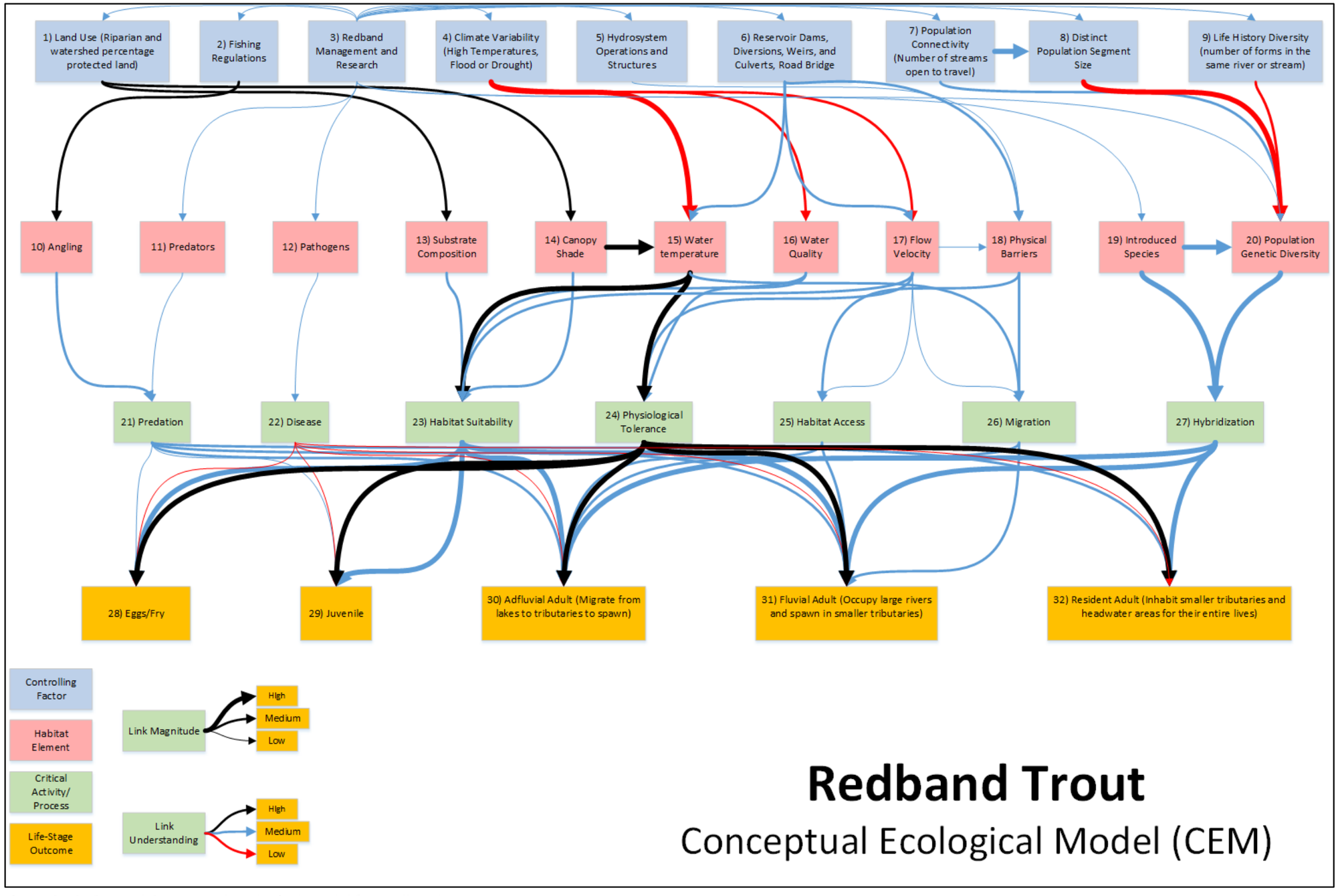

Figure 2-13. General Conceptual Ecological Model for Redband Trout.

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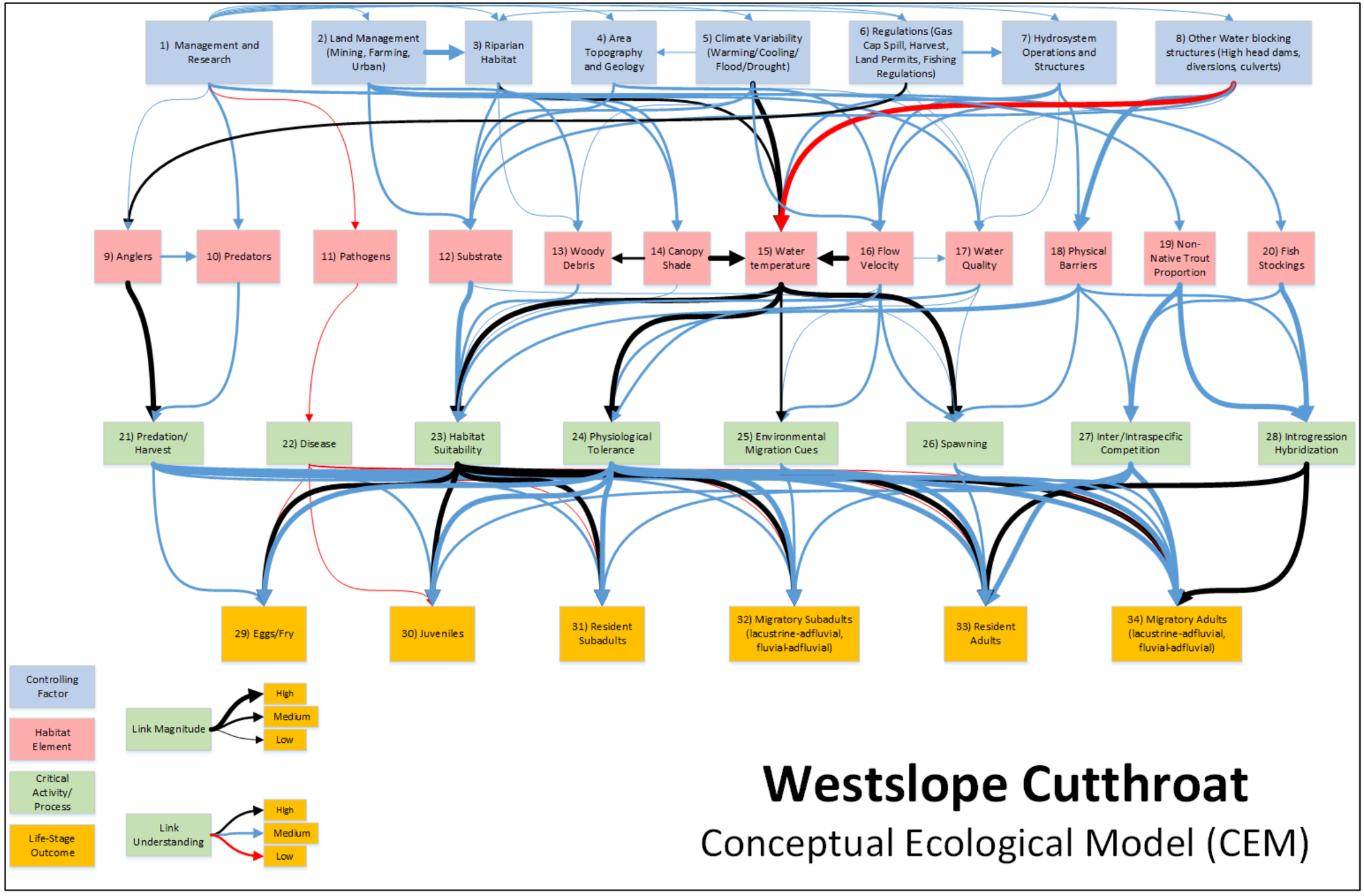

Figure 2-14. General Conceptual Ecological Model for Westslope Cutthroat Trout.

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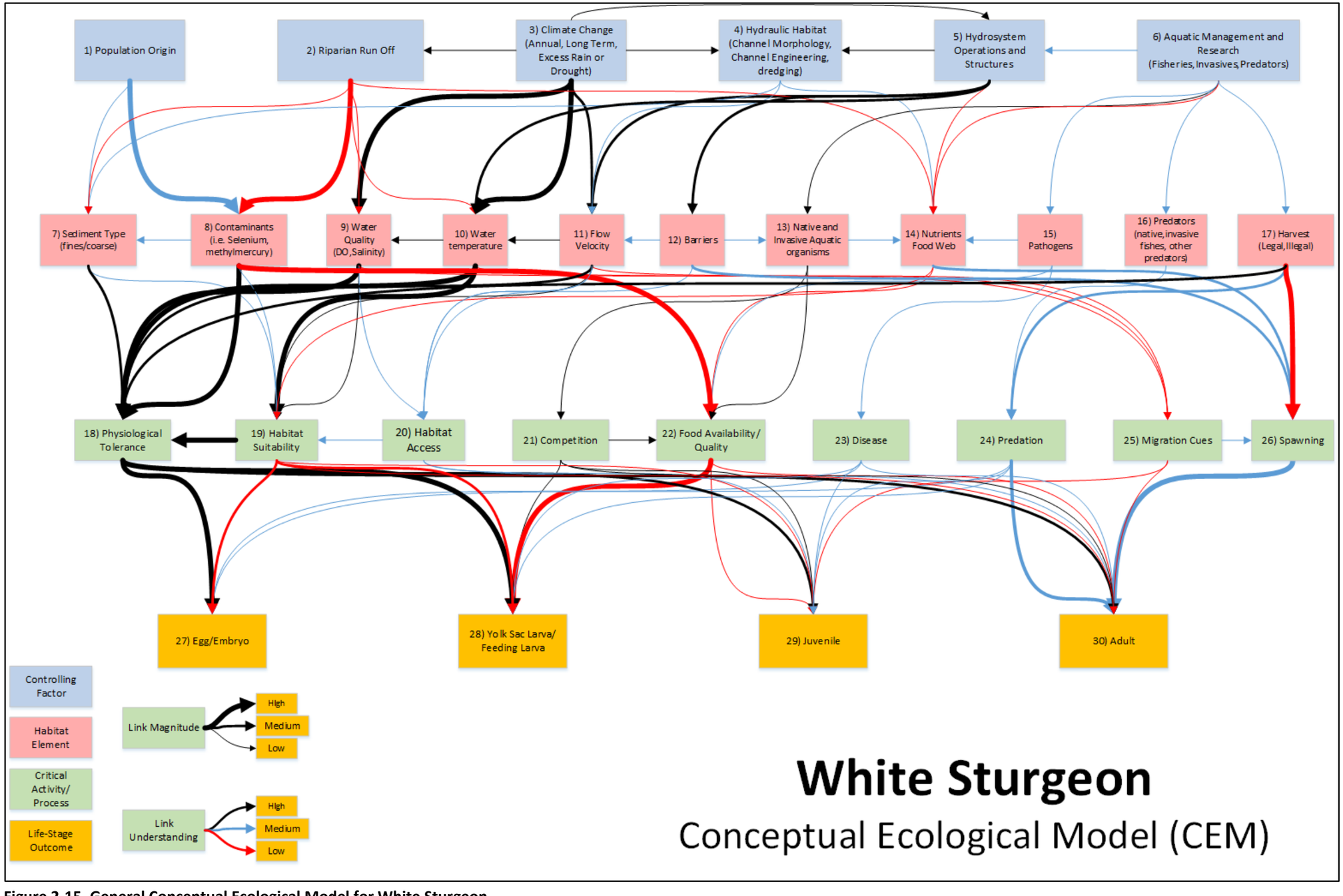

Figure 2-15. General Conceptual Ecological Model for White Sturgeon.

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2.17 QUALITATIVE ANALYSES

CEMs illustrate the relationships between controlling factors (drivers), environmental factors, critical processes, and life history requirements at the species level. In this EIS, many species or communities were analyzed using the relationships in the CEMs to inform qualitative analyses that was done in a combination of individual (by fish team members) and workshop settings using matrices to document analyses. Some species, such as Pacific eulachon, green sturgeon, lamprey, etc. was done at that species level. Other species were analyzed on a more regional or local scale, such as sockeye salmon that were analyzed in different workgroups for Upper Columbia sockeye salmon and Snake River sockeye salmon, for example. Still others, as in the case of resident fish, were analyzed in workgroups organized by regions and fish were considered at the fish community level to understand how they interact with one another and the environmental factors. Some key species were documented on a dedicated matrix in these communities and others were lumped into groups such as “gamefish” or “native fish” for analysis documentation. Finally, white sturgeon are understood to exhibit both anadromous and resident behaviors; they are discussed and documented under resident fish in the different regions in this EIS, but in Region D (below McNary Dam) they were analyzed in the same workgroup as lower river anadromous species such as green sturgeon and Pacific eulachon.

As mentioned, qualitative analyses was guided and documented using a matrix. A sample of the matrix columns are shown, for illustrative purposes, for analyzing the effects of just one parameter. In this example, as many rows as necessary were populated with important relationships between environmental factors and the fish life history stages. This relationship and criteria (if known) are documented in the first column and the second column is for the metric that was used to measure the change to that relationship. The fish team used outputs, either numerical or qualitative, from the Hydrology and Hydraulics, Water Quality, Sediment, and other teams as appropriate to determine the effects on the fish resource under evaluation. The output for the No Action Alternative would be captured as shown, and the group discussed what the effects of No Action are, based upon model outputs and current knowledge informing what would be expected if the NAA operations and configurations continued into the future. Notes that did not necessarily describe the effect but informed the discussion were captured in the notes column. The data for the same parameter for an alternative, again from hydrology or water quality modeling, or in some cases qualitative outputs, for the Alternative under consideration was documented and the team then discussed the effects of that change and information was documented in the same manner.

Table 2-1. Sample Matrix Analysis Table.

Relationship/Criteria	Metric	NAA Data	NAA Effects	NAA Notes	Alt 0 Data	Alt 0 Effects	Alt 0 Notes
Higher flows in May result in further upstream movements of species X, which increases spawning success.	May mean monthly flows at McNary Dam	205kcfs	Current level of spawning success would continue	Monitoring results show good success.	195kcfs (5kcfs lower)	Adverse effect due to decreased May flows	Spawning success known to drop x% in years with less than 200kcfs flows.

In this hypothetical and simplified example, it was established that higher flows increases spawning success, and the best metric to measure that is the mean monthly flow in May at McNary Dam; spawning is successful under the NAA, but the Alternative 0 would reduce average flows in May by 10kcfs and this would be expected to reduce spawning success. This example shows just one relationship; several key relationships and their relative importance were developed and discussed, as needed, to complete a thorough analysis of the fish resource. For each alternative, columns were added to the matrix and the same process followed.

Typically the description of the resources (Affected Environment), the important relationships/criteria and metrics, and the effects of the NAA were developed in one workshop, and subsequent workshops and followup work was completed as data became available for each of the four Multi-Objective alternatives (MO1, MO2, MO3, MO4). The workshops were led by fish team leads or subbasin leads for some resident fish sections, and teams were formed by self-selection based on interest and expertise. For example, a workgroup would typically include a team lead, co-lead agency members with expertise in that particular species or area, and cooperating agency members with expertise, interest, or managing authority. The team lead prepared and organized information, such as data and other resources, for the workshops and teams worked together to complete the analyses. Additionally, in some cases as the group worked through the analyses of alternatives they would identify additional resources or information that would strengthen it and this further work was completed either individually by a fish team lead or member or small groups and brought back to the team for further discussion. Species-specific or region-specific methods that were developed through the process are further described either in the matrices or introductory information in the Data/Results section of this appendix. Teams were generally able to come to agreement on effects, but if there were dissenting opinions these were captured in the matrix. After the workshops, the work team was given an opportunity to review the matrices, then they were used to draft the effects analyses sections in Chapter 3.5.

CHAPTER 3 - DATA AND RESULTS

3.1 UPPER COLUMBIA RIVER SALMON AND STEELHEAD

3.1.1 Upper Columbia Spring-Run Chinook Salmon

3.1.1.1 COMPASS Results

Table 3-1. Summary results for Upper Columbia River spring Chinook by Alternative.

Alternative	Mean Survival (RIS to BON)	Mean Survival (MCN to BON)	SD survival (year-to-year)	Mean Arrival at BON	Proportion Destined for Transport	Mean Gas Exposure	Proportion Powerhouse Passage	Mean Traveltime (RIS-MCN) (Days)	Mean Traveltime (MCN-BON) (Days)	Mean Migration Rate (RIS-MCN) (mi/day)	Mean Migration Rate (MCN-BON) (mi/day)	Mean Temp Experience (RIS-Hanford)	Mean Temp Experience (Lower Columbia)	Mean Flow Experience (RIS-Hanford)	Mean Flow Experience (Lower Columbia)	Mean Gas Experience (RIS-Hanford)	Mean Gas Experience (Lower Columbia)	Avg. Num Bypasses	Avg. Num Turbine Passages	Avg. Num Spill Passages
NAA	0.5007	0.6947	0.03233	147.76	0.00	0.5007	0.471	14.52	6.05	13.48	29.62	12.16	15.02	164.07	293.22	103.35	115.83	1.11	2.18	3.71
MO1	0.5038	0.7000	0.03436	147.79	0.00	111.40	0.440	14.75	5.79	13.29	30.07	12.19	15.05	159.26	288.18	102.97	115.84	0.97	2.11	3.92
MO2	0.4956	0.6868	0.03718	148.12	0.00	104.44	0.523	14.58	6.33	13.68	30.47	12.13	15.06	161.66	291.81	100.77	105.73	0.73	2.93	3.34
MO3	0.5087	0.7061	0.03444	147.37	0.00	103.19	0.413	14.75	5.39	13.52	33.01	12.13	14.96	158.85	286.53	100.80	102.76	0.81	2.09	4.11
MO4	0.5117	0.7101	0.03045	147.12	0.00	112.69	0.362	14.55	5.29	13.44	31.95	12.16	14.96	163.74	291.32	102.14	119.05	0.71	1.82	4.47

3.1.1.2 TDG Tool Results

Table 3-2. Mean survival, Reach Average Exposure (RAE), and number of days (80 year) when RAE is greater or equal to 120% TDG for Upper Columbia River juvenile Spring Chinook from MCN – BON

Alternative	Survival (%)	RAE TDG %	No. Years RAE >= 120%
NAA_UC	97.7	115.9	4
MO1_UC	97.8	116	3
MO2_UC	98.8	113	2
MO3_UC	97.6	116.7	3
MO4_UC	95.8	119.3	27

3.1.1.3 Life Cycle Model Results

Northwest Fisheries Science Center (NWFSC) Life Cycle Modeling (LCM) uses COMPASS inputs to produce estimates of adult return metrics for one population (Wenatchee) of Upper Columbia Spring Chinook salmon. This information was used as an indicator to compare the adult returns of the Upper Columbia Spring-Run Chinook salmon ESU across the alternatives.

Table 3-3. NWFSC Life Cycle Model Upper Columbia River Spring-Run Chinook Salmon SAR (Rock Island to Bonneville) Results.

Alternative	Juvenile Survival	SAR
NAA	0.501	0.0094
MO1	0.504	0.0095
MO2	0.491	0.0093
MO3	0.504	0.0095
MO4	0.512	0.0096

Table 3-4. Quantiles of the Geometric Mean Abundance (across all years) for Wenatchee River Spring-Run Chinook Salmon.

Alternative	2.5 Quantile	25 Quantile	50 Quantile	75 Quantile	97.5 Quantile
NAA	161	323	498	733	1641
MO1	166	345	526	812	1622
MO1 + 10% LM	189	378	570	870	1677
MO1 + 25% LM	209	465	690	1043	2023
MO1 + 50% LM	276	557	822	1228	2415
MO1 + 100% LM	690	1562	2174	2986	4978
MO2	152	321	482	723	1546
MO3	153	328	519	781	1593
MO3 + 10% LM	189	405	636	957	1844
MO3 + 25% LM	230	576	882	1278	2483
MO3 + 50% LM	371	816	1228	1749	3298
MO3 + 100% LM	1685	3134	4245	5570	8768
MO4	170	347	513	785	1599

Alternative	2.5 Quantile	25 Quantile	50 Quantile	75 Quantile	97.5 Quantile
MO4 + 10% LM	195	441	673	990	1886
MO4 + 25% LM	260	582	901	1306	2442
MO4 + 50% LM	420	897	1308	1829	3269
MO4 + 100% LM	1804	3285	4422	5715	8664

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3.2 UPPER COLUMBIA RIVER STEELHEAD

3.2.1 COMPASS Results

Table 3-5. Summary results for Upper Columbia River Steelhead by Alternative

Alternative	Mean Survival (RIS to BON)	Mean Survival (MCN to BON)	SD survival (year-to-year)	Mean Arrival at BON	Proportion Destined for Transport	Mean Gas Exposure	Proportion Powerhouse Passage	Mean Traveltime (RIS-MCN) (Days)	Mean Traveltime (MCN-BON) (Days)	Mean Migration Rate (RIS-MCN) (mi/day)	Mean Migration Rate (MCN-BON) (mi/day)	Mean Temp Experience (RIS-Hanford)	Mean Temp Experience (Lower Columbia)	Mean Flow Experience (RIS-Hanford)	Mean Flow Experience (Lower Columbia)	Mean Gas Experience (RIS-Hanford)	Mean Gas Experience (Lower Columbia)	Avg. Num Bypasses	Avg. Num Turbine Passages	Avg. Num Spill Passages
NAA	0.4782	0.6575	0.03473	147.65	0.00	111.63	0.389	7.79	6.63	29.98	25.09	12.46	14.89	168.00	299.03	103.29	115.90	1.12	1.60	4.28
MO1	0.4748	0.6559	0.03781	147.91	0.00	111.46	0.370	8.14	6.66	29.38	24.96	12.47	14.95	163.09	294.78	102.89	115.91	1.03	1.56	4.41
MO2	0.4660	0.6395	0.03775	147.53	0.00	104.34	0.413	7.86	6.44	31.33	26.50	12.42	14.87	165.40	296.73	100.54	105.88	0.83	2.06	4.11
MO3	0.4808	0.6621	0.03775	147.62	0.00	103.03	0.360	8.08	6.46	30.83	26.60	12.41	14.84	162.55	293.49	100.61	102.64	0.96	1.56	4.48
MO4	0.4817	0.6610	0.03165	147.54	0.00	112.78	0.331	7.65	6.63	30.12	25.09	12.45	14.89	168.40	298.18	102.07	119.21	0.88	1.43	4.69

3.2.2 TDG Tool Results

Table 3-6. Mean Reach Average Exposure (RAE) results for Upper Columbia River juvenile Steelhead in Lower Columbia reach (MCN – BON)

Alternative	RAE (%)
NAA_UC	116
MO1_UC	116.1
MO2_UC	113.1
MO3_UC	117
MO4_UC	119.6

Table 3-7. Mean survival results for Upper Columbia River juvenile Steelhead in Lower Columbia reach (MCN – BON)

Alternative	Survival (%)
NAA_UC	96.9
MO1_UC	96.9
MO2_UC	98.1
MO3_UC	96.3
MO4_UC	93.9

Table 3-8. Counts of years when Reach Average Exposure (RAE) is greater than, or equal to 120% for juvenile Upper Columbia Steelhead in Lower Columbia reach (MCN – BON)

Alternative	Counts of years when RAE is >= 120% for Lower Columbia (MCN-BON)
NAA_UC	5
MO1_UC	4
MO2_UC	2
MO3_UC	3
MO4_UC	34

3.3 UPPER COLUMBIA RIVER COHO SALMON

Table 3-9. Upper Columbia River Coho Salmon Qualitative Effects Analysis Matrix

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Effects to Resource NAA	Effects to Resource MO1	Effects to Resource MO2	Effects to Resource MO3	Effects to Resource MO4	Notes
Juvenile passage at the four lower Columbia River dams affects in-river survival rate (MCN to BON) of juvenile coho salmon returning to the upper Columbia River (upstream of MCN).	Juvenile upper Columbia River spring Chinook salmon as surrogate for juvenile coho response for this metric. Reference survival for upper Columbia coho (UC/Yakima) No Action Alternative. Estimate change in in-river survival (e.g., MO1-NAA/NAA) for juvenile Snake River spring Chinook as surrogate for coho using COMPASS and CSS in-river survival estimates.[1]	2007-2017 MCN to BON average upper Columbia River coho in-river survival (95% lower and upper confidence intervals) from Widener et al. (2018), Table 33: 86% (75% to 96%)	See change in upper Columbia River spring Chinook salmon downstream passage.	See change in upper Columbia River spring Chinook salmon downstream passage.	See change in upper Columbia River spring Chinook salmon downstream passage.	See change in upper Columbia River spring Chinook salmon downstream passage.	Widener et al. (2018), Table 33, for in-river survival estimate for UC/Yakima coho. Re-grouping to combine cohorts for this EIS was performed by Dan Widener in 2019 for purposes of NAA estimate of in-river survival. Another citation from previous year annual report: Faulkner, James R., Daniel L. Widener, Steven G. Smith, Tiffani M. Marsh, and Richard W. Zabel. NOAA, April 2017, Appendix B9-10.
Predation in reservoirs – changes in the LGR to BON reservoir environments (relative to the NAA) may change the susceptibility of Snake River juvenile coho salmon to avian and piscine predators.	Susceptibility of juvenile coho to predators (avian and piscine) in reservoirs. The fish team will also evaluate measures that affect the predation rate. Change in piscine predator activity is captured at least in part by COMPASS in-river survival response (juvenile upper Columbia spring Chinook) above and does not need duplication or double counting. Metrics: 1) Change in proportion turbine passage (an increase may signify higher susceptibility to predation); 2) Improved fish passage (IFP) turbines (this measure should pass fish with less impact than non-IFP turbines); and 3) Change in travel time (an increase may signify higher susceptibility to predation).	1) 0.82 average turbine passages for upper Columbia River spring Chinook salmon from Rock Island to BON (COMPASS). 2) IFP turbines at IHR and MCN, not JDA. 3) Travel time 6.1 days juvenile upper Columbia Chinook salmon average travel time from MCN to BON (COMPASS). CSS estimates only for LGR to BON travel time and powerhouse passages (bypass, turbine, ITS routes combined.	1) and 3) See change in upper Columbia River spring Chinook downstream passage. 2) IFP turbines from NAA, also JDA.	1) and 3) See change in upper Columbia River spring Chinook downstream passage. 2) IFP turbines from NAA, also JDA.	1) and 3) See change in upper Columbia River spring Chinook downstream passage. 2) IFP turbines from NAA, also JDA.	1) and 3) See change in upper Columbia River spring Chinook downstream passage. 2) IFP turbines from NAA, also JDA.	Tiffan and Connor (2018) for piscine predators; BPA project reports – pikeminnow sport reward and USGS reports OSU and RealTime Research reports for avian predation Collins et al., 1998 Ward, 1996
Adult upstream passage at the four lower Columbia River dams affects in-river survival rate of adult upper Columbia River coho salmon.	Use adult upper Columbia River fall Chinook salmon passage analysis as proxy for adult coho passage considerations.[2]	Adult survival estimate BON to MCN for upper Columbia River coho or upper Columbia River fall Chinook salmon.	See change in fall Chinook salmon upstream passage for MO1.	See change in fall Chinook salmon upstream passage for MO2.	See change in fall Chinook salmon upstream passage for MO3.	See change in fall Chinook salmon upstream passage for MO4.	CP: For fall Chinook there are two Jeff Fryer projects – tribes tag juvenile fall Chinook at Vernita Bar (would need to ask for upstream survival), and project 200851800 also tags fall Chinook salmon.

[1]Coho-specific dam survival measurements are not available, but coho-specific in-river survival estimates are available for current system conditions. There are no coho-specific models available to predict changes in these metrics from CRS alternatives. However, survival models that project changes in these metrics based on changes in hydrosystem operation and configurations are available for spring Chinook salmon and steelhead (COMPASS, CSS). Coho salmon outmigration timing generally overlaps with both spring Chinook salmon and steelhead, and all three species have dominant stream-type life histories. However, the size of juvenile coho and juvenile spring Chinook salmon tend to be more closely aligned than juvenile steelhead. Therefore, juvenile spring Chinook salmon

will be considered the appropriate surrogate for juvenile coho salmon for purposes of qualitative effects analysis of changes in passage. This use of juvenile Snake River spring Chinook salmon as a surrogate for juvenile lower Columbia River coho salmon is consistent with the 2008 FCRSP BiOp, 2013 Recovery Plan, and 2019 CRS BiOp.

[2]Dam survival and reach survival measurements specific to adult coho are not available for the previous 10-year period. Adult Coho salmon upstream migration timing general overlaps with fall Chinook salmon, through fall Chinook salmon migration timing tends to start earlier in some years (DART). Far more adult fall Chinook salmon enter the CRS system than Coho salmon adults, so survival estimates generally have higher certainty for the former than the latter. Adult fall Chinook salmon will be considered the appropriate surrogate for adult coho salmon for purpose of qualitative effects analysis of changes in passage. This use of adult Snake River fall Chinook salmon as a surrogate for adult lower Columbia River coho salmon is consistent with the 2008 FCRPS BiOp, 2013 Recovery Plan, and 2019 CRS BiOp.

NOTE ABOUT OCEAN SURVIVAL: The CSS (2017) makes no prediction in terms of survival benefits for lower Columbia River, upper Columbia River, or lower Snake River coho salmon. The CSS predicts that increased spill could substantially reduce latent mortality of juvenile yearling Chinook salmon and steelhead moving downstream through the mainstem dams. If this were to occur for coho salmon, SARs would also be improved for the XX populations that pass above XX dams and migrate during the spring, and the potential benefit would generally be less than what may occur for species that experience passage through a greater number of Columbia and Snake River mainstem dams (NMFS, 2019). The COM

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3.4 UPPER COLUMBIA RIVER SOCKEYE SALMON

Table 3-10. Columbia River Sockeye Salmon Qualitative Effects Analysis Matrix

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Effects to Resource NAA	Effects to Resource MO1	Effects to Resource MO2	Effects to Resource MO3	Effects to Resource MO4	Notes
Juvenile Mainstem Passage							
Juvenile travel time corresponds with juvenile survival.	Downstream travel time (PRD to BON): Surrogates Chinook. Survival of surrogates	Travel Time = 20.56 Days Juvenile fish will survive at similar rates under the NAA.	Travel time = 20.54 Days No change from NAA	Travel time = 20.91 Days - 8 hours longer. Negligible change from NAA	Travel time = 20.14 Days - 10 hours shorter. Negligible change from NAA	Travel time = 19.84 days is 3.0% shorter than NAA (~ 17 hours shorter) Minor decrease from NAA should lead to minor increases in survival	Flow Augmentation water may be more effective in low water years. * Can the team get travel times by water years?
Transport as juveniles results in more fallback and longer migration time, and more straying during upstream adult migration (Crozier et al., 2018). This relationship is much weaker for Upper Columbia River sockeye.	Percent of juvenile sockeye transported, fallback rates.	No transportation of CR sockeye now. The component of fallback attributed to sockeye is not an issue in the NAA.	No transportation of CR sockeye now. No change from the NAA.	Transport potential at MCN. Transportation at MCN would increase juvenile survival and decrease adult delay. Look at MCN transport data for Sockeye. May use a different collection system.	No transportation of CR sockeye now. No change from the NAA.	No transportation of CR sockeye now. No change from the NAA.	Straying, not shown a correlation with transport, but assume more fallback causes more straying. Few PIT tags in juvenile CR sockeye, so difficult to monitor. Fallback relationship to transport is much weaker in UC Sockeye. Transported fish have higher juvenile survival.
Flows can affect downstream juvenile migration rates.	Low Flow (75th percentile?) at MCN from Apr 15 - Jun 15. Migration Rate May want to look at bracketing the major portion of the migration.	75% Flow at MCN (Apr 15 - Jun 15) is 208,432 cfs. Mean Travel time is 20.57 days RIS to BON. Use Migration rate alone? Under the NAA sockeye would continue migrate at the current rates.	75% flow at MCN (Apr 15 to Jun 15) is 203,038 cfs Under driest 25% of years MO1 has slightly lower flows during outmigration. Mean TT is 20.54 days RIS to BON (No change).	75% flow at MCN (Apr 15 to Jun 15) is 204,824 cfs Under driest 25% of years MO2 has slightly lower flows during outmigration than NAA. Mean TT is 20.91 days RIS to BON (No change).	75% flow at MCN (Apr 15 to Jun 15) is 202,827 cfs Under driest 25% of years MO3 has the lowest flows during migration. Mean TT is 20.14 days RIS to BON (No change).	75% flow at MCN (Apr 15 to Jun 15) is 208,944 cfs. Under driest 25% of years MO4 has the highest flow during migration. Mean TT is 19.84 days RIS to BON (fastest). Under low flow years expect to see larger difference from NAA.	Dates specific to Rock Island tagged fish - encounters at McNary. Wenatchee fish arrive earlier than Okanagan fish, but not a strong relationship. Low Flow years more critical - review 25th percentile for differences. There does not appear to be a correlation between mean flow at MCN from mid Apr to mid Jun and migration rate. Why does migration in PUDs take so much longer than MCN to BON?
Predation in reservoirs – changes in the reservoir environment (relative to the NAA) may change the susceptibility of juvenile sockeye to avian and piscine predators.	Risk of predation to piscine predators. Use temperature during outmigration (Apr 15 - May 31 at MCN) as a surrogate for piscine predation. Use habitat increase or decrease for avian predators (See below)	Mean Water temperature April 15 - May under NAA is 12.03C degrees (SD 2.17). Under the NAA an unknown number of juvenile sockeye will be removed from the population by piscine predators. Literature estimates that smallmouth bass, Walleye, and NPM	Mean Water temperature April 15 - May under NAA is 12.06C degrees (SD 2.15). No change from NAA	Mean Water temperature April 15 - May under NAA is 12.05C degrees (SD 2.13). No change from NAA.	Mean Water temperature April 15 - May under NAA is 12.05C degrees (SD 2.12). Under MO3 piscine predator numbers may be reduced or experience significant habitat alterations because of high sediment and low dissolved oxygen concentrations during	Mean Water temperature April 15 - May under NAA is 12.05C degrees (SD 2.12). No change from NAA.	Generally, temp results on predation are not expected to affect sockeye. Oregon looks at predation in terms of abundance x rate of predation. If measure is likely to change either abundance or rate, then assume changing. Then compensatory or additive. No abundance data. Note: change in piscine predator activity is captured at least in part by COMPASS (juvenile Chinook) via the temperature relationship.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Effects to Resource NAA	Effects to Resource MO1	Effects to Resource MO2	Effects to Resource MO3	Effects to Resource MO4	Notes
		remove large numbers of smolts. Erhardt et al. (2018) and Tiffen et al. (2018) found that SMB consumed over 300,000 sub adult chinook in a 22 km study reach. MCN pool is a predator refuge.			dam breaching on the Lower Snake River. The team expects displacement of some predators below the confluence for a short time. Overall there will be a decrease in risk to piscine predation at the time of breaching followed by gradual increases in risk.		
Avian predation – avian nesting habitat increases or decreases	Increase or decrease in avian nesting habitat.	Mean Water temperature April 15 - May under NAA is 12.03°C degrees (SD 2.17). Under the NAA, an unknown number of juvenile sockeye will be removed from the population by piscine predators. Literature estimates that smallmouth bass, Walleye, and northern pikeminnow remove large numbers of smolts. Erhardt et al. (2018) and Tiffen et al. (2018) found that smallmouth bass consumed over 300,000 sub adult Chinook in a 22-km study reach. MCN pool is a predator refuge.	Mean Water temperature April 15 - May under NAA is 12.06°C degrees (SD 2.15). No change from NAA	Mean Water temperature April 15 - May under NAA is 12.05°C degrees (SD 2.13). No change from NAA.	Mean Water temperature April 15 - May under NAA is 12.05°C degrees (SD 2.12). Under MO3, piscine predator numbers may be reduced or experience significant habitat alterations because of high sediment and low dissolved oxygen concentrations during dam breaching on the lower Snake River. The team expects displacement of some predators below the confluence for a short time. Overall there will be a decrease in risk to piscine predation at the time of breaching followed by gradual increases in risk.	Mean Water temperature April 15 - May under NAA is 12.0°5C degrees (SD 2.12). No change from NAA.	18°C is inflection point for survival/temp relationship. This relationship is not as strong for Upper Columbia Sockeye because they typically migrate 5 to 7 days earlier than Snake River Sockeye. Okanagan sockeye arrive when temps are > 21° C and hold in the mainstem. Fish hold in mainstem until they get a temperature break in the Okanagan and move up. Earlier runs do best. Cumulative stress of moving up through warm water in Columbia, then warm at confluence of Okanagan decreases survival and gamete viability.
Spill affects juvenile migration routes through the projects. Increased spill = faster travel time, beneficial to juveniles; potentially higher fallback and delays at BON. More spill = fewer powerhouse encounters? See Snake River sockeye metric for question on this one.	Surrogate in-river survival and SARs Chinook as surrogate Look at low flow years in separate analysis.	Average 50.1% in-river survival for juvenile Chinook Under the NAA sockeye survival is not expected to change.	Average 50.4% in river survival No change from NAA	Average 50.0% in river survival No change from NAA	Average 50.9% in river survival Minor increase in survival from NAA Turbidity levels may help survival of smolts Additional smolts from Snake River may also help with predator swamping.	Average 51.2% in river survival Minor increase in survival from NAA	Not much research done on Columbia River sockeye, use Snake River relationships. When do sockeye pass (Columbia River fish peak around 7pm and Snake River sockeye peak in afternoon). See CSS and Faulkner estimates for Snake River sockeye in-river survival and SARs. Potentially PITPH if available. Look at variability in flow years. Low flows may be more important than other years.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Effects to Resource NAA	Effects to Resource MO1	Effects to Resource MO2	Effects to Resource MO3	Effects to Resource MO4	Notes
Adult Mainstem Passage							
Higher water temperatures correspond to lower adult survival (less than 50% when water temperature is greater than 18°C). When Okanagan River gets to 21°C to 22°C, fish stop moving into Okanagan River. Survival then depends on temperatures in the Columbia River for survival.	Percent of total days mean temperature exceeds 18C at MCN and CHJ Jun through Aug Check variability of temperatures - MO3 fluctuations. July 1 - August.	MCN = 72.4% CHJ = 24.9% Temperatures would exceed 18°C at MCN dam (Jun-AUG) ~ 72% of the time and at CHJ dam 25% of the time. Some years, temperature will continue to have negative impacts to the species. Should expect 50% survival or less on hot years.	MCN = 73.0% CHJ = 25.7% No Difference from NAA	MCN = 73.0% CHJ = 26.6% Negligible increase of ~ 2 days over 18°C at CHJ MCN no change from NAA	MCN = 73.7% CHJ = 25.6% No change from NAA	MCN = 73.0% CHJ = 35.0% Minor increase - 10% increase in days over 18°C at CHJ - No Difference from NAA at MCN MCN augmentation water would run out in dry years and leave less water for later in the summer = more hot days and a decrease in Upper Columbia survival	18°C is inflection point for survival/temp relationship. This relationship is not as strong for Upper Columbia sockeye because they typically migrate 5 to 7 days earlier than Snake River sockeye. Okanagan sockeye arrive when temps are > 21° C and hold in the mainstem. Fish hold in mainstem until they get a temperature break in Okanagan and move up. Earlier runs do best. Cumulative stress of moving up through warm water in Columbia, then warm at confluence of Okanagan decreases survival and gamete viability.
Hydrosystem delays (operations and natural) result in migration period where unregulated corridor temperatures have become too warm. May need better or different metric to capture delay effects.	Arrival timing at PRD Mean Temp Jun 15 to Jul 31 and percent of Days over 18°C	On average temps reach 18°C at PRD on July 1. On this date, 74.4% of the run still remains. Mean temp Jun15-Jul31 = 18.06°C; % of days over 18°C = 52.4 A proportion of the run (74.4 %) would reach PRD after the river reaches 18C. This proportion of sockeye run may experience delays due to the arrival timing/warm temperatures correlation.	On average temps reach 18°C at PRD on July 1. On this date, 74.4% of the run still remains in river. No difference from NAA Mean temp Jun15-Jul31 = 18.04°C; % of days over 18°C = 48.7 ~ 1.5 days less. Slight reduction in heat induced stress under MO1 compared with NAA.	On average temps reach 18°C at PRD on June 30. On this date, 79.2% of the run still remains in river. No difference from NAA Mean temp Jun15-Jul31 = 18.05°C; % of days over 18°C = 48.8 ~ 1.5 days less. Slight reduction in heat induced stress under MO1 compared with NAA.	On average temps reach 18°C at PRD on June 30. On this date, 79.2% of the run still remains in river. No difference from NAA Mean temp Jun15-Jul31 = 18.10°C; % of days over 18°C = 49.5 ~ 1 days less. Slight reduction in heat induced stress under MO1 compared with NAA.	On average temps reach 18°C at PRD on June 30. On this date, 79.2% of the run still remains in river. No difference from NAA Mean temp Jun15-Jul31 = 18.23°C; % of days over 18°C = 49.8 ~ 1 days less. Slight reduction in heat induced stress under MO1 compared with NAA.	Can the team develop a relationship between temperature and arrival timing? Snake River Sockeye have different arrival timing but same temperature relationships. See Jeff Fryer reports. Arrivals early and late tend to do poorer than those in the middle of the run. Wenatchee run is earlier than Okanagan, but PIT shows Okanagan fish early and late, bigger run too. Could also be adapting to better conditions. Optimum temp/flows for fastest migration - Very low and hot = slow, low flow can lead to faster reservoir passage. This metric does not distinguish between the alternatives - Recommend deletion.
Temperatures cause migration delays where sockeyes are more susceptible to harvest (in harvest area for more time). More delay – later arrival and more likely to encounter war tributaries. Forced to hold in mainstem areas with anglers.	Temperature, compare alternative temp to NAA. Temp in Okanagan River relates to Wells pool staging. Okanagan River sockeye stage until temperatures drop in Okanagan River. Any alternative that changes the temperature would change risk of harvest for these fish. Do any of the alternatives have potential to change migration timing?	–	Temperature, compare alternative temp to NAA. Temp in Okanagan River relates to Wells pool staging. Okanagan River sockeye stage until temperatures drop in Okanagan River. Any alternative that changes the temperature would change risk of harvest for these fish. Do any of the alternatives have potential to change migration timing?	–	–	–	Temperatures in Wells pool and Okanagan river affect how long fish stage at the mouth where they are susceptible to harvest. Adults use Wells pool as thermal refugia until tributary temps cool and are conducive to survival. Delay is a function of tributary temperature and is generally unaffected by CRSO. Sockeye harvest is targeted to Mid-Columbia stocks. If Snake River stock is delayed they get into the harvest. Snake River harvest explicitly capped at 5% to 7% and Upper Columbia sockeye harvest kept at that level in fisheries on mixed stocks, so susceptibility to harvest may not change with temperature. Wells pool, if no temp barrier there is limited harvest. May also have higher temp tolerance, and shorter migration.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Effects to Resource NAA	Effects to Resource MO1	Effects to Resource MO2	Effects to Resource MO3	Effects to Resource MO4	Notes
Is the proportion of sockeye using navigation locks rather than fish ladders related to total migration survival, and does flow or temp influence use navigation lock? Crozier et al. (2016) shows detection efficiencies of between 88% and 98%. Likely a surrogate for NavLock passage ~ 1% at most.	If navigation lock use is a function of flow or temp, those are the metrics.	Output: Analyze ladder counts to estimate proportion of run using navigation locks, then compare with annual temp/flow data Ladder count at MCN and PRD ~ if PRD ladder count is higher than Nav lock fish must make difference. Effects: Proportions using NavLock and total adult survival do not change under the NAA.	–	–	–	–	Sockeye are known to migrate through navigation locks in significant numbers but proportion of the run using them, mechanisms influencing use, and effect on migration survival may not be known. Talk with Derek Fryer. Crozier et al. 2016 shows detection efficiencies of between 88% and 98%. Likely a surrogate for NavLock passage ~ 10% at most. Could not establish metric to determine differences. Recommend deletion.
TDG risk. To get at TDG in PUDs, look at forebay TDG at MCN. Make sure TDG is 90% for migration.	TDG: number of days over 120%, 125% at BON, MCN, CHJ	BON: 120 = 10.8%; 125 = 3.3% MCN: 120 = 6.8%; 125 = 2.1% CHJ: 120 = 0.0%; 125 = 0.0% Under NAA minor negative impacts expected to migrating Sockeye Salmon.	BON: 120 = 10.6; 125 = 2.9 MCN: 120 = 6.8; 125 = 1.8 CHJ: 120 < 0.1% ; 125 = 0.0% No difference from NAA	BON: 120 = 8.9; 125 = 2.4% MCN: 120 = 4.3; 125 = 1.2 CHJ: 120 < 0.0% ; 125 = 0.0% Negligible decrease in risk of gas bubble disease from TDG under MO2	BON: 120 = 10.7; 125 = 2.3% MCN: 120 = 9.4; 125 = 1.4 CHJ: 120 < 0.0% ; 125 = 0.0% No difference from NAA	BON: 120 = 25.8; 125 = 3.7 MCN: 120 = 13.3; 125 = 3.0 CHJ: 120 < 0.1%; 125 = 0.0% Minor Increase over those of NAA would increase risk of gas bubble disease	Sockeye are susceptible to TDG, could become an issue. Late 90's report. Check Chief Joe TDG. Should see higher TDG.
Structures affect upstream passage – spawning success. The Dalles ladder?	Look at structural measures again - are there any that should change delays?	Outputs: Spillway weirs may have greater potential for fallback - check on timing of current weir operation vs new weirs.	–	–	–	–	Delays at Tumwater Dam, but not much problem in the Columbia River dams. For Upper Columbia sockeye, fallback is highest at Bonneville then Wells. However, fallback is not significant predictor of survival for UC Sockeye. Not a predictor of effects at alternatives - Delete.
Flows affect adult migration. Sockeye migrate faster at higher flows, but are likely confounded by temperature. Flow is not a significant predictor of UC sockeye salmon survival. Use temperature instead.	Flows and temp links. Peak flow dates 90th percentile of high flows. datesadd temp.	–	No difference from NAA.	–	–	MO4 flows are slightly higher during early part of adult migration on low water years - expect a minor improvement in adult conversion.	–

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4868 ### *3.4.1.1 Upper Columbia River Summer/Fall-Run Chinook Salmon*

4869 **Table 3-11. Upper Columbia River Summer and Fall Chinook Qualitative Effects Analysis Matrix**

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Spawning, Incubation, and Egress							
Vernita Bar operations is in place to protect redds below Priest Rapids Dam.	Frequency of meeting Vernita Bar operation.	Frequency of meeting the operation = 100%. No change from NAA	Frequency of meeting the operation = 99.9%. No change from NAA.	Frequency of meeting the operation = 99.9%. No change from NAA.	Frequency of meeting the operation = 99.9%. No change from NAA.	Frequency of meeting the operation = 99.9%. No change from NAA.	Note: We always meet Vernita Bar operation unless VDL minimum. Mid-Columbia Fall Chinook only (not Upper Columbia River Summer/Fall or Lower Columbia Fall Chinook). Metric was not useful for separating alternatives.
Flow from CHJ October 1 to November 7 (spawning) and February 1 to March 15 (emergence) provides water depth for spawning and cleaning gravel for redds. Relevant for both dewatering and raising tailwater too high.	Option 1: Ordinary high water line in the Chief Joe tailrace from October 1-Nov 7 and Feb 1-March 15. Option 2: CHJ tailwater elevation (Oct 1 – Nov 7 and Feb 1 – March 15). Wildlife team assisting with this for #1, if not, will do #2.	In progress. See notes.	In progress. See notes.	In progress. See notes.	In progress. See notes.	In progress. See notes.	The Columbia River Bridge at Bridgeport, State Route 17 spanning Columbia River, Bridgeport, Douglas County, WA bridge is a flow constriction. Metric withdrawn, no meaningful change anticipated. Upper Columbia River Summer/Fall Chinook only (not Mid-Columbia Fall or Lower Columbia Fall Chinook)
Temperature relationship for spawning areas.	Change in water temperature in spawning areas in winter (October 1 - November 7). Temperatures over 20C reduce survival.	No expected change over next 25 years. High water temp. 303(d) listing for CHJ tailrace. In Lower Columbia (MCN-below Bonneville), climate change could increase summer temperatures, but otherwise no change expected, will remain on 303(d) list. No days over 20°C.	No expected change from NAA. No days over 20°C.	Similar or slightly cooler (1°-2°F), except Average Flow/ Average Temperature and Low Flow/High Temperature in the spring and early summer are expected to be 1°to 2°F warmer in CHJ tailrace. In Lower Columbia (MCN-below Bonneville), no expected change. No days over 20°C.	Slightly cooler (0.5°-2°F) in CHJ tailrace. In Lower Columbia (MCN-below Bonneville), possible diel and day-to-day variability, but little expected temperature change. No days over 20°C.	Little change except for low flow scenarios where spring/summer temperatures are 1.5°-3°F higher in CHJ tailrace. In Lower Columbia (MCN-below Bonneville), Little or no expected change. No days over 20°C.	Does a <3° F change produce a meaningful change for spawning? Placeholder: need literature for spawning temperature range. If so, metric would be frequency of deviation from spawning temp range. No impact from the metric for this effect. There are no days over20°C in any alternative for Oct and Nov. Upper Columbia Summer/Fall, Mid-Columbia Fall and Lower Columbia Fall Chinook (all three groups).
Elevated TDG may affect summer and fall Chinook salmon.	TDG in spawning areas from March 1 – Sept 1. March 1-Sept 1 covers emergence period when spill may affect spawning areas. Many juveniles between confluence of Okanogan and GCL. TDG over 120% would reduce egg and fry survival. Percent of days over 120% at MNC Forebay and CHJ TW.	Deflectors will continue to be operational. Will decrease forebay TDG; some violations to state/tribal water quality standards will continue. TDG. 303(d) listing likely to remain in place. Days TDG over 120% MCN = 0.7% CHJ = 0.0%	Days TDG over 120% MCN = 0.5% CHJ = 0.1% No change from NAA.	Days TDG over 120% MCN = 0.3% CHJ = 0.1% No change from NAA.	Days TDG over 120% MCN = 0.1% CHJ = 0.0% No change from NAA.	Days TDG over 120% MCN = 0.2% CHJ = 0.1% No change from NAA.	FPC TDG monitoring possibly; Chelan Public Utility Department reports may have differential effects of TDG on yearling/subyearlings. Smaller summer/fall or fall migrants tend to be smaller, may be more susceptible than yearlings to TDG. Rearing habitat for juveniles (in-river and hatcheries); degraded with elevated TDG, restricting upper part of shallow water. Metric is not effective at separating alternatives. Upper Columbia Summer/Fall, Mid-Columbia Fall and Lower Columbia Fall Chinook (all three groups)

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Juvenile Mainstem Rearing and Passage							
Juvenile rearing habitat (JDA pool).	Presence of the pool; May also add JDA flow/velocity or stage criteria, if relationship known.	Prof. Kennedy (UI), Jessica Miller? What proportion of Upper Columbia summer/fall Chinook are rearing/spending time in reservoirs? WDFW Andrew Murdock. Can be highly variable among brood years. Kirk will also check scales for life history strategies too.	–	–	–	–	Check Tiffan (2002) for flow/stage relationships. Model has several inputs, including bathymetry and local calculations like an HSI. Difficult to pull specific relationships tied to operations without running model with current bathymetry. No flow/ stage relationships in Tiffan (2002). The farther downstream, the faster Upper Columbia Summer/Fall Chinook migrate. Some rear while moving downstream. Most rearing habitat in the JDA pool is in the upper third, shallow water habitat. No information submitted on specific temp criteria or months in tech review. Criteria needed. Metric not used. Upper Columbia Summer/Fall and Mid-Columbia Fall Chinook only (not Lower Columbia Fall Chinook).
Water temperature in mainstem Lower Columbia River affects piscine predation rate during juvenile outmigration.	Water temperatures during outmigration period as surrogate for piscine predator activity at Lower Columbia projects. Use McNary as reference point for mainstem estimate. Mean Temperature and Percent days over 20°C from May 1 thru Aug 31 (90% of the run). Reported as relative risk of predation.	Average 18.1°C Days over 20°C = 41.6%	No change in temp. Mean Temp = 18.1°C Days over 20°C = 41.4% Piscine predation rate would not change under MO1.	No change in temp. Mean Temp = 18.1°C Days over 20°C = 41.4% Piscine predation rate would not change under MO1.	Mean Temp = 18.1°C Days over 20°C = 43.2% 2 More days over 20°C Negligible increase in predation rate under MO3.	No change in temp. Mean Temp = 18.1°C Days over 2°0C = 41.3% Piscine predation rate would not change under MO1. McNary measure is likely driving this, per water quality presentation.	Tiffan & Connor (2018) for piscine predators. FPC reports on columnaris; [Hyatt et al. (2003), Keefer et al. (2008); Keefer et al. (2019]. Smallmouth, pikeminnow, and walleye increasing; birds reduced. Warmer temperatures and concentrations of juveniles/predators at dam structures make juvenile salmonids more susceptible to piscine predators (channel catfish, walleye, pikeminnow, smallmouth bass. Affects survival via predation and increased energetic requirements; disease (columnaris). Compensatory mortality (swamping predators) - easier to account for spring migrants than fall chinook; not a metric per se but account for this in predation effects analysis/estimates. Note: no standard deviation available to estimate statistical significance. Upper Columbia Summer/Fall, Mid-Columbia Fall and Lower Columbia Fall Chinook (all three groups)

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Predation in reservoirs. Changes in the reservoir environment (relative to the NAA) may change the susceptibility of juvenile Upper Columbia Summer and Fall Chinook salmon to avian predation (gulls, cormorants, terns, pelicans). Blalock Island inundation measure in MO1 is designed to prevent nesting.	Travel time (exposure) and change in susceptibility to predation events. No Travel time estimates for these fish. No Surrogates used. Avian Habitat changes for qualitative analysis.	Estimate for travel time? Maybe can do water travel time as next best option if not fish travel time. Would need to caveat. NWFSC nor FPC have estimates from MCN-BON for NAA.	Travel time: Turbine passage would likely decrease with increased spill in MO1 ~ decreased travel time. Decrease in predation risk from Blalock island inundation measure.	Travel time: Turbine passage would likely increase with decreased spill in MO1 ~ increased travel time.	Travel time: In addition to other measures, JDA full pool will affect travel time. Turbine passage would likely decrease with increased spill in MO3 until July 31 ~ decreased travel time.	Travel time: Turbine passage would likely decrease with increased spill in MO4 ~ decreased travel time.	Compensatory mortality (swamping predators) - easier to account for spring migrants than fall chinook; not a metric per se but account for this in predation effects analysis/estimates. Turbines have been traditionally associated with higher injury/ mortality than other passage routes. Important: check how many juvenile migrants are coming out after July 31st. Check PUD reports too. Upper Columbia Summer/Fall, Mid-Columbia Fall and Lower Columbia Fall Chinook (all three groups)
Higher turbidity decreases predation rates. Higher turbidity within a range hides juveniles so predation rates would decrease.	(WQ) total suspended solids/turbidity metric.	No expected change over time for CHJ tailrace. From MCN-Warrendale, turbidity not expected to change over time, but highly dependent on watershed land-use practices.	No expected change relative to NAA.	No expected change relative to NAA.	No expected change relative to NAA until McNary pool. Snake River under MO3 is expected to show an increase in turbidity year round, but especially during runoff. Breaching of the lower Snake River dams may slightly decrease predation risk due to increased turbidity.	No expected change over time for CHJ tailrace. Drawdown to MOP may have minor turbidity impacts; impacts expected to be minor in large reservoirs.	Upper Columbia Summer/Fall, Mid-Columbia Fall and Lower Columbia Fall Chinook (all three groups).
BON – BON (Estuary, Plume, Ocean							
Rearing habitat in Columbia River estuary?	Change in shallow water habitat (SWH) availability downstream of Bonneville Dam. No Analysis conducted	Restoration monitoring reports for information. Maybe would use more under breach, but speculative. No Change in water elevation	In progress. See Wildlife Results No change from NAA	In progress. See Wildlife Results No change from NAA	In progress. See Wildlife Results No change from NAA	In progress. See Wildlife Results No change from NAA	Upper Columbia Summer/Fall, Mid-Columbia Fall and Lower Columbia Fall Chinook (all three groups)

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Adult Mainstem Passage							
Water temperatures above 20°C (68°F) can cause adult salmon to stop or delay their migration, may increase fallback at a dam, and may increase fish susceptibility to disease.	Frequency of mainstem water temperatures from Lower Granite to Bonneville that exceed 20°C (68°F) from July 1 – November 30. As measured at McNary tailrace. Average number of days exceeding 20°C in 80 year water record. Frequency of water temperatures from Lower Granite to Bonneville that exceed 20 °C (68 °F) from May 15 – October 31. MCN TW	Climate change could increase summer temperatures, but otherwise no change expected, Will remain on 303(d) list. Percent of Days over 20°C = 34.1% (57.6 Days)	No expected change. Percent of Days over 20°C = 34.3% (57.9 Days)	No expected change. Percent of Days over 20°C = 34.1% (57.6 Days)	Possible diel and day-to-day variability, but little expected change. Percent of Days over 20°C = 33.5% (56.6 Days)	Minor temperature increase during the summer in low flow years below McNary Dam, no expected change downstream to Warrendale. Percent of Days over 20°C = 34.1% (57.6 Days)	May be able to get a list of references from the EPA Coldwater Refuges report. Chinook have slightly higher thermal threshold relative to steelhead. Update: tentatively, draft in June/July and final in November 2019. Increased temperatures reduce survival and spawning success (gamete viability included). Increased adult straying with elevated temps (e.g. Deschutes/thermal refuges) - see Snake River Sockeye for DWA language for adults. Upper Columbia Summer/Fall, Mid-Columbia Fall and Lower Columbia Fall Chinook (all three groups). Metric did not separate alternatives.
Okanogan Upper Columbia Summer/Fall Chinook salmon will hold at mouth of Okanogan when temperatures are 21°C and above, and will not move upstream until temperatures in the Okanogan are below 21°C. Mainstem temperatures must stay below 20°C for holding area until Okanogan fish can pass.	Frequency of water temperatures exceeding 21°C (70°F) during summer – fall (July 1 – September 15) at Chief Joseph tailrace. Frequency of water temperatures exceeding 21°C (70°F) during summer fall at the mouth of the Okanogan. Measured broad-scale as change in Chief Joseph tailrace temperature relative to NAA.	No expected change. High water temp. 303(d) listing. Days above 21°C = 0.0%; over 20°C = 0.0%	No expected change. Days above 21°C = 0.0%; over 20°C = 0.0%	No expected change. Days above 21°C = 0.0%; over 20°C = 0.1%	Slightly cooler (0.5°-2°F) temperature in Chief Joseph tailrace. Days above 21°C = 0.0%; over 20°C = 0.0%	Little change except for low flow scenarios where spring/summer temperatures are 1.5°-3°F higher in Chief Joseph tailrace. Days above 21°C = 0.0%; over 20°C = 1.1% Slight increase in temperatures that may impact fish holding at the Okanogan River.	Upper Columbia Summer/Fall Chinook only (not Mid-Columbia Fall or Lower Columbia Fall Chinook)
Adult ladder differentials of ?2°C can delay adult migration.	Temperature difference between forebay and tailrace of =2 °C (=3.6 °F) from June 1 to September 30, Bonneville to McNary. Frequency of adult ladder temperature differentials of =2 °C (=3.6 °F)	Days of exceedance at MCN = 2.8%	Days of exceedance at MCN dam = 4.2%	Days of exceedance at MCN dam = 2.9%	Days of exceedance at MCN dam = 3.1%	Days of exceedance at MCN dam = 3.8%	Most work has been at the lower Snake projects; unclear if info is available for Lower Columbia. We don't know of any ladder delays in the Lower Columbia due to ladder differentials at this time. Upper Columbia Summer/Fall, Mid-Columbia Fall and Lower Columbia Fall Chinook (all three groups). Metric not effective in selecting an alternative.

Connor, William P., Kenneth F. Tiffan, James A. Chandler, Dennis W. Rondorf, Billy D. Arnsberg & Kelvin C. Anderson (2018): Upstream Migration and Spawning Success of Chinook Salmon in a Highly Developed, Seasonally Warm River System, Reviews in Fisheries Science & Aquaculture. https://doi.org/10.1080/23308249.2018.1477736.

Hyatt K.D., Stockwell M.M., Rankin D.P. (2003) Impact and adaptation responses of Okanagan River sockeye salmon (Oncorhynchus nerka) to climate variation and change effects during freshwater migration: stock restoration and fisheries management implications. Can. Water Res. J. 2003;28:689–713.

Keefer ML, Clabough TS, Jepson MA, Bowerman T, Caudill CC. 2019. Temperature and depth profiles of Chinook salmon and the energetic costs of their long-distance homing migrations. Journal of thermal biology. 2019 Jan 1;79:155-65.

Keefer et al., 2008

Tiffan, 2002

3.5 MIDDLE COLUMBIA RIVER SALMON AND STEELHEAD

3.5.1 Mid-Columbia Spring-Run Chinook Salmon

See Upper Columbia Spring Chinook Salmon COMPASS results

3.5.2 Mid-Columbia River Steelhead

See Upper Columbia Steelhead COMPASS results

3.6 SNAKE RIVER SALMON AND STEELHEAD

3.6.1 Snake River Spring /Summer-Run Chinook Salmon

3.6.1.1 COMPASS Juvenile Results

Table 3-12. Summary results for Snake River spring-summer Chinook by Alternative.

Alternative	Mean Survival	95% CI Survival	Mean Arrival at BON	Proportion Destined for Transport	Mean Gas Exposure	Proportion Powerhouse Passage	Mean Travel time (LGR-MCN) (Days)	Mean Travel time (MCN-BON) (Days)	Mean Migration Rate (LGR-MCN) (mi/day)	Mean Migration Rate (MCN-BON) (mi/day)	Mean Temp Experience (Snake)	Mean Temp Experience (Columbia)	Mean Flow Experience (Snake)	Mean Flow Experience (Columbia)	Mean Gas Experience (Snake)	Mean Gas Experience (Columbia)	Avg. Num Bypasses	Avg. Num Turbine Passages	Avg. Num Spill Passages
NAA	0.5037	0.4574-0.5444	136.35	0.3851	114.70	0.281	10.20	7.51	12.75	23.19	11.34	13.41	90.49	272.84	112.05	115.13	1.43	0.82	5.75
MO1	0.5096	0.4618-0.5519	136.18	0.3779	114.89	0.235	10.10	7.27	13.06	23.30	11.34	13.44	90.77	267.67	112.44	115.24	1.15	0.73	6.12
MO2	0.5010	0.4623-0.5344	135.39	0.4742	112.76	0.378	10.62	7.72	12.32	22.73	11.24	13.33	90.29	268.73	110.77	112.12	1.15	1.87	4.98
MO3-GRNIMN-WH	0.5510	0.4909-0.6070	137.78	0.0000	111.76	0.168	8.45	6.98	12.39	24.41	11.73	13.77	91.48	271.95	101.08	117.33	0.19	0.48	3.33
MO3-SAL-WH	0.5999	0.5476-0.6462	132.90	0.0000	111.45	0.165	4.65	7.50	20.28	22.43	11.22	12.95	88.97	258.67	101.01	116.86	0.18	0.48	3.34
MO3-SAL-W	0.5992	Not Estimated	132.94	0.0000	111.45	0.185	4.65	7.54	20.28	22.40	11.22	12.96	88.97	258.82	101.01	116.86	0.21	0.53	3.26
MO3-SNK-WH	0.6318	0.5770-0.6756	131.23	0.0000	111.39	0.161	3.58	7.63	27.22	21.94	11.09	12.74	88.29	255.19	101.00	116.78	0.18	0.47	3.36
MO4	0.5070	0.4603-0.5491	138.33	0.0725	118.14	0.061	9.23	6.95	14.00	24.37	11.49	13.62	92.27	279.43	116.02	118.66	0.24	0.25	7.51

3.6.2 CSS Juvenile Results

3.6.2.1 CSS Juvenile metrics tables

Table 3-13. Predicted juvenile survival (LGR-BON) with no surface passage (0%), 10%, 20%, and 30% surface passage efficiencies using the cohort-specific model

Alternative and Passage Efficency	NAA 0%	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
Yearling Chinook	0.576	0.579	0.580	0.582	0.583	0.520	0.526	0.531	0.537	0.680	0.681	0.682	0.682	0.632	0.633	0.634	0.635

Table 3-14. Predicted Juvenile Chinook Travel Times (LGR-BON) with No Surface Passage (0%), 10%, 20%, and 30% Surface Passage Efficiencies Using the Cohort-Specific Model

Alternative by Passage Efficiency	NAA 0%	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
Yearling Chinook	15.8	15.7	15.6	15.5	15.5	18.3	18.0	17.8	17.5	12.5	12.5	12.5	12.4	13.7	13.7	13.7	13.6

4891 **Table 3-15. Mean Seasonal Average PITPH (95% confidence interval) for Spring/Summer Chinook Over the 80-Year Water Record for each CRSO EIS Alternative Used in the CSS Modeling**

Species	EIS Alternative	No PHSP	PSP–10% Efficiency	PSP–20% Efficiency	PSP–30% Efficiency
Chinook	NAA[A]	2.15 (2.06-2.23)	–	–	–
Chinook	MO1	1.85 (1.72-1.97)	1.81 (1.69-1.94)	1.78 (1.65-1.90)	1.74 (1.62-1.87)
Chinook	MO2	3.90 (3.82-3.98)	3.76 (3.68-3.84)	3.62 (3.54-3.70)	3.48 (3.41-3.56)
Chinook	MO3	0.62 (0.57-0.67)	0.60 (0.55-0.65)	0.58 (0.53-0.63)	0.56 (0.51-0.61)
Chinook	MO4	0.45 (0.40-0.50)	0.41 (0.37-0.46)	0.38 (0.33-0.42)	0.34 (0.30-0.38)

4892 Notes: [A] There are no PSP structures in the NAA. Therefore, the CSS did not estimate PITPH under the 10%, 20%, and 30% efficiencies for this alternative.
4893 PSP refers to the addition of Powerhouse Surface Passage structures, with assumed 10%, 20% and 30% efficiencies.

3.6.2.2 TDG Tool Results

Table 3-16. Mean Reach Average Exposure (RAE) results for Snake River juvenile Spring Chinook in both Allriver (LWG-BON) and Lower Columbia (MCN – BON) reaches, under the different alternatives.

Alternative	RAE (%) for Allriver (LWG-BON)	RAE (%) for Lower Columbia (MCN-BON)
NAA	115.1	115.4
MO1	115.5	115.6
MO2	112.8	112.3
MO3.SAL	109.2	116.6
MO3.GRNIMN	109.3	116.8
MO3.SNK	109.2	116.6
MO4	119.6	119.2

Note: The Allriver model run used transportation rules, whereas the Lower Columbia run did not.

Table 3-17. Mean survival results for Snake River juvenile Spring Chinook in both Allriver (LWG-BON) and Lower Columbia (MCN – BON) reaches, under the different alternatives.

Alternative	Survival (%) for Allriver (LWG-BON)	Survival (%) for Lower Columbia (MCN-BON)
NAA	97.3	98.4
MO1	96.9	98.5
MO2	98.7	99.2
MO3.SAL	97.7	97.7
MO3.GRNIMN	97.8	97.8
MO3.SNK	97.7	97.7
MO4	82.8	95.7

Note: The Allriver model run used transportation rules, whereas the Lower Columbia run did not.

4902 ### 3.6.3 Adult Results Summary

4903 #### *3.6.3.1 Adult metrics:*

4904 **Table 3-18. Predicted Adult Fish Ocean Survival Rates with No Surface Passage (0%), 10 %, 20%, and 30% Surface Passage Efficiencies using the Cohort-Specific Model**

Alternative by Species	NAA 0%	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
Yearling Chinook	0.036	0.038	0.039	0.039	0.039	0.025	0.026	0.027	0.028	0.059	0.059	0.059	0.060	0.055	0.056	0.056	0.057

4905 **Table 3-19. Predicted SARs with no surface passage (0%), 10%, 20%, and 30% surface passage efficiencies using the cohort-specific model**

Alternative by Species	NAA 0%	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
Yearling Chinook	0.020	0.021	0.021	0.021	0.022	0.012	0.013	0.014	0.014	0.042	0.042	0.043	0.043	0.034	0.034	0.035	0.035

4906 **Table 3-20. 50th Quantile of the Geometric Mean Abundance for Snake River Spring-Run Chinook Salmon Populations predicted by NWFSC Life Cycle Model**

Chinook Population and Totals	NAA	MO1	MO1 + 10% LM	MO1 + 25% LM	MO1 + 50% LM	MO2	MO3.SAL	MO3.SAL + 10% LM	MO3.SAL + 25% LM	MO3.SAL + 50% LM	MO4	MO4 + 10% LM	MO4 + 25% LM	MO4 + 50% LM
Bear Valley	291	302	329	365	430	324	325	396	502	706	185	233	298	430
Big Creek	150	149	159	169	184	154	159	180	205	275	112	129	152	184
Camas Creek	61	62	63	64	72	63	62	68	78	95	49	55	61	73
Loon Creek	56	58	62	67	75	62	61	76	88	118	39	48	57	77
Marsh Creek	143	145	163	189	231	175	174	225	283	445	79	108	145	255
Sulphur Creek	56	56	58	65	74	61	59	68	88	117	35	44	57	74
Secesh	291	295	306	324	363	309	308	354	415	529	219	250	290	368
SF Salmon	479	484	508	541	604	510	511	584	686	875	361	406	488	599
East Fork Salmon	51	54	66	83	110	70	88	135	194	330	22	38	68	136
Lemhi	38	36	47	62	88	53	75	123	197	382	11	26	51	129
North Fork Salmon	14	16	18	21	26	19	24	38	63	118	6	10	19	40
Pahsimeroi	133	142	151	180	225	159	192	248	367	536	68	96	158	280
Panther	28	29	31	40	50	34	42	57	84	131	14	19	35	64
Upper Main Salmon	487	502	517	553	627	518	564	659	819	1060	353	429	521	701
Valley	50	57	58	69	84	61	77	107	149	235	24	39	62	111
Yankee Fork	22	24	28	35	46	28	42	62	93	161	10	15	29	64
Total All Populations	**2351**	**2411**	**2563**	**2826**	**3290**	**2602**	**2764**	**3378**	**4311**	**6113**	**1590**	**1944**	**2489**	**3586**
Change from NAA	N/A	60	212	474	938	250	413	1027	1960	3761	-761	-407	138	1235
% Change	N/A	3%	9%	20%	40%	11%	18%	44%	83%	160%	-32%	-17%	6%	53%

4907 **Table 3-21. Median Abundance for Snake River Spring-Run Chinook Salmon populations predicted by CSS**

Salmon Population or Totals	NAA	MO1	MO1 + 10% LM	MO1 + 25% LM	MO1 + 50% LM	MO2	MO3.SAL	MO3.SAL + 10% LM	MO3.SAL + 25% LM	MO3.SAL + 50% LM	MO4	MO4 + 10% LM	MO4 + 25% LM	MO4 + 50% LM
Upper Grande Ronde	258	289	N/A	N/A	N/A	128	766	N/A	N/A	N/A	633	N/A	N/A	N/A
Imnaha	2549	2649	N/A	N/A	N/A	1573	5351	N/A	N/A	N/A	4696	N/A	N/A	N/A
Lostine/Wallowa	742	787	N/A	N/A	N/A	436	1655	N/A	N/A	N/A	1442	N/A	N/A	N/A
Minam	1140	1196	N/A	N/A	N/A	705	2416	N/A	N/A	N/A	2126	N/A	N/A	N/A
Wenaha	1193	1261	N/A	N/A	N/A	538	3306	N/A	N/A	N/A	2792	N/A	N/A	N/A
Total	**6114**	**6428**	**–**	**–**	**–**	**3508**	**14055**	**–**	**–**	**–**	**12159**	**–**	**–**	**–**

Salmon Population or Totals	NAA	MO1	MO1 + 10% LM	MO1 + 25% LM	MO1 + 50% LM	MO2	MO3.SAL	MO3.SAL + 10% LM	MO3.SAL + 25% LM	MO3.SAL + 50% LM	MO4	MO4 + 10% LM	MO4 + 25% LM	MO4 + 50% LM
Change from NAA	–	314	–	–	–	-2606	7941	–	–	–	6045	–	–	–
% Change	–	5%	–	–	–	-43%	130%	–	–	–	99%	–	–	–

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3.6.3.2 NWFSC Life Cycle Model Results

Table 3-22. NWFSC Life Cycle Model Snake River Spring-Summer Run Chinook Salmon SAR (Lower Granite to Bonneville) Results

Alternative	SAR inriver	SAR transport	In-River Survival	Transported Survival	Proportion Transported	LGR-BON SAR	SAR Change from NAA	% Change
NAA	0.0155	0.0105	0.5037	0.98	0.3851	0.0088		
MO1	0.0155	0.0104	0.5096	0.98	0.3779	0.0088	0.0000	0%
MO1 + 10% LM	0.0171	0.0104	0.5096	0.98	0.3779	0.0093	0.0005	5%
MO1 + 25% LM	0.0194	0.0104	0.5096	0.98	0.3779	0.0100	0.0012	14%
MO1 + 50% LM	0.0233	0.0104	0.5096	0.98	0.3779	0.0112	0.0024	28%
MO1 + 100% LM	0.0311	0.0104	0.5096	0.98	0.3779	0.0137	0.0049	56%
MO2	0.0158	0.0105	0.5010	0.98	0.4742	0.0090	0.0002	3%
MO3.GRNIMN	0.0144	0	0.5510	0.98	0.0000	0.0079	-0.0009	-10%
MO3.GRNIMN + 10% LM	0.0159	0	0.5510	0.98	0.0000	0.0088	0.0000	0%
MO3.GRNIMN + 25% LM	0.018	0	0.5510	0.98	0.0000	0.0099	0.0011	13%
MO3.GRNIMN + 50% LM	0.0217	0	0.5510	0.98	0.0000	0.0120	0.0032	36%
MO3.GRNIMN + 100% LM	0.0289	0	0.5510	0.98	0.0000	0.0159	0.0071	81%
MO3.SAL	0.0166	0	0.5999	0.98	0.0000	0.0100	0.0012	13%
MO3.SAL + 10% LM	0.0182	0	0.5999	0.98	0.0000	0.0109	0.0021	24%
MO3.SAL + 25% LM	0.0207	0	0.5999	0.98	0.0000	0.0124	0.0036	41%
MO3.SAL + 50% LM	0.0249	0	0.5999	0.98	0.0000	0.0149	0.0061	70%
MO3.SAL + 100% LM	0.0331	0	0.5999	0.98	0.0000	0.0199	0.0111	126%
MO3.SNK	0.0171	0	0.6318	0.98	0.0000	0.0108	0.0020	23%
MO3.SNK + 10% LM	0.0188	0	0.6318	0.98	0.0000	0.0119	0.0031	35%
MO3.SNK + 25% LM	0.0214	0	0.6318	0.98	0.0000	0.0135	0.0047	54%
MO3.SNK + 50% LM	0.0257	0	0.6318	0.98	0.0000	0.0162	0.0074	85%
MO3.SNK + 100% LM	0.0342	0	0.6318	0.98	0.0000	0.0216	0.0128	146%
MO4	0.0148	0.0103	0.5070	0.98	0.0725	0.0077	-0.0011	-13%
MO4 + 10% LM	0.0163	0.0103	0.5070	0.98	0.0725	0.0084	-0.0004	-5%
MO4 + 25% LM	0.0185	0.0103	0.5070	0.98	0.0725	0.0094	0.0006	7%
MO4 + 50% LM	0.0222	0.0103	0.5070	0.98	0.0725	0.0112	0.0024	27%
MO4 + 100% LM	0.0296	0.0103	0.5070	0.98	0.0725	0.0147	0.0059	67%

3.6.4 Tables 3-23 through 3-39 NWFSC Life Cycle Model abundance results, by population, of Upper Snake River Spring/Summer Run Chinook Salmon.

Table 3-23. Quantiles (Q) of the Geometric Mean Abundance (across all years) for Bear Valley Creek

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	4.2	173.6	291.1	445.7	839
MO1	2.7	182.6	302.3	474.6	891.4
MO1 + 10% LM	5.5	198.6	328.7	486.4	915.9
MO1 + 25% LM	10.6	217.7	365.3	552.8	1047.3
MO1 + 50% LM	15.9	283.8	430.3	609.2	1095.4
MO1 + 100% LM	25.4	363.7	539	763.7	1354.3
MO2	9.1	208.2	324.3	476.5	873.2
MO3.GRNIMN	0.6	100.5	196	315.3	613.6
MO3.GRNIMN + 10% LM	1.2	136.5	240.1	397.5	786.3
MO3.GRNIMN + 25% LM	1.1	190.2	333.1	505.8	976.5
MO3.GRNIMN + 50% LM	4.6	297.7	468.6	702.4	1288.5
MO3.GRNIMN + 100% LM	20.5	530.5	772.2	1086.2	1889.8
MO3.SAL	4.7	199.3	324.8	503	954.8
MO3.SAL + 10% LM	10.3	244.6	395.8	611.9	1142.9
MO3.SAL + 25% LM	16.2	326.3	501.8	743	1361.4
MO3.SAL + 50% LM	48.4	482.6	705.6	976.2	1715.6
MO3.SAL + 100% LM	178.9	797.9	1106.5	1506.7	2560.2
MO3.SNK	9.5	240.6	388.4	590.1	1110.4
MO3.SNK + 10% LM	22.6	297.1	478	684.7	1264.9
MO3.SNK + 25% LM	46.8	398.8	605.5	888.7	1617.3
MO3.SNK + 50% LM	71.3	545.7	808.8	1127	1973.7
MO3.SNK + 100% LM	188.9	900.7	1228.8	1647.8	2757.6
MO4	1.5	91.1	184.9	310.7	637.3
MO4 + 10% LM	1.4	127.9	232.6	380.6	758.3
MO4 + 25% LM	5.8	168.1	297.8	468.9	918.4
MO4 + 50% LM	15.7	275.7	430.2	643.4	1176.5
MO4 + 100% LM	52.2	480.6	717.6	1015.5	1812.9

Table 3-24. Quantiles (Q) of the Geometric Mean Abundance (across all years) for Big Creek

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	13.9	110.6	150	194.4	318.7
MO1	11.9	107.4	149.2	198.5	331.6
MO1 + 10% LM	24.4	116.9	158.9	207.3	340.8
MO1 + 25% LM	32.4	125.9	168.8	223.2	364.9
MO1 + 50% LM	30.6	138.2	184.4	240.6	389.8
MO1 + 100% LM	38.6	163.3	211.3	284.6	461.9
MO2	27.3	116.5	154.4	202.6	331.7
MO3.GRNIMN	5.6	84.2	116.4	157.5	265.9

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
MO3.GRNIMN + 10% LM	19.8	100.4	135.3	177.6	293.2
MO3.GRNIMN + 25% LM	22.1	115.2	154.8	205.1	333
MO3.GRNIMN + 50% LM	36.3	153.5	200.3	256.5	409.4
MO3.GRNIMN + 100% LM	67.2	215.5	281.5	363.6	580.3
MO3.SAL	20.9	115	158.6	207.6	346.1
MO3.SAL + 10% LM	34.5	135.7	180	234.5	380.8
MO3.SAL + 25% LM	55.6	158.4	205.2	274.2	444.8
MO3.SAL + 50% LM	60.5	202	275.1	344.5	550.4
MO3.SAL + 100% LM	101.5	289.1	369.9	472.4	746.5
MO3.SNK	40.5	128.1	172.1	231.7	383.7
MO3.SNK + 10% LM	49.3	149.7	195.9	253.6	404
MO3.SNK + 25% LM	56.6	172.8	228.8	298.3	483.6
MO3.SNK + 50% LM	76.1	221.1	291.2	381.3	619
MO3.SNK + 100% LM	159.5	309.3	399.3	512	815.2
MO4	7.4	78.3	112.3	151.5	260.4
MO4 + 10% LM	10.5	91.5	129.1	170.8	287
MO4 + 25% LM	21.5	112.2	152.1	201.8	333.3
MO4 + 50% LM	40.5	140.6	183.9	239	383.4
MO4 + 100% LM	90.4	204.1	264.8	344.4	546.8

Table 3-25. Quantiles (Q) of the Geometric Mean Abundance (across all years) for Camas Creek

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	19.8	46.9	61.1	79.3	127.4
MO1	18.8	47.3	61.8	79.9	128.4
MO1 + 10% LM	12.1	47.9	62.7	81.8	132.3
MO1 + 25% LM	19.5	49.3	64	86.1	140.2
MO1 + 50% LM	20	54.6	71.7	90.3	143.8
MO1 + 100% LM	23.4	62.2	80.8	106.2	171.8
MO2	17.9	48.8	63.2	82.7	132.9
MO3.GRNIMN	12.3	37.8	49.8	65.6	106.6
MO3.GRNIMN + 10% LM	13.2	41.6	55.4	72.7	119.3
MO3.GRNIMN + 25% LM	18.8	47	62.5	81.6	133.5
MO3.GRNIMN + 50% LM	24.8	57.7	73.5	99.4	159.7
MO3.GRNIMN + 100% LM	21.2	75.1	100.2	130	212.3
MO3.SAL	17.6	46.6	62.1	81.2	132.3
MO3.SAL + 10% LM	18.5	51.6	68.1	89.5	143.4
MO3.SAL + 25% LM	23.9	59.8	78	103.2	165.3
MO3.SAL + 50% LM	24.5	71.9	95	124.9	204.1
MO3.SAL + 100% LM	28.2	93.4	123.4	164.3	270.4
MO3.SNK	23.2	51.1	68	91.6	151
MO3.SNK + 10% LM	18.7	56.8	75.5	96	154.6
MO3.SNK + 25% LM	23.6	63	83.9	112.5	186.6

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
MO3.SNK + 50% LM	31.6	76.1	104.5	132.5	215.5
MO3.SNK + 100% LM	40.2	103.3	139.2	175.6	283.3
MO4	11.9	37.2	49.1	65.6	108.1
MO4 + 10% LM	13.5	41.3	54.6	70.5	112.7
MO4 + 25% LM	14.5	47.7	61.4	79.2	124.7
MO4 + 50% LM	23.1	54.7	72.9	95.7	156.9
MO4 + 100% LM	29.6	71.7	95.8	126.8	209.4

4919 **Table 3-26. Quantiles of the Geometric Mean Abundance (across all years) for Loon Creek**

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	0.3	31.9	55.9	91.1	178.2
MO1	0	34.1	57.8	90.1	172.1
MO1 + 10% LM	0.8	34.5	61.8	92.3	178.3
MO1 + 25% LM	1.2	41.2	67.2	102.4	193.8
MO1 + 50% LM	0.8	48.1	75.4	110.1	202.5
MO1 + 100% LM	1.8	61.3	92.5	140.4	258.6
MO2	0.3	36.7	62.2	96.8	184.1
MO3.GRNIMN	0	20	39.8	64	128.5
MO3.GRNIMN + 10% LM	0.1	26.1	47.5	77.1	152.7
MO3.GRNIMN + 25% LM	0.8	33.6	58.8	90.8	176.4
MO3.GRNIMN + 50% LM	0.9	53	85.8	127.2	233.7
MO3.GRNIMN + 100% LM	2.3	84.3	128.3	188.8	340.9
MO3.SAL	0.2	36.2	61.1	94.2	180.4
MO3.SAL + 10% LM	1.2	42.1	75.6	114.5	223
MO3.SAL + 25% LM	1.4	54.3	87.9	136.3	259.2
MO3.SAL + 50% LM	5.8	78.1	117.7	172.7	314
MO3.SAL + 100% LM	7.5	126.7	181.1	261	460.7
MO3.SNK	0.4	40.3	71.3	111.2	217.6
MO3.SNK + 10% LM	0.9	48.2	81.6	125.8	242.1
MO3.SNK + 25% LM	1.8	63.5	101.2	148	274.6
MO3.SNK + 50% LM	1.1	87.1	132.2	193.7	352.5
MO3.SNK + 100% LM	9	136.5	206.3	291.4	522.8
MO4	0.2	18.4	39.3	63.5	126.5
MO4 + 10% LM	0.2	25.1	47.7	72.7	143.6
MO4 + 25% LM	0	35	56.9	92.3	175.8
MO4 + 50% LM	0.3	45.5	77.4	118.1	226.4
MO4 + 100% LM	5	80.4	126	182.8	336.2

4920 **Table 3-27. Geometric Mean Abundance (across all years) for Marsh Creek**

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	0.6	71.7	142.9	279.2	587.4
MO1	0.2	73.2	145	276.2	575.3
MO1 + 10% LM	1.4	76.3	162.6	282.5	591.7

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
MO1 + 25% LM	1.5	91.3	188.6	331.9	685.7
MO1 + 50% LM	1.1	121.9	230.5	401.3	816.8
MO1 + 100% LM	2.9	181.8	310.8	495	951.3
MO2	1.5	85.6	175	301.1	614
MO3.GRNIMN	0.6	34.3	92.2	185.4	387.1
MO3.GRNIMN + 10% LM	0.1	45.4	109	227.1	497.1
MO3.GRNIMN + 25% LM	0.5	80.1	174	311.7	653.2
MO3.GRNIMN + 50% LM	2.9	144.4	272	446.3	896.1
MO3.GRNIMN + 100% LM	17.4	310.1	484.2	746	1392.1
MO3.SAL	0.4	79.5	174	307.8	631.2
MO3.SAL + 10% LM	0.7	110.5	224.9	389.1	805.7
MO3.SAL + 25% LM	1.1	155.4	283.4	458.4	906.8
MO3.SAL + 50% LM	7.1	265.5	445.4	661	1237.8
MO3.SAL + 100% LM	51	483.9	722.6	1061.5	1913.6
MO3.SNK	0.7	103.2	216.6	374.4	778.1
MO3.SNK + 10% LM	2.8	148.2	264.2	440.7	875.3
MO3.SNK + 25% LM	7.5	196.6	341	565.7	1117.7
MO3.SNK + 50% LM	34.1	300.1	492.5	756.8	1432.5
MO3.SNK + 100% LM	44.6	555.5	818.9	1203.5	2175.5
MO4	0.1	29.6	79.2	173.7	382.6
MO4 + 10% LM	0.2	43.6	107.9	213	458.8
MO4 + 25% LM	0.5	70.5	144.7	281	595.3
MO4 + 50% LM	2	128.2	254.8	420.6	856.3
MO4 + 100% LM	4.5	265.9	436.7	671.3	1273.1

4921 **Table 3-28. Quantiles of the Geometric Mean Abundance (across all years) for Sulphur Creek**

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	0.8	35.4	55.8	80.3	145.9
MO1	0.7	35.6	56.1	82.8	153.2
MO1 + 10% LM	0.9	37.7	58.4	83.3	151.3
MO1 + 25% LM	3	43.1	64.5	94.1	168.9
MO1 + 50% LM	1.9	50.2	74.1	102.8	181.5
MO1 + 100% LM	2.4	64	90.7	127.3	218.6
MO2	1.1	40	61.3	89.2	162
MO3.GRNIMN	0.3	21.4	37.6	59.3	114.6
MO3.GRNIMN + 10% LM	0.5	28.1	47.3	71.6	136.8
MO3.GRNIMN + 25% LM	0.9	38.3	58.5	87.1	159.9
MO3.GRNIMN + 50% LM	3.4	54.4	81.2	115.9	206.2
MO3.GRNIMN + 100% LM	10.7	88.9	127.7	173.3	299.8
MO3.SAL	1.7	36.2	59	86.9	162.3
MO3.SAL + 10% LM	3.9	45.7	67.9	100.1	181.3
MO3.SAL + 25% LM	4.8	60.1	87.9	124.2	219.9
MO3.SAL + 50% LM	9.7	82.1	117.2	158.8	271

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
MO3.SAL + 100% LM	18.8	131.3	176.5	237	394.9
MO3.SNK	3.1	44.2	68.8	99.3	181.9
MO3.SNK + 10% LM	4.9	52.7	79.3	115	208.1
MO3.SNK + 25% LM	9.7	68.3	104.3	140.8	249
MO3.SNK + 50% LM	13.6	93.9	133.2	178.9	306.2
MO3.SNK + 100% LM	44.2	144.7	196.3	261.8	428.2
MO4	0.2	20.9	35.3	56.5	109.1
MO4 + 10% LM	0.2	27.1	44.3	66.3	125.2
MO4 + 25% LM	0.7	34	56.5	84.6	160
MO4 + 50% LM	2.5	51.4	74.2	103.2	178.6
MO4 + 100% LM	14.7	85.9	118.8	165.9	284.6

4922 **Table 3-29. Quantiles of the Geometric Mean Abundance (across all years) for Secesh River**

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	19.3	218.8	291.1	375.5	608.9
MO1	17.1	217.5	295.1	381.5	627.2
MO1 + 10% LM	34.8	231.6	306	403.7	657
MO1 + 25% LM	6.6	247.9	323.6	427.5	692.3
MO1 + 50% LM	45.3	279	363.1	472.1	761.3
MO1 + 100% LM	42.7	332.7	423.9	551.3	871.3
MO2	7.8	232.3	309.1	396.8	642.7
MO3.GRNIMN	4.9	159.8	221.8	301	512
MO3.GRNIMN + 10% LM	11.4	186.1	259.4	342.2	574.1
MO3.GRNIMN + 25% LM	18.7	233.7	313.7	405.5	660.9
MO3.GRNIMN + 50% LM	27.5	293.6	393	521	860.6
MO3.GRNIMN + 100% LM	94.4	434.7	572.7	739.7	1195.3
MO3.SAL	23.1	226.1	308.3	405.8	675.3
MO3.SAL + 10% LM	17.9	263.7	354.3	470.5	779.8
MO3.SAL + 25% LM	54.5	316.8	414.9	539.3	863
MO3.SAL + 50% LM	90.6	394	528.5	681.2	1111.3
MO3.SAL + 100% LM	184.3	562.4	736.9	937.6	1495.1
MO3.SNK	42.1	259	350.7	456.7	750
MO3.SNK + 10% LM	61.4	298.4	390.5	516.9	844.1
MO3.SNK + 25% LM	89.6	343.4	454.7	604.6	992.6
MO3.SNK + 50% LM	150.4	447.1	576	750.6	1197.4
MO3.SNK + 100% LM	262.8	616.6	791.7	1032.2	1648.4
MO4	9.2	152.3	219.4	294.2	504.5
MO4 + 10% LM	5.7	175.2	250.1	330.4	562
MO4 + 25% LM	16.3	218.1	289.7	387.5	641.3
MO4 + 50% LM	26.3	272.8	368.4	484.3	799.4
MO4 + 100% LM	66.4	403.3	534.4	699.4	1140.5

Table 3-30. Quantiles of the Geometric Mean Abundance (across all years) for South Fork Salmon River

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	39.3	338.6	478.8	633.9	1076.6
MO1	32.1	353	484.3	643.3	1059
MO1 + 10% LM	41.2	363.1	508.4	676.9	1141.7
MO1 + 25% LM	37.7	396.9	541.2	709.8	1172.6
MO1 + 50% LM	37	448.5	604.3	809.4	1339.1
MO1 + 100% LM	103.9	539.9	726.9	966.3	1602.2
MO2	34.9	377.2	509.6	686.5	1144.3
MO3.GRNIMN	9.2	253.4	362.1	519.3	914
MO3.GRNIMN + 10% LM	5.2	299.2	417.1	586.6	1017.1
MO3.GRNIMN + 25% LM	39.1	356.8	510.9	684.2	1166.5
MO3.GRNIMN + 50% LM	60.5	479.1	661	889.9	1497.4
MO3.GRNIMN + 100% LM	63.4	723.4	961.4	1254.1	2045.5
MO3.SAL	8.4	369.5	511.4	694	1177.9
MO3.SAL + 10% LM	38.2	420.3	584.3	790.6	1335.2
MO3.SAL + 25% LM	37.7	505.6	685.7	921.4	1529.1
MO3.SAL + 50% LM	124	654.4	875.4	1162.9	1907.4
MO3.SAL + 100% LM	271.7	955.3	1270.9	1648.2	2684.7
MO3.SNK	29	402.9	584.3	779.8	1342.1
MO3.SNK + 10% LM	53.5	484.1	660.6	885	1474.7
MO3.SNK + 25% LM	112.8	548.6	777	1020.1	1722.9
MO3.SNK + 50% LM	208.6	725.9	956	1274	2079.5
MO3.SNK + 100% LM	394.6	1028.6	1371	1796	2938
MO4	9.8	247.2	361.3	505.2	892
MO4 + 10% LM	10.1	280.5	405.6	547.2	946.2
MO4 + 25% LM	29	343.9	487.5	656.8	1111.6
MO4 + 50% LM	57.1	445.6	598.7	826.9	1390.3
MO4 + 100% LM	126.2	657.9	889.4	1179.1	1959.5

Table 3-31. Quantiles of the Geometric Mean Abundance (across all years) for Valley Creek

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	4	75.3	107.8	148.2	257.3
MO1	3.1	79.2	110.9	153.7	263.8
MO1 + 10% LM	7.9	82	116.3	159.9	274.5
MO1 + 25% LM	8.6	86.8	123.8	166.8	285.8
MO1 + 50% LM	3.9	97.6	135.2	184.1	309.7
MO1 + 100% LM	23.4	122.4	161.6	222	362.6
MO2	7.3	85.2	121.9	162.7	277.2
MO3.GRNIMN	0.5	57	87	117.6	208.3
MO3.GRNIMN + 10% LM	0.3	64.3	95.3	133.8	232.8
MO3.GRNIMN + 25% LM	1.5	82.2	117.8	164.5	286

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
MO3.GRNIMN + 50% LM	1	106.4	145.9	208.3	357.3
MO3.GRNIMN + 100% LM	41.4	162	213.8	297.6	500.2
MO3.SAL	14.1	80.6	114.8	160.2	278.6
MO3.SAL + 10% LM	5.3	96.1	132.5	189.4	324.9
MO3.SAL + 25% LM	21.5	115.4	157.3	217	365.4
MO3.SAL + 50% LM	30.1	147.7	201.8	275.2	464.6
MO3.SAL + 100% LM	62.8	210.7	288.5	379.5	628.6
MO3.SNK	3.7	92.1	130.3	180.7	309.1
MO3.SNK + 10% LM	6	103.5	149.1	203.4	353
MO3.SNK + 25% LM	11.5	130.5	182.6	249.1	425.1
MO3.SNK + 50% LM	15.7	165.9	224.4	297.7	494.1
MO3.SNK + 100% LM	72	237	314.2	429.4	707.2
MO4	1.5	52.5	80.3	113	201.5
MO4 + 10% LM	0.8	62.4	91.4	133.9	238.4
MO4 + 25% LM	7	77.5	111.9	151.6	262.7
MO4 + 50% LM	9.4	104.5	140.8	204.1	350.1
MO4 + 100% LM	34.6	151.1	199.4	269.6	443.9

Table 3-32. Quantiles of the Geometric Mean Abundance (across all years) for Salmon River East Fork Salmon

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	6.2	26.1	51.2	90.8	167.4
MO1	9.7	26.2	53.9	94.6	181.0
MO1 + 10% LM	9.8	36.0	66.0	110.3	185.5
MO1 + 25% LM	17.5	46.7	82.5	128.0	213.9
MO1 + 50% LM	24.5	64.6	110.0	169.2	276.7
MO1 + 100% LM	44.5	103.0	156.0	231.3	346.6
MO2	10.3	39.7	70.2	115.5	201.2
MO3.GRNIMN	2.7	11.8	27.2	57.2	129.0
MO3.GRNIMN + 10% LM	5.5	20.7	45.6	81.9	178.6
MO3.GRNIMN + 25% LM	13.9	46.7	90.6	146.3	229.6
MO3.GRNIMN + 50% LM	56.8	110.6	176.2	249.9	370.9
MO3.GRNIMN + 100% LM	198.7	306.4	398.1	504.7	700.1
MO3.SAL	15.1	50.2	88.4	149.4	242.5
MO3.SAL + 10% LM	30.0	76.2	134.6	192.8	311.9
MO3.SAL + 25% LM	69.6	126.2	193.5	283.7	423.3
MO3.SAL + 50% LM	133.9	243.1	330.3	448.3	618.1
MO3.SAL + 100% LM	333.7	494.3	628.3	765.5	1021.8
MO3.SNK	27.4	71.8	116.0	188.4	292.7
MO3.SNK + 10% LM	54.4	114.4	173.8	263.1	399.1
MO3.SNK + 25% LM	109.1	196.9	268.3	364.1	513.7
MO3.SNK + 50% LM	189.2	305.6	406.5	526.4	701.8
MO3.SNK + 100% LM	450.2	596.9	727.7	899.5	1182.5

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
MO4	2.1	9.0	22.3	48.6	107.0
MO4 + 10% LM	4.0	17.3	38.5	75.4	134.7
MO4 + 25% LM	13.7	37.4	68.4	113.1	213.5
MO4 + 50% LM	25.1	85.7	135.6	202.5	335.2
MO4 + 100% LM	126.1	241.7	331.7	418.4	615.8

Table 3-33. Quantiles of the Geometric Mean Abundance (across all years) for Salmon River Lemhi

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	4.3	15.0	37.9	78.6	156.6
MO1	3.8	14.2	35.9	82.6	172.3
MO1 + 10% LM	5.0	19.4	46.8	89.3	202.4
MO1 + 25% LM	7.8	26.2	62.5	109.0	224.1
MO1 + 50% LM	9.4	39.8	87.6	148.5	255.3
MO1 + 100% LM	37.4	90.0	153.1	260.4	413.4
MO2	5.6	23.4	53.3	109.3	192.2
MO3.GRNIMN	1.9	5.5	15.0	37.4	106.3
MO3.GRNIMN + 10% LM	2.5	11.4	32.0	67.0	165.3
MO3.GRNIMN + 25% LM	9.3	31.7	77.9	135.2	255.8
MO3.GRNIMN + 50% LM	39.2	101.3	178.2	271.1	466.4
MO3.GRNIMN + 100% LM	184.6	328.9	479.3	611.5	1007.7
MO3.SAL	6.0	28.1	74.7	136.9	298.1
MO3.SAL + 10% LM	14.9	59.9	123.4	214.7	374.9
MO3.SAL + 25% LM	50.7	117.7	197.2	285.3	513.9
MO3.SAL + 50% LM	139.6	256.2	381.8	542.3	832.1
MO3.SAL + 100% LM	413.1	611.3	802.2	1019.9	1446.9
MO3.SNK	13.6	52.0	111.8	196.8	353.7
MO3.SNK + 10% LM	32.9	100.6	165.5	267.6	435.8
MO3.SNK + 25% LM	77.4	184.9	273.1	386.7	615.0
MO3.SNK + 50% LM	184.2	322.4	468.6	648.8	960.0
MO3.SNK + 100% LM	550.0	775.1	999.7	1246.0	1715.2
MO4	1.3	3.9	11.4	31.2	92.3
MO4 + 10% LM	2.3	10.3	26.3	60.2	128.2
MO4 + 25% LM	4.6	22.6	50.7	102.1	222.5
MO4 + 50% LM	18.3	72.1	128.6	221.4	355.6
MO4 + 100% LM	119.5	257.6	378.1	514.1	726.2

Table 3-34. Quantiles of the Geometric Mean Abundance (across all years) for Salmon River North Fork Salmon

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	2.4	6.6	13.9	25.1	50.8
MO1	2.4	6.4	15.6	28.7	54.7
MO1 + 10% LM	3.2	9.1	18.0	31.0	58.8

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
MO1 + 25% LM	2.7	9.3	21.0	39.4	63.1
MO1 + 50% LM	4.1	14.0	26.4	45.2	84.7
MO1 + 100% LM	11.6	30.5	51.3	74.3	111.5
MO2	2.8	9.7	19.3	33.3	62.0
MO3.GRNIMN	1.3	2.9	6.8	14.4	31.5
MO3.GRNIMN + 10% LM	1.7	5.0	11.3	21.2	46.6
MO3.GRNIMN + 25% LM	3.7	12.9	24.7	40.9	81.7
MO3.GRNIMN + 50% LM	11.1	28.7	52.2	76.0	122.2
MO3.GRNIMN + 100% LM	52.8	93.7	134.6	174.0	239.4
MO3.SAL	3.6	13.5	24.0	42.3	81.7
MO3.SAL + 10% LM	6.8	20.7	37.6	60.4	104.4
MO3.SAL + 25% LM	14.1	39.6	63.3	92.6	144.7
MO3.SAL + 50% LM	43.7	84.5	117.9	156.1	216.7
MO3.SAL + 100% LM	125.9	173.8	220.5	278.9	360.0
MO3.SNK	6.2	19.2	37.3	61.2	96.3
MO3.SNK + 10% LM	12.8	31.2	50.3	75.9	123.1
MO3.SNK + 25% LM	28.8	60.0	85.0	119.0	167.7
MO3.SNK + 50% LM	58.8	103.3	138.0	183.5	242.0
MO3.SNK + 100% LM	153.8	208.8	269.6	333.5	430.7
MO4	1.2	2.6	5.9	11.5	29.2
MO4 + 10% LM	1.4	4.3	9.6	18.5	44.0
MO4 + 25% LM	2.2	7.8	18.8	33.3	61.4
MO4 + 50% LM	6.4	21.4	40.4	63.1	103.7
MO4 + 100% LM	34.1	73.8	103.6	136.4	210.2

Table 3-35. Quantiles of the Geometric Mean Abundance (across all years) for Salmon River Pahsimeroi

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	36.8	83.9	133.3	197.6	303.9
MO1	37.3	93.4	142.5	210.4	298.1
MO1 + 10% LM	41.8	95.1	151.0	222.0	328.3
MO1 + 25% LM	48.8	113.7	179.8	256.4	355.1
MO1 + 50% LM	70.8	152.6	225.5	295.6	406.9
MO1 + 100% LM	138.4	222.2	299.6	400.2	547.8
MO2	48.6	106.4	158.8	221.5	349.1
MO3.GRNIMN	11.9	34.9	76.9	129.0	233.2
MO3.GRNIMN + 10% LM	25.7	65.9	113.8	172.6	293.3
MO3.GRNIMN + 25% LM	58.0	119.8	192.1	261.1	409.2
MO3.GRNIMN + 50% LM	138.0	231.4	316.1	409.3	550.0
MO3.GRNIMN + 100% LM	327.2	501.3	633.1	791.3	998.8
MO3.SAL	53.9	118.4	192.1	273.9	409.7
MO3.SAL + 10% LM	89.6	178.2	247.9	341.2	493.9
MO3.SAL + 25% LM	149.1	271.0	367.2	473.5	676.3

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
MO3.SAL + 50% LM	309.2	446.2	536.3	684.4	891.7
MO3.SAL + 100% LM	566.9	772.2	952.1	1153.0	1463.3
MO3.SNK	88.8	174.2	252.9	353.0	514.5
MO3.SNK + 10% LM	121.3	222.2	311.7	429.4	596.5
MO3.SNK + 25% LM	212.3	324.0	429.4	557.9	807.9
MO3.SNK + 50% LM	371.1	507.9	644.4	812.6	1086.3
MO3.SNK + 100% LM	707.9	935.5	1129.3	1326.8	1654.0
MO4	8.2	33.0	68.3	111.9	198.9
MO4 + 10% LM	11.8	49.6	96.1	147.4	266.4
MO4 + 25% LM	32.0	90.1	158.1	225.2	359.4
MO4 + 50% LM	95.0	183.7	280.2	373.4	525.9
MO4 + 100% LM	240.4	408.8	519.8	642.3	891.5

Table 3-36. Quantiles of the Geometric Mean Abundance (across all years) for Salmon River Panther Creek

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	5.1	15.2	28.5	42.6	73.9
MO1	5.5	17.4	29.0	45.1	74.2
MO1 + 10% LM	6.6	18.4	31.3	48.2	75.9
MO1 + 25% LM	8.9	24.5	39.5	60.4	87.9
MO1 + 50% LM	11.3	29.7	49.7	70.0	98.0
MO1 + 100% LM	22.4	47.5	69.8	93.0	127.9
MO2	7.7	19.9	33.6	56.0	81.9
MO3.GRNIMN	2.6	7.2	15.1	28.8	51.3
MO3.GRNIMN + 10% LM	4.9	13.7	25.0	38.4	67.7
MO3.GRNIMN + 25% LM	9.0	24.8	42.5	58.8	92.2
MO3.GRNIMN + 50% LM	29.6	51.8	74.2	95.7	146.5
MO3.GRNIMN + 100% LM	77.0	120.8	157.2	195.4	247.9
MO3.SAL	11.0	26.4	42.2	63.0	90.9
MO3.SAL + 10% LM	13.4	38.4	56.7	79.4	114.8
MO3.SAL + 25% LM	31.5	60.1	83.7	115.7	163.4
MO3.SAL + 50% LM	61.6	99.0	130.6	161.4	217.9
MO3.SAL + 100% LM	133.5	189.1	226.9	277.5	353.7
MO3.SNK	13.5	33.0	48.9	75.4	109.7
MO3.SNK + 10% LM	26.0	52.1	72.3	100.8	140.9
MO3.SNK + 25% LM	45.0	78.3	104.3	135.1	187.8
MO3.SNK + 50% LM	79.6	118.9	154.6	194.4	264.0
MO3.SNK + 100% LM	165.4	219.0	266.6	321.2	402.9
MO4	1.9	6.4	13.7	25.4	48.7
MO4 + 10% LM	2.6	9.1	18.7	31.9	58.3
MO4 + 25% LM	5.9	18.9	34.9	53.4	81.9
MO4 + 50% LM	16.8	44.5	64.2	85.9	125.2
MO4 + 100% LM	53.2	94.0	123.1	153.5	202.2

Table 3-37. Quantiles of the Geometric Mean Abundance (across all years) for Salmon River Upper Main

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	283.9	397.2	487.5	596.3	757.2
MO1	302.1	409.4	502.2	610.5	754.1
MO1 + 10% LM	303.7	427.6	516.8	615.7	775.5
MO1 + 25% LM	323.4	463.7	552.8	657.3	812.3
MO1 + 50% LM	382.5	508.7	627.1	741.7	924.6
MO1 + 100% LM	506.5	650.8	763.9	901.9	1075.4
MO2	315.8	427.2	517.7	624.3	754.6
MO3.GRNIMN	202.1	287.6	374.7	451.9	587.4
MO3.GRNIMN + 10% LM	261.5	367.5	451.6	562.6	742.1
MO3.GRNIMN + 25% LM	367.0	466.5	585.4	693.9	894.0
MO3.GRNIMN + 50% LM	504.9	657.0	788.7	910.4	1110.1
MO3.GRNIMN + 100% LM	802.1	996.6	1166.7	1354.0	1721.3
MO3.SAL	347.5	464.3	564.4	695.2	880.7
MO3.SAL + 10% LM	413.6	563.6	658.8	800.6	977.8
MO3.SAL + 25% LM	518.0	692.9	819.1	963.2	1207.4
MO3.SAL + 50% LM	730.2	899.4	1059.9	1245.9	1619.4
MO3.SAL + 100% LM	1140.6	1404.9	1608.1	1844.5	2231.3
MO3.SNK	443.6	544.4	654.4	777.8	988.9
MO3.SNK + 10% LM	495.9	630.7	744.6	884.1	1118.2
MO3.SNK + 25% LM	641.4	788.9	944.0	1121.5	1368.7
MO3.SNK + 50% LM	880.1	1032.7	1216.7	1443.0	1818.0
MO3.SNK + 100% LM	1273.5	1545.7	1776.7	2042.3	2516.6
MO4	174.2	274.6	353.4	430.0	579.3
MO4 + 10% LM	238.9	343.6	428.7	516.1	654.9
MO4 + 25% LM	298.4	431.1	521.1	633.0	787.3
MO4 + 50% LM	434.6	600.1	701.0	824.3	1025.0
MO4 + 100% LM	711.4	924.3	1064.0	1223.4	1489.3

Table 3-38. Quantiles of the Geometric Mean Abundance (across all years) for Salmon River Valley Creek

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	9.4	30.2	50.0	80.5	131.6
MO1	11.3	30.8	56.5	86.0	137.3
MO1 + 10% LM	11.5	33.8	57.7	85.4	141.1
MO1 + 25% LM	17.1	41.4	69.0	99.9	163.2
MO1 + 50% LM	20.3	54.2	84.0	116.7	183.4
MO1 + 100% LM	44.4	81.6	123.0	168.1	244.9
MO2	13.6	41.0	61.4	93.1	146.4
MO3.GRNIMN	4.2	14.0	29.7	52.1	92.8
MO3.GRNIMN + 10% LM	8.1	24.1	44.9	72.4	127.9

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
MO3.GRNIMN + 25% LM	18.4	44.7	71.6	109.4	170.1
MO3.GRNIMN + 50% LM	53.7	98.2	141.9	190.0	270.5
MO3.GRNIMN + 100% LM	137.8	212.1	277.1	356.6	478.5
MO3.SAL	18.5	48.6	77.3	110.3	175.0
MO3.SAL + 10% LM	36.5	68.7	107.0	149.5	219.9
MO3.SAL + 25% LM	59.7	106.3	149.4	207.4	296.1
MO3.SAL + 50% LM	110.7	186.8	234.9	301.9	427.1
MO3.SAL + 100% LM	259.1	363.8	442.2	539.7	693.4
MO3.SNK	31.1	62.9	97.5	144.1	218.3
MO3.SNK + 10% LM	51.1	94.6	132.8	189.6	264.4
MO3.SNK + 25% LM	83.3	135.1	178.6	252.1	339.5
MO3.SNK + 50% LM	156.0	223.8	290.5	368.2	473.7
MO3.SNK + 100% LM	291.3	398.5	480.9	584.2	771.2
MO4	3.5	10.4	24.0	45.7	83.6
MO4 + 10% LM	4.6	20.9	39.1	62.7	113.1
MO4 + 25% LM	11.4	35.0	61.7	88.7	153.0
MO4 + 50% LM	25.6	71.4	111.5	149.6	234.8
MO4 + 100% LM	95.4	171.1	226.7	280.9	394.2

4940 **Table 3-39. Quantiles of the Geometric Mean Abundance (across all years) for Salmon River**
4941 **Yankee Fork Salmon**

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
NAA	3.3	10.6	22.2	40.1	76.1
MO1	3.3	12.0	23.9	44.7	84.7
MO1 + 10% LM	3.6	14.0	27.7	51.9	86.8
MO1 + 25% LM	5.5	17.9	35.2	62.1	103.2
MO1 + 50% LM	9.1	25.6	45.5	75.0	121.1
MO1 + 100% LM	15.9	47.3	75.7	109.2	164.8
MO2	3.9	15.5	28.2	51.6	90.7
MO3.GRNIMN	1.7	4.6	10.0	22.6	53.3
MO3.GRNIMN + 10% LM	2.7	7.2	18.5	35.4	74.7
MO3.GRNIMN + 25% LM	6.6	20.8	38.8	60.5	106.6
MO3.GRNIMN + 50% LM	25.3	57.5	82.8	119.0	183.9
MO3.GRNIMN + 100% LM	86.7	140.6	187.5	239.9	336.6
MO3.SAL	5.5	19.9	41.9	72.0	121.3
MO3.SAL + 10% LM	10.4	34.9	61.5	95.6	156.0
MO3.SAL + 25% LM	21.9	59.7	92.7	134.2	210.7
MO3.SAL + 50% LM	67.3	119.0	161.2	217.6	293.4
MO3.SAL + 100% LM	165.8	244.5	301.4	381.1	493.4
MO3.SNK	12.3	33.0	56.0	92.3	151.3
MO3.SNK + 10% LM	25.3	52.3	82.9	119.6	202.5
MO3.SNK + 25% LM	42.4	85.6	120.4	162.2	239.3
MO3.SNK + 50% LM	79.1	148.1	194.6	257.6	354.5

Alternative	2.5 Q	25 Q	50 Q	75 Q	97.5 Q
MO3.SNK + 100% LM	206.5	289.0	357.8	427.9	577.9
MO4	1.4	4.2	10.1	20.4	52.4
MO4 + 10% LM	2.0	6.6	15.4	30.8	65.1
MO4 + 25% LM	4.7	14.7	29.2	50.6	91.4
MO4 + 50% LM	10.3	36.7	64.1	98.8	162.9
MO4 + 100% LM	58.9	106.8	151.1	197.1	273.2

4942 CSS Adult Metric Results

4943 **Table 3-40. Predicted Adult Fish Ocean Survival Rates with No Surface Passage (0%), 10 %, 20%, and 30% Surface Passage Efficiencies using the Cohort-Specific Model**

Alternative by Species	NAA 0%	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
Yearling Chinook	0.036	0.038	0.039	0.039	0.039	0.025	0.026	0.027	0.028	0.059	0.059	0.059	0.060	0.055	0.056	0.056	0.057

4944 **Table 3-41. Predicted SARs with no surface passage (0%), 10%, 20%, and 30% surface passage efficiencies using Life-Cycle Model**

Alternative / Population Percentage	NAA 0%	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
CC	0.027	0.028	0.028	0.028	0.028	0.018	0.018	0.019	0.019	0.049	0.049	0.049	0.049	0.044	0.044	0.044	0.045
GR	0.028	0.028	0.028	0.028	0.028	0.018	0.018	0.019	0.019	0.049	0.049	0.050	0.050	0.043	0.044	0.044	0.045
IMN	0.028	0.028	0.028	0.028	0.028	0.018	0.018	0.019	0.019	0.049	0.050	0.050	0.050	0.044	0.044	0.044	0.045
LOS	0.028	0.028	0.028	0.028	0.029	0.018	0.018	0.019	0.019	0.049	0.050	0.050	0.050	0.044	0.044	0.045	0.045
MIN	0.028	0.028	0.028	0.028	0.028	0.018	0.018	0.019	0.019	0.049	0.050	0.050	0.050	0.044	0.044	0.045	0.045
WEN	0.028	0.028	0.028	0.028	0.028	0.018	0.018	0.019	0.019	0.049	0.049	0.050	0.050	0.044	0.044	0.044	0.045

4945 **Table 3-42. Performance of SARs relative to the NAA , with no surface passage (0%), 10%, 20%, and 30% surface passage efficiencies using Life-Cycle Model. Values greater than 1 indicate the relative increase over the**
4946 **NAA**

Alternative / Population	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
CC	1.01	1.02	1.03	1.03	0.64	0.66	0.68	0.70	1.77	1.78	1.79	1.80	1.59	1.60	1.61	1.62
GR	1.01	1.02	1.02	1.03	0.64	0.66	0.68	0.70	1.77	1.78	1.79	1.80	1.57	1.58	1.60	1.61
IMN	1.01	1.02	1.03	1.03	0.64	0.66	0.68	0.70	1.79	1.80	1.81	1.81	1.58	1.59	1.61	1.62
LOS	1.01	1.02	1.02	1.03	0.64	0.65	0.67	0.69	1.77	1.78	1.79	1.79	1.57	1.59	1.60	1.62
MIN	1.01	1.01	1.02	1.03	0.64	0.65	0.67	0.69	1.79	1.80	1.81	1.82	1.59	1.60	1.61	1.63
WEN	1.01	1.01	1.02	1.03	0.64	0.66	0.67	0.69	1.78	1.79	1.79	1.80	1.57	1.59	1.60	1.61

4947 **Table 3-43. Predicted abundances with no surface passage (0%), 10%, 20%, and 30% surface passage efficiencies using Life-Cycle Model**

Alternative / Population Percentage	NAA 0%	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
CC	232	237	239	244	246	103	109	122	128	548	551	560	561	450	456	464	470
GR	258	266	278	286	289	91	99	119	128	739	743	764	766	600	609	625	633
IMN	2549	2577	2587	2626	2649	1395	1446	1519	1573	5297	5315	5325	5351	4537	4591	4648	4696
LOS	742	763	764	780	787	374	391	417	436	1650	1656	1658	1665	1391	1409	1426	1442
MIN	1140	1162	1169	1184	1196	621	647	676	705	2385	2394	2403	2416	2054	2077	2102	2126
WEN	1193	1205	1226	1243	1261	442	469	504	538	3241	3265	3287	3306	2662	2701	2745	2792

4948 **Table 3-44. Abundances relative to the NAA, with no surface passage (0%), 10%, 20%, and 30% surface passage efficiencies using Life-Cycle Model. Values greater than 1 indicate the relative increase over the NAA**

Alternative / Population Percentage	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
CC	1.02	1.03	1.05	1.06	0.45	0.47	0.53	0.55	2.37	2.38	2.42	2.42	1.94	1.97	2.00	2.03
GR	1.03	1.08	1.11	1.12	0.35	0.38	0.46	0.50	2.87	2.88	2.97	2.97	2.33	2.37	2.43	2.46
IMN	1.01	1.01	1.03	1.04	0.55	0.57	0.60	0.62	2.08	2.09	2.09	2.10	1.78	1.80	1.82	1.84
LOS	1.03	1.03	1.05	1.06	0.50	0.53	0.56	0.59	2.22	2.23	2.23	2.24	1.87	1.90	1.92	1.94
MIN	1.02	1.03	1.04	1.05	0.55	0.57	0.59	0.62	2.09	2.10	2.11	2.12	1.80	1.82	1.84	1.87
WEN	1.01	1.03	1.04	1.06	0.37	0.39	0.42	0.45	2.72	2.74	2.76	2.77	2.23	2.26	2.30	2.34

4949 **Table 3-45. Predicted Transport: In-river Ratios (TIRs) with no surface passage (0%), 10%, 20%, and 30% surface passage efficiencies. No transportation would occur under MO3**

Alternative by Species	NAA 0%	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
Wild Yearling Chinook	0.86	0.69	0.69	0.68	0.68	1.29	1.26	1.22	1.18	NA	NA	NA	NA	0.58	0.57	0.56	0.56

4950

3.6.4.1 TDG Tool Results

3.6.5 Snake River Spring Chinook

Table 3-46. Mean Reach Average Exposure (RAE) results for Snake River juvenile Spring Chinook in both Allriver (LWG-BON) and Lower Columbia (MCN – BON) reaches, under the different alternatives.

Alternative	RAE (%) for Allriver (LWG-BON)	RAE (%) for Lower Columbia (MCN-BON)
NAA	115.1	115.4
MO1	115.5	115.6
MO2	112.8	112.3
MO3.SAL	109.2	116.6
MO3.GRNIMN	109.3	116.8
MO3.SNK	109.2	116.6
MO4	119.6	119.2

Note: The Allriver model run used transportation rules, whereas the Lower Columbia run did not.

Table 3-47. Mean survival results for Snake River juvenile Spring Chinook in both Allriver (LWG-BON) and Lower Columbia (MCN – BON) reaches, under the different alternatives. The Allriver model run used transportation rules, whereas the Lower Columbia run did not.

Alternative	Survival (%) for Allriver (LWG-BON)	Survival (%) for Lower Columbia (MCN-BON)
NAA	97.3	98.4
MO1	96.9	98.5
MO2	98.7	99.2
MO3.SAL	97.7	97.7
MO3.GRNIMN	97.8	97.8
MO3.SNK	97.7	97.7
MO4	82.8	95.7

Table 3-48. Counts of years when Reach Average Exposure (RAE) is greater than, or equal to 120% for Snake River juvenile Spring Chinook in both Allriver (LWG-BON) and Lower Columbia (MCN – BON) reaches, under the different alternatives.

Alternative	Counts of years when RAE is >= 120% for Allriver (LWG-BON)	Counts of years when RAE is >= 120% for Lower Columbia (MCN-BON)
NAA	1	3
MO1	1	2
MO2	1	1
MO3.SAL	0	1
MO3.GRNIMN	0	2
MO3.SNK	0	1
MO4	36	28

Note: The Allriver model run used transportation rules, whereas the Lower Columbia run did not.

3.6.6 Snake River Steelhead

3.6.6.1 COMPASS Results

Table 3-49. Summary results for Snake River Steelhead by Alternative

Alternative	Mean Survival	95% CI Survival	Mean Arrival at BON	Proportion Destined for Transport	Mean Gas Exposure	Proportion Powerhouse Passage	Mean Travel time (LGR-MCN) (Days)	Mean Travel time (MCN-BON) (Days)	Mean Migration Rate (LGR-MCN) (mi/day)	Mean Migration Rate (MCN-BON) (mi/day)	Mean Temp Experience (Snake)	Mean Temp Experience (Columbia)	Mean Flow Experience (Snake)	Mean Flow Experience (Columbia)	Mean Gas Experience (Snake)	Mean Gas Experience (Columbia)	Avg. Num Bypasses	Avg. Num Turbine Passages	Avg. Num Spill Passages
NAA	0.4271	0.3682-0.4821	133.19	0.3968	114.71	0.216	9.65	6.74	13.23	26.64	11.31	13.26	91.52	270.71	112.03	115.07	1.29	0.44	6.27
MO1	0.4224	0.3631-0.4778	133.46	0.3908	114.91	0.184	9.60	6.78	13.27	26.42	11.32	13.33	91.82	266.06	112.42	115.22	1.07	0.41	6.53
MO2	0.4016	0.3591-0.4391	131.63	0.4773	112.71	0.282	10.03	6.88	12.84	26.10	11.20	13.14	90.70	265.44	110.65	112.00	1.12	1.13	5.74
MO3-GRNIMN-WH	0.5107	0.4250-0.5913	141.15	0.0000	111.87	0.109	8.94	6.27	11.06	28.43	12.00	14.20	95.04	279.55	101.11	117.48	0.17	0.27	3.56
MO3-SAL-WH	0.5268	0.4555-0.5930	134.25	0.0000	111.54	0.105	4.21	6.88	20.86	26.38	11.37	13.13	91.96	264.85	101.03	116.99	0.16	0.26	3.58
MO3-SAL-W	0.5263	Not Estimated	134.26	0.0000	111.54	0.107	4.21	6.88	20.86	26.38	11.37	13.13	91.96	264.85	101.03	116.99	0.16	0.27	3.57
MO3-SNK-WH	0.5646	0.4890-0.6277	131.73	0.0000	111.32	0.110	1.81	7.19	47.34	25.49	11.15	12.74	90.39	258.77	100.99	116.63	0.16	0.28	3.56
MO4	0.4314	0.3676-0.4895	138.17	0.0719	118.26	0.043	8.71	6.35	14.37	27.97	11.58	13.72	94.74	281.85	116.24	118.74	0.21	0.13	7.65

3.6.6.2 CSS Juvenile Metrics Results

Table 3-50. Predicted juvenile survival (LGR-BON) with no surface passage (0%), 10%, 20%, and 30% surface passage efficiencies using the cohort-specific model

Alternative and Passage Efficency	NAA 0%	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
Steelhead	0.571	0.578	0.581	0.585	0.588	0.394	0.411	0.427	0.444	0.829	0.830	0.830	0.831	0.729	0.732	0.734	0.737

Table 3-51. Predicted Juvenile Steelhead Travel Times (LGR-BON) with No Surface Passage (0%), 10%, 20%, and 30% Surface Passage Efficiencies Using the Cohort-Specific Model

Alternative by Passage Efficiency	NAA 0%	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
Steelhead	16.2	16.3	16.3	16.2	16.2	17.6	17.5	17.4	17.2	11.0	11.0	11.0	11.0	14.7	14.7	14.6	14.6

Table 3-52. Mean Seasonal Average PITPH (95% Confidence Interval) for Spring/Summer Steelhead Over the 80-Year Water Record for Each CRSO EIS Alternative Used in the CSS Modeling

Species	EIS Alternative	No PHSP	PSP–10% Efficiency	PSP–20% Efficiency	PSP–30% Efficiency
Steelhead	NAAA	1.96 (1.85-2.06)	–	–	–
Steelhead	MO1	1.69 (1.56-1.83)	1.68 (1.54-1.81)	1.66 (1.53-1.79)	1.64 (1.51-1.77)
Steelhead	MO2	3.65 (3.55-3.75)	3.52 (3.43-3.62)	3.39 (3.3-3.48)	3.26 (3.18-3.35)
Steelhead	MO3	0.47 (0.42-0.52)	0.47 (0.42-0.52)	0.46 (0.41-0.51)	0.46 (0.41-0.51)
Steelhead	MO4	0.36 (0.31-0.42)	0.34 (0.29-0.39)	0.31 (0.26-0.36)	0.28 (0.24-0.32)

Notes: [A] There are no PSP structures in the NAA. Therefore, the CSS did not estimate PITPH under the 10%, 20%, and 30% efficiencies for this alternative.
PSP refers to the addition of Powerhouse Surface Passage structures, with assumed 10%, 20% and 30% efficiencies.

3.6.6.3 CSS Adult Metrics Results

Table 3-53. Predicted Adult Fish Ocean Survival Rates with No Surface Passage (0%), 10%, 20%, and 30% Surface Passage Efficiencies using the Cohort-Specific Model.

Alternative by Species	NAA 0%	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
Steelhead	0.029	0.029	0.029	0.030	0.030	0.024	0.024	0.025	0.025	0.039	0.039	0.039	0.040	0.035	0.035	0.035	0.036

Table 3-54. Predicted SARs with no surface passage (0%), 10%, 20%, and 30% surface passage efficiencies using the cohort-specific model.

Alternative by Species	NAA 0%	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
Steelhead	0.018	0.018	0.019	0.019	0.019	0.012	0.012	0.013	0.013	0.050	0.050	0.050	0.050	0.030	0.031	0.031	0.031

Table 3-55. Predicted Transport: In-river Ratios (TIRs) with no surface passage (0%), 10%, 20%, and 30% surface passage efficiencies.

Alternative by Species	NAA 0%	MO1 0%	MO1 10%	MO1 20%	MO1 30%	MO2 0%	MO2 10%	MO2 20%	MO2 30%	MO3 0%	MO3 10%	MO3 20%	MO3 30%	MO4 0%	MO4 10%	MO4 20%	MO4 30%
Steelhead	1.41	1.09	1.10	1.07	1.08	2.51	2.41	2.32	2.23	NA	NA	NA	NA	0.82	0.82	0.80	0.79

Note: No transportation would occur under MO3.

3.6.6.4 TDG Tool Results

Table 3-56. Mean Reach Average Exposure (RAE) results for Snake River juvenile Steelhead in both Allriver (LWG-BON) and Lower Columbia (MCN – BON) reaches, under the different alternatives. The Allriver model run used transportation rules, whereas the Lower Columbia run did not.

Alternative	RAE (%) for Allriver (LWG-BON)	RAE (%) for Lower Columbia (MCN-BON)
NAA	115.1	115.3
MO1	115.5	115.6
MO2	112.7	112.1
MO3.SAL	109.2	116.6
MO3.GRNIMN	109.4	116.9
MO3.SNK	109	116.3
MO4	119.8	119.3

Table 3-57. Mean survival results for Snake River juvenile Steelhead in both Allriver (LWG-BON) and Lower Columbia (MCN – BON) reaches, under the different alternatives. The Allriver model run used transportation rules, whereas the Lower Columbia run did not.

Alternative	Survival (%) for Allriver (LWG-BON)	Survival (%) for Lower Columbia (MCN-BON)
NAA	97.3	94.6
MO1	97.3	94
MO2	98.4	96.9
MO3.SAL	96.6	96.5
MO3.GRNIMN	96.6	96.5
MO3.SNK	96.6	96.6
MO4	94.7	78

Table 3-58. Counts of years when Reach Average Exposure (RAE) is greater than, or equal to 120% for Snake River juvenile Steelhead in both Allriver (LWG-BON) and Lower Columbia (MCN – BON) reaches, under the different alternatives. The Allriver model run used transportation rules, whereas the Lower Columbia run did not.

Alternative	Counts of years when RAE is >= 120% for Allriver (LWG-BON)	Counts of years when RAE is >= 120% for Lower Columbia (MCN-BON)
NAA	1	2
MO1	2	2
MO2	0	0
MO3.SAL	0	2
MO3.GRNIMN	0	2
MO3.SNK	0	1
MO4	37	25

3.6.7 Snake River Coho Salmon

Table 3-59. Snake River Coho Salmon Qualitative Effects Analysis Matrix

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Juvenile passage at the four lower Columbia River dams and four lower Snake River dams affects dam-specific and in-river survival rate of juvenile Snake River coho salmon.	Juvenile Snake River spring Chinook salmon as surrogate for juvenile Snake River coho response for this metric. Use direct estimate of in-river survival for Snake River coho No Action Alternative. Estimate change in in-river survival (e.g., MO1-NAA/NAA) for juvenile Snake River spring Chinook as surrogate for coho using COMPASS and CSS in-river survival estimates.[1]	2007-2017 LGR to MCN average Snake River coho in-river survival (95% lower and upper confidence intervals) from Widener et al. (2019) analysis: 79% (71% to 87%) 2007 to 2017 LGR to BON average in-river survival for Snake River PIT-tagged coho (95% lower and upper confidence intervals): 68%	See change in Snake River spring/summer Chinook salmon downstream passage.	See change in Snake River spring/summer Chinook salmon downstream passage.	See change in Snake River spring/summer Chinook salmon downstream passage.	See change in Snake River spring/summer Chinook salmon downstream passage.	Dan Widener (2019). Apply change in COMPASS and CSS in-river survival for juvenile spring Chinook salmon as qualitative surrogate for Snake River coho salmon.
Predation in reservoirs – changes in the LGR to BON reservoir environments (relative to the NAA) may change the susceptibility of Snake River juvenile coho salmon to avian and piscine predators.	Susceptibility of juvenile coho to predators (avian and piscine) in reservoirs. The fish team will also evaluate measures that affect the predation rate. Change in piscine predator activity is captured at least in part by COMPASS in-river survival response (juvenile Snake River spring Chinook) above and does not need duplication or double counting here. Metrics: 1) Change in proportion turbine passage (an increase may signify higher susceptibility to predation); 2) Improved fish passage (IFP) turbines (this measure should pass fish with less impact than non-IFP turbines); and 3) Change in travel time (an increase may signify higher susceptibility to predation).	1) 0.82 average turbine passages for Snake River spring Chinook salmon from LGR to BON (COMPASS). 2) IFP turbines at IHR and MCN, not JDA. 3) Travel time 17.7 days juvenile Snake River spring Chinook salmon average travel time from LGR to BON (COMPASS).	1) and 3) See change in Snake River spring/summer Chinook downstream passage. 2) IFP turbines from NAA, also JDA.	1) and 3) See change in Snake River spring/summer Chinook downstream passage. 2) IFP turbines from NAA, also JDA.	1) and 3) See change in Snake River spring/summer Chinook downstream passage. 2) IFP turbines from NAA, also JDA.	1) and 3) See change in Snake River spring/summer Chinook downstream passage. 2) IFP turbines from NAA, also JDA.	CP: Using spring Chinook salmon as the surrogate, the team can consider active tag survival tests showing outcome by route – could the team cite the whole set of these? Steelhead have the highest avian predation, followed by CH1, than CH0. We may presume that most mortality of smolts through a route is due to predation rather than direct mortality. Most dams have small to moderately lower immediate survival for turbine passage (with route fraction from 2% to 17% for dams except BON). Of note, BON has the highest turbine route fraction of 8 dams (29% in 2011) and slightly higher survival than the spillway (~96%). For travel time, the acoustic tag tests typically report cohort tailrace egress time rather than by route.
Adult upstream passage at the four lower Columbia River dams and four lower Snake River dams affects in-river survival rate of juvenile Snake River coho salmon.	Use adult Snake River fall Chinook salmon passage analysis as proxy for adult coho passage considerations.[2]	BON to LGR adult Snake River fall Chinook salmon average survival 80.4% to 88.8% (depending on whether migrated in-river or were transported as juveniles) estimate from 2019 CRS BiOp, page 853.	See change in fall Chinook salmon upstream passage for MO1.	See change in fall Chinook salmon upstream passage for MO2.	See change in fall Chinook salmon upstream passage for MO3.	See change in fall Chinook salmon upstream passage for MO4.	2019 CRS BiOp, page 853.

[1]Coho-specific dam survival measurements are not available, but coho-specific in-river survival estimates are available for current system conditions. There are no coho-specific models available to predict changes in these metrics from CRS alternatives. However, survival models that project changes in these metrics based on changes in hydrosystem operation and configurations are available for spring Chinook salmon and steelhead (COMPASS, CSS). Coho salmon outmigration timing generally overlaps with both spring Chinook salmon and steelhead, and all three species have dominant stream-type life histories. However, the size of juvenile coho and juvenile spring Chinook salmon tend to be more closely aligned than juvenile steelhead. Therefore, juvenile spring Chinook salmon will be considered the appropriate surrogate for juvenile coho salmon for purposes of qualitative effects analysis of changes in passage. This use of juvenile Snake River spring Chinook salmon as a surrogate for juvenile lower Columbia River coho salmon is consistent with the 2008 FCRSP BiOp, 2013 Recovery Plan, and 2019 CRS BiOp.

[2]Dam survival and reach survival measurements specific to adult coho are not available for the previous 10-year period. Adult Coho salmon upstream migration timing general overlaps with fall Chinook salmon, through fall Chinook salmon migration timing tends to start earlier in some years (DART). Far more adult fall Chinook salmon enter the CRS system than Coho salmon adults, so survival estimates generally have higher certainty for the former than the latter. Adult fall Chinook salmon will be considered the appropriate surrogate for adult coho salmon for purpose of qualitative effects analysis of changes in passage. This use of adult Snake River fall Chinook salmon as a surrogate for adult lower Columbia River coho salmon is consistent with the 2008 FCRPS BiOp, 2013 Recovery Plan, and 2019 CRS BiOp.

NOTE ABOUT OCEAN SURVIVAL: The CSS (2017) makes no prediction in terms of survival benefits for lower Columbia River, upper Columbia River, or lower Snake River coho salmon. The CSS predicts that increased spill could substantially reduce latent mortality of juvenile yearling Chinook salmon and steelhead moving downstream through the mainstem dams. If this were to occur for coho salmon, SARs would also be improved for the XX populations that pass above XX dams and migrate during the spring, and the potential benefit would generally be less than what may occur for species that experience passage through a greater number of Columbia and Snake River mainstem dams (NMFS, 2019). The COMPASS and LCM models do not ascribe latent effects to specific routes of passage, but the NWFSC considered four latent mortality reduction scenarios that were estimated to represent the ranges of potential outcomes (increased productivity) indicated by the CSS (2017) for the CRSO alternatives compared to the CRSO No Action Alternative spill operations.

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3.6.8 Snake River Sockeye Salmon

Table 3-60. Snake River Sockeye Salmon Qualitative Effects Analysis Matrix

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Juvenile Mainstem Passage							
Juvenile travel time affects juvenile survival.	Downstream Travel Time Fish modeling travel time changes for juvenile spring Chinook as surrogate for change in juvenile sockeye travel time. COMPASS and CSS travel times are for in-river fish only. Transported travel times are faster still.	Avg. travel time 17.71 days for juvenile Chinook (COMPASS: LWG-BON) Note: no confidence intervals calculated for juvenile chinook travel time. While sockeye are slightly smaller than their surrogate (Chinook) they generally have shorter travel times. These data should be used for relative differences in alternatives Under the NAA Snake River sockeye will likely experience a travel time slightly shorter than 17.71 days.	Negligible decrease. (17.37 days - 8 hours shorter) Negligible decrease in travel time under MO1	Minor increase. (18.34 days - 15 hours longer) Assume minor increase in travel times and poorer survival under MO2	Decrease. (12.15 days - 5.5 days shorter) Assume a Major reduction in travel time. Assume better survival under MO3	Decrease. (16.18 days - 36 hours shorter) Assume minor decrease in travel times and better survival under MO4	Smolt survival is inversely related to travel time. Question: why not just use in-river chinook survival as a surrogate for sockeye? Used spring Chinook. Use Faulkner report for current travel times as well. Sockeye travel times are usually much faster than Chinook travel time. Note: no confidence intervals calculated for juvenile Chinook travel time.
Transport as juveniles is associated with lower adult survival in the BON to MCN reach (Crozier et al., 2018). However, juvenile transport is also associated with higher juvenile survival.	% of juvenile sockeye transported	% of fish transported: 39.0% of juvenile Chinook are destined for transport. Assume a similar percent of Sockeye would also be transported	% of fish transported: 38% Note: no confidence intervals calculated for juvenile chinook destined for transport. No change from NAA	% of fish transported: 47% Note: no confidence intervals calculated for juvenile chinook destined for transport. 8% increase in transport. These fish will have minor increase in initial survival rates, and minor increases in straying.	% of fish transported: No Transport Under this alternative fish will have moderate increases in juvenile survival and adult returns.	% of fish transported: 7% Note: no confidence intervals calculated for juvenile chinook destined for transport. Assume minor decreases in juvenile survival and adult straying.	Use COMPASS for proportion transported (Chinook as surrogate for this metric)? Check relationship for survival in transport. CSS annual report does bypass and transport comparison. Larger hatchery smolts benefited most from transport, while smaller natural smolts did not benefit. Use sockeye data from 2011 to set expectations for surrogate. Suggest deleting this relationship as it is not certain the overall effect of transport on survival.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Spill affects juvenile migration routes through the projects. Increased spill generally reduces travel time as fish find spill routes more readily than turbine routes. More spill generally means fewer powerhouse encounters.	In-river survival from COMPASS Modeling - use spring/summer Chinook as surrogate. Add Powerhouse encounter rate as well.	In-river survival average: 50.4% (95% CI: 45.7%-54.4) for juvenile chinook COMPASS: Prop Power house = 0.28 Under the NAA SR sockeye will continue to survive at the approximately the same levels as shown in the recent years. Power house encounter will also continue at approximately the same rate.	In-river survival average: 51.0% (95% CI: 46.2-55.2%) Prop Power house = 0.24 Negligible Increase, but not a statistically significant change. No difference from NAA.	In-river survival average: 50.1% (95% CI: 46.2-53.4%) Prop Power house = 0.38 Negligible Increase, but not a statistically significant change Higher proportion of powerhouse but no difference from NAA survival.	In-river survival average: 60.0% (95% CI: 54.8-64.6%) Prop Power house = 0.17 Significant difference from NAA survival. Moderate increase in survival and moderate decrease in powerhouse encounter.	In-river survival average: 50.7% (95% CI: 46.0-54.9%) Prop Power house = 0.06 Significant reduction in Power House Encounter did not equate to significant change in survival = because transported fish survive at 98%. No change in survival, Major change in powerhouse encounters.	While Chinook was used as a surrogate for sockeye, the smaller size of sockeye makes it unlikely they survive as well as Chinook. Assume survival is slightly lower. Relative survivals should be used to determine impacts from alternatives. Check to see if survival for in-river only differs from In-river and transported. Consider using both in the analysis. Note: no confidence intervals calculated for juvenile Chinook travel time. Can use actual Sockeye data to compare with Surrogate data.
Predation in reservoirs – changes in the reservoir environment (relative to the NAA) may change the susceptibility of juvenile sockeye to avian and piscine predators.	Risk of predation to piscine predators. Use temperature during outmigration (April-June at IHR) as a surrogate for piscine predation. Use habitat increase or decrease for Avian Predators	Mean Water temperature April - June under NAA is 13.03°C degrees. No change from current. Under the NAA an unknown number of juvenile sockeye will be removed from the population by piscine predators. Literature estimates that smallmouth bass, Walleye, and NPM remove large numbers of smolts. Erhardt et al. (2018) and Tiffen et al. (2018) found that SMB consumed over 300,000 sub adult Chinook in a 22-km study reach.	Mean Water temperature April - June under NAA is 13.03C degrees (1.5 degree SD). No change from NAA JDA operations in MO1 will raise water elevations to prevent Avian nesting and reduce risk of predation from avian predators.	Mean Water temperature April - June under NAA is 13.00°C (1.6 degree SD). No change from NAA.	Under MO3, large numbers of predators will be eliminated because of high sediment and low dissolved oxygen concentrations during dam breaching. SMB are expected to return to pre-breaching densities. We expect long term reductions in Walleye, and other lentic species. In addition, water travel time will decrease dramatically reducing exposure to SR predators. Overall, there will be a major decrease in risk to piscine predation at the time of breaching followed by gradual increases in risk of exposure to these predators. Turbidity is expected to increase and will reduce predation risk as well.	Mean Water temperature April - June under NAA is 13.03°C (3.3 degree SD). No change from NAA. MOP operations at projects may increase nesting habitat and risk of avian predation.	Oregon looks at predation in terms of abundance x rate of predation. If measure is likely to change either abundance or rate, then assume changing. Then compensatory or additive. No abundance data. See Fall Chinook matrix for general relationships for Piscine Predators Avian predation reduced for Sockeye relative to steelhead. Size selectivity. Note: change in piscine predator activity is captured at least in part by COMPASS (juvenile Chinook) in-river survival response above, specifically the temperature relationship.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Avian predation – avian nesting habitat increases or decreases.	Increase or decrease in avian nesting habitat.	Avian nesting habitat and risk to avian predators is expected to have minor decreases under ongoing avian management plans under NAA.	Reduced nesting habitat relative to the NAA will likely reduce avian predation risk under MO1 - a result of JDA pool operations to dissuade nesting at Blalock. Earlier migrants (steelhead and Sockeye) are more impacted.	No change from NAA	Increase in nesting habitat expected in lower Ice Harbor pool. Only those islands that would not be inundated in spring flows and are suitable habitat. Potential increase in risk from added nesting habitat would likely be offset by significant decreases in travel times - reducing exposure to avian predators. (see travel times under MO3).	No change from NAA	Islands in free-flowing Snake River do not have avian colonies. Would they use the lower Snake? Get information from avian team to discuss potential use of snake river islands. Note: Wildlife team is assessing change in habitat opportunity for avian predators. Resident fish team is assessing change in piscine predators.
Adult Passage							
Juvenile transport results in higher rate of fallback and straying relative to in-river migrants and, therefore, longer adult migration time. Transported sockeye are 2.9 times more likely to fall back (Crozier et al., 2015). Use COMPASS for proportion transported (steelhead as surrogate for this metric)?	Percent of juvenile sockeye transported, use SARs from Chinook as a surrogate measure for relative differences in Alternatives Use sockeye data to test surrogate use. Conduct PTAGIS Search	Under the NAA ~ 39% of all Snake River sockeye will continue to be transported. These fish would be ~ 2.9 times more likely to fall back and experience delay. (Crozier et al., 2015)	No change ~ 39% Note: no confidence intervals calculated for juvenile chinook destined for transport. No Difference from NAA	Increase. (47%) Note: no confidence intervals calculated for juvenile chinook destined for transport. Expect increase in fallback when compared to the NAA	No Transport Expect reductions in fallback under MO3	Decrease. (7%) Note: no confidence intervals calculated for juvenile chinook destined for transport. Assume fallback, and lower migration delays.	Get data from NOAA, need to align with NAA spill. Straying, not shown a correlation with transport, but assume more fallback is correlated to more straying. Get baseline % from FPC/NOAA. 10-year average is 65,000 juveniles, need to convert to %: LWG is about 15%. Temperature and flow confound fallback - higher temperatures and higher flows lead to higher fallback (Crozier et al. 2018).
Higher water temperatures correspond to lower adult survival (less than 50% when water temperature is greater than 18°C ~ specific to BON). Use temperature for overriding predictor.	Temp - % days temps exceed 18°C at IHR Crozier used temp at Ice Harbor on the day of passage. Jun 21 thru July 31 to bracket 95% of the run. Used 80 year data set: % of all days Jun 21 - Jul 31 over 18°C	Percent of Days over 18°C Jun 21-July 31 at IHR: 78.7% Temperatures would exceed 18°C at Ice Harbor ~ 78% of all days during sockeye migration. Some years, temperature would continue to have negative impacts to the species. Extremely hot and dry years (e.g., 2015) would continue to result in losses to the sockeye run. Climate change could increase summer temperatures, but otherwise no change expected. Temperatures will continue to be above 18° C for periods of the year.	Percent of Days over 18C Jun 21-July 31 at IHR: 77.5% No change from NAA	Percent of Days over 18°C Jun 21-July 31 at IHR: 78.8% No change from NAA	Percent of Days over 18°C Jun 21-July 31 at IHR: 87.3% ~ three additional days over 18°C Under MO3 Sockeye would have greater thermal stress than under the NAA. However, removal of dams may reduce delays and decrease the time fish are exposed to these thermal stressor. Also would not have transportation effects that increase fallback.	Percent of Days over 18°C Jun 21 - Jul 31 at IHR: 78.7% No change from NAA	18°C is inflection point for survival/temp relationship at BON. Water quality standards vary; include narrative water quality standards. Cumulative temperature is critical at higher temperatures. Climate change impacts may be important for these fish. Compare water years at each alternative. Mitigation: additional cooling measures at LWG and other dams.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Hydrosystem delays (operations and natural) result in migration period in later, hotter period). Transported fish are more likely to stray and spend additional time in hot water. Crozier may have relationship that the team can model.	Arrival timing at LGR correlated with temps at BON, MCN, LGR (from previous relationship).	In some years, sockeye would continue to be lost due to arrival timing coinciding with years where mainstem water temperatures become too high before the fish move through this corridor.	–	–	–	–	Later portion of the run gets too warm to survive. How would the team evaluate this? How do you predict arrival time? Do operations in system dictate or impact the arrival timing. Temperature already covers much of the delay. Covered in temperature metric above - delete.
Temps – delay in upstream adult migration more susceptible to harvest (in harvest area more time), and increase harvest in the thermal refugia areas. See temperature delays above.	Temps at MCN, BON, during upstream migration period Look at hottest years for differences in alternatives. Is this covered in Temperature metric above?	Influences of migration delays and warm temperatures would continue current levels influence on harvest exploitation rates.	–	–	–	–	Transported fish may also move back and forth through the harvest fishery area more. If temps increase, it would result in potentially more exploitation. However, does not affect total allowable harvest. Sockeye harvest is targeted to Mid-C stocks. If SR stock is delayed they get into the harvest. Metric did not detect differences in any alternative. Delete.
Flows affect adult migration – sockeye migrate faster at higher flows, but are likely confounded by temperature. Is this covered in the temperature metric above?	Flows and temp links. Mean flow at IHR Jun 21 – Jul 31	55,005 cfs Under the NAA SR Sockeye will continue to migrate upstream June through August.	56,675 cfs No change from NAA	52,082 cfs Under MO2 there will be a slight reduction in flows during SR Sockeye migration period. This reduction is ~ 5% of the normal flow under NAA. Negligible change in migration rate compared to the NAA.	54,975 cfs No difference from the NAA Need to discuss upstream migration in free flowing river vs reservoir environment in the EIS. Citations and write up - PTAGIS.	55,027 cfs No change from NAA	Migrate on descending end of the hydrograph. Correlate peak flows with temperatures. Sockeye show migration rates of between 17-30 miles per day. Flows can either induce migration or slow it. Follow up with Lisa Crozier. Team - need help on how to measure this relationship. Discuss at MO1 meeting. Suggest deleting.
Longer adult travel times correspond to lower adult survival. Conduct PTAGIS search for river travel times versus reservoir travel times.	Upstream Travel Time (Relationship with Flow?)	Adult fish will be delayed and survive at similar rates under the NAA.	–	–	–	–	Team – discuss how to predict increases or decreases in adult travel times. Travel time is tied to temperature and flow. Both already explored. Transportation effects on travel time also covers this. Was not the best predictor in Crozier et al. (2018).
Fallback – ladder temperatures can increase fallback if too warm. Currently, pumps cool the water; in NAA). Check Crozier et al. (2018) = Ladder temperature differential at Lower Granite was a significant predictor of fallback at Lower Granite.	Qualitatively describe if measures to improve ladder temps are in alternative.	–	–	–	–	–	Highest fallback rates, LGR, BON; This metric is tied to transport and temperature. Temperature differentials were not a good indicator of fallback in this analysis and transport analysis are done above. Differentials at LWG are already mitigated by pump. Delete.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Adult ladder differentials of ≥2°C can delay adult migration.	Frequency of adult ladder temp differentials of ≥2°C (% days differential > 2c at LMO Jun 20 thru Jul 31 ~ 95% of the migration). Difference between modeled surface and TW.	50.1% of all days with greater than 2°C differential. Under the NAA there is a risk of ladder delays on ~ 50% of all days during the migration.	65.5% of all days with > 2°C differential. There will be more risk of delay at Ladders under MO1. Installation of Pumps may reduce number of days with differentials	53.2% of all days with > 2°C differential. One day difference from NAA. No difference from NAA.	No Dams = No differentials. Any delays would not be the result of ladder temperature differentials.	58.9% of all days in Aug and Sep with > 2°C differential. Potential for more delay under MO4 Installation of Pumps May reduce number of days with differentials	Highest fallback rates, LGR, BON; This metric is tied to transport and temperature. Temperature differentials were not a good indicator of fallback in this analysis and transport analysis are done above. Make sure qualitative discussion covers the measures with pump installation. LMO had highest ladder differentials (Crozier et al. 2018).
TDG and Adults: What are the impacts to adults – research implications? Document TDG during time of migration – not total spill.	TDG: number of days over 120%, 125% at BON, MCN, LGR	BON: 120 = 10.8; 125 = 3.2 MCN: 120 = 6.8; 125 = 2.1 LGR: 120 = 2.7; 125 = 1.3 Under the NAA there would be minor impacts to Sockeye from TDG. GBD Impacts from elevated gas generally increase at 120%.	BON: 120 = 10.6; 125 = 2.9 MCN: 120 = 6.8; 125 = 1.8 LGR: 120 = 3.0; 125 = 1.5 No change from NAA	BON: 120 = 8.9%; 125 = 2.4% MCN: 120 = 4.4%; 125 = 1.2% LGR: 120 = 2.1%; 125 = 0.9% Under MO2, there would be fewer days over 120 and 125% TDG at all projects. Reduced negative impacts compared to NAA.	BON: 120 = 10.7%; 125 = 2.8% MCN: 120 = 9.4%; 125 = 1.4% LGR: 120 = 0.0%; 125 = 0.0% For BON and MCN, no difference from NAA. The lower Snake River projects would be removed and TDG would be greatly reduced. Reduced negative impacts to Sockeye.	BON: 120 = 25.8%; 125 = 3.7% MCN: 120 = 13.3%; 125 = 3.0% LGR: 120 = 22.6%; 125 = 12.9% More days over 120 and 125% would have greater negative impacts to Sockeye	Data collected during high flow conditions. Will begin to operate for high TDG under all flows. Talk to hatchery and adult trap personnel about effects to sockeye adults. TDG will be dropping as Sockeye adults pass dams. Look at TDG modeling for migration peak. Crozier et al. (2015 or 2018) discusses Gas metric. Shows negative relationship with survival and positive relationship with fallback. Spill driven?
TDG and Juveniles: Document TDG for outmigrating sockeye, not total spill.	TDG: number of days over 120%, 125% at BON, MCN, LGR	BON: 120 = 10.8; 125 = 3.2 MCN: 120 = 6.8; 125 = 2.1 LGR: 120 = 2.7; 125 = 1.3 Under the NAA there would be minor impacts to Sockeye from TDG. GBD Impacts from elevated gas generally increase at 120%.	BON: 120 = 10.6; 125 = 2.9 MCN: 120 = 6.8; 125 = 1.8 LGR: 120 = 3.0; 125 = 1.5 No change from NAA	BON: 120 = 8.9%; 125 = 2.4% MCN: 120 = 4.4%; 125 = 1.2% LGR: 120 = 2.1%; 125 = 0.9% Under MO2 there would be fewer days over 120 and 125% TDG at all projects. Reduced negative impacts compared to NAA.	BON: 120 = 10.7%; 125 = 2.8% MCN: 120 = 9.4%; 125 = 1.4% LGR: 120 = 0.0%; 125 = 0.0% For BON and MCN no difference from NAA. The lower Snake River projects would be removed and TDG would be greatly reduced. Reduced negative impacts to sockeye.	BON: 120 = 25.8%; 125 = 3.7% MCN: 120 = 13.3%; 125 = 3.0% LGR: 120 = 22.6%; 125 = 12.9% More days over 120 and 125% would have greater negative impacts to Sockeye	Data collected during high flow conditions. Will begin to operate for high TDG under all flows. Benefits can outweigh TDG negative effects.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Tolerance to Sediment	Sediment levels in mg/l	Average concentration under current conditions ~ 2 mg/l Under the NAA no negative impacts are expected from sediment levels.	No change from NAA	No change from NAA	Estimates of nearly 25,000 mg/l during breach and 30 mg/l after breach. 27 days over 5,000 mg/l. Timing of breach currently occurs at the tail end of the sockeye migration. Severity index (Newcombe et al., 1996) of 11 indicates mortality between 20% and 40% of fish downstream of these dams. However, most of the Sockeye run will have passed the dams by the time these levels are reached. No change from NAA. May be long term impacts from spring freshets the following years.	–	–
Tolerance to DO levels	DO concentrations	Under the NAA, Most stations on the Snake River are between 9.5 and 11 mg/l. Under the NAA, no negative impacts are expected from reduced Oxygen concentrations.	No change from NAA	No change from NAA	Estimate of dissolved oxygen levels dropping to ~ 2 mg/l throughout the LGS and LMO pool in year one. May be some loss of late migrating sockeye in these two pools during the peak of sediment release, but most of them will have already passed.	–	–

Note: + Reference to surrogate

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5048 ### 3.6.9 Snake River Fall-Run Chinook Salmon

5049 **Table 3-61. Snake River Fall Chinook Salmon Qualitative Effects Analysis Matrix**

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Spawning, Incubation, and Egress							
Access to acceptable size spawning gravel affects spawning success.	Availability of substrate with sediment size from 1-12 inches - (spring/summer Chinook can use gravel down to pea size, would assume fall Chinook would as well if that was only available. 12" seems too large for the size of most SR fall Chinook to move).	Suitable substrates occur mainly in tailraces below project dams. Mainstem spawning is limited in the CRSO project area, primarily in lower Snake dam tailraces. Additional spawning upstream of CRSO project area between Hells Canyon Complex and upstream of Lower Granite reservoir, including the Clearwater River. Construction of the Lower Snake projects inundated fall Chinook spawning habitat. (Corps, 2002).	Sediment distribution assumed similar to NAA.	Sediment distribution assumed similar to NAA.	2002 LSR Feasibility Report estimates and increase from 226 to 3,521 acres of spawning habitat for fall chinook in the lower Snake River (15-fold increase) under a breach scenario.	Sediment distribution assumed similar to NAA.	Some indication of flattening in S/R relationship which may indicate spawning/rearing habitat limitation at some streams.
Acceptable water depth is necessary for successful spawning.	Availability of water depth from 4-8.1 meters. Use the values below for MO3 and other river reaches. However, same study showed that fall chinook used different depths in river reaches (i.e., <1-4 meters in Hells Canyon Reach). Combine metric - depths 1 to 8 meters in depth.	Depth is not a limiting factor for Fall Chinook spawning. Mainstem spawning is limited in the CRSO project area, primarily in lower Snake dam tailraces. Additional spawning upstream of CRSO project area between Hells Canyon Complex and upstream of Lower Granite reservoir, including the Clearwater River. Construction of the Lower Snake projects inundated fall Chinook spawning habitat. (Corps, 2002).	Depth availability assumed similar to current conditions. No Effect	Depth availability assumed similar to current conditions. No Effect	Mean depths will be dramatically reduced. However, studies showed that fall chinook used different depths in river reaches (i.e. 1-4 meters in Hells Canyon Reach). 2002 LSR Feasibility Report estimates and increase from 226 to 3,521 acres of spawning habitat for fall chinook. MO3 would lead to increases in spawning habitat and Improved conditions for spawning	Depth will be 0.75 feet greater for ~60% of years. No Effect	Dauble et al. (1998) from survey data 1993-1997: "Redds were in water from 4.0 to 8.1 m deep and on cobble substrate. All redds were adjacent to the outfall flow from juvenile fish bypass systems and on the powerhouse side of the river." In the Upper and Lower Hells Canyon reach, spawning in 1993-1995 redds were primarily at 1-4.5m depths (Connor et al 2018, data reproduced from Groves and Chandler 1999). Note: current operations (flows) at DWA do not adversely affect current available spawning habitat. However, the presence of Dworshak Dam precludes access to historical spawning and rearing habitat. No underwater spawning surveys were conducted below any of the four lower Snake River dams during 2018. Surveys have shown that Snake River Fall Chinook spawn in some areas in the tailraces of the projects.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Juvenile transportation affects adult returns and adult stray rates (relative to juvenile in-river migration).	Proportion and timing of juveniles transported downstream from collector projects.	NAA fall chinook transportation rate = 39% transported under NAA Transport effects on Snake River fall Chinook juveniles: - Mixed/uncertain from mid-May to mid-June - Improves adult returns from mid-June to end of November	38% transported under MO1 No difference in returns or stray rates when compared to the NAA	Maximum transport under MO2 - 47% transported under MO2. NOAA modeling for spring/summer Chinook shows increases in adult returns, while CSS modeling shows a decrease in adult returns under MO2. Stray rates would likely increase relative to the NAA.	No transport under MO3 Reduced stray rates relative to the NAA Increased returns relative to the NAA.	7% transported under MO4 Spill will reduce transport of Fall Chinook under MO4 Arrival timing will be later Reduced strays relative to NAA NOAA modeling for spring/summer Chinook show decreases in adult returns, while CSS modeling shows an increase in adult returns under MO4. Likely reduced survival of juvenile population.	CSS SAR: LGR to LGR ratios (TIR) from 2006-2015, 52 cohorts: 31 cohorts higher LWG-LWG for juveniles migrating in-river, 19 cohorts lower LWG-LWG for juveniles migrating in-river (transport benefit). Significant difference from 0 reduces these differences. With current spill program we generally collects and transport more juveniles in higher water years (higher proportion spill in low water year and same proportion spill more effective in a low water year. Need qualitative discussion of water year differences. Low water years generally have higher transportation. Based on Smith et al 2018 transportation does not provide a consistent survival advantage early in the season. However, beginning in July there is a transport advantage later in the season.
Juvenile Mainstem Rearing and Passage							
Warmer water temperatures and concentrations of juveniles/predators at dam structures make juvenile salmonids more susceptible to piscine predators (channel catfish, walleye, pikeminnow, smallmouth bass; Northern Pike are coming).	Increase or decrease in mainstem temperatures during migration as a surrogate for predation risk. May - July average temperature at IHR and Percent of days over 20°C	Mean Temp NAA 16.5. 26.6% of days over 20°C. Currently exceeding 20°C in nearly every year. Current water temperatures would have minor impacts to juvenile chinook. An unknown number of these fish would be lost to predation.	Mean temp 16.4 25.2% of days over 20°C Slightly lower temperatures and fewer days over 20°C when compared to the NAA. Under MO1 there would be a negligible reduction in predation risk May through July.	Mean water temperature for May through July = 16.7C. 27.0% of days over 20°C No difference from NAA	Mean Water temperature for May through July = 16.7C. 35.6% of days over 20°C Slight increase in temperatures and days over 20C compared with the NAA. The cold water flow augmentation from DWR should be more effective with smaller cross sectional area to cool down in July and August Assumed that current holdovers will move from the Snake River - MCN pool or downstream and assume that proportion of holdovers will be reduced. Significantly Faster travel times would reduce predation risk substantially.	Mean temp 16.5. 26.4% of days over 20°C No Difference from NAA	Piscine predators include Smallmouth, northern pikeminnow, Walleye, and catfish. Walleye are increasing in abundance. Compensatory mortality (swamping predators) - easier to account for spring migrants than fall chinook; not a metric per se but account for this in predation effects analysis/estimates Could use survival of fish from upriver traps to LGR as a surrogate for lower Snake River survival in predation. 20°C may capture the relative change, but these piscine predators become very active at even cooler temperatures Temperatures affect survival via predation and increased energetic requirements; disease (columnaris).

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Avian predation – avian nesting habitat increases or decreases.	Increase or decrease in avian nesting habitat.	No change in avian nesting is expected. Predation would not change under the NAA.	Reduced nesting habitat via Blalock island inundation and additional hazing. Predation Risk may decrease as a result of JDA pool operations – dissuade nesting at Blalock – limited in fall chinook. Earlier migrants (steelhead and Sockeye) are more impacted.	No change from NAA	Increase in nesting habitat expected in lower Ice Harbor pool. Only those islands that would not be inundated in spring flows and are suitable habitat. Risk of avian predation will likely decrease as travel times decrease and turbidity increases under MO3 and reduce exposure to avian predators. (see travel times under MO3)	No change from NAA	Islands in free flowing Snake River do not have avian colonies. Would they use the lower Snake? Predation rate trend (or abundance if predation rate unknown). Estimate of 11.6% predation on Chinook by avian predators in 2014. Compensatory mortality (swamping predators) - easier to account for spring migrants than fall chinook; not a metric per se but account for this in predation effects analysis/estimates
Rearing habitat in reservoirs supports overwintering fall Chinook life history.	Presence absence of reservoirs	Reservoirs Present. Reservoirs provide rearing habitat for one of the fall chinook life histories that overwinters in reservoirs.	No change from NAA Some holdover may be due to cool water refugia in reservoirs. Reduced summer cooling water in MO1 may reduce quality of rearing habitat to Holdover fish.	No change from NAA	Reservoirs not present - Holdover fish would likely move to MCN and JDA to overwinter or outmigrate to the ocean. We expect fewer holdovers under MO3.	No Change from NAA	Presence absence of reservoirs
TDG downstream of DWA.	Elevated TDG (specific criteria?) degrades juvenile rearing habitat and may negatively affect downstream hatcheries. Mean, Maximum and % days over 110%.	TDG below DWA: Mean = 101.5; Max = 130.9; % over 110 = 2.8% TDG in the Clearwater downstream from DWA would have negligible impact to fish populations.	Mean = 101.7; Max ~ 130.2; % over 110 = 3.0% No difference from NAA	Mean = 101.5; Max = 131.6; % over 110 = 2.5% No difference from NAA	Mean = 101.3; Max = 130.9; % over 110 = 2.9% No difference from NAA	Mean = 101.2; Max = 130.9; % over 110 = 2.9% No difference from NAA	Restricting upper part of shallow water Hatchery risks to TDG – Call to get value of concern > 105% TDG Recommend deleting this variable as it does not help in decision making
Higher turbidity decreases predation rates. Higher turbidity within a range hides juveniles so predation rates would decrease.	Expected increase or decrease in water turbidity, especially near dam structures. Are there specific criteria? Turbidity during outmigration May-July - use sediment data as surrogate ~	2 mg/l on average year (not spring freshet). Current River mechanics data. Current	No Expected Change relative to NAA	No Expected Change relative to NAA	Expect higher sediment under MO3 ~ 30 mg/l on average. Outmigrating fall chinook would experience a decrease in predation risk under MO3. Current River mechanics data.	No expected change relative to NAA until McNary tailrace. Forebay elevation manipulations at JDA to disrupt bass/walleye spawning and drawdown to MOP measures may have minor TSS/turbidity impacts, but impacts not expected to be great in large reservoirs.	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
BON – BON (Estuary, Plume, Ocean)							
Predation by non-SRKW marine mammals (sea lions, seals, otters) will continue and may increase.	CRSO Wildlife Team - pinniped abundance trends by location (Astoria, BON).	Pinnipeds growing in numbers - expect	No change from NAA Check with Bjorn on Spill sea lion relationship.	No change from NAA	No change from NAA	No Change from NAA	Compensatory mortality (swamping predators) - easier to account for spring migrants than fall chinook; not a metric per se but account for this in predation effects analysis/estimates Emerging stellar sea lion numbers eating adult fall chinook (and others); some prey switching suspected from w. sturgeon to salmonids.
Predation by SRKWs will continue and may decrease.	Predation rate trend (or abundance if predation rate unknown)	No Measure changes risk to predation from Orcas.	No change from NAA	No change from NAA	No change from NAA	No Change from NAA	SRKWs are feeding on adult fall Chinook during XX months. Unclear if diet analysis for SRKW; spatial seasonality. Orca task force, ranking salmonids in terms of diet importance. No known measures that puts Chinook at greater risk to predation from SRKW - Remove.
Adult Mainstem Passage							
High water temperatures can cause migrating adult salmon to stop or delay their migration or can increase fallback at a dam. Water temperatures delay adult migration during summer/fall when they exceed 20°C (68°F).	Frequency of water temperatures from Lower Granite to Bonneville that exceed 20 °C (68 °F) August through September at MCN and IHR and BON	Percent of days over 20°C: MCN 58.3% of all days over 20°C; Mean temp = 20.3°C IHR 54.3% BON 46.8% During August and September under the NAA nearly 60 percent of all days at MCN dam are over 20°C. Would expect potential delays in adult migration as a result of elevated temperatures during August. Effect generally Reduced as you move downriver.	MCN 59.3% of all days over 20°C; Mean temp = 20.4°C IHR 62.7% BON 45.2% Minor increase in risk of delay and fallback under MO1 because of changes to cooling water augmentation from DWA.	MCN 57.6% of all days over 20°C; Mean temp = 20.3°C IHR 54.4% BON 45.2% No change from NAA.	MCN 52.4% of all days over 20°C; Mean temp = 20.1°C IHR 29.2% BON 45.2% Minor decrease in risk of delay as Cooler late summer and fall waters would reduce delays in August under MO3.	MCN 58.9% of all days over 20°C; Mean temp = 20.4°C IHR 54.3% BON 45.7% No change from NAA.	Warm water temperatures can also increase the fishes' susceptibility to disease. All reduce survival and spawning success (gamete viability included). Increased adult straying with elevated temps (e.g., Deschutes/thermal refuges). Mean water temperature is not an effective measure in this metric. Need to look at annual variation. Egg viability would decrease and pre-spawn mortality would increase as temperatures increase. - Check literature for metric. Cumulative thermal stress on migrating adults - Transported adults vs in river migrants on warm water years. Note: no standard deviation available to estimate statistical significance.
Adult ladder differentials of ≥2°C can delay adult migration.	Frequency of adult ladder temp differentials of >2°C (% days differential > 2°C at LMN August through September).	50.1% of all days with greater than 2°C differential. Potential for delay under NAA is about 50%.	65.5% of all days in Aug and Sep with > 2°C differential. Increase risk of delay under MO1 ~ 9 more days with > 2°C differentials than the NAA. Installation of pumps may reduce number of days with differentials.	53.2% of all days in Aug and Sep with > 2°C differential. No difference from NAA.	No Dams = No differentials.	58.6% of all days in Aug and Sep with > 2°C differential. Slight increase in risk of delay under MO4 ~ 5 more days with > 2°C differentials than the NAA. Installation of Pumps may reduce number of days with differentials.	Can use relationship between surface and deep water to modify current water quality output at dams with pumps installed. Assume low water years with higher temperatures would have much greater differential delays.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Dworshak cooler temperature releases during summer affect the proportion of juveniles with reservoir rearing life history.	Continuation of Dworshak cool water releases in July-August Temperature at DWA tailwater July-August Relative increase or decrease in the reservoir rearing juvenile life history?	North Fork Clearwater mean temperature for July and August = 6.88 Under NAA cold water releases from DWA will continue to suppress juvenile growth and induce holdover fish.	North Fork Clearwater mean temperature for July and August = 7.23 Warmer water in August may increase juvenile growth rates slightly (not statistically significant SD = 1.01)	North Fork Clearwater mean temperature for July and August = 6.89 No change from NAA	North Fork Clearwater mean temperature for July and August = 6.84 No change from NAA	North Fork Clearwater mean temperature for July and August = 7.01 Warmer water in August may increase juvenile growth rates slightly (not statistically significant SD = 1.01)	The spawn timing also starts earlier in the Clearwater. Surrogate: use gauge above the north fork confluence for water temperatures. Is this a good metric for separating alternatives? Operations are not changing that much at DWA. Not used. Look at August and July separately to see differences. Sudden increases in august temperatures will be detrimental for smolts The temperature releases affect juvenile growth in the Clearwater and yearling/subyearling proportions (life history proportion for Clearwater). Cooler water reduces growth rates and induces holdover of fall chinook.
Dworshak temperature releases related to refugia for adult fish.	Continuation of Dworshak cool water releases in July-August	Current conditions provide refuge for Steelhead	Reduction in cold water for August would increase temperature stress of adult steelhead and chinook.	No change from NAA	No change from NAA	Reduction in cold water for August would increase temperature stress of adult steelhead and chinook.	Coldwater in the Clearwater River creates a refuge from hot water in the snake river for adult fall Chinook and steelhead. However, this metric is only changed in MO1 and is not otherwise useful for identifying an alternative.
Tolerance to sediment.	Sediment concentrations measured in mg/l	Average concentration under current conditions ~ 2 mg/l Under the NAA no negative impacts are expected from sediment levels.	No change from NAA	No change from NAA	Estimates of nearly 25,000 mg/l during breach and 30 mg/l after breach. 27 days over 5,000 mg/l. Timing of breach currently occurs in the fall chinook, steelhead, and coho migrations. Severity index of 11 indicates mortality between 20 and 40 percent.	No change from NAA	See Newcombe et al. (1996) for severity index from sediment loads.
Tolerance to DO levels.	Temperature at DWA tailwater July-August	Saturations. Most stations on the Snake River are between 9.5 and 11 mg/l. Under the NAA no negative impacts are expected from reduced Oxygen concentrations.	No change from NAA	No change from NAA	Estimate of dissolved oxygen levels dropping to ~ 2.5 mg/l throughout the LGS and LMO pool in year one. Expect loss of fall chinook, coho, and steelhead in these two pools during the peak of sediment release.	No change from NAA	–

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3.6.10 Lower Columbia River Coho Salmon

Table 3-62. Lower Columbia River Coho Salmon Qualitative Effects Analysis Matrix

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Project survival through BON reservoir and dam affects the juvenile lower Columbia Gorge coho salmon from BON pool tributaries.	There is no direct estimate of BON project survival (dam and reservoir) specific to coho, so juvenile Snake River spring Chinook BON project survival as a surrogate estimate.[1]|Estimate change in BOLN survival (e.g., MO1-NAA)/NAA), for juvenile Snake River spring Chinook using COMPASS survival estimates as surrogate for lower Columbia River coho.	Estimated BON project survival (95% lower and upper confidence intervals) from 2019 CRS BiOp, page 861: |95.5% (94.6% to 96.2%)	0.2% survival decrease relative to NAA (COMPASS).|No dam-specific survival estimate available from CSS.	0.6% survival increase relative to NAA (COMPASS).|No dam-specific survival estimate available from CSS.	0.5% to 0.8% survival increase relative to NAA (COMPASS).|No dam-specific survival estimate available from CSS.	0.9% survival decrease relative to NAA (COMPASS).|No dam-specific survival estimate available from CSS.|NOTE: This alternative does not contain BON 150 kcfs voluntary spill constraint associated with stilling basin integrity. Adding the constraint would reduce SPE.	Apply change in survival for spring Chinook salmon as qualitative surrogate for LCR coho. Surrogate for lower Columbia River coho was Snake River spring Chinook in 2008 BiOp, 2013 Recovery Plan, 2019 BiOp, due to lack of dam passage survival estimate specific to lower Columbia River coho salmon.|Same estimated response as lower Columbia River Chinook and Columbia River chum – 2013 Recover Plan, Table 4-4 (citing NMFS 2008a; 201a), Appendix E, Table 3 (page 32).
Adult upstream passage at BON and reservoir affects survival rate for the coho populations that migrate to natal streams within BON pool.	Adult Snake River fall Chinook salmon passage analysis at BON as surrogate for adult coho passage considerations.2	BON dam and pool survival 97.6 (94.5 to 100), estimate from 2019 CRS BiOp, |page 854.	See change in fall Chinook salmon upstream passage for MO1.	See change in fall Chinook salmon upstream passage for MO1.	See change in fall Chinook salmon upstream passage for MO1.	See change in fall Chinook salmon upstream passage for MO1.	Same estimated response as lower Columbia River Chinook adults (fall run) and Columbia River chum – 2013 Recovery Plan, Table 4-4 (citing NMFS 2008a, 2010a), Appendix E, Table 1, page. 26).|Use DART for adult coho return timing (http://www.cbr.washington.edu/dart/quick_look/adult).

[1]Coho-specific dam survival measurements are not available, but coho-specific in-river survival estimates are available for current system conditions. There are no coho-specific models available to predict changes in these metrics from CRS alternatives. However, survival models that project changes in these metrics based on changes in hydrosystem operation and configurations are available for spring Chinook salmon and steelhead (COMPASS, CSS). Coho salmon outmigration timing generally overlaps with both spring Chinook salmon and steelhead, and all three species have dominant stream-type life histories. However, the size of juvenile coho and juvenile spring Chinook salmon tend to be more closely aligned than juvenile steelhead. Therefore, juvenile spring Chinook salmon will be considered the appropriate surrogate for juvenile coho salmon for purposes of qualitative effects analysis of changes in passage. This use of juvenile Snake River spring Chinook salmon as a surrogate for juvenile lower Columbia River coho salmon is consistent with the 2008 FCRSP BiOp, 2013 Recovery Plan, and 2019 CRS BiOp.

[2]Dam survival and reach survival measurements specific to adult coho are not available for the previous 10-year period. Adult Coho salmon upstream migration timing general overlaps with fall Chinook salmon, through fall Chinook salmon migration timing tends to start earlier in some years (DART). Far more adult fall Chinook salmon enter the CRS system than Coho salmon adults, so survival estimates generally have higher certainty for the former than the latter. Adult fall Chinook salmon will be considered the appropriate surrogate for adult coho salmon for purpose of qualitative effects analysis of changes in passage. This use of adult Snake River fall Chinook salmon as a surrogate for adult lower Columbia River coho salmon is consistent with the 2008 FCRPS BiOp, 2013 Recovery Plan, and 2019 CRS BiOp.

NOTE ABOUT OCEAN SURVIVAL: The CSS (2017) makes no prediction in terms of survival benefits for lower Columbia River, upper Columbia River, or lower Snake River coho salmon. The CSS predicts that increased spill could substantially reduce latent mortality of juvenile yearling Chinook salmon and steelhead moving downstream through the mainstem dams. If this were to occur for coho salmon, SARs would also be improved for the XX populations that pass above XX dams and migrate during the spring, and the potential benefit would generally be less than what may occur for species that experience passage through a greater number of Columbia and Snake River mainstem dams (NMFS, 2019). The COM

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3.6.11 Lower Columbia River Chum Salmon

Table 3-63. Lower Columbia River Chum Salmon Qualitative Effects Analysis Matrix

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes Spawning, Incubation, and Egress
Ability to meet the chum operation. BON tailwater elevation (measured at Tanner Creek gage) affects chum access to the Ives/Pierce Islands spawning area and local tributaries: BON tailwater elevation below 11.3 feet creates connectivity issues to spawning channels and poorer conditions in the lower spawning elevation habitat. Chum have access to spawning habitat when BON tailwater elevation ranges from 11.3 feet to 13.5 feet. When elevation exceeds 16.5 feet, chum are unable to hold in typical	(1a) Frequency (years) of meeting chum operation, without tradeoff between abandoning chum or lower April 10 elevation at GCL and (1b) (In those years when chum redds/fry would be abandoned without additional releases from upstream storage) The water volume that would need to be released from storage to meet the chum operation (lowest is best).	(1a) 92% of years (1b) 0.18 Maf	(1a) 90% of years (additional releases from upstream storage needed in more years, relative to NAA) (1b) 0.13 Maf (in years that upstream storage needed to meet chum operation, less water needed from upstream storage relative to NAA)	(1a) 89% of years (additional releases from upstream storage needed in more years, relative to NAA) (1b) 0.12 Maf (in years that upstream storage needed to meet chum operation, less water needed from upstream storage relative to NAA)	(1a) 93% of years (additional releases from upstream storage needed in fewer years, relative to NAA) (1b) 0.08 Maf (in years that upstream storage needed to meet chum operation, less water needed from upstream storage relative to NAA)	(1a) 80% of years (additional releases from upstream storage needed in more years, relative to NAA) (1b) 0.24 Maf (in years that upstream storage needed to meet chum operation, more water needed from upstream storage relative to NAA)	2008/2010/2014 NOAA Fisheries BiOp RPA 17 Chum Spawning Flows (page 19) 2019 BiOp (pages 267-668) 2018 Water Management Plan (pages 9, 34, 40-46) Tomaro et al 2007 PNNI - 20035 Grays/Chinook, Washougal, and lower Gorge populations together produce the majority of Columbia River chum salmon. Grand Coulee is operated to balance the needs of chum flows, Hanford reach ops, and spring flow augmentation from two months before the start of chum spawning in Nov through the end of chum emergence (approximately end of Apr) to maintain sufficient water depth to protect chum spawning and incubation habitat at the Ives Island complex below BON.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes Spawning, Incubation, and Egress
spawning areas due to water velocities. Protection level is set by spawning elevations identified by field verification in late December (may be 11.3 feet to 12.0 feet, depending on surveys) so the redds have sufficient water covering them to prevent desiccation post-spawning and this water level is maintained until Apr 9, though chum emergence typically ends by the end of Mar. Allowance for periods rewetting depending on water availability, in-season adaptive management by TMT.							
105% TDG appears to provide a sufficient level of protection to chum salmon sac fry incubating in the gravel downstream of BON in the Ives/Pierce Island Complex. TDG must remain at or below 105% after depth compensation of 3% per foot from Nov 1 to Apr 30.	Average number of years TDG exceeds 105% in chum spawning areas in the Ives/Pierce Island areas between Nov 1 and Apr 30. This will be measured consistent with TMT method for estimating Ives/Pierce TDG: Based on WRNO gage, calculating feet of depth compensation required to reach 105% TDG; Subtracting 11.3 feet from BON tailwater elevation (Tanner Creek gage) to determine feet of depth compensation; If the TDG estimate exceeds 105% at Ives/Pierce Island, then the assumption is that the chum redds were exposed to TDG in excess of 105%.	5 years out of 80; average exceedance 107% TDG	7 years out of 80; average exceedance 106% TDG (increase in frequency of exposing chum fry relative to NAA)	4 years out of 80; average exceedance 106% TDG (decrease in frequency of exposing chum fry relative to NAA)	7 years out of 80; average exceedance 106% TDG (increase in frequency of exposing chum fry relative to NAA)	30 years out of 80; average exceedance 107% TDG (increase in frequency of exposing chum fry relative to NAA)	Chum fry emerge in the Ives Island area until approximately the end of March (Hamilton & Hardy Creek, Hamilton Springs fry; Ives area fry emerge earlier due to warmer incubation temps). NAA spring spill for upstream salmon and steelhead starts April 10th. From PNNL-16200: Both the Ives and Multnomah Falls sites were influenced by groundwater. However, at Multnomah Falls, despite significant fluctuations in river concentrations of total dissolved gas, dissolved oxygen, and temperature, egg pocket concentrations remained stable, suggesting relatively constant groundwater discharge there. In contrast, egg pocket responses at the Ives Island site fluctuated widely in response to changes in river water quality, suggesting spawning gravels in the Ives area are in much closer contact with river water. From PNNL-18081: Surface water TDG was generally lower at Bonneville and Ives Island stations compared to that measured at Warrendale and Camas/Washougal. The TDG records from all of the sites were very highly correlated with one another (correlation coefficient of at least 0.84) except for Cascades Island, which had a correlation coefficient of between 0.60 and 0.69 when compared to the other locations. Excluding Cascades Island, all correlation coefficients from the 2007 monitoring season were above 0.91.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes Spawning, Incubation, and Egress
Juvenile Mainstem Passage							
BON dam passage route affects survival for juvenile upper Gorge chum that pass BON. Note: Few juvenile chum migrate through the BON pool and dam, most chum spawn downstream of BON.	There is no direct estimate of BON project survival (dam and reservoir) specific to juvenile chum, so juvenile Snake River spring Chinook BON project survival will be used as a surrogate estimate.1 Estimate change in BON survival, e.g. (MO1-NAA)/ (NAA), for juvenile SR spring chinook using COMPASS survival estimates as surrogate for Columbia River chum response. WA comments that models using spring chinook smolts to identify increases or decreases in survival among different operational options for Bonneville Dam will not provide accurate information for chum fry (and age 0 spring Chinook fry) and is not supported by WDFW. WDFW is concerned that operating Bonneville's second powerhouse above the mid-point of the 1 % efficiency curve will result in higher levels of mortality, injury and descaling to juvenile chum salmon when they are present.	Estimated BON project survival (95% lower and upper confidence intervals) from 2019 CRS BiOp p. 861: 95.5% (94.6% – 96.2%)	0.2% survival decrease relative to NAA (COMPASS) No dam-specific survival estimate available from CSS. (no change relative to relative to NAA)	0.6% survival increase relative to NAA (COMPASS) No dam-specific survival estimate available from CSS. (about 1% increase in project survival relative to NAA)	0.5-0.8% survival increase relative to NAA (COMPASS) No dam-specific survival estimate available from CSS. (about 1% increase in project survival relative to NAA)	0.9% survival decrease relative to NAA (COMPASS) No dam-specific survival estimate available from CSS. (about 1% decrease in project survival relative to NAA)	Surrogate for juvenile Columbia River chum passing BON was SR spring Chinook in 2008 BiOp, 2013 Recovery Plan, 2019 BiOp due to lack of dam passage survival estimate specific to Columbia River chum. Same estimated response as lower Columbia River Chinook and coho salmon - 2013 Recovery Plan Table 4-4 (citing NMFS 2008a; 2010a), Appendix E Table 3 (p. 32).

Arntzen et al. (2009) Total Dissolved Gas Effects on Incubating Chum Salmon Below Bonneville Dam. PNNL-18081. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-18081.pdf

Arntzen et al. (2009) Effects of Total Dissolved Gas on Chum Salmon Fry Incubating in the Lower Columbia River. PNNL-17132. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-17132.pdf

Bonneville Power Administration, US Bureau of Reclamation, and US Army Corps of Engineers. 2018 Draft Water Management Plan. http://pweb.crohms.org/tmt/documents/wmp/2018/.

Bonneville Power Administration, BPA Annual Reports from Hilson; may also be a peer-reviewed publication (Christine?)

Franklin T, Carim K, Young M, McKelvey K, and M. Schwartz (2017) Project: Environmental DNA sampling for the detection of chum salmon by the Oregon Department of Fish and Wildlife. Report from National Genomics Center-USFS Rocky Mountain Research Station. Group website: https://www.fs.fed.us/research/genomics-center/edna/

Murray, C. J., Geist, D. R., Arntzen, E. V., Bott, Y. J., & Nabelek, M. A. (2011). Development of a conceptual Chum Salmon emergence model for Ives Island (No. PNNL-20035). Pacific Northwest National Lab.(PNNL), Richland, WA (United States). http://www.pnl.gov/main/publications/external/technical_reports/PNNL-20035.pdf =

National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 2014. Biological Opinions (2008, 2010, 2014). https://www.westcoast.fisheries.noaa.gov/publications/hydropower/fcrps/2014_supplemental_fcrps_biop_final.pdf.

National Marine Fisheries Service, Northwest Region. June 2013. ESA Recovery Plan for Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, and Lower Columbia River Steelhead. https://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/willamette_lowercol/lower_columbia/final_plan_documents/final_lcr_plan_june_2013_-corrected.pdf (Accessed 10 February 2019).

Northwest Power and Conservation Council, April 20, 2017. Bonneville Dam Sea Lion Tour. April 20, 2017. https://www.nwcouncil.org/sites/default/files/2017sealionsforweb_0.pdf.

Pearson et al. 2006. A Study of Stranding of Juvenile Salmon by Ship Wakes Along the Lower Columbia River Using a Before-and-After Design: Before-Phase Results. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-15400.pdf.

Tomaro L, van der Naald W, Brooks R, Jones T, Friesen T. Evaluation of chum and fall Chinook salmon spawning below Bonneville Dam. Report to the Bonneville Power Administration, Contract. 2007 Jan 29512. https://www.dfw.state.or.us/fish/oscrp/cri/docs/Chum%20Annual%20Report%202005-2006%20Final.pdf.

3.7 OTHER ANADROMOUS FISH

3.7.1 Pacific Eulachon

Table 3-64. Pacific Eulachon Qualitative Effects Analysis Matrix

<table>
<tr><th>Affected Environment Important Relationships/Criteria</th><th>Affected Environment Metric</th><th>Environmental Consequences NAA</th><th>Environmental Consequences MO1</th><th>Environmental Consequences MO2</th><th>Environmental Consequences MO3</th><th>Environmental Consequences MO4</th><th>References</th></tr>
<tr>
<td>Criteria for eulachon: 7-day average of the daily maximum temperatures no exceed 12°C to 14°C prior to May 1, with no single daily maximum temperature greater than 16°C.</td>
<td>BON tailwater temperature: Dec 1 to May 1 (from extended year set 5 water year types).</td>
<td>H&H and WQ Outputs:
2011: All temps <9.0°C
2012: All temps <11.7°C
2013: All temps <11.4°C
2014: All temps <10.8°C
2015: All temps <12.2°C
Effects to Resource NAA:
All temperatures from Dec 1 to May 1 (modeled) well below the threshold of 12°C to 14°C. Temperatures would continue to be suitable for eulachon.
Notes: Added from recovery plan.</td>
<td>Data Outputs:
2011: All temps <9.0°C
2012: All temps <11.6°C
2013: All temps <11.7°C
2014: All temps <11.0°C
2015: All temps <12.2°C
Effects of MO1 compared to NAA:
Same as NAA.</td>
<td>Data:
Same as NAA. All temps within 0.6° of NAA.
Effects:
Same as NAA.</td>
<td>Data:
2011: All temps <9.3°C
2012: All temps <12.0°C
2013: All temps <11.5°C
2014: All temps <11.1°C
2015: All temps <12.3°C
Note: Average monthly temps about 0.2°-0.3° cooler in winter months.
Effects:
Same as NAA.</td>
<td>Data Outputs:
2011: All temps <9.0°C
2012: All temps <11.6°C
2013: All temps <11.4°C
2014: All temps <11.1°C
2015: All temps <12.1°C
Effects of MO4 compared to NAA:
Same as NAA.</td>
<td>NMFS 2017</td>
</tr>
<tr>
<td>Predation: Avian predation risk can be influenced by flow – higher flows are linked to more eulachon and salmon predation, with lower flows, the birds tend to switch to marine prey.</td>
<td>Qualitative change in avian predation risk, based on change in flows. Mean monthly flows; Columbia and Willamette, Nov to Jun.</td>
<td>H&H and WQ Outputs:
<table>
<tr><th>Month</th><th>25%</th><th>Med</th><th>75%</th></tr>
<tr><td>Nov</td><td>218919</td><td>177945</td><td>155471</td></tr>
<tr><td>Dec</td><td>275908</td><td>225221</td><td>185592</td></tr>
<tr><td>Jan</td><td>308713</td><td>251732</td><td>195846</td></tr>
<tr><td>Feb</td><td>318765</td><td>266760</td><td>216851</td></tr>
<tr><td>Mar</td><td>282091</td><td>232780</td><td>195023</td></tr>
<tr><td>Apr</td><td>307054</td><td>260370</td><td>210833</td></tr>
<tr><td>May</td><td>366718</td><td>314137</td><td>274443</td></tr>
<tr><td>Jun</td><td>390625</td><td>319041</td><td>256963</td></tr>
</table>
Effects to Resource NAA:
Eulachon would continue to be affected by predation, dependent upon a number of factors that affect predation risk.</td>
<td>Data Outputs:
Percent Change by Month
<table>
<tr><th>Month</th><th>25%</th><th>Med</th><th>75%</th></tr>
<tr><td>Nov</td><td>0%</td><td>0%</td><td>0%</td></tr>
<tr><td>Dec</td><td>1%</td><td>2%</td><td>3%</td></tr>
<tr><td>Jan</td><td>0%</td><td>0%</td><td>1%</td></tr>
<tr><td>Feb</td><td>-1%</td><td>-1%</td><td>-1%</td></tr>
<tr><td>Mar</td><td>-1%</td><td>-1%</td><td>-2%</td></tr>
<tr><td>Apr</td><td>-2%</td><td>-2%</td><td>-2%</td></tr>
<tr><td>May</td><td>-2%</td><td>-2%</td><td>-2%</td></tr>
<tr><td>Jun</td><td>-1%</td><td>-1%</td><td>-1%</td></tr>
</table>
Effects of MO1 compared to NAA:
Relatively little change (0% to 3%) in all months and water year types. Slightly higher flows in December could increase predation risk, slightly lower in Feb to June could result in slightly less predation risk if the birds switch to more readily available marine prey. Early portion of run comes in about Nov to Dec timeframe may be more subject to predation. Note the change is likely immeasurable. Such a slight change in flow likely not cause an effect on the biological scale.
Notes: No present in July to Oct.</td>
<td>Data:
Median:
Nov: +2%
Dec: +6%
Jan: +2%
Feb: -1%
Mar: -4%
Apr: -2%
May:-1%
June: -1%
Effects:
Higher flows in winter (Nov to Jan) could increase predation risk when the bulk of the eulachon run is migrating up the Columbia River.</td>
<td>Data:
Percent Change by Month
<table>
<tr><th>Month</th><th>25%</th><th>Med</th><th>75%</th></tr>
<tr><td>Nov</td><td>2%</td><td>2%</td><td>2%</td></tr>
<tr><td>Dec</td><td>1%</td><td>2%</td><td>4%</td></tr>
<tr><td>Jan</td><td>-2%</td><td>-2%</td><td>1%</td></tr>
<tr><td>Feb</td><td>0%</td><td>0%</td><td>0%</td></tr>
<tr><td>Mar</td><td>-1%</td><td>-1%</td><td>-1%</td></tr>
<tr><td>Apr</td><td>-2%</td><td>-2%</td><td>-2%</td></tr>
<tr><td>May</td><td>-2%</td><td>-2%</td><td>-2%</td></tr>
<tr><td>Jun</td><td>-1%</td><td>-1%</td><td>-2%</td></tr>
</table>
Effects:
Slightly higher flows in Nov to Dec; slight increase in predation risk to early run.</td>
<td>Data Outputs:
Percent Change by Month
<table>
<tr><th>Month</th><th>25%</th><th>Med</th><th>75%</th></tr>
<tr><td>Nov</td><td>-1%</td><td>-1%</td><td>0%</td></tr>
<tr><td>Dec</td><td>1%</td><td>1%</td><td>3%</td></tr>
<tr><td>Jan</td><td>0%</td><td>1%</td><td>3%</td></tr>
<tr><td>Feb</td><td>-1%</td><td>-2%</td><td>-2%</td></tr>
<tr><td>Mar</td><td>1%</td><td>1%</td><td>-1%</td></tr>
<tr><td>Apr</td><td>-2%</td><td>-2%</td><td>-2%</td></tr>
<tr><td>May</td><td>-1%</td><td>-1%</td><td>1%</td></tr>
<tr><td>Jun</td><td>-1%</td><td>-1%</td><td>1%</td></tr>
</table>
See attached file for values.
Effects of MO4 compared to NAA:
Wet and average years similar to NAA (1% to 2% change). Dry years – no change or slightly lower risk in Feb to June, and slightly higher risk in Dec to Jan. In extremely dry years (99% exceedance), May outflows 10% higher than NAA, which could make them more susceptible to predation but tradeoff for higher flows could be beneficial? Early portion of the run may be</td>
<td>Regarding flow - higher rainfall as opposed to snowmelt-driven flows cause higher turbidity which, as a rule, reduces predation due to visibility (Muir and Williams 2011)</td>
</tr>
</table>

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	References
						susceptible to slightly higher predation risk than NAA. Such a slight change in flow will likely not cause an effect on the biological side. **Notes:** Need to re-look with water year types (with and without McNary measure triggered). Note - included text 6/10 on dry years.	
Adult Upstream Migration and Spawning							
Adult spawning migration: Water temperature influences run timing (NMFS, 2017). Eulachon are typically present in the Columbia River from 2°C to 10°C, with spawning triggered at 4°C.	Temp BON tailrace or below, dates of migration (2° to 10°C) and spawning (4°C) cues.	H&H and WQ Outputs: Running through the dataset, Date first dropped below 10°C, then 4° in each migration season. 10°C 4°C 01/02/11 11/14/11 12/22/11 11/23/12 01/01/13 11/11/13 12/09/13 11/13/14 01/09/15 11/20/15 12/30/15 (4.08°) **Effects to Resource NAA:** Temps in Columbia River (modeled Bonneville tailwater temps) would typically be conducive to trigger upstream migration by mid- to late-November, with the spawning trigger of 4°C occurring in late December/early January of each run year. Differing temperatures, from year to year, as well as the timing of high tides (NMFS, 2017) can affect timing and location of spawning. **Notes:** Present 4.4°-10°, spawn at about 6°C (WDFW and ODFW, 2001).	**Data Outputs:** Running through the dataset, Date first dropped below 10°C, then 4° in each migration season. 10°C 4°C 01/02/11 11/14/11 12/23/11 11/23/12 01/01/13 11/11/13 12/09/13 11/13/14 01/09/15 11/20/15 12/30/15 (4.26°) Effects of MO1 compared to NAA: Modeled dates of reaching migration and spawning trigger dates were either the same, or within a day of the NAA. Effects would be the same as NAA.	Data: Running through the dataset, Date first dropped below 10°C, then 4° in each migration season. 10°C 4°C 01/02/11 11/14/11 12/23/11 11/23/12 01/01/13 11/11/13 12/10/13 11/14/14 01/08/15 11/20/15 12/30/15 (4.33°) **Effects:** Same as MO1, all triggers within a day of NAA.	– Data: Running through the dataset, Date first dropped below 10°C, then 4° in each migration season. 10°C 4°C 01/02/11 11/13/11 2/20/11 11/18/12* 12/31/12 11/09/13 12/09/13 11/13/14 01/08/15 11/18/15 12/30/15 (4.01°) *11/20 and 11/21 just barely over 10°C **Effects:** Within a day of NAA, same as NAA.	**Data Outputs:** Running through the dataset, Date first dropped below 10°C, then 4° in each migration season. 10°C 4°C 01/02/11 11/14/11 12/23/11 11/23/12 01/01/13 11/11/13 12/09/13 11/13/14 01/08/15 11/19/15 12/30/15 (4.29°) Effects of MO4 compared to NAA: Modeled dates of reaching migration and spawning trigger dates were either the same, or within a day of the NAA. Effects would be the same as NAA.	–
Adult migration barriers: Physical barriers can impede migration and limit available spawning habitat. BON is potential barrier. Upstream migration distance dependent on abundance, migration to Bonneville is rare, but	Presence of barrier, consider structural or spill measures for any potential effects.	H&H and WQ Outputs: Current configuration Spill **Effects to Resource NAA:** BON is near the upstream range of spawning, but could continue to impede access further upstream in years of very large eulachon runs. When passing through Bonneville	**Data Outputs:** S4: Modify upper ladder serpentine flow control ladder (vertical slot) S7: Turbine cooling water strainers? S8: Modify turbine intake bypass screens S9: Modify existing ladders (ramps, diffuser grating plating)	Data: Lamprey passage ladder modifications **Effects:** Same as NAA.	Data: Modify Bonneville ladder serpentine weir. **Effects:** Same as MO1.	**Data Outputs:** S7: Lamprey Passage Ladder Modifications Effects of MO4 compared to NAA: Same as NAA	NMFS 2010

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	References
may hinder migration or cause mortalities (mechanical stress in projects) in years of abundant runs. Eulachon can pass through the ship locks.		dam, some eulachon injury or mortality could continue. **Notes:** Only reach BON in very large run years. Mainstem spawning is about 50% of run, mostly lower River. Tributaries (Cowlitz/Lewis) are major spawning areas. No issues with river stage affecting these tributaries access. Note to writers: this is a very minor impact, but important to describe that it is minor.	Spill: Spring Block spill test 100 kcfs, 120%/115% spill; Summer spill 95 kcfs Effects of MO1 compared to NAA: Structural measures could allow eulachon to pass through the ladders more effectively. **Notes:** Team - the team didn't discuss structural or spill measures; could either of these affect the number of eulachon able to pass or the mortality/injury? Workshop Note: Previous matrices included potential river stage issues. Sue called Art 3/19/19 – he had brought them up for coho and not necessarily eulachon, but also checked with biologists from OR and WA and thought any access issues had already been addressed so this is not an issue. River stage issues deleted from this version.				
Substrate for mainstem spawning: need pea-sized gravel and coarse sand. Substrate can be affected by flows, particularly with changes in peak flows.	Peak flows at BON	H&H and WQ Outputs: Peak flows in June: mean monthly outflows in June: 295,706 **Effects to Resource NAA:** A portion of eulachon would continue mainstem spawning where appropriate substrate exists.	**Data Outputs:** 0.9% decrease in mean monthly outflows of median water year in June (June: 293,731) Effects of MO1 compared to NAA: Same as NAA.	Data: 1% decrease in Mean monthly outflows in June. **Effects:** Same as NAA.	Data: 1% decrease in Mean monthly outflows in June. **Effects:** Same as NAA.	**Data Outputs:** 1.1% decrease in mean monthly outflows of median water year in June (292,998 (-1.1%) Noted - in extremely dry years (99% exceedance) May flows 10% higher than NAA. Effects of MO4 compared to NAA: Similar to NAA. In very dry years, there would be more flow in May than under NAA, but little channel maintenance is likely occurring in these low flow years under any scenario.	Regarding flow - higher rainfall as opposed to snowmelt driven flows cause higher turbidity which as a rule reduces predation due to visibility (Muir and Williams, 2011)
Flow-migration timing: Low flows and temperature triggers for spawning, followed by timely freshet to disperse larvae during yolk sac survival period.	Time between temperature spawning trigger and freshet from summary hydrograph Columbia and Willamette flows	H&H and WQ Outputs: Spawn trigger date from above, compared to peak flow in Columbia and Willamette flows summary hydrograph for high (25%), Ave (50%) and Low (25%) flows. Difference calculated in days between those dates.	**Data Outputs:** Spawn trigger date from above, compared to peak flow in Columbia and Willamette flows summary hydrograph for high (25%), Ave (50%) and Low (25%) flows. Difference calculated in days between those dates.	Data: Spawn trigger date from above, compared to peak flow in Columbia and Willamette flows summary hydrograph for high (25%), Ave	Data: Spawn trigger date from above, compared to peak flow in Columbia and Willamette flows summary hydrograph for high (25%), Ave (50%) and Low (25%)	Data: Spawn trigger date from above, compared to peak flow in Columbia and Willamette flows summary hydrograph for high (25%), Ave (50%) and Low (25%)	–

<table>
<tr><th>Affected Environment Important Relationships/Criteria</th><th>Affected Environment Metric</th><th>Environmental Consequences NAA</th><th>Environmental Consequences MO1</th><th>Environmental Consequences MO2</th><th>Environmental Consequences MO3</th><th>Environmental Consequences MO4</th><th>References</th></tr>
<tr>
<td></td>
<td></td>
<td>Spawn Trigger Peak Flow Diff
High
(2011): 01/01/11 06/08 158 days
Ave
(2012): 12/22/11 06/08 168 days
Low
(2013): 01/01/13 06/06 156 days
Extreme low: 05/19
Extreme low years, May mean monthly discharge = 216798
Discharge duration 90% exceedance = 217603
Discharge duration 90% exceedance = 190,088
Effects to Resource NAA:
The NAA hydrograph maintains a spring peak freshet that is timed with the winter migration and spawning period to match the outmigration of larval eulachon with the freshet. Modeled temperatures and hydrology estimates 155 to 168 days from spawning trigger to peak of the freshet.
Notes:
Temperature triggers spawning. Staging in estuary waiting for right temp. Move up to adequate habitat. Deepwater spawning in mainstem; depth not as important.</td>
<td>Spawn Trigger Peak Flow Diff
High
(2011): 01/02/11 06/08 157 days
Ave
(2012): 12/23/11 06/05 164 days
Low
(2013): 01/01/13 06/07 157 days
Effects of MO1 compared to NAA: Same as NAA.
Notes:</td>
<td>(50%) and Low (25%) flows. Difference calculated in days between those dates.
Spawn Trigger Peak Flow Diff
High
(2011): 01/02/11 06/08 157 days
Ave
(2012): 12/23/11 06/05 164 days
Low
(2013): 01/01/13 06/07 157 days
Effects:
Same as NAA.</td>
<td>flows. Difference calculated in days between those dates.
Spawn Trigger Peak Flow Diff
High
(2011): 01/01/11 06/08 158 days
Ave
(2012): 12/22/11 06/05 166 days
Low
(2013): 01/01/13 06/07 157 days
Effects:
Same as NAA.</td>
<td>flows. Difference calculated in days between those dates.
Spawn Trigger Peak Flow Diff
High
(2011): 01/02/11 06/08 157 days
Ave
(2012): 12/23/11 06/05 164 days
Low
(2013): 01/01/13 06/07 157 days
Extreme low: 05/17
Note: in extremely low (99%) Mean monthly flows in May – 237997, about 21,200 cfs (9%) higher than NAA.
May discharge duration 90% exceedance – 239435 (+21,832 – 9%)
June discharge duration 90% exceedance = 2-6,980 (16,892 – 8%)
Effects: In most water year types, the timing of spawning triggers and the peak hydrograph would be similar to the NAA.
In extremely dry years (the lowest 1%), the freshet would begin a couple of days earlier, but would be sustained longer. Driest 10% of years the discharge duration is sustained about 8% to 9% higher in May and June, which may increase larval dispersal downstream in very low water years.</td>
<td></td>
</tr>
<tr><td colspan="8">Juvenile Growth and Survival</td></tr>
<tr>
<td>Size of plume affects early ocean survival. More plume distributes larvae further out into the ocean (more flow=larger plume=better</td>
<td>Columbia and Willamette flows. Mean monthly flows (Feb to May) in median, 25%, and 75% exceedance. If potential effect, estimate plume size.</td>
<td>H&H and WQ Outputs:
<table>
<tr><th>Month</th><th>25%</th><th>Med</th><th>75%</th></tr>
<tr><td>Feb</td><td>318765</td><td>266760</td><td>216851</td></tr>
<tr><td>Mar</td><td>282091</td><td>232780</td><td>195023</td></tr>
<tr><td>Apr</td><td>307054</td><td>260370</td><td>210833</td></tr>
</table></td>
<td>Data Outputs:
<table>
<tr><th colspan="4">25%</th></tr>
<tr><td>Month</td><td>Flow</td><td>Change</td><td>Percent Change</td></tr>
<tr><td>Feb</td><td>316274</td><td>-2491</td><td>-1%</td></tr>
</table></td>
<td>Data:
Feb: Same as NAA.
Mar: -3%
Apr: -2%
May: -1%</td>
<td>Data:
Feb: Same as NAA.
Mar: -1%
Apr: -2%
May: -2%</td>
<td>Data Outputs:
<table>
<tr><th colspan="4">25%</th></tr>
<tr><td>Month</td><td>Flow</td><td>Change</td><td>Percent</td></tr>
</table></td>
<td>Outflow plume relationship: Antonio Baptista, Oregon HSU Langness and Heironimus, personal communication Indicators: Joint staff reports – Laura send link</td>
</tr>
</table>

<table>
<tr><th>Affected Environment Important Relationships/Criteria</th><th>Affected Environment Metric</th><th>Environmental Consequences NAA</th><th>Environmental Consequences MO1</th><th>Environmental Consequences MO2</th><th>Environmental Consequences MO3</th><th>Environmental Consequences MO4</th><th>References</th></tr>
<tr>
<td>distribution). Higher outflows from BON = more flume.</td>
<td></td>
<td>
<table>
<tr><td>May</td><td>366718</td><td>314137</td><td>274443</td></tr>
</table>
Effects to Resource NAA:
Median flow years and above would continue to relate to better survival, based on larger plume and faster passage through the estuary.
Notes: Smaller plume tends to push them southward, closer inland; larger plume pushes northward and further. Spawn Jan to Mar. Dispersal in Feb to May. Relationship – big plume or don’t. At very low flows, they don’t get pushed out of estuary at all. (Tributaries below BON also influence.)
</td>
<td>
<table>
<tr><td>Mar</td><td>280677</td><td>-1414</td><td>-1%</td></tr>
<tr><td>Apr</td><td>301154</td><td>-5900</td><td>-2%</td></tr>
<tr><td>May</td><td>361290</td><td>-5428</td><td>-2%</td></tr>
</table>
<table>
<tr><th colspan="4">Median</th></tr>
<tr><td>Month</td><td>Flow</td><td>Change</td><td>Percent Change</td></tr>
<tr><td>Feb</td><td>262834</td><td>-3927</td><td>-1%</td></tr>
<tr><td>Mar</td><td>231161</td><td>-1620</td><td>-1%</td></tr>
<tr><td>Apr</td><td>255722</td><td>-4648</td><td>-2%</td></tr>
<tr><td>May</td><td>308143</td><td>-5994</td><td>-2%</td></tr>
</table>
<table>
<tr><th colspan="4">75%</th></tr>
<tr><td>Month</td><td>Flow</td><td>Change</td><td>Percent Change</td></tr>
<tr><td>Feb</td><td>214469</td><td>-2382</td><td>-1%</td></tr>
<tr><td>Mar</td><td>192116</td><td>-2907</td><td>-2%</td></tr>
<tr><td>Apr</td><td>207704</td><td>-3129</td><td>-2%</td></tr>
<tr><td>May</td><td>269430</td><td>-5013</td><td>-2%</td></tr>
</table>
Effects of MO1 compared to NAA:
About 1% to 2% lower flows during outmigration timing. Relationship of BON outflow to plume size is not certain, but could result in slightly less distribution of larvae. No measureable change.
Notes: Flows making a big enough plume, metric is the size of the plume at that time. CMOP.org – check for linkage between BON outflows and plume. (Sue, look it up. If further coordination is needed, ask Laura). Stccmop.org.
Water particle travel time through the estuary; could stall in estuary in low flows. Complete analyses; include low water years for this relationship.
</td>
<td>Effects:
Similar to MO1, slightly less outflow in spring months could result in slightly less distribution of larvae compared to NAA.</td>
<td>Effects:
Similar to MO1, slightly less outflow in spring months could result in slightly less distribution of larvae compared to NAA.</td>
<td>
<table>
<tr><td></td><td></td><td></td><td>Change</td></tr>
<tr><td>Feb</td><td>315882</td><td>-2883</td><td>-1%</td></tr>
<tr><td>Mar</td><td>284344</td><td>2253</td><td>1%</td></tr>
<tr><td>Apr</td><td>300980</td><td>-6074</td><td>-2%</td></tr>
<tr><td>May</td><td>361427</td><td>-5291</td><td>-1%</td></tr>
</table>
<table>
<tr><th colspan="4">Median</th></tr>
<tr><td></td><td>Flow</td><td>Change</td><td>Percent Change</td></tr>
<tr><td>Feb</td><td>262696</td><td>-4064</td><td>-2%</td></tr>
<tr><td>Mar</td><td>234927</td><td>2146</td><td>1%</td></tr>
<tr><td>Apr</td><td>255136</td><td>-5233</td><td>-2%</td></tr>
<tr><td>May</td><td>310032</td><td>-4104</td><td>-1%</td></tr>
</table>
<table>
<tr><th colspan="4">75%</th></tr>
<tr><td></td><td>Flow</td><td>Change</td><td>Percent Change</td></tr>
<tr><td>Feb</td><td>213124</td><td>-3727</td><td>-2%</td></tr>
<tr><td>Mar</td><td>193961</td><td>-1063</td><td>-1%</td></tr>
<tr><td>Apr</td><td>207002</td><td>-3831</td><td>-2%</td></tr>
<tr><td>May</td><td>277378</td><td>2934</td><td>1%</td></tr>
</table>
Effects of MO4 compared to NAA:
1% to 2% increase or decrease, depending on the month and water year. Driest years could see 1% to
</td>
<td></td>
</tr>
</table>

<table>
<tr><th>Affected Environment Important Relationships/Criteria</th><th>Affected Environment Metric</th><th>Environmental Consequences NAA</th><th>Environmental Consequences MO1</th><th>Environmental Consequences MO2</th><th>Environmental Consequences MO3</th><th>Environmental Consequences MO4</th><th>References</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>2% decrease in Feb to Apr, up to 10% increase in May. Increased flows in May of dry years could help with distribution of larvae.
Notes: Refer to size of the plume. Variable plume size, consider flows at site further down from BON. Don’t have flow data there, but the team does have BON plus Willamette. Response – Team – found out there are recorded flows at Columbia and Willamette, and adjusted the metrics.</td><td></td></tr>
<tr><td>Freshwater inputs to the nearshore ocean environment can affect the planktonic food supply and other processes important food supply and other processes important to larval eulachon. Decreased freshwater input may lead to lower survival.</td><td>Freshwater inputs – Columbia and Willamette flows, Apr to Jul</td><td>H&H and WQ Outputs:
<table><tr><th>Month</th><th>25%</th><th>Med</th><th>75%</th></tr><tr><td>Apr</td><td>307054</td><td>260370</td><td>210833</td></tr><tr><td>May</td><td>366718</td><td>314137</td><td>274443</td></tr><tr><td>Jun</td><td>390625</td><td>319041</td><td>256963</td></tr><tr><td>Jul</td><td>264978</td><td>216458</td><td>165721</td></tr></table>Effects to Resource NAA:
Relatively low freshwater inputs into the nearshore environment would continue to moderately limit plankton food supply for larval eulachon in the Apr to Jul period.
Notes: From recovery plan. (From Amy: helpful to clarify that larval survival decreases when there is a mish-mash of planktonic food supply, environmental ocean conditions, and eulachon larvae. Results from decrease in primary productivity).</td><td>Data Outputs:
<table><tr><th colspan="4">Percent Change</th></tr><tr><td>Month</td><td>25%</td><td>Med</td><td>75%</td></tr><tr><td>Apr</td><td>-3%</td><td>-2%</td><td>-2%</td></tr><tr><td>May</td><td>-2%</td><td>-2%</td><td>-2%</td></tr><tr><td>Jun</td><td>-1%</td><td>-1%</td><td>-1%</td></tr><tr><td>Jul</td><td>-2%</td><td>-1%</td><td>0%</td></tr></table>Effects of MO1 compared to NAA:
Very small (1% to 2%) reduction in freshwater inputs could potentially result in lower plankton availability for larval eulachon food supply, but likely unmeasurable.
Notes: No data to quantify a relationship, but could potentially affect.</td><td>Data:
Apr: -2%
May: -2%
Jun: -1%
Jul: Same as NAA.
Effects:
Very small (1% to 2%) reduction in freshwater inputs could potentially result in lower plankton availability for larval eulachon.</td><td>Data:
Apr: -2%
May: -2%
Jun: -1%
Jul: -2%
Effects:
Very small (1% to 2%) reduction in freshwater inputs could potentially result in lower plankton availability for larval eulachon.</td><td>Data Outputs:
<table><tr><th colspan="4">Percent Change</th></tr><tr><td>Month</td><td>25%</td><td>Median</td><td>75%</td></tr><tr><td>Apr</td><td>-2%</td><td>-2%</td><td>-2%</td></tr><tr><td>May</td><td>-1%</td><td>-1%</td><td>1%</td></tr><tr><td>Jun</td><td>-1%</td><td>-1%</td><td>1%</td></tr><tr><td>Jul</td><td>-2%</td><td>0%</td><td>4%</td></tr></table>Effects of MO4 compared to NAA:
Very small (1% to 2%) reduction in freshwater inputs could potentially result in lower plankton availability for larval eulachon.</td><td>NMFS 2017</td></tr>
<tr><td>Turbidity – relationships not clear. Higher turbidity (Jan-Mar) may provide protection from predators, but may hinder migration.</td><td>Turbidity qual.</td><td>H&H and WQ Outputs:
Qual baseline turbidity from water quality.</td><td>Data Outputs:
No change to turbidity.</td><td>Data:
Same as NAA.
Effects:
Same as NAA.</td><td>Data:
No change.
Effects:
No change.</td><td>Data Outputs:
No change.
Effects of MO4 compared to NAA:
No change.</td><td>No citation provided, and not consistent with recovery plan that references decreased spring turbidity compared to historical. Text document cites recovery plan info.</td></tr>
<tr><td>Changes in flow can change the location of the saltwater/ freshwater interface important to eulachon feeding.</td><td>Flow at BON, summary hydrograph.</td><td>Saltwater wedge is highly variable (check with Olaf on relationship). Wedge is probably no affecting them directly, but another measurement of flow. (Don’t write up as an effect. Keep notes here.) There are</td><td>Data Outputs:
Amy note on plume and productivity. Oregon State University website includes description of Columbia River bringing buoyant freshwater to the</td><td>–</td><td>–</td><td>–</td><td>Olaf provide website citation for saltwater wedge (see eulachon). From Amy: http://mixing.coas.oregonstate.edu/research/river_plumes/. Structure and dynamics of</td></tr>
</table>

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	References
		numerous estuary studies (Bottom, Simenstad, Weitkamp, etc.) showing abundance of zooplankton and forage fish in the estuary in relation to salinity and other factors. A top one couldn't be identified for eulachon, but the team can easily cover estuary productivity in general. Note: this relationship is more relative to green sturgeon.	Pacific Ocean, along with dissolved silicate and iron.				the Columbia River tidal plume front.
Increased barge traffic could increase predation. Structures could change Pinniped behavior and predation.	–	–	**Data Outputs:** No change to barge traffic. No changes to pinniped behavior note. Effects of MO1 compared to NAA: Same as NAA.	Data: No change to barge traffic. **Effects:** Same as NAA.	Data: No change to barge traffic (T. Teed email).	**Data Outputs:** No change to barge traffic. No changes to pinniped behavior noted. Effects of MO4 compared to NAA: Same as NAA.	NMFS, 2017

Howell, 2001
Kilcher and Nash. 2010. Structure and dynamics of the Columbia River tidal plume front. J. Geophys. Res., 115, C05S90.
Muir and Williams, 2011
National Marine Fisheries Service, 2017. Recovery Plan for the Southern Distinct Population Segment of Eulachon (Thaleichthys pacificus). National Marine Fisheries Service, West Coast Region, Protected Resources Division, Portland, OR, 97232. September 2017.
National Marine Fisheries Service, 2010. Status Review Update for Eulachon in Washington, Oregon, and California. January 21, 2010. 443 pp.
Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife, 2001. Washington and Oregon Eulachon Management Plan. WDFW, Ridgefield, WA.

3.7.2 Green Sturgeon

Table 3-65. Green Sturgeon Qualitative Effects Analysis Matrix

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Estuary Occupation	Greens primarily transient, use fall/summer in Columbia River. Not considered spawning habitat. Seen evidence of green sturgeon young-of-year at Bonneville (note from Amy that cited paper describes a single young-of-year in the Columbia River), operations that affect white sturgeon probably apply, limited, to greens as well. The young-of-year were Northern DPS. Southern DPS is Sacramento, Northern in elsewhere. Columbia typically dominated by Southern (listed). 80% southerns in most years. Estuary is critical to greens. Diet, prey availability, to grow and reproduce.						

Affected Environment Important Relationships/Criteria	**Affected Environment Metric**	**Environmental Consequences NAA**	**Environmental Consequences MO1**	**Environmental Consequences MO2**	**Environmental Consequences MO3**	**Environmental Consequences MO4**	**Notes**
Temperatures in the estuary cue the arrival in spring and departure of green sturgeon in the fall. 15°C in the estuary (use as trigger arrival, but based on differential to ocean temperature).	Temperatures at BON to Warrendale: index BON tailwater temperature, extended year set, date first reached 15°C in spring, then drop below 15°C in fall.	**Data Outputs:** 2011 (HF/LT): 06/21-10/20 2012 (AF/LT): 06/02 (1 day, then again on 6/16)-10/19 2013 (LF/AT): 06/03-10/12 2014 (AF/AT): 05/23-10/26 2015 (LF/HT): 05-19-10/25 **Effects to Resource:** Currently arrive about June, leave about Sep/Oct. Some years, as early as May and as late as Dec. Currently supports adequate rearing conditions for green sturgeon. Expected to continue. NAA **Notes:** Temperatures will vary greatly from BON down, ocean affects.	**Data Outputs:** 2011: 06/21-10/20 2012: 06/02 (1 day, then again on 6/16) – 10/19 2013: 0604 (06/03 was 14.99°C – 10/12 2014: 05/23 – 10/26 (same as NAA 2015: 05/19 – 10/26 (1 day later) **Effects to Resource:** Same as NAA. **Notes:** NA	**Data Outputs:** Water quality states no change to water temperature sin lower river. **Effects to Resource:** Expect same as NAA. **Notes:** NA	**Data Outputs:** 2011: 06/21 – 10/19 (1 day earlier) 2012: 06/17 (later than NAA, 0.3° to 0.5° cooler) – 10/18 (1 day earlier) 2013: 06/04 (06/03 was 14.99°C – 10/12 2014: 05/23 – 10/26 2015: 05/19 – 10/25 **Effects to Resource:** Similar to NAA. **Notes:** NA	**Data Outputs:** 2011: 06/21 – 10/20 2012: 06/16 (6/2 was 14.99°C, then dropped) 2013: 06/04 (06/03 was 14.89°C) – 10/11 (1 day earlier) 2014: 05/23 – 10/26 2015: 05/20 (05/19 was 14.95°C) – 10/25 **Effects to Resource:** Same as NAA. **Notes:** NA	Moser and Lindley, 2007 Schreier et al., 2016 (sent to Sue)

<table>
<tr><th>Affected Environment Important Relationships/Criteria</th><th>Affected Environment Metric</th><th>Environmental Consequences NAA</th><th>Environmental Consequences MO1</th><th>Environmental Consequences MO2</th><th>Environmental Consequences MO3</th><th>Environmental Consequences MO4</th><th>Notes</th></tr>
<tr>
<td>Changes in flow can change the location of the saltwater/ freshwater interface that is important to green sturgeon feeding.</td>
<td>Flows: Columbia plus Willamette, June to Oct.</td>
<td>Data Outputs:
<table>
<tr><th>Month</th><th>1%</th><th>25%</th><th>Media</th></tr>
<tr><td>Oct</td><td>185362</td><td>119899</td><td>10814</td></tr>
<tr><td>Jun</td><td>619863</td><td>389625</td><td>31894</td></tr>
<tr><td>Jul</td><td>365538</td><td>264978</td><td>21645</td></tr>
<tr><td>Aug</td><td>246255</td><td>180337</td><td>15891</td></tr>
<tr><td>Sep</td><td>175464</td><td>121950</td><td>11148</td></tr>
</table>
<table>
<tr><th>Month</th><th>75%</th><th>99%</th></tr>
<tr><td>Oct</td><td>98340</td><td>89754</td></tr>
<tr><td>Jun</td><td>256963</td><td>185448</td></tr>
<tr><td>Jul</td><td>165721</td><td>138448</td></tr>
<tr><td>Aug</td><td>138262</td><td>128607</td></tr>
<tr><td>Sep</td><td>105437</td><td>96564</td></tr>
</table>
Effects to Resource:
Currently arrive about June, leave about Sep/Oct. Some years as early as May and late as Dec. Currently supports adequate rearing conditions for green sturgeon.
Notes:
Freshwater/salt ratio, provides food source (benthic), changing location of that interface could change sturgeon use. Temp window. Look during summer months. Low flow pushes it upriver, more downriver. Direct relationship not known. Saltwater wedge is highly variable. Pushed down as far as East Mooring basin, up to Sand Island.</td>
<td>Data Outputs:
<table>
<tr><th></th><th colspan="3">Percent Change</th></tr>
<tr><td>Month</td><td>25%</td><td>Median</td><td>75%</td></tr>
<tr><td>Oct</td><td>0%</td><td>0%</td><td>0%</td></tr>
<tr><td>Jun</td><td>-1%</td><td>-1%</td><td>-1%</td></tr>
<tr><td>Jul</td><td>-2%</td><td>-1%</td><td>0%</td></tr>
<tr><td>Aug</td><td>-4%</td><td>-5%</td><td>-5%</td></tr>
<tr><td>Sep</td><td>-1%</td><td>-1%</td><td>-2%</td></tr>
</table>
Effects to Resource:
Slight decrease (4% to 5%) in flows could result in slight changes in the location of the saltwater wedge in August (pushed further upstream). The effects to green sturgeon are not well understood.
Notes:
NA</td>
<td>Data Outputs:
June: -1%
Jul: Same as NAA
Aug: -1%
Sep: +2%
Oct: -2%
Effects to Resource:
Similar to NAA (0% to 2% change). However, the change from higher in Sep to lower in Oct could mean the change in the location of feeding activity moves between Sep (further downstream) to further upstream in Oct).
Notes:
NA</td>
<td>Data Outputs:
Jun: -1%
Jul: -2%
Aug: -3%
Sep: -2%
Oct: Same as NAA
Effects to Resource:
Feeding locations could be slightly further upstream than the NAA.
Notes:
NA</td>
<td>Data Outputs:
<table>
<tr><th></th><th colspan="3">Percent Change</th></tr>
<tr><td>Month</td><td>25%</td><td>Med</td><td>75%</td></tr>
<tr><td>Oct</td><td>-3%</td><td>-4%</td><td>-4%</td></tr>
<tr><td>Jun</td><td>-1%</td><td>-1%</td><td>1%</td></tr>
<tr><td>Jul</td><td>-2%</td><td>0%</td><td>4%</td></tr>
<tr><td>Aug</td><td>-4%</td><td>-4%</td><td>-5%</td></tr>
<tr><td>Sep</td><td>-3%</td><td>-6%</td><td>-9%</td></tr>
</table>
Effects to Resource:
Slightly different flows could change the location of the saltwater wedge, but likely immeasurably. Further upstream in Jun, Aug, Sep, Oct, and further downstream in Jul as compared to the NAA. Fluctuation of wedge (further downstream in Jul, further upstream in Aug to Oct) could be an additional stressor, but effect not known.
Notes:
July and August are peak months.</td>
<td>–</td>
</tr>
</table>

<table>
<tr>
<td>Changes in estuary temperatures could alter productivity and food sources in the estuary.</td>
<td>Temperature at BON to Warrendale: index BON tailwater temperature, extended year set, average monthly temperature, May to Oct.</td>
<td>
Data Outputs:
<table>
<tr><th colspan="2">2011 (HF/LT)</th><th colspan="2">2012 (AF/LT)</th></tr>
<tr><td>May</td><td>11.79</td><td>May</td><td>12.52</td></tr>
<tr><td>Jun</td><td>14.73</td><td>Jun</td><td>15.38</td></tr>
<tr><td>Jul</td><td>16,72</td><td>Jul</td><td>18.81</td></tr>
<tr><td>Aug</td><td>20.16</td><td>Aug</td><td>20.77</td></tr>
<tr><td>Sep</td><td>18,56</td><td>Sep</td><td>18.56</td></tr>
<tr><td>Oct</td><td>15.58</td><td>Oct</td><td>15.03</td></tr>
</table>
<table>
<tr><th colspan="2">2013 (LF/AT)</th><th colspan="2">2014 (AF/AT)</th></tr>
<tr><td>May</td><td>13.77</td><td>May</td><td>13.19</td></tr>
<tr><td>Jun</td><td>16.66</td><td>Jun</td><td>16.55</td></tr>
<tr><td>Jul</td><td>20.37</td><td>Jul</td><td>20.73</td></tr>
<tr><td>Aug</td><td>21.76</td><td>Aug</td><td>22.14</td></tr>
<tr><td>Sep</td><td>20.19</td><td>Sep</td><td>19.54</td></tr>
<tr><td>Oct</td><td>14.35</td><td>Oct</td><td>16.32</td></tr>
</table>
<table>
<tr><th colspan="2">2015 (LF/HT)</th></tr>
<tr><td>May</td><td>14.61</td></tr>
<tr><td>Jun</td><td>19.69</td></tr>
<tr><td>Jul</td><td>21.95</td></tr>
<tr><td>Aug</td><td>21.45</td></tr>
<tr><td>Sep</td><td>18.60</td></tr>
<tr><td>Oct</td><td>16.05</td></tr>
</table>
Effects to Resource:
Would continue to provide a good food source relative to their home estuary; green sturgeon would continue to use the estuary as transient habitat.
Notes:
Estuary provides large food source as related to Sacramento (related to why greens migrate out of their own estuary into the Columbia River). Opportunistic predators, generally well-supported by current conditions.
</td>
<td>
Data Outputs:
<table>
<tr><th colspan="3">2011 (HF/LT)</th></tr>
<tr><td>May</td><td>NAA</td><td>MO1</td></tr>
<tr><td></td><td>11.79</td><td>11.79</td></tr>
<tr><td>Jun</td><td>14.73</td><td>14.74</td></tr>
<tr><td>Jul</td><td>17.82</td><td>17.82</td></tr>
<tr><td>Aug</td><td>20.16</td><td>20.15</td></tr>
<tr><td>Sep</td><td>19.56</td><td>19.59</td></tr>
<tr><td>Oct</td><td>15.58</td><td>15.61</td></tr>
<tr><td>2012 (AF/LT)</td><td></td><td></td></tr>
<tr><td>May</td><td>NAA</td><td>MO1</td></tr>
<tr><td></td><td>12.52</td><td>12.72</td></tr>
<tr><td>Jun</td><td>15.38</td><td>15.29</td></tr>
<tr><td>Jul</td><td>18.81</td><td>18.76</td></tr>
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Data Outputs:
Water states quality no change to water temperatures in lower river. Will check data.
Effects to Resource:
Same as NAA.
Notes:
NA
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<td>Moser and Lindley, 2007.</td>
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</table>

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
			Oct 16.05 16.12 **Effects to Resource:** Average monthly temperatures for all months in the representative flow/air temperature types were within 2/10ths of a degree from the NAA. Effect to green sturgeon would be the same as NAA. **Notes:** NA		Oct 16.05 15.98 **Effects to Resource:** Similar to NAA except May 2012 (AF/LT) 0.69° warmer than NAA. **Notes:** NA	Oct 16.05 16.02 **Effects to Resource:** All average monthly temperatures were within 2/10ths of the NAA, with the exception of Jul and Aug in low flow, high air temperature years (such as 2015); in this case, the MO4 mean monthly was 0.29°C (July) and 0.50°C higher than NAA. The biological effect would likely be the same as NAA. **Notes:** Team – would 0.5° difference be measurable to the relationship of productivity and food sources?	
Channel maintenance operations can affect green sturgeon through displacement and disruption of food sources.		**Data Outputs:** NA **Effects to Resource:** Check if CRSO would affect any channel maintenance operations. If not, keep notes here for cumulative effects. **Notes:** Possible displacement, disruption of food, etc. Parsley et al., white sturgeon fidelity of habitat (not green sturgeon).	**Data Outputs:** NA **Effects to Resource:** NA – keep notes for cumulative effects. **Notes:** Any alternatives potentially result in placement of more material downstream of BON and, therefore, require additional dredging.	**Data Outputs:** NA **Effects to Resource:** NA **Notes:**	**Data Outputs:** Similar to NAA. **Effects to Resource:** Same as NAA. **Notes:**	**Data Outputs:** Similar to NAA. Dry years slightly warmer and higher summer flows may influence slightly, but likely not a population level effect. **Effects to Resource:** NA **Notes:** None	NA

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Coastal bays and estuaries, including the Columbia River estuary, are used for feeding, and these food sources could be negatively affected by the shift from native to non-native fish assemblages.	Qualitative, trend of native versus non-native assemblages.	**Data Outputs:** N/A **Effects to Resource:** Coordinate effects with fish community. The estuary would continue to provide food sources for transitory green sturgeon, but this food source may diminish over time if the fish community shifts from native to non-native dominance. **Notes:** Greens primarily transient, use fall/summer in Columbia River. Not considered spawning habitat. Seen evidence of green sturgeon young-of-year at BON, ops that affect white sturgeon probably apply, limited, to greens as well. The young-of-year were Northern DPS. Southern DPS is Sacramento, Northern in elsewhere. Columbia typically dominated by Southern. (listed). 80% southerns in most years. Estuary is critical to greens. Diet, prey availability, to grow and reproduce.	**Data Outputs:** Similar to NAA. **Effects to Resource:** Similar to NAA.	**Data Outputs:** Similar to NAA. **Effects to Resource:** Same as NAA. **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** Same as NAA. **Notes:** None	WDFW Reports NMFS, 2018

Moser, Mary L., and Steven T. Lindley. Use of Washington estuaries by subadult and adult green sturgeon. Environ Biol Fish (2007) 79:243–253.
National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 2018. Recovery Plan for the Southern Distinct Population Segment of North American Green Sturgeon (Acipenser medirostris). National Marine Fisheries Service, Sacramento, CA.

3.7.3 Pacific Lamprey

Table 3-66. Lamprey Qualitative Effects Analysis Matrix

Affected Environment Important Relationships / Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Adult Mainstem Passage							
Mainstem dams can inhibit upstream migration to spawning areas. The drivers for this effect are the following: 1) lower fishway sections, slow velocities, and turbulence can cause turnarounds; and	Dam passage efficiency, dam to dam escapement, counts index at each dam.	A portion of lamprey that enter the Columbia River and attempt to move upstream are able to pass the dams and move into desired spawning areas upstream. The proportion depends on location in the basin; further upstream = more dams	Lower spill than NAA, potentially change routes of passage in lower river. In the Snake River, potentially better passage with less spill. Bonneville -Getting fish into the fishway (S6 -expand network of LPS to bypass impediments in	Effects are the same as for MO1. **DATA:** S6: Lamprey passage structures S9: Lamprey passage ladder modifications Decreased spill and TDG – see below relationships.	The Columbia River projects would have the same effects as for MO1. Long-term Snake River: lamprey passage at Snake River dam locations would be likely mostly supported with current configurations of feasibility level	The effects would be the same as for MO1. **DATA:** S5: Lamprey Passage Structures S7: Lamprey Passage Ladder Modifications	Keefer Corps summary reports CRITFC carcass survey grad student (Siena) Clabough et al., 2015 Keefer et al., 2012 Corps, 2019

Affected Environment Important Relationships / Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
2) velocity and structural issues in the ladders (angles, corners, flow concentrations, etc.) cause difficulty.		encountered. Attrition through the system leads to fewer and fewer lamprey able to make it up further into the system. Dams reduce access to desired spawning locations. Some mitigation of lamprey passage effects occurs by translocation programs. Distribution effects, limiting total population size, may displace spawning individuals. Reduced distribution and abundance reduces attraction pheromone cues. Reduced ecosystem/food web effects (lamprey transfer nutrients upstream (Dunkle, 2017 in McIlraith, 2017). Adult lamprey passage metrics are expected to remain consistent in near future and improve incrementally as conventional fishway structures and operations are modified and LPSs are installed. **DATA:** Median Dam passage efficiencies across all study years, 1997-2010 (Keefer et al. 2012)* BON = 44% (n=10 years) TDA = 68% (n=10 years) JDA = 46% (n=6 years) MCN = 64%/81% (MCN tagged fish/BON tagged fish, n=6 years) Dam passage efficiency, 2014 (Clabough et al., 2015): "Dam passage efficiency (the number of tagged lamprey that passed the dam divided by the number that approached a fishway) were 49-52% (n = 453-473 approached) at Bonneville Dam (first number excludes 20 recaptured fish). Dam passage efficiency was 47% (n = 157) at The Dalles Dam, 83% (n = 48) at John Day Dam, and 100% (n = 7) at McNary Dam." 2015: Lower Snake Dams	existing ladders, and improvements to ladders S9) would be substantial improvement to improve percentage of fish getting into the fish ladders at Bonneville. LPS probably more benefit than ladder improvements because the lamprey do not make it into the structures at Bradford Island fishway. For context, improvements at JDA ladders to improve lamprey entrance into fishways resulted in increased dam passage efficiency from 46% to 83% (Clabough et al., 2015). Dynamics at each dam are very different so cannot infer directly across, but do see improvements in overall dam passage efficiency with improvements in ladder entrance efficiency. Bonneville is a large structure and requires more improvements on the smaller scale to make a difference on the overall dam passage efficiency; likely improvement would be less. S4: Modify serpentine section - would also improve passage efficiency for lamprey. TDA - North ladder LPS - have passage there, incremental benefit but not as drastic as BON. JDA - LPS on south and extension on north would continue to moderately improve overall dam passage efficiency incrementally (has already improved in NAA). S3: would improve lamprey passage issues at the adult trap (allow to pass when not trapping). S5: Cooler water in the ladders; LMN and IHR. This has been done at LGO and IHR and was successful in cooling the ladder; would be expected to benefit		sketches. Issues could arise from lamprey coming up the structure side and getting caught with a high velocity barrier at concrete corners at high flows. The armoring substrate would be riprap, and would require burst swimming speeds over riprap. In some locations, the velocities could be limiting just upstream but likely a relic of previous deposition that would be flushed through with a dam breach. Early migrants could see velocities above their burst speeds; considerations would be made in design phase. Passage through dam breaches would be better passage than in the NAA ladders. **DATA:** Lower Columbia dams: S7: Lamprey Passage Structures S10: Lamprey Passage Ladder Modifications For the Dam breach on Snake River measure, see Hydraulic Engineering presentation of site configuration and hydraulics. **NOTES:** Mesa et al. (2003) state 2.6 fps swim speed for lamprey. The max burst swimming speed is 8.2 to 9.8 fps from Kiefer et al., 2010. In a white paper on adult passage, 7.0 fps is the burst swimming speed. 3.0 fps is regular swim speed obtained by averaging over different studies. Snake timing - late May leading, mostly in June, Jul, Aug. Overwintering fish may be trying to move sooner.		McIlraith ,2017 (BPA Report 2008-524-00 2016 Annual Report) CRITFC 2011.Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin.

Affected Environment Important Relationships / Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		(Stevens et al., 2016) IHR = 47% LMO = 68% LGO = 41% LGR = 67% **NOTES:** There is uncertainty with escapement counts, but they are used as an index. Attrition occurs through the system. Tag effects in studies likely underestimate passage success (size effect, larger ones tend to make it further; may be somewhat attributed to tag burden effect), but the relationship is seen in PIT tagged (not radio-tagged) fish as well. Data for upstream projects is less certain due to small sample size. **Structural issues at BON: add more detail on structural issues. This is more important at Bonneville. **Cumulative effects/attrition occur through multiple dams. Calculation – 1. NOAA/UofI, Keefer – general migration report. Percentage released below BON that make it to The Dalles, John Day. Check mainstem implementation plan or FWS assessment. Estimate based on RT data in different fishways. Keefer "bottleneck exercise" combined with observed collection efficiencies. Range of anticipated collection and potential benefits. Use as a percentage. The NWW sample sizes are so small it is hard to make an estimate on previous studies. The wintering over strategy makes it hard to extrapolate as well.	lamprey. S9: Mods to LMN - diffuser grate plating. Has been done at all other ladders except LMN and demonstrated slight benefits to lamprey passage. Additional work at LMN would increase this benefit incrementally. Weir caps to entrances - would assist fish into adult ladders (reduce issues with right angles) (Moser et al., 2003 and Daigle et al., 2005). Overall passage efficiency would likely improve incrementally over time as individual modifications were implemented. **NOTES:** Improved dam passage efficiency in 2014 at JDA (83% in 2014 vs. a historic median of 46%) suggests that extensive incorporation of lamprey passage features in FCRPS BiOp-mandated JDA North Ladder improvements in the lower and upper fishway segments (completed between 2010 and 2013) likely resulted in meaningful improvements to dam passage efficiency. Studies in 2018-2019 provide the opportunity to verify improved passage at JDA. The number of BON-tagged lamprey that approach JDA are small, so these metrics are based on relatively small sample sizes. Each structural measure is intended to increase dam passage efficiency. Each project is unique: BON - WA shore fishway LFS expected to be substantial improvement, wanted to improve entrance efficiency, but not effective. Bottleneck at BON is getting fish into the fishway (about 50% approach didn't make it into fishway).				

Affected Environment Important Relationships / Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Translocation programs in the basin help mitigate for dam passage impediments.	Number of translocated lamprey.	Three of the CRITFC member tribes participate in translocation, the NPT, CTUIR, and YN. Translocation was implemented to immediately address the threat that lack of passage poses for Pacific lamprey and return lamprey to high quality habitat where they were once abundant but were extirpated or near extirpated. Translocation has resulted in successful spawning and increases in larval lamprey density, which in turn provides attraction to adult migrating lamprey. Between 2013 and 2018, total collections of adult lamprey for tribal translocation programs from all three dams combined is >17,100 adult lamprey. Numbers of translocated lamprey have increased from 1,480 in 2013 to 4,738 in 2018. Lamprey translocation numbers would continue to increase accordingly with population increases. **DATA:** 2013: BON TDA JDA Total 2013: 714 304 462 1480 2014: 762 793 642 2197 2015: 867 1110 875 2852 2016: 645 784 1018 2447 2017: 1107 1588 742 3437 2018: 2137 483 2118 4738 **NOTES:** The Tribal Guidelines for translocation are contained within the Tribal Pacific Lamprey Restoration Plan and were modified in 2017 to read:	No change anticipated. Translocation programs would likely continue to mitigate for dam passage impediments. Translocation program serves other purposes: establishing broodstock and reestablishing populations, enhancing pheromone cues, providing nutrients, benefits to overall ecosystem health.	Same as MO1.	Same as MO1 **NOTES:** Dam breach would have harmful short-term effects, so agencies may consider additional translocation as mitigation.	The effects would be the same as for MO1.	–

Affected Environment Important Relationships / Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		Collection of adult lamprey from Bonneville dam shall not exceed 50% of the total collection of adult lamprey during the active migration at any Columbia River dam (4d., page 67). Total collection of adult lamprey during the active migration at Columbia River dams by the CRITFC tribes shall not exceed 8% of the 2-year running average of the total adjusted count of upriver annual adult lamprey population based on total counts past Bonneville Dam (2% per Tribe) (4c., page 67). Based on this change, 4% shall be changed to 8% where appropriate throughout the Tribal Guidelines for Translocation (4c., 4d., and 4g.).					
Mainstem dams can cause direct mortality or physical stress among adult lamprey that use lamprey passage structures (LPS) or are otherwise diverted into collection structures or traps.	Mortality counts, rejected fish, observations of poor conditions.	Corps biologists and Corps-funded researchers periodically find dead individual lamprey in Lamprey Passage Structures (LPSs) or in holding tanks. Mortality causes are sometimes unknown (e.g. one or two individuals are found in an LPS rest box or collection tank that is operating as designed). In other instances, equipment failures (e.g. LPS pump failure due to electrical power interruption or blockages within LPSs that cause lamprey to exit the structures) lead to direct mortalities. High temperatures or other water quality issues may cause physical stress or direct mortality of individuals, particularly as lamprey are held in holding tanks for longer periods during extended periods of high temperatures. Mortality removes individuals from the system, but the number of reported mortalities is low compared to lamprey numbers.	Measure S6 is applicable. Increased passage should decrease susceptibility to physical stress and mortality. Less holding time is beneficial. Additional LPSs could slightly increase injury/stress due to LPS use, but overall benefit over fish ladder passage.	Same as MO1. **DATA:** S6: Lamprey Passage Structures	Columbia River: Same as MO1 Snake River: Dam breach would allow riverine passage; there is no LPS now. **DATA:** S7: Lamprey Passage Structures S1, S2, O1, O2: Dam Breach Snake River - See hydraulics and configuration data.	The effects would be the same as for MO1. **DATA:** S5 and S7.	FPOM website coordination memos (Erin Kovalchuk). Each tribe provides summary reports: Todd Sween (NP), Aaron Jackson CTUIR, Ralph Lampman (YN), Cyndi Baker or Andy Johnsen (Warm Springs). Check U of I reports or Moser

Affected Environment Important Relationships / Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		DATA: Observed mortalities at Corps-operated dams are reported to FPOM in the form of MFRs, which are posted to the FPOM website. There should be a decreasing trend in mortality over time as the Corps and others who collect and transport lamprey continue to identify problem areas and apply solutions. **NOTES:** Most issues are being addressed as they arise. The temporary/ experimental nature of some structures has contributed to reliability issues with some LPSs (e.g., pump failures, lack of low water alarms, etc.). In recent years, Corps has been converting experimental structures into operational systems to improve reliability. Access to fresh, clean, cold water for collection and holding tanks can be a challenge at many locations. Tribal staff and Corps-funded researchers sometimes reject lamprey for translocation or research purposes due to poor condition, evidence of disease. Lamprey may get stressed during trapping, holding, and transport between dams and to Tribal holding facilities. CRITFC and Tribes monitor water conditions and fish conditions during holding and transport. Fish that appear lethargic or unfit are rejected from traps.					
Mainstem dams can cause direct mortality or physical stress among adult lamprey that use conventional fishways.	Mortality counts, rejected fish, observations of poor conditions.	Dead adult lamprey in various states of decomposition (i.e. single mortality events over time) are periodically found within conventional fishways. Common locations where mortalities are found include:	The effects are the same as for MO1. **DATA:** S9: Lamprey passage ladder modifications	No fishways on Snake River; eliminates any injury/mortality from ladders on Lower Snake River dams. **DATA:** S10: Lamprey Passage Modifications	The effects would be the same as for MO1. **DATA:** S5.	Summarized in Keefer et al., 2013; Physical stress - Mesa and Keefer et al., 2012; Mesa et al., 2003	–

Affected Environment Important Relationships / Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		1) BON Adult Fish Facility drain trash racks; 2) Underneath BON Bradford Island and Washington Shore fish ladder count station crowder boxes; 3) Picketed leads at various projects; 4) Underneath floor diffuser grating; 5) Upstream of picketed leads at Upstream Migrant Tunnel (UMT) junction at Cascades Island Ladder. Dead lamprey are also recovered in various fishway locations during winter maintenance dewatering events. Lamprey have been trapped under diffuser grating or in otherwise inaccessible areas, causing mortality events involving many animals. Numbers of observed mortalities are relatively minor compared to fish counts; there is a poor understanding of magnitude of the impact to populations. Improving dewatering procedures continue to adapt to reduce individual mortality. Picketed lead changed at BON Cascades Island Ladder, (prevent lamprey from getting to area where mortality occurs, have reduced impact, but not eliminated). Aside from dewatering events, causes of observed mortalities in fishways are unknown. Mesa et al. (2003) estimated the critical swimming speed (Ucrit) and documented the physiological responses of radio-tagged and untagged adult lampreys exercised to exhaustion. Results suggested that lamprey may have difficulty negotiating conventional fishways at lower Columbia River and lower Snake River dams, where water velocities in some areas approach 2 m/s – velocities well above the mean		S1, S2, O1, O2: Dam breach.			

Affected Environment Important Relationships / Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		Ucrit of test fish. These are less likely to have been collected than LPS morts. There is poor understanding of the magnitude of the impact to the run. Staff only know what shows up on picket leads or observed mortality such as impingements. Measure S6 is applicable. Idea is beneficial to use an LPS instead of fishway. Expect decreasing trend in lamprey mortality as measures are implemented.					
Flow and spill interacting with project structures and temperatures can slow migration rate/passage success. High flows and lower water temperatures have been roughly correlated to poorer passage success and slower migration speed.	BON outflows/ temperatures	Much is unknown about the migration cues used by adult lamprey and how these and migration timing interact. Keefer et al. (2012) speculated that higher flows associated with higher tailwater elevations at BON may compromise attraction to fishway entrances, collection channels and transition pools of ladders. Can affect distribution of lamprey throughout the basin, but lamprey appear to have a relatively flexible migration strategy, overwintering up to two years before spawning. Impacts of different mainstem flow and temperature conditions on spawning success unclear. Within fishways, collection efficiency of LPS can be affected by discharge of LPS relative to the bulk flow within the fishway and location of the LPS. **NOTES:** Based on radio-telemetry and PIT tag studies, larger lamprey are more likely to pass through the hydrosystem to upstream dams. Associations are across years and interact with other factors; it is unclear why larger fish migrate farther upriver. Lowered fishway entrance velocities or flows at night improved entrance efficiency at	Attraction maintained under fish passage criteria. Likely not much change for adults migrating up. Can shift where lamprey pass, but overall passage efficiency likely not affected. Lamprey find alternative routes depending of spill and flow. **DATA:** MCN, JDA, TDA, BON outflows: Dec: 2%-3% higher Jun, Jul, Sep: 1% lower Apr-May: 2% lower Aug: 5-6% lower **NOTES:** Unknown whether spill could also affect passage efficiency; may affect what route they pass. Last year (2018), had a quick drop in spill and lamprey immediately starting passing. Not a straight relationship of more flow = less efficient passage. Tailor operations to optimize attraction. WA shore flume structure doesn't work well, but better under high flow, high tailwater.	The effects are similar to the NAA. In passage season, the 1% is within confidence intervals. **DATA:** MCN, JDA, TDA, BON outflows: Mar: 4% lower Apr: 2% lower May: 1% lower Jun: 1% lower Jul: Very similar to NAA Aug: 1% lower **NOTES:** Outflows are higher in Nov to Jan, but unknown whether this is important.	Snake River - there would be no spill issues; breach passage would be better for lamprey than ladders. Columbia River - Effects would be similar to MO2, similar to NAA but slightly lower; likely not a discernable difference in migration. **DATA:** MCN, JDA, TDA, BON outflows: Mar:2% lower Apr:2% lower May:3% lower Jun: 1% lower Jul: 2% lower Aug:3% lower	In wet and average years, a slight increase in flows similar to MO1 would likely not affect migration success. In dry years, the flows would be considerably higher than in the NAA in May, but in low flow years this would not likely affect migration. Higher temps in June/July could cause migration delays. **DATA:** Low water years: Mar, Apr: 2%-3% lower May, Jun, Jul: 2%-4% higher Normal and above years: Apr:3% lower May:2% lower Jun: 1% lower Jul: Same as NAA May to Mid-June in dry years would be about 20 kcfs higher than in the NAA.	Keefer, 2013 Johnson et al., 2011

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		BON Washington Shore Ladder (Johnson et al., 2011). Preliminary results from a 2018 study suggest a similar result at BON Bradford Island Ladder and possibly at TDA East Ladder. Lamprey passage distribution correlates with bulk flow at BON; switch from PH1 to PH2 powerhouse priority affected distribution of lamprey passage route use at BON, with more lamprey using Washington Shore Ladder in recent years. This has likely had an overall net negative effect on dam passage efficiency for lamprey, as Bradford Island Ladder consistently performs better than Washington Shore Ladder. LPSs are most effective at dead ends and narrow channels. Speculation - U of I 2014, LPS flume system at BON WA shore north downstream entrance attraction swamped by high tailwater.					
Some evidence shows adult lamprey passage efficiency may decrease with higher spill, and lower spill may increase ability of lamprey to enter fishways (Keefer et al., 2013, R. Walker, personal communication).	Spill at Columbia and Snake River dams.	NAA spill would continue to influence passage similar to recent years. The relationship is not clear but there is some evidence that continued spill increases made in may have contributed to a drop in passage efficiency that would continue, but adaptations would also continue to improve conditions for passage. **NOTES:** It is a challenge to pin down spill affecting passage with overall discharge and passage. Radio-telemetry and PIT studies were used to evaluate specific fishway modifications and to assess overall dam passage at BON and upstream dams. Keefer et al. (2013) reported a median fishway passage efficiency (unique lampreys that passed /	Difficult to visualize a relationship between spill and passage; increased spill periods may make it more challenging for lamprey to find fishway entrances. Similar to NAA. Block spill test design may allow opportunity to study lamprey passage. **DATA:** Block spill test, alternate base spill/test spill. See WQ spill presentation.	There is lower spill than in the NAA; this potentially changes routes of passage in lower river and may make it easier for adult lamprey to find entrances to fishways and LPSs. In Snake River, the relationship isn't studied; if spill affects passage, MO2 could increase passage. **DATA:** Spill to max 110%TDG; Less fish spill, more lack of market spill. Little Goose and Lower Granite not much change (LOM). Much lower spill at most projects in spring/ summer/August. See Spill presentation for specific results. BON: 30% to 40% less spill; 50kcfs	Columbia River: Higher spill in spring/summer could cause delays. With no August spill, the tail end of migrating adults would potentially see enhanced passage compared to NAA. Snake River: Effects eliminated. **DATA:** No SR Dams so no spill; LC Spill to 120% TDG End summer spill July 31. See spill presentation for specific results. **NOTES:** Slightly higher potential for delays if there is a relationship.	Higher spill may make it more challenging for lamprey to find entrances to fishways and could reduce dam passage efficiency. Adult passage improvements would likely incorporate increased spill into planning to optimize adult passage as possible. **DATA:** Spill to 125% TDG BON: 220-252 kcfs	Keefer et al., 2013

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		unique lampreys that approached an entrance) from 1997 to 2010 of 0.52 at BON. Keefer et al. (2013) contrasted lamprey passage efficiency with that of adult salmonids, which averages 0.95 at BON. Dam passage efficiency at BON generally increased from the beginning of the Accords period to 2014 (Figure 29). However, passage efficiencies observed in recent years were similar from 1999 to 2002. In 2002, new spillway deflectors were installed and spill patterns changed as a result. Additionally, in 2006 spring day and night spill operations were increased to 100 Kcfs. Some of these changes may have contributed to the observed drop in passage efficiency seen between 2002 and 2007. Changes in how lamprey were tagged and handled also occurred during this time, which may have influenced lamprey passage efficiency results. It should be noted that implanting radio-transmitters in lamprey can have a tag effect that increases with tag mass in relation to fish mass (i.e., tag burden) (Keefer et al., 2012) and girth size (Lampman, 2011). The ongoing 2018 to 2019 adult lamprey passage evaluation will likely shed additional light on lamprey passage benefits resulting from lamprey passage features implemented at BON and elsewhere. There is evidence that lower spill is correlated with better entrance into fishways, but staff don't know if this affects overall dam passage; it may just change routes of passage.					

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Temperatures greater than 72°F (22.2°C) cause stress to adult lamprey and can reduce migration success.	Temperatures (throughout the basin) from the date the water reaches 72° at each project.	Temps over 72°F (22°C) cause stress and reduce migration success. Between Chief Joseph and McNary dams, the temperatures would not likely be over 22°C, but below McNary there would continue to be periods of temperatures over 22°C from a week to almost a month in most year types and up to almost two months in extreme low flow/high air temperature year types. **DATA:** Note: no days over 22°C in any alt. CHJ: 3d over 20°C in 2015 Ext Yr set MCN Days>22° C: AF/AT= 22, LF/HT= 56 BON Days>22°C: AF/LT=5, LF/AT=14, AF/AT = 22, LF/HT = 26 **NOTES:** During migration stage the initial migration goes up until temps are too high; fish may migrate faster to get out. Warm makes them active until too warm, then they lose energy and hunker down, overwinter, then continue next spring. Warm= faster is true in free flowing rivers, but interaction with dams means the stress of warm water could affect their passage efficiency.	Four fewer days exceed 22°C at McNary, but one day more at BON, minor improvement in days in high temp, low flow years in the area below McNary. May slightly improve migration in Columbia River, but likely similar to NAA. Snake River slightly cooler than NAA in July and after mid-Sept, but considerably higher than NAA in the month of August and first week or so of September (see WQ graph in presentation.) Late migrants in Snake River would likely be delayed or be temperature-stressed more than under NAA. **DATA:** No days over 22°C in any alt. CHJ: 2d over 20° in 2015 Ext Yr set MCN Days>22° C: AF/AT=23 , LF/HT= 52 BON Days>22°C: AF/LT=5, LF/AT=12, AF/AT = 22, LF/HT = 27 **NOTES:** Increased furunculosis at higher temps, likely within the confidence intervals though. Lamprey move into Snake about mid-July.	Effects would have no substantial difference from the NAA in the Columbia River. Snake River - temperatures in July and early August would be considerably warmer than in the NAA; effects would be increased thermal stress and migration delays in July. **DATA:** Little to no change in Lower Columbia River Note: no days over 22 in any alt. CHJ: 5d over 20° in LF/HT MCN Days>22° C: AF/AT= 22, LF/HT=58 BON Days>22°C: AF/LT=5, LF/AT= 15, AF/AT = 22, LF/HT = 27 **NOTES:** 1 or 2 days difference from NAA, likely not substantial difference.	Snake River: More days in July over 22°C could slow migration and cause thermal stress. Diel fluctuations would result in warmer days and cooler nights, which could be beneficial to lamprey migration; they move at night and seek refuge during day. Likely better for migration even though overall day temps are higher. Exposure may be reduced with faster migration times from dam breaches. June temps are highest. Peak migrations occur in July when starts to get cooler quicker. 10 fewer days over 22° in LF/HT years at MCN, 2 days more than NAA out of BON. **DATA:** Note: no days over 22 in any alt. CHJ: 3d over 20° in 2015 Ext Yr set MCN Days>22° C: AF/AT= 22, LF/HT= 46 BON Days>22°C: AF/LT=4, LF/AT=13, AF/AT = 23, LF/HT = 28 **NOTES:** Criteria to quit tagging is 74.	In low flow years, McNary Flow Target measure is triggered and results in more days over 22°C from McNary to Bonneville, and temps through the section from Chief Joseph to McNary had more days over 20° than NAA, although no days over 22° in any alts. At Bonneville in LF/HT years, there would be 8 more days over 22°C. These slightly warmer flows in extreme low flow/hot summer events may increase adult mortality and reduce migration success. Snake River effects would be the same as in the NAA. **DATA:** Minor summer increases in temperature in July in low flow years in Mid-C through MCN, but would be cooler in August. No difference in Snake River. Negligible difference in Lower Columbia No days over 22°C in any alternative. CHJ: 13d over 20° in 2015 Ext Yr set MCN Days>22° C: AF/AT= 22, LF/HT= 57 BON Days>22°C: AF/LT=5, LF/AT= 14, AF/AT = 22, LF/HT = 34 **NOTES:** At BON in low flow year 2015, from Jun 27-Aug 19, 36 days were over 22 C, compared to 26 days in the NAA. However, the average change in that period was an increase of 0.32°C, which is within modeling error. At CHJ, the average change from June 1 to July 30 was 1.0°C in low flow, high temp year (2015). For MO1, 2, and 3, the average increase over the NAA was 0.3°.	Keefer et al., 2013

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Predation on lamprey occurs at structures including pinnipeds at BON, sturgeon at BON, TDA, JDA and other dams. An otter was observed at BON in 2018. Dam structures and operations increase the presence or effectiveness of predators, resulting in increased predation on adult lamprey.	Observed sea lion predation on lamprey, sea lion abundance and seasonal distribution.	LPSs are covered in part to reduce predation by birds (herons, etc). Stellars are at BON almost year-round (has changed), timing more conducive to observed lamprey predation. Entrance efficiency delays into structures (fishways, LPS, etc. exposes lamprey to more predation. Nighttime velocities are reduced to enhance passage entrance and reduce predation exposure. Direct mortality due to river otter predation and indirect impacts on lamprey passage success at Corps dams is not well-documented. In September 2018, a river otter was observed on nighttime video recorded in the BON Washington Shore Ladder count slot. The presence of the otter coincided with a large downstream movement of lamprey (-336 on the night of 9/18/18) followed by an increase in the BON Washington Shore AWS Channel LPS use on 9/19/18. Bonneville project staff were unable to successfully trap and remove the animal and it is still periodically observed in the area. It is unknown whether similar incidents occur unnoticed at this and other locations. **DATA:** Pinniped trend and counts; Sturgeon indices. The Corps, Portland District. Fisheries Field Unit (FFU) has been monitoring pinniped predation in the BON tailrace in the spring (approximately March 1 to June 1) since 2002. In more recent years, presence of Stellar sea lions in late summer through the winter months has prompted additional monitoring from mid-August through the end of December. Sea lion abundance and	Dam passage efficiency improvements would help reduce predation risk. Lower river – little change in hydro other than spill. Spill likely doesn't affect pinniped predation (they adapt and find prey no matter what spill).	Same as MO1 **NOTES:** Lower river - little change in hydro operations other than spill. See coho/ chum matrices for discussion - spill likely doesn't affect pinniped predation (they adapt and find prey no matter what spill).	Effects would be the same as MO1 **DATA:** Same as MO1 in lower Columbia. Snake River - no reservoirs; expect reduced piscine predators. **NOTES:** Lower river - little change in hydro other than spill. See coho/chum matrices for discussion - spill likely doesn't affect pinniped predation (they adapt and find prey no matter what spill).	Same as MO1 **NOTES:** In the lower river, there would be little change in hydrology other than spill. (See coho/chum matrices for discussion.) Spill likely doesn't affect pinniped predation (they adapt and find prey no matter what spill).	BON pinniped predation reports may be found at: http://pweb.crohms.org/tmt/documents/FPOM/2010/Task%20Groups/Task%20Group%20Pinnipeds/ Kirk et al., 2014 FPOM coordination MFRs for each operating project may be found at: http://pweb.crohms.org/tmt/documents/FPOM/2010/ WA and OR sea lion reports Wolf and Jones, 1989 Bell, 1967. Merrell, 1959. Collis et al., 2015 Wagner et al., 2011.

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		predation activity peaks in May, coinciding with the early part of the adult Pacific lamprey run (which peaks in July at BON). Expanded estimates of Pacific lamprey consumption by pinnipeds at BON (during monitored months, which vary from year to year) from 2002 to 2018 ranged from 33 (2011, 0.4% of observed fish catch) to 816 (2004, 25.1% of observed catch). In 2018, estimated lamprey consumption was 58 (0.04% of total observed catch). These predation estimates are based on surface observations. Given the relatively small body size of Pacific lamprey, it is likely that additional predation occurs below the surface. The Corps considers these as minimum estimates. In 2017 and 2018, observers noted that lamprey predation events peaked during crepuscular hours. It is important to note that in some years, pulses of predation occurred in February or March, long before adult lamprey are seen passing BON count stations. It is possible that many of these lamprey are overwintered adults. WA and OR do stomach analyses of sea lions lethally removed. See their annual reports. Concentrations of sturgeon noted during fishway dewaterings, but stomach contents samples do not have lamprey evidence. Direct v indirect predation, sturgeon in fish ladders, lots of turnaround in fishways (sturgeon related?) alarm cues, pheromones, etc. Avian predation - great blue herons. Lamprey are known to respond to odorants (alarm cues, predators, pheromones, etc.); however, further research is needed to understand which					

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		odors and in what concentrations. Lamprey were found to be present in the diet of Caspian terns in southeastern Oregon and northeastern California (Collis et al., 2015).					
Juveniles							
Juveniles can be harmed by impingement in screens, mostly extended length submersible bar screens (ESBS) at MCN, LGO, and LGR.	Number impinged.	Relative route use is poorly understood, so overall impacts are not known. Fyke net evaluations of run-of-river fish at JDA, MCN, BON and other dams, the majority (>70%) of juvenile lamprey appeared to move downstream low in the water column, below the turbine intake bypass screens installed for salmonids (BioAnalysts Inc. 2000; Moursund et al., 2003; Monk et al., 2004). Bar screens cause impingement and entanglement as lamprey juveniles get tails caught in them. Direct mortality of juveniles is observed; number of fish entangled is counted. This effect description is based on observations (Moursund et al. 2002, 2003). Bar screen installations have been delayed until mid-April at McNary since 2009 to reduce effect (timing of lamprey migration). At other locations, lamprey and salmon timing conflict so bar screen installation is not delayed. Note that some dams and powerhouses have no turbine intake bypass screens (BON B1 and TDA) and that other dams have what appear to be relatively benign STSs. **DATA:** Results of fyke net studies provide an estimate of relative use of turbines vs. juvenile bypass systems. Direct observations of entanglement, impingement and mortalities on turbine intake bypass screens.	S8: Lamprey get impinged and potentially stuck in the 1/8-in ESBSs (extended submersible bar screens). Would convert 1/8-in ESBS to 2/29-in bar screen or 1/11-in woven screen to reduce impingement (Moursund et al., 2003b). STS screens or 3/32-in ESBSs greatly reduces impingement (Moursund et al., 2001). Laboratory studies: 3/32'' ESBS 0% "stuck"; 1/8'' STS ~13% stuck at 3ft/s sweeping velocities; 1/8'' ESBS ~13% stuck @ 2 ft/s, ~38% stuck @ 3ft/s, and ~70% stuck @ 4 ft/s (Moursund et al., 2001). "Stuck" defined by Moursund et al. (2001) as fish that could not free itself during a 10-min rest period when flows in test chamber were reduced to zero ft/s. Moursund et al. (2003a) verified that that 2/29-in bar screen (ESBS) at John Day did minimize lamprey impingement.	The effects would be the same as for MO1.	Snake River projects - effects would be eliminated as dams are breached. Columbia River same effects as in MO1. **DATA:** S1, S2, O1, O2: Dam breach measures S4: Fewer Fish Screens (no installation of fish screens at McNary)	Same as MO1	Bioanalysts, Inc., 2000 Monk et al., 2004 Moursund et al., 2003 Moursund et al., 2001 Mesa et al., 2015 FPOM summarized in notes. (Peery or Eric Hockersmith)

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		NOTES: Raceways for transport facilities; criteria applied from literature, increased opening mesh size so lamprey could pass out (avoid transport). Majority probably passing below the screens. Replacement of ESBSs with STSs and/or delayed installation in spring were contemplated in the 2008 Fish Accords MOA. While the operational change was made at MCN, the high estimated costs relative funding and technical feasibility issues precluded replacement. The magnitude of impact not well-understood, as relative passage distribution and magnitude across all passage routes is not known. Acoustic telemetry studies using the newly developed juvenile lamprey acoustic tag would provide the opportunity to understand relative route use, collection efficiency of bypass systems, and survival by passage route.					
Turbine cooling water strainers entrain juvenile lamprey.	Number from count and inspections.	Cooling water strainers entrain lamprey in the turbine scroll case (upstream of turbines) results in mortality. Mortality counts from routine cooling water strainer inspections at NWW dams. Mortalities are collected by CRITFC for genetic sampling. **NOTES:** NWW has developed a design for exclusion of juvenile lamprey and other fish from cooling water strainer intakes. The design will be tested at Ice Harbor as turbines are replaced. Design approved by FFDRWG and reviewed by the Corps' Hydroelectric Design Center (HDC) uses a vent-like cover that uses sweeping flow to prevent fish from entering the cooling	S7: Would reduce (but not likely eliminate) mortality from cooling water strainers. Expect screens to greatly reduce mortality to near zero assuming all cooling water intakes are screened. However, this assumption would need to be tested. **DATA:** See FPOM website for mortality counts from strainers and index counts from what CRITFC received for genotyping. **NOTES:** Have a design for in turbine strainers, but difficult to move forward due to magnitude of work required in turbines to install.	The effects would be the same as for MO1. **DATA:** S7: Turbine strainer lamprey exclusion	Same effects as in MO1. **DATA:** S1, S2, O1, O2: Dam breach measures S8: Turbine Strainer Lamprey Exclusion	The effects would be the same as for the NAA. **DATA:** There is no measure for cooling water strainers.	

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		water intakes. 2018 Fish Accords extension MOA included commitment to seek funding to develop and implement a juvenile passage RME plan. The MOA included a commitment to develop a plan lamprey design guidelines into O&M activities. The analysis of larval mortalities from LGR Dam have provided the means to estimate effective numbers of spawners, relative reproductive success of various translocation release groups, age at outmigration, and time of migration for Pacific lamprey from the Snake River Basin. Further, the team can use sibship analysis to identify full siblings of the LGR Dam juveniles among adult collections from particular sites around the Columbia river basin and thereby identify adults with Snake River natal origins and estimate the approximate number of years these adults spent in the ocean before returning to freshwater.					
Juvenile lamprey pass via spillways causing injury, mortality, or indirect effects. Note: all passage routes can cause injury, but it is not known which route has more/less effect than others.	–	Relative route use is poorly understood, so overall impacts are not known. Cumulative effects of repeated dam passage are unknown. Results of fyke net studies provide an estimate of relative use of turbines vs. juvenile bypass systems and suggest that juvenile lamprey migrate low in the water column (perhaps reducing likelihood of spillway passage) but do not directly inform estimates of passage via spillways. Direct observation of tailrace predation by gulls is reported (Zorich et al., 2010, 2011, 2012). **NOTES:** Mesa et al. (2015) summarized RME associated with lamprey passage and is a good resource	S1 and S2 (additional powerhouse surface passage at Ice Harbor and McNary and ASWeirs) would change dynamics of lamprey passage (as well as salmon). More (higher percentage) lamprey would be expected to pass via surface routes vs the turbine in relation to the NAA. Don't know overall effects of this dynamic. **NOTES:** The distribution of juvenile lamprey is low through spillway; some pass but it's an unknown percentage. Juvenile passage - also not known if spillway is detrimental. Lamprey typically migrating in lower part of water column; spillway use - Studies at JDA and	The effects would be similar to those in MO1; the structural measures may change the dynamics of lamprey passage. A higher percentage of juvenile lamprey may pass surface routes rather than turbines with these structures, but decreased spill may lower the proportion that pass over the spillway. The overall dynamic effect to juvenile survival is not well understood. **DATA:** S2: Additional Powerhouse Surface Passage and S4: Upgrade to Adjustable Spillway Weirs Spill to 110%	Snake River projects - effects would be eliminated as dams are breached. Columbia River - increased spill may increase proportion over spillways, overall dynamic impact on survival not well understood. **DATA:** S1, S2, O1, O2: Dam breach measures Spill to 120 on Lower Columbia dams	A higher percentage of juvenile lamprey may pass surface routes rather than turbines with these structures, and increased spill may further increase the proportion over spillways rather than turbines. The overall effect on survival is not known. **DATA:** S1: Additional Powerhouse Surface Passage S8: Spillway Weir Notch Inserts? Spill to 125% TDG	Mesa et al., 2015 Zorich et al., 2010 Zorich et al., 2011 Zorich et al., 2012

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		for summarizing what is/is not known about potential effects of the existing structures and operations. The magnitude of impact not well-understood, as relatively passage distribution and magnitude is not known. Acoustic telemetry studies using the newly developed juvenile lamprey acoustic tag would provide the opportunity to understand relative route use, collection efficiency of bypass systems, and survival by passage route.	MCN netted screens and did capture juvenile lamprey. If they encounter screens, they are either guided up to spillways or guided into juvenile bypass facility. Some are near the surface, some are lower in water column, but don't know what the proportions are. (Moursund, 2003)				
Juvenile lamprey pass via turbines causing injury, mortality, or indirect effects.	–	Relative route use is poorly understood, so overall impacts are not known. Fyke net evaluations of run-of-river fish at JDA, MCN, BON and other dams show the majority (>70%) of juvenile lamprey appeared to move downstream low in the water column below the turbine intake bypass screens installed for salmonids (BioAnalysts Inc. 2000; Moursund et al. 2003; Monk et al. 2004). Laboratory experiments by Colotelo et al. (2012) suggest that turbine passage may be relatively benign for juvenile lamprey as compared to salmonids. Cumulative effects of repeated dam passage are unknown. Results of fyke net studies provide an estimate of relative use of turbines (~70%) vs. juvenile bypass systems (~30%). Direct observations of predation on juvenile lamprey in powerhouse tailraces suggest passage via this route is substantial. **NOTES:** Mesa et al. (2015) summarized RME associated with lamprey passage and is a good resource for summarizing what is/is not	S10: Improved Fish Passage Turbines See above. Proportion of lamprey passing through turbines, and those that did may experience similar or slightly better survival with improved turbines, though turbine passage is somewhat benign for lamprey. Overall net effect to juvenile survival not known. **NOTES:** Spill is generalized just according to the measures in each alternative; should go to actual spill data for more in-depth analysis of actual spill at each project; but the relationship is not well understood so general is about as good as it gets.	See above for context. IFP turbines may be a slight improvement or no change to lamprey survival. **DATA:** S1: Improved Fish Passage Turbines Spill to 110% **NOTES:** Spill is generalized according to the measures in each alternative; should go to actual spill data for more in-depth analysis of actual spill at each project; but the relationship is not well understood so general is about as good as it gets.	Snake River - no more turbines after dams are breached. Columbia River - turbine passage potentially reduced with higher spill, survival either similar or slightly improved with IFPs. **DATA:** S11: Improved Fish Passage Turbines at JDA Spill to 120 on Lower Columbia **NOTES:** Spill is generalized according to the measures in each alternative; should go to actual spill data for more in-depth analysis of actual spill at each project; but the relationship is not well understood so general is about as good as it gets.	Turbine passage would potentially be reduced with higher spill; survival would be either similar or slightly improved with IFPs. **DATA:** S4: Improved Fish Passage Turbines Spill to 125% **NOTES:** Spill is generalized according to the measures in each alternative; will use actual spill data for more in-depth analysis of actual spill at each project; but the relationship is not well understood so general is about as good as it gets.	–

Affected Environment Important Relationships / Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		known about potential effects of the existing structures and operations. The magnitude of impact not well-understood, as relatively passage distribution and magnitude is not known. Acoustic telemetry studies using the newly developed juvenile lamprey acoustic tag would provide the opportunity to understand relative route use, collection efficiency of bypass systems, and survival by passage route.					
High flow freshet events typically trigger outmigration events.	Summary hydrographs, freshet events in winter.	See MCN and TDA Flow Comparison. **NOTES:** Outmigration typically in high flow events, which are triggered with freshets. Mesa et al. (2015) summarized what was known about passage timing and outmigration based on Smolt Monitoring Program and other inputs. Juvenile bypass and monitoring facilities are not operated during winter months due to winter maintenance requirements and design limitations relative to cold temperatures (ice issues). This precludes direct monitoring of lamprey passing dams during winter months.	MCN and TDA Flow Forecast Comparisons Looked at summary hydrograph, discharge through the winter/ spring outmigration period appears to be similar durations and magnitudes; the timing of freshets may be slightly different. At the tail end…May/June, there is less flow in very low water years; could reduce lamprey outmigration at the tail of the migration in very low water years. MO1 shows an increased outflows in January; could increase outmigration speed of juveniles, particularly from the Umatilla and Yakima where winter rain events trigger outmigrations into the mainstem Columbia. **NOTES:** FPC report has outmigration timing of lamprey. Check HH data to quantify change in flow.	There is little habitat for juvenile rearing in Clearwater below Dworshak; lamprey are likely not affected by increased flows in December. December flows are within the range that occurs during fall rain events: will be more sustained and less flashy. **DATA:** MCN and TDA Flow Forecast Comparisons Flows show higher freshets in Dec-Jan flows, January moderately higher, lower than the NAA in March. DWR: Much higher flows in Jan-Feb in average years; wet years higher Jan but lower Feb/Mar; dry years same as the NAA in Dec-Apr, freshets in May. **NOTES:** Snake River effects are unknown.	Outmigration would occur in Snake in riverine environment, no reservoirs would improve swimming and reduce predation, natural freshet events would move larvae out more naturally to the Columbia River. MCN would have slightly less flow in low years could be slight decrease in outmigration. Grand Coulee would have reduced flows in spring, especially May and June (use HH data to quantify difference). Expect reduced outmigration through CHJ to MCN. **DATA:** MCN flows would be slightly higher flows in Dec, peaks look similar to NAA in all water years, slightly lower in Jan, similar to NAA in Feb, slightly lower in March. DWK same as NAA.	An increased hydrograph in May/June in low water years could increase outmigration triggers and speed. This could be beneficial to lamprey from upper river areas such as Upper Columbia and Upper Snake. In median water years and above, the flows are similar to the NAA. **DATA:** Data show higher freshets in Dec, more variability in the hydrograph, Jan-Feb flows would be higher in dry years with more peaks, and there is similar in median and slightly lower in wet years. In March, there is a peak in a freshet but maybe a modeling artifact; May-June in dry years sustains flows higher than in the NAA to meet 220kcfs flow target. DWK: Same as NAA. **NOTES:** JDA has lamprey counts encountered in annual reports. Use March-October. Umatilla outmigration is dependent more on rain events.	–
Hydrosystem operations affect larval lamprey rearing in shallow waters due to elevation fluctuations dewatering larvae. Fluctuation rates less than 10 cm/hour are “natural,” faster	Elevation changes at reservoirs.	Distribution of rearing habitat, and direct mortality, increased exposure to predation. MCN : 338.7 all year	BON pool elevations: Median - MO1 same as NAA - straight across 76 ft. elevation. Extreme years (1% and 99%) show some slight variation	Daily fluctuations could affect lamprey if drop ramping rates within day; stranding is not expected. **DATA:**	JDA drops in early June, which could strand juveniles. No Snake River reservoirs. O5a: Ramping Rates for Safety (eliminate ramping rate	Drawdowns in late March, could dewater larval lamprey rearing in sediment. Ramping rates outside of ramping rate could dewater them. Fine sediment at tributary junctions, most have lamprey,	USGS, FWS, PNNL

Affected Environment Important Relationships / Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
rates than that can strand lamprey.		JDA: See hydrograph; 1' slow drop in Dec, 0.25' drop in Mar/early Apr TDA: 158.1' all year BON: 76' all year **NOTES:** The Corps funded a series of preliminary studies to evaluate potential effects of hydrosystem operations: Jolley et al. (2014, 2016) conducted surveys in mainstem areas of Columbia and lower Snake Rivers to determine presence/absence of rearing ammocoete in shallow water areas potentially vulnerable to dewatering. Lamprey ammocoetes were found at various depths in the mainstem Columbia and Snake rivers and were commonly found near tributary deltas, in areas vulnerable to changes (seasonal or otherwise) in surface elevation. Mueller et al. (2015) used existing bathymetry and operations information to model relative risk of dewatering. Liedtke et al. (2015) conducted laboratory experiments with ammocoetes, simulating dewatering events and monitoring lamprey response.	MCN: 338.7 all year. (Same as NAA) JDA: About 1' Higher than NAA Apr-Jun (see summary hydrograph), drop 1' in June TDA: Same as NAA BON: Same as NAA **NOTES:** Drops in pool elevation at JDA in June could strand and dewater juvenile lamprey. **NOTES:** Less fluctuation is better. The issue is dewatering rates, too quickly (faster than about 10cm per hour) results in stranding, and more often dewatering is more stressful for lamprey. Per H&H team - ramping rates do not change for MO1 or MO4. Daily changes, or even within a week, changes do not show up in modeling. The BON pool elevation hydrograph shows some changes in pool elevation to MO1.	O2a: Ramping Rates for Safety (eliminate ramping rate restrictions for all other purposes). MCN: 338.7 all year. (Same as NAA) JDA: Same as NAA TDA: Same as NAA BON: Same as NAA **NOTES:** See John Day Pool Elevations summary hydrograph for comparisons of elevations. View all elevation hydrograph data to see if any other effects would be noted that may not have been considered.	restrictions for all other purposes). MCN: Same as NAA JDA: about 0.75' higher Apr-May, drops early June TDA: Same as NAA BON: Same as NAA	Could reduce amount of habitat available for larval lamprey (Jolley et al.), difficult to quantify but anticipate an effect, probably minor to moderate. **DATA:** MO4 is different in drops to 72' elevation April through mid-August (drawdown to MOP). H&H indicates no change in ramping rates. Straight line across in median and 25/75 % water years, extreme years show fluctuation similar to the NAA. April drawdown on 1% down to 70' elevation lasts longer (earlier and later) than NAA. BON: Drops 3.75 ft March 25 until mid-August MCN: Drops 1.2 feet March 25 (until mid-August) JDA: Drops 2' March 25, through August is 261.75' elev. TDA: Drops 2.35 ft March 25, through Aug 14 **NOTES:** Lifting forebay operating restrictions may increase flexibility to operate daily fluctuations. It is unclear whether this flexibility would lead to increased drawdown rates. Ramping rates and frequency are both important.	
Temperature affects outmigration: juveniles move out of the system faster in warmer temperatures.	Temperatures through the system.	Juveniles move out of the higher systems. #Days>State temp standards: LWG: 4.4d LGS: 37d LMN: 47.2d **NOTES:** Juveniles move out of the system faster in warmer temps. For both experiments there was little to no tag loss, and juvenile lampreys in freshwater showed high survival at all temperatures at 7 d (95–100%) and 14 d (88–	DWA ops difference in Snake: LGR: Cooler June-Aug 1, warmer early Aug to mid Sept., Cooler mid-Sept-Oct.; increase up to 4°F with rapid fluctuation to about 3°F cooler in about a week. LGR results in several days >20°C compared to none in NAA. (from presentation, get details from WQ files). Effect continues downstream and gets attenuated. Lower Columbia similar to NAA. #Days>State temp standards:	Negligible impacts are expected based on slightly warmer temperatures in LF/HT years. Deeper winter drafts that lower outflows in spring may delay outmigration and therefore may affect juvenile lamprey by increased predation risk and increase in disease prevalence caused by warmer temps. **DATA:** Snake River: Check for a possible modeling error; expected to be similar to NAA. Columbia River:	Temps in early spring would be warmer than in the NAA, which would tend to increase outmigration speed, but the change to river environment likely outweighs any influence of temperature on outmigration speed. **DATA:** Snake River - No reservoirs; faster heating and cooling of water. Warmer early Jun-early July, cooler mid-July to Sept. #Days>State temp standards:	The effects would be no impact to negligible impact based on minor increases in summer temperatures in Columbia River. Effects in the Snake River would be the same as in the NAA. **DATA:** Snake River - same as NAA There would be minor summer increases in summer temperatures in July in low flow years in Mid-C through MCN. Cooler in August. There would be no difference in Snake. There	Lampman et al. Mesa et al., 2012 Meeuwig et al., 2005

Affected Environment Important Relationships / Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		100%) posttagging. Prolonged holding (40 d) resulted in significantly lower survival (28% to 79%) at warmer temperatures (12?C to 18?C).	LWG: 22.6 days (18.2 more than NAA) LGS: 45.6 (8.6 more than NAA) LMN: 54.4 (7.2 more than NAA) For lower Columbia River, no impact based on similarity to NAA. In Snake River, cooler in July and warmer in Aug/Sept could influence outmigration timing.	temperatures would be slightly different below GCD, slightly warmer in LF/HT year like 2015. Deeper winter draft for hydropower would mean lower outflows in spring. **NOTES:** Snake River, updated modeling shows temperatures would be similar to the NAA.	LWG: 16.8 days (12.4 more than NAA) LGS: 44.6 (7.6 more than NAA) LMN: 51.8 (4.6 more than NAA) See WQ/Sediment joint presentations for details. Columbia River effects would be similar to those in the NAA.	would be negligible difference in Lower Columbia River.	
Temperatures affect juvenile growth; they grow slower in cooler water, and water temperature in Clearwater River can be influenced by Dworshak releases.	Temperatures in the Clearwater River.	Cold water released from DWA for temperature control may slow juvenile lamprey growth in that area.	O15: Modified Dworshak Summer Draft Cooler June 21-Aug1, much warmer Aug to mid-Sept. Potentially slower growth of larvae in Clearwater River in June and July, but warmer in Aug to mid-Sept, but temps still within the temperature tolerance for lamprey larvae.	After the model re-run, Temperatures are similar to the NAA.	Effects would be the same as in the NAA. **DATA:** Similar to the NAA	The effects would be the same as in the NAA. **DATA:** Similar to NAA	–
Contaminants (mainstem). Juvenile lamprey are sensitive to contaminant.	Sediment mobilization	All life stages of Pacific lamprey can be affected by contaminants (CRITFC, 2011). Contaminants, such as methylmercury, are bioaccumaleted in larval lamprey and can have ecosystem effects on predators that prey on them (Bettaso and Goodman, 2008). Nilsen et al (2007) found 13 known endocrine disrupting compounds in the lower Columbia basin. Geeraerts and Belpaire (2010) found, in European eels, contaminants can disturb the immune system, reproductive system, nervous system and endocrine system at the subcellular, organ, individual, and population levels. However, direct effects have not been studied in lampreys. Studies looking at salmonids have shown direct effects of contaminants, such as increases in susceptibility to disease (Arkoosh et al. 2010) and negative effects on growth and reproduction (Depew et al. 2012). Lamprey overlap or have similar habitats and lipid content	**NOTES:** Look at Outflow comparison to see if any expected differences to sediment mobilization. Potential change in mercury methylation events?	NOTE: Look at outflow comparison to see if there are any expected differences to sediment mobilization. Unknown whether there is a potential change in mercury methylation events.	Long-term effects would be similar to the NAA. **DATA:** See WQ/Sediment joint presentations for details. Analyze long-term effects in this row. Short-term impacts of actual breach are in separate a row below.	NOTE: Look at Outflow comparison to see if any expected differences to sediment mobilization. Look for potential change in mercury methylation events.	Elena Nilsen et al., 2007 and 2015

Affected Environment Important Relationships / Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		as salmonids and therefore effects of contaminants on salmonids may provide information on contaminant effects on lampreys (Nilsen et al. 2015).					
Juvenile predation: Juvenile lamprey can become disoriented at powerhouses and become more susceptible to predation by gulls.		Relative route use is poorly understood, so overall impacts are not known. Fyke net evaluations of run-of-river fish at JDA, MCN, BON and other dams, the majority (>70%) of juvenile lamprey appeared to move downstream low in the water column, below the turbine intake bypass screens installed for salmonids (BioAnalysts Inc., 2000; Moursund et al. ,2003; Monk et al.,2004). Predation in powerhouse tailraces observed by Zorich et al. (2010, 2011, 2012) and anecdotal observations by pikeminnow anglers (Mesa et al., 2015) suggests that many lamprey likely pass via turbines and that they are at least temporarily vulnerable to predation immediately following turbine passage. Avian predation deterrence in the form of Corps-funded hazing and presence of avian wire arrays and other passive features will continue. **NOTES:** Mesa et al. (2015) summarized RME associated with lamprey passage and is a good resource for summarizing what is/is not known about potential effects of the existing structures and operations. Observations of gulls switching from salmon at spillways to lamprey at powerhouses at JDA and TDA. Studies document walleye/small mouth bass predation on lamprey, and avian predation.	MCN and TDA: Flows are very similar to NAA except slight decreases under MO1. Are these slight decreases in flow biologically relevant? Understanding the effects of these flow relationships, routes of passage and route survival are not well understood. Therefore, impacts are unknown but likely negligible. **DATA:** See flow and spill relationships.	Same response as MO1. **DATA:** See flow and spill relationships. **NOTES:** Powerhouse encounters for lamprey are uncertain.	Effects would be beneficial to juvenile lamprey in the Snake River. Lower Columbia River effects would be similar to those in the NAA. **DATA:** Dam breach - fewer powerhouse encounters.	MCN has large spikes in flow at the end of March and a large drop in flows mid-August. TDA has similar spikes that are smaller in magnitude. It is difficult to determine how these impact juveniles for the same reasons explained in NAA. However, increased flows will likely result in fast outmigration resulting in a benefit and less flow in slower migration increasing predation risk. There are likely overall minor impacts under low flow conditions in mid-August and a benefit in high flows at the end of March. Lamprey juveniles are present during both the low spike and high spike. **DATA:** See flow and spill relationships.	Summarized in Mesa, 2015 Zorich et al.

Affected Environment Important Relationships / Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Dredging as part of ongoing project O&M can harm juvenile lamprey.	Juveniles detected in dredging area	The Corps periodically dredges at BON forebay locations, including immediately upstream of Bradford Island Fish Ladder exit and upstream of Washington shore fish turbine units. Dredging is necessary to remove debris and ensure that fish passage facilities are operating as designed. O&M dredging at BON is expected to continue as needed. **NOTES:** USFWS biologists used deepwater electrofishing/suction dredge equipment to sample for lamprey ammocoetes in proximity of the BON Bradford Island Fish Ladder exit in January 2016 in advance of dredging activity in this area. According to a memo documenting findings, six of 17 10x10 m quadrats contained lamprey ammocoetes, representing a detection rate of 0.35 (the highest detection rate observed by the USFWS team). An abundance estimate for the area was approximately 3,500 individuals. Impacts on lamprey present are unknown but larval lamprey are present and abundant in the area.	Similar to NAA based on reduced flows under MO1 reducing sediment transport resulting in the same or less dredging.	Increase in flows likely result in increases in dredging and therefore minor impacts to larval lamprey.	Potentially more dredging upstream of MCN.	Higher flows in some water years and months could result in increased dredging frequency and therefore minor impacts to larval lamprey. (Minor because the dredged areas in the BON forebay did have larval lamprey, but the overall population effect is likely minor).	Jeff Jolley, USFWS memorandum "Bonneville Forebay Larval Lamprey Sampling 2016" (dated 1/27/16).
Federal navigation channel maintenance dredging in the lower Snake River and below BON.		Navigation channel maintenance will continue to occur periodically. Although juvenile lamprey may be present in areas targeted for dredging, densities are thought to be site-specific and most likely seasonal. Direct effects of the dredging action on juvenile lamprey are not well understood. **NOTES:** Pre- and post-dredge monitoring may be important to understand effects.	Same as NAA. **DATA:** No change to dredging **NOTES:** Sediment team concluded no increase in dredging anticipated under any of the alternatives.	The same effects would be expected as for the NAA. **DATA:** No change to dredging. NOTE: See MO3 note.	The effects would be the same as for the NAA. **DATA:** No change to dredging. **NOTES:** Sediment team concluded no increase in dredging anticipated under any of the alternatives.	The effects would be the same as for the NAA. **DATA:** No change to dredging. **NOTES:** See MO3 Note.	–

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3.7.3.1 MO3: Dam Breach Measure

Dam breach could result in perched tributaries: Tucannon and Palouse could have short-term passage issues. Could implement a translocation program moving lamprey into tributaries.

Dissolved Oxygen - lamprey overwintering in headwaters area of LMN could see effects going into winter mode. Peak 1 in mid-Sept would likely impact adults, in Oct may survive due to low oxygen demand as going to overwinter mode. This would impact the end of the run in Sept. of active migrants. Shifting later could lower lamprey effects, but construction timing is likely tailored to salmonids. There would be local effects to LMN fish (check passage counts, assume some overwintering, check Nez Perce for translocation info), but the amount is uncertain; some migration would be coming through.

Juveniles - larval survive very low DO, (0.1mg/l) (Barren and Gannan research). Reservoirs being dewatered would result in exposing tributary mouth sediments, 2ft/day dewatering rate, larval lamprey would likely move out with the dewatering.

Suspended sediments could impact ability of adults to cue in on pheromones from larvae.

Dam breach activities are likely to mobilize contaminants in sediments from reservoirs in Snake River for 5 to 7 years until system reaches equilibrium.

DATA:

Short-term data for analysis: 2 construction seasons; sediment movement; anoxia would occur into river and unbreached reservoirs - DO expected to endure for an estimated 10-15 days < 2.5mg/L in Aug and Oct.; suspended sediment would be high concentrations; contaminants may mobilize and cause bioaccumulation. See sediment movement presentation for data.

Tributary deposition would occur in backwater areas, and there would be a temporarily denuded floodplain. Bed material quality would have deposited fines over bed material. The estimate is that it would take over 100kcfs to clear, but would likely take a flood event. Long-term data for analysis: See velocities and depths from the Dam breach presentation from the Hydraulic Engineer team.

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5264 **Table 3-67. Columbia River Shad Salmon Qualitative Effects Analysis Matrix**

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Juvenile Mainstem Passage							
Presence of reservoirs positively affects shad spawning and rearing habitat area. Shad spawn in shallow water with depth of 3 feet to 30 feet over sand and gravel. There is rearing in the main channel and off-channel areas with dense aquatic vegetation.	Change in reservoir shoreline area.	H&H and Water Quality Outputs: Reservoir shoreline analysis (Section 3.6). Effects to Resource – NAA Shad have been steadily increasing in abundance in the Columbia and Snake Rivers. In the last 20 years, 3% to 13% of shad counted at BON have also passed IHR and entered the Snake River. Several thousand have reached LGR reservoir in recent years. Shad do not migrate as far during years with high flow/spill. Shad are also abundant below Bonneville Dam where iteroparity is observed. Off channel rearing habitat most available in McNary reservoir and estuary.	Minor changes in depth and flows are unlikely to affect ability of shad to spawn. There will be an increased forebay range at JDA, 1 foot higher in Apr to Jun.	Minor changes are unlikely to affect spawning and rearing (up to 0.5-foot difference in surface elevations). Conditions similar to NAA.	Lower Columbia will have minor changes (JDA 1 foot higher in April-June). Snake River will no longer have reservoir environment. Average decrease in width of 500 feet. Expect high mortality during dam breach. Long term expectation of much lower rearing capacity, and lower migration into Snake River. Sediment from Snake could create additional wetland area in MCN pool.	At each project, drop in elevation could potentially change reservoir conditions, but the reservoirs are so big it likely would not change conditions for shad. Drawdown to MOP BON: Drops 3.75 feet Mar 25 until mid-Aug MCN: Drops 1.2 feet Mar 25 (until mid-Aug) JDA: Drops 2 feet Mar 25, through Aug. Elevation 261.75 feet TDA: Drops 2.35 feet Mar 25, through Aug 14.	Petersen et al. 2003, Gadomski and Barfoot 1998, Hinrichsen et al 2013, Hasselman et al. 2012a, b; Quinn and Adams 1996.
Rearing juvenile shad consume a large percentage of zooplankton production, especially Daphnia spp., and compete with rearing subyearling Chinook salmon in early summer.	Change in reservoir zooplankton.	H&H and Water Quality Outputs: Zooplankton qualitative assessment from water quality analysis. Effects to Resource – NAA Years with higher temperatures increase zooplankton primary production. Higher summer flows decrease reservoir retention time of zooplankton. Adults do not feed during migration. After spawning, shad provide large inputs of marine derived nutrients and may thus increase zooplankton productivity.	LGR pool: downstream to MCN dam- Possible species composition shift, but could also have more growth in summer. MCN to BON - no change expected. Shad are generalists. A shift in zooplankton community composition is unlikely to result in strong effect. LGR to MCN- no change expected. MCN to BON - no change expected.	Lower Granite to MCN: Very different food web dynamics - riverine instead of reservoir. Secondary productivity will eventually shift to benthic macroinvertebrates. Would expect fewer shad in Snake River. Zooplankton less than 1/10th of NAA. MCN to BON Short term: heavy sediment loads reduce zooplankton development for 2 to 7 years. New equilibrium of zooplankton density and species composition may be fairly similar.	LGR to MCN - No expected change. MCN downstream - Little or no expected change.	–	Haskell et al., 2013, Haskell et al., 2017, Haskell et al., 2018, Haskell et al., 2006, Hammann, 1981

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Juvenile shad present in the river basin predated on by fall Chinook salmon, bass, catfish, pikeminnow and walleye.	Change in predatory fish.	H&H and Water Quality Outputs: Resident fish analysis Effects to Resource – NAA Complex food web relationships. The presence of juvenile shad increases growth of fish predators, including pikeminnow, bass, catfish and walleye and contributes to the overwinter survival and it could increase predation on salmonids. Yet, juvenile shad are a major food source for fall Chinook in late summer. Chinook also predate on shad eggs. Shad tend to swamp avian predators at East Sand Island during salmon outmigration.	LGR to MCN - no change expected. MCN to BON - no change expected.	LGR to MCN - no change expected. MCN to BON - no change expected.	LGR to MCN – reduction in warm water predators (bass, walleye, pikeminnow) due to reduction of habitat. Fall Chinook may increase. MCN to BON - no change expected.	LGR to MCN - no change expected. MCN to BON - no change expected.	Harvey and Kareiva, 2005 Sanderson et al., 2009 Hinrichsen et al., 2013,

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5279 **3.8 RESIDENT FISH**

5280 **3.8.1 Region A**

5281 ***3.8.1.1 Kootenai Basin***

5282 **Table 3-68. Columbia River Kootenai Regional Qualitative Effects Analysis Matrix**

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Ecosystem Metabolism							
Reservoir Discharge Effects							
Higher and prolonged early spring Libby Dam flow for riverine ecosystem function mid-March through mid-May	Departure from pre-dam (1943-1972) rate of LIBBY DAM FLOW increase (425.7 cfs/day) 15 March - 15 May	Rate of LIBBY DAM FLOW increase of 157 (50 - 295) cfs/day between mid-March and mid-May NAA rate of spring freshet flow increase provides ~ 1/3 of the pre-dam mean rate of flow increase.	99 (-2 - 238) cfs/day MO1 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	93 (18 - 223) cfs/day MO2 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	93 (18 - 224) cfs/day MO3 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	104 (-2 - 249) cfs/day MO4 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	During this period, it is critical for river flow and stage to rise and inundate riparian and side channel habitat to commence and sustain ecosystem productivity. Delay in commencement of river productivity is detrimental to ALL species and ALL life stages, and prevents establishment of self-sustaining populations of endangered, threatened, and sensitive fish species due to impacts to physiological development. VARQ operations at Libby Dam (ALL Alternatives) delays normative (pre-dam) discharge increases by ~ 6 weeks
Temperature Effects							
Temperature for life history physiology: Mid-March = 6°C Mid-April = 8°C Mid-May = 10°C	Mean monthly reservoir temperatures for: Mid-March Mid-April, and Mid-May	NAA Mean Monthly Bonners Ferry Temperatures: MAR: 3.83°C APR: 5.65°C MAY: 8.29°C NAA (and current) spring temperatures are much too cold for ALL species' developmental physiology.	MO1 Median 3.83°C 5.65°C 8.32°C MO1 Spring temperatures are not different from the NAA.	MO2 Median 3.83°C 5.65°C 8.32°C MO1 Spring temperatures are not different from the NAA.	MO3 Median 3.83°C 5.65°C 8.35°C MO1 Spring temperatures are not different from the NAA.	MO4 Median 3.83°C 5.65°C 8.35°C MO1 Spring temperatures are not different from the NAA.	Mean monthly reservoir temperature influences mean monthly Bonners Ferry Temperature. MO3 is potentially beneficial in that it drafts the reservoir deeper through the winter (median) than NAA, and thus may enhance reservoir warming during spring and early summer, though All MO's achieve similar maximum drawdown in April. Best temperature management capability for spring and early summer is present when the reservoir is drafted deep during winter and early spring.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Riparian Function							
Reservoir Discharge Effects							
Libby Dam flow fluctuations during the winter impact benthic ecology.	Daily flow shape	No data available to assess within day variability. No analysis conducted for this metric.					All Alternative winter operations (relaxed ramping rates) allow for varial zone desiccation, re-inundation, and freezing. May impact species bioenergetics - increased metabolic activity. Winter load shaping/following is deleterious to benthic ecology.
River Stage Effects							
Bonners Ferry elevation difference between spring freshet and winter peak are important for riparian community establishment and survival. The larger the number, the greater chance for revegetation.	Number of days when winter peak stage does not exceed seeding peak (15 June to 15 July) stage	NAA: 15 Days (2-30) On average, about half the time flows would exceed the seeding peak under the NAA.	18 (6-30) There would be a minor decrease in the number of days seeding peak would be exceeded.	16 (4 - 30) Only one day difference from NAA. No change from the NAA.	16 (4 - 30) Only one day difference from NAA. No change from the NAA.	19 (6-30) There would be a minor decrease in the number of days seeding peak would be exceeded.	Annually, cottonwood and willow seeds establish within the spring peak zone below existing vegetation and survive throughout the growing season. However, they are no longer present in the early spring, likely due to the impacts of winter operations (peak flows, ramping, shear stress, etc.). During high water years (e.g., 2006, 2011, 2012), seedlings have successfully established and survived well above winter flow impact areas. Seedling survival is decreased due to the duration of exposure to winter inundation, load shaping, shear stress and erosion.
Difference in Bonners Ferry stage between seeding period (15 June to 15 July) and winter peak stage. The greater the difference, the greater the area of potential revegetation.	Difference in river stage between the seeding (15 June to 15 July) and winter peak stage	NAA: 1.0 NAA provides a one foot band of potential revegetation.	1.2 Stage difference increases by 2.4 inches under MO1 - negligible increase in potential revegetation.	-0.3 Stage difference decreases by 130% under MO2 - Minor increase in potential revegetation.	-0.3 Stage difference decreases by 130% under MO3 - Minor increase in potential revegetation.	1.8 Stage difference increases by 80%, or ~ 10 inches, under MO4 - moderate increase in potential revegetation.	The larger the difference between peak seeding and peak winter flows, the more area is available for riparian establishment. Relationship between area and river stage is dependent on geomorphology (i.e., Canyon vs Meander reaches).

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Rate of Bonners Ferry flow recession is related to cottonwood recruitment.	Recession rate of less than 1" (2.5 cm)/day during seeding season (15 June to 15 July)	NAA Recession Rate = 4.3 cm/day. Exceeds optimal recession rate by 1.8 cm/day - Cottonwood recruitment may be limited under the NAA.	Recession Rate = 4.2 cm/day. Exceeds optimal recession rate by 1.7 cm/day - Cottonwood recruitment may be limited under the NAA.	Recession Rate = 4.2 cm/day. Exceeds optimal recession rate by 1.7 cm/day - Cottonwood recruitment may be limited under theNAA	Recession Rate = 4.2 cm/day. Exceeds optimal recession rate by 1.7 cm/day - Cottonwood recruitment may be limited under the NAA.	Recession Rate = 3.6 cm/dayExceeds optimal recession rate by 1.1 cm/day - Cottonwood recruitment may be limited under the NAA.	Cottonwood roots must stay in contact with moist soil and grow approximately 1" (2.5 cm)/day. In fine soils and with spring moisture, soils likely stay moist in the root zone, even when recession rates decline faster than root growth can occur. Maintaining recession rates (less than 2.5"/day) would better promote cottonwood establishment, but a steeper decline may be offset by other factors such as soil type and precipitation. All MOs have average recession rates that are faster than what is considered optimal, but due to spring precipitation and soil wicking, seedlings may be able to maintain contact with moist soil to prevent desiccation. MO4 has a slower rate which could be more beneficial to cottonwood survival. It would be more beneficial to continue the declining limb consistently to the base flow period, as with the other MOs, than dropping the stage substantially in August, as depicted under MO4.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Kootenai River White Sturgeon							
Reservoir Discharge Effects							
Higher and prolonged peak Bonners Ferry flow for spawning mid-May through mid-July. Longer the peak, the more likely sturgeon are to be attracted to suitable spawning habitats.	Number of consecutive days of high/prolonged BONNERS FERRY FLOW of 30+ kcfs at Bonners Ferry (magnitude and duration) desired for sturgeon spawning	NAA provides 19 (14 - 25) days of PEAK BONNERS FERRY FLOW of 30+ kcfs between 15 May and 15 July	18 (11 - 25) days MO1 would have 1 day less than the NAA of peak flows - Negligible effect on sturgeon attraction compared to the NAA.	18 (10 - 25) days MO2 would have 1 day less than the NAA of peak flows - Negligible effect on sturgeon attraction compared to the NAA.	18 (10 - 25) days MO3 would have 1 day less than the NAA of peak flows - Negligible effect on sturgeon attraction compared to the NAA.	19 (12 - 26) days MO4 would not differ from the NAA.	Sturgeon spawning habitat is more suitable upstream of Bonners Ferry. Reducing the number of days where flow >30k cfs will reduce the proportion of spawning sturgeon that migrate to this habitat. Increasing the likelihood of fish migrating to these habitats may increase the probability of successful spawning, egg incubation, and juvenile rearing (natural recruitment is a condition of species recovery). Effects are unknown - this metric was unable to detect differences in the alternatives.
Bonners Ferry flow freshet shape – ramping rates pre-spawn, spawn, and post-spawn. Shape of receding limb to summer flow is important for egg deposition.	Mean BONNERS FERRY FLOW (kcfs) and BONNERS FERRY ELEVATION (MSL) reduction between PEAK BONNERS FERRY FLOW and 15 July	NAA provides a FRESHET SHAPE of 50-54 days between BONNERS FERRY FLOW PEAK (23 - 27 May) and 15 July @ 406.7 - 499.3 cfs/day	50 - 54 days / 23 - 27 May / 357.0 - 499.5 cfs/day MO1 would not differ from the NAA	42 - 54 days / 23 May - 04 June / 384.7 - 510.4 cfs/day MO2 could have a shorter freshet that may occur later in the season when compared to the NAA	42 - 54 days / 23 May - 04 June / 384.7 - 510.4 cfs/day MO3 could have a shorter freshet that may occur later in the season when compared to the NAA	51 - 53 days / 24 - 26 May / 329.7 - 448.7 cfs/day MO4 could have a longer freshet compared to the NAA	BONNERS FERRY FLOW PEAK is related to sturgeon spawning behavior; relationship to wild recruitment is unknown. This metric does not detect differences in the alternatives. Rate of recession of the hydrograph appears to provide cues to trigger egg deposition (with understanding that there is variation for shaping of the hydrograph adaptively in-season via BiOp FPIP process). Decreased rates of flow recession increase the duration of egg deposition. It remains unclear whether increased period duration of egg deposition is beneficial or deleterious to sturgeon egg incubation and recruitment.
Higher and prolonged early spring Libby Dam flow for riverine ecosystem function mid-March through mid-May.	Departure from pre-dam (1943-1972) rate of LIBBY DAM FLOW increase (425.7 cfs/day) 15 March - 15 May	Rate of LIBBY DAM FLOW increase of 157 (50 - 295) cfs/day between mid-March and mid-MayNAA rate of spring freshet flow increase provides ~ 1/3 of the pre-dam mean rate of flow increase.	99 (-2 - 238) C10cfs/dayMO1 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	93 (18 - 223) cfs/dayMO2 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	93 (18 - 224) cfs/dayMO3 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	104 (-2 - 249) cfs/dayMO4 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
River Stage Effects							
Difference in Bonners Ferry stage between the seeding period (15 June to 15 July) and winter peak stage. The greater the difference, the greater the area of potential revegetation.	Difference in river stage between the seeding (15 June to 15 July) and winter peak stage	NAA: 1.0 NAA provides a one foot band of potential revegetation.	1.2 Stage difference increases by 2.4 inches under MO1 - negligible increase in potential revegetation.	-0.3 Stage difference decreases by 130% under MO2 - Minor increase in potential revegetation.	-0.3 Stage difference decreases by 130% under MO3 - Minor increase in potential revegetation.	1.8 Stage difference increases by 80% or ~ 10 inches under MO4 - moderate increase in potential revegetation.	Effects to Sturgeon are unknown. Unconnected floodplains have the potential to strand juvenile sturgeon. Juvenile sturgeon have become stranded over winter in off channel habitat following high water events. Intent is to maximize aerial extent of spring-inundated areas that are not re-inundated the following winter.
Bonners Ferry flow peak and duration of high flows provides backwater and slough habitat important for larval and juvenile rearing. Floodplain connection linked to high runoff and wet years.	Number of days above BONNERS FERRY ELEVATION 1758' (surrogate for duration) at Nimz Ranch reference site	NAA provides 7 days above 1758' during larval emergence and development stage NAA Median provides sufficient floodplain connectivity at Nimz Ranch reference site.	16 days MO1 would have one day less of flows above 1758 = Negligible decrease compared to the NAA.	16 days MO2 would have one day less of flows above 1758 = Negligible decrease compared to the NAA.	16 days MO3 would have one day less of flows above 1758 = Negligible decrease compared to the NAA.	17 days MO4 would not differ from the NAA.	Currently unknown if juvenile sturgeon occupy this habitat. Believe any increase in access to juvenile rearing habitat (e.g. floodplain habitat) would be beneficial. However, over winter stranding is a concern with an increase in connectivity. Connectivity of floodplain habitats may increase food production for larval and juvenile sturgeon, but this is currently unknown. Relation is confounded by other temperature and productivity relations. If too cold no production in backwater habitat. Desire is to maximize aerial extent and duration of spring-inundated areas correlated with Klockmann gage to determine connection. Ecosystem functions include food and hiding habitat, warmer water for better growth and productivity.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Temperature Effects							
Mean monthly reservoir temperature profile (winter/spring) – discharge temperature is influenced by Libby elevation. Later winter/early spring (March to early May), higher pool elevations result in cooler discharge. Warmer water (10°C) is needed for spawning (late May to early July).	MEAN MONTHLY RESERVOIR TEMPERATURE influences discharge LIBBY DAM DISCHARGE TEMPERATURE	NAA Median MEAN MONTHLY RESERVOIR TEMPERATURE: MAR: 3.51°C APR: 3.79°C MAY: 6.22°C JUN: 9.17°C JUL: 10.78°C No difference from the NAA	MO1 Median 3.51°C 3.79°C 6.25°C 8.94°C 10.72°C No difference from the NAA	MO2 Median 3.51°C 3.79°C 6.28°C 9.00°C 10.44°C No difference from the NAA	MO3 Median 3.51°C 3.79°C 6.28°C 9.00°C 10.44°C No difference from the NAA	MO4 Median 3.51°C 3.79°C 6.25°C 8.89°C 10.50°C No difference from the NAA	Egg deposition generally occurs at temperatures >8°C with a peak at approximately 9.5°C to 9.9°C. Duration of egg incubation is inversely related to temperature (e.g., higher temperatures reduce incubation time). The effects of the MOs on temperature are not significantly different than the NAA. Higher pool elevation through the winter associated with VARQ can result in a colder thermal mass that warms slower than optimal - lower pool elevation can result in quicker springtime warming of the forebay, and thus warmer discharge temperature during spring and early summer.
Bonners Ferry temperature of 8.5°C to 12°C during mid-May through mid-July to initiate and support sturgeon spawning.	MEAN MONTHLY BONNERS FERRY TEMPERATURE between May and June of 8.5°C to 12 °C	NAA Median: MAY: 8.29°C JUN: 11.08°C°C JUL: 13.54°C (based on MEAN MONTHLY RESERVOIR ELEVATION and EMPIRICAL DATA).	MO1 Median 8.32°C 10.85°C 13.49°C No difference from the NAA	MO2 Median 8.35°C 10.91°C 13.21°C No difference from the NAA	MO3 Median 8.35°C 10.91°C 13.21°C No difference from the NAA	MO4 Median 8.32°C 10.80°C 13.26°C No difference from the NAA	Egg deposition generally occurs at temperatures >8°C with a peak at approximately 9.5°C to 9.9°C. Duration of egg incubation is inversely related to temperature (e.g., higher temperatures reduce incubation time).
Bonners Ferry temperature progression to allow for progression of species physiology: Mid-March: 6°C Mid-April: 8°C Mid-May: 10°C Mid-June: 12°C End-June: 14°C	MEAN MONTHLY RESERVOIR TEMPERATURE influences MEAN MONTHLY BONNERS FERRY TEMPERATURE	NAA Medians FEB: 2.83°C MAR: 3.83°C APR: 5.65°C MAY: 8.29°C JUN: 11.08°C JUL: 13.54°C NAA Does not provide appropriate mean monthly temperatures at Bonners Ferry for physiological progression of Sturgeon. Spring temperatures increase too slowly because of reservoir water mass and is too cold to allow for proper body development, growth, and survival.	MO1 Medians 2.83°C 3.83°C 5.65°C 8.32°C 10.85°C 13.56°C Does not differ from the NAA.	MO2 Medians 2.83°C 3.83°C 5.65°C 8.32°C 10.80°C 13.26°C Does not differ from the NAA.	MO3 Medians 2.83°C 3.83°C 5.65°C 8.35°C 10.91°C 13.21°C Does not differ from the NAA.	MO4 Medians 2.83°C 3.83°C 5.65°C 8.35°C 10.91°C 13.21°C Does not differ from the NAA.	Pre-dam temperatures in the Kootenai River were consistently cold in the winter months (i.e., November-March) and the sharply rose in the spring (i.e., April, May, and June). This thermograph provided suitable temperature for sturgeon spawning, egg incubation, larval development and feeding in the spring and summer. All MOs offer only marginal differences from the NAA, so it is likely there would be no benefit or detriment to sturgeon due to Libby Dam's temperature management capabilities. However, alternatives that reduce winter volume in Lake Koocanusa may be more allow for warmer water during the critical spring period.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Burbot							
Reservoir Elevation Effects							
Entrainment of eggs and larval burbot through Libby Dam during March through early April.	MEAN LIBBY DAM FLOW between 01 March and 15 April	Mean Libby Out Flow: 4.0 - 11.0 kcfs Lower discharge entrains fewer eggs and larvae. Some unknown number of eggs and larvae would be entrained.	4.0 - 14.1 kcfs Negligible effects. No change from NAA.	4.0 - 12.6 kcfs Negligible effects. No change from NAA.	4.0 - 12.6 kcfs Negligible effects. No change from NAA.	4.0 - 13.4 kcfs Negligible effects. No change from NAA.	Although not explicitly quantified, lower discharge entrains fewer eggs and larvae.
Reservoir Discharge Effects							
Higher and prolonged early spring Libby Dam flow for riverine ecosystem function mid-March through mid-May.	Departure from pre-dam (1943-1972) rate of Libby Dam flow increase (425.7 cfs/day) 15 March to 15 May	Rate of Libby Dam flow increase of 157 (50 - 295) cfs/day between mid-March and mid-May NAA rate of spring freshet flow increase provides ~ 1/3 of the pre-dam mean rate of flow increase.	99 (-2 - 238) cfs/day MO1 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	93 (18 - 223) cfs/day MO2 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	93 (18 - 224) cfs/day MO3 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	104 (-2 - 249) cfs/day MO4 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	During this period, it is critical for river flow and stage to rise and inundate riparian and side channel habitat to commence and sustain ecosystem productivity. Delay in commencement of river productivity is detrimental to ALL species and ALL life stages, and prevents establishment of self-sustaining populations of endangered, threatened, and sensitive fish species due to impacts to physiological development. VARQ operations at Libby Dam (ALL Alternatives) delays normative (pre-dam) discharge increases by ~ 6 weeks

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
River Stage Effects							
Altered seasonal flow regime/floodplain connectivity.	Number of days above BONNERS FERRY ELEVATION 1758' (surrogate for duration) at Nimz Ranch reference site	NAA provides 17 days above 1758' during larval emergence and development stageNAA Median provides sufficient floodplain connectivity at Nimz Ranch reference site for burbot; however, it is likely that larval and juvenile burbot would benefit from an even longer duration of inundation.	16 days: MO1 would have one day less of flows above 1758 = Negligible decrease compared to the NAA.	16 days: MO2 would have one day less of flows above 1758 = Negligible decrease compared to the NAA.	16 days: MO3 would have one day less of flows above 1758 = Negligible decrease compared to the NAA.	17 days: MO4 would not differ from the NAA.	Off-channel habitats are important for larval and juvenile burbot in the Meander Reach (Bonners Ferry to Kootenay Lake). These habitats provide warmer water, cover, and food, and also may provide nutritional (zooplankton) sources for the mainstem Kootenai River. Seasonal access to off-channel habitats is important for burbot, as well as for Ecosystem and Riparian function. All MO medians of days of floodplain connectivity are similar to those of the NAA, suggesting that ALL MOs would operate similar to the NAA in terms of connectivity. It is likely larval and juvenile burbot would benefit from even longer durations of inundation by providing access to larval rearing habitats and prey sources.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Winter Libby Dam discharge regime needs to be low, steady flow, and cold temperature.	BONNERS FERRY FLOW variability between 01 January and 30 April	NAA provides BONNERS FERRY FLOW: MEAN: 9.89 kcfs (18.99 to 6.50) NAA Median DOES NOT provide appropriate discharge regime for successful burbot recruitment; however, it is unknown if river flow is the single factor limiting burbot recruitment (Too much variability).	MO1 Median 11.62 (17.76 - 8.50) MO1 and MO4 appear to be the most stable flow schedules likely to imitate pre-dam hydrographs; therefore, these two MOs would be preferred.	MO2 Median 8.50 (21.02 - 5.37) MO2 and MO3 show greater flow variability relative to the NAA and would have greater impacts to burbot than MO1 and MO4.	MO3 Median 8.50 (21.02 - 5.37) MO2 and MO3 show greater flow variability relative to the NAA and would have greater impacts to burbot than MO1 and MO4.	MO4 Median 11.34 (16.49 - 8.50) MO1 and MO4 appear to be the most stable flow schedules likely to imitate pre-dam hydrographs; therefore, these two MOs would be preferred.	High and variable flows result in interrupted spawning migrations. Low (4kcfs) and stable winter flows = spawning congregations (based on empirical catch rates). Daily load shaping and load following results in high and variable flows, leading to potential for interrupted spawning migrations of adult burbot, which may then further inhibit successful recruitment. Further and more recent data need to be collected to confirm this with the recent increases in burbot densities. Power generation on coldest days results in higher flows, whereas it is believed burbot need lower, more stable flows on the colder days. Pre-dam flows and temperatures in the Kootenai River from November-March were low, stable, and cold. As such, temperature and flow patterns that mimic pre-dam conditions are desirable.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Temperature Effects							
Temperature for life history physiology Mid-Feb: 2°C - spawning, egg incubation/survival Mid-March: 6°C - lethal egg incubation, stimulate egg hatch at appropriate time Mid-April: 8°C - proper body development Mid-May: 10°C - growth Mid-June: 12°C - growth End-June: 14°C - growth	MEAN MONTHLY RESERVOIR TEMPERATURE influences MEAN MONTHLY BONNERS FERRY TEMPERATURE	NAA Medians FEB: 2.83°C MAR: 3.83°C APR: 5.65°C MAY: 8.29°C JUN: 11.08°C JUL: 13.54°C NAA Does not provide appropriate mean monthly temperatures at Bonners Ferry for physiological progression of burbot. Early winter temperature is often too warm for spawning and egg development, and can be lethal to eggs at 6°C. Spring temperature is too cold to allow for proper body development, growth, and survival.	MO1 Medians 2.83°C 3.83°C 5.65°C 8.32°C 10.85°C 13.56°C Does not differ from the NAA.	MO2 Medians 2.83°C 3.83°C 5.65°C 8.32°C 10.80°C 13.26°C Does not differ from the NAA.	MO3 Medians 2.83°C 3.83°C 5.65°C 8.35°C 10.91°C 13.21°C Does not differ from the NAA.	MO4 Medians 2.83°C 3.83°C 5.65°C 8.35°C 10.91°C 13.21°C Does not differ from the NAA.	Current spring temperatures are too cold for good productivity. March, April, June colder than historic values. Development is slow, not enough zooplankton to feed, and starve within 7 to 10 days of hatch. Very significant mortality in many years. Pre-dam temperatures in the Kootenai River were consistently cold in the winter months (i.e., November-March) and the sharply rose in the spring (i.e., April, May, and June). This thermograph provided suitable temperature for burbot spawning and egg incubation in the winter, followed by suitable temperatures for larval development and feeding in the spring and summer.
Kokanee							
Reservoir Discharge Effects							
Higher and prolonged early spring Libby Dam flow for riverine ecosystem function mid-March through mid-May.	Departure from pre-dam (1943-1972) rate of LIBBY DAM FLOW increase (425.7 cfs/day) 15 March - 15 May	Rate of LIBBY DAM FLOW increase of 157 (50 - 295) cfs/day between mid-March and mid-May NAA rate of spring freshet flow increase provides ~ 1/3 of the pre-dam mean rate of flow increase.	99 (-2 - 238) C10cfs/day MO1 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	93 (18 - 223) cfs/day MO2 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	93 (18 - 224) cfs/day MO3 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	104 (-2 - 249) cfs/day MO4 rates of spring freshet flow increase are lower than the NAA (Decreases in river productivity).	During this period, it is critical for river flow and stage to rise and inundate riparian and side channel habitat to commence and sustain ecosytem productivity. Delay in commencement of river productivity is detrimental to ALL species and ALL life stages, and prevents establishment of self-sustaining populations of endangered, threatened, and sensitive fish species due to impacts to physiological development.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Reservoir Discharge Effects							
Entrainment of young-of-year and adult kokanee through Libby Dam. Peak entrainment densities can occur early spring into mid-summer, and during fall through early winter. Higher discharge entrains more fish.	MEAN LIBBY DAM FLOW between: 1) 15 April and 15 July; and 2) 01 October and 31 December	NAA MEAN LIBBY DAM FLOW: 1) 10.5 - 16.8 kcfs 2) 8.8 - 13.3 kcfs Under the NAA an unknown number of Kokanee would be entrained in spring and fall releases.	1) 9.4 - 16.1 2) 9.6 - 12.1 MO1 would decrease flows in these periods but would have a negligible impact relative to the NAA.	1) 8.7 - 15.6 2) 13.4 - 15.8 MO2 would decrease flows in the spring, but increase it in the fall and would have a negligible impact relative to the NAA.	1) 8.7 - 15.6 2) 13.4 - 15.8 MO3 would decrease flows in the spring, but increase it in the fall and would have a negligible impact relative to the NAA.	1) 9.9 - 16.7 2) 7.3 - 11.7 MO4 would not differ from the NAA in spring flows, but would decrease fall flows. These changes would have a negligible impact relative to the NAA.	Peak rates of entrainment of kokanee are not precisely quantifiable, but pass through Libby Dam during early spring through mid-summer, and during fall through early winter, was documented by Skaar (1996). Entrainment is believed to be beneficial to kokanee upstream of the dam related to density dependency effects. Kokanee are a food source for bull trout and rainbow trout upstream and downstream of the dam.
Bull Trout							
Reservoir Elevation Effects							
Libby Dam elevation during summer months determines area of euphotic zone related to reservoir productivity. Higher elevation = more productivity.	Number of days KOOCANUSA ELEVATION is > 2450' 15 June through 15 September	NAA provides 44 days (range of 0 - 66 for 25 and 75%) of Koocanusa elevation > 2450' during the summer period of productivity (15 June to 15 September).	51 (43-68) Provides 7 days more than the NAA. The expected result would be minor increase in productivity and increased food web for MO1.	46 (18-66) Provides 2 days more than NAA - Negligible increase in productivity	46 (18-66) Provides 2 days more than NAA - Negligible increase in productivity	33 (0-59) Provides 11 days less than NAA - moderate reduction in productivity	Higher lake elevations in the warm summer months provides a larger body of warm euphotic zone for primary production and zooplankton production. Bull trout food base relies on this production for food the following winter. The expected result may be increased primary and secondary production that would likely positively impact bull trout growth and/or survival.
Minimum Libby Dam elevation in one year influences insect larvae production the following year. Lower drafts limit production the following year.	MINIMUM LIBBY ELEVATION (typically in mid-April)	NAA MINIMUM KOOCANUSA ELEVATION is 2366' (median) 2320' -2408' (25 and 75%).	2364 (2327-2406) Lower Draft by 2 foot compared to NAA - negligible change in productivity	2359 (2328-2392) Lower Draft by7 feet compared to NAA - Minor reduction in productivity	2359 (2328-2392) Lower Draft by7 feet compared to NAA - Minor reduction in productivity	2366 (2329-2407) No change from the NAA	Benefits to bull trout would likely be limited to juvenile bull trout prior to their switch to a piscivorous diet. Maximum elevation draft in one year affects insect larvae production the following year. All MO's may decrease bull trout growth and/or survival. However, in all cases the 25th percentile is higher for the MO's - More benefit on high water years.
Maximum Libby Dam elevation is related to volume and surface area, as well as to proximity of the surface to terrestrial deposition. Higher elevation = more terrestrial productivity.	MAXIMUM LIBBY ELEVATION (typically early-August)	NAA MAXIMUM KOOCANUSA ELEVATION is 2451 feet median and 2449 -2455 (75 and 25%)	2453 (2452 - 2456) Maximum elevation is 2 foot higher than NAA - Minor increase in shoreline contribution to productivity.	2452 (2450 - 2456) Maximum elevation is 1 foot higher than NAA - Negligible increase in shoreline contribution to productivity.	2452 (2450 - 2456) Maximum elevation is 1 foot higher than NAA - Negligible increase in shoreline contribution to productivity.	2451 (2447 - 2456) No change from the NAA	This metric was not effective in separating the alternatives. MO1 provides the most promise for terrestrial inputs.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Reservoir Flow Effects							
Bull trout weighted usable area in the Kootenai River for juvenile bull trout during the night-time hours is maximized at 4,000 cfs discharge from Libby Dam. Juvenile bull trout weighted usable area during daylight hours and adult bull trout weighted useable area (day and night) are both maximized at 5,000 cfs discharge.	Weighted usable area (square miles) for juvenile (day and night) and adult bull trout based on the mean discharge for the period May 15 to Sept 30 for the median, 25th, and 75th percentiles.	The NAA has a mean flow of 12,388 cfs (median) and flows of 14,445 and 10,301 cfs for the 25 and 75th percentiles from May 15 to Sept 30. WUA in square meters. WUA JuvBTNight: 489,188 WUA JuvBTDay: 1,282,860 WUA AduBTDay: 1,488,901	12,081 cfs (median) and 14,194 and 9,758 cfs (25 and 75%) WUA JuvBTNight: 500,336 WUA JuvBTDay: 1,303,385 WUA AduBTDay: 1,505,322 MO1 would increase WUA by between 1% to 2% = negligible increase	11,700 cfs (median) and 13,842 and 9,281 cfs (25 and 75%) WUA JuvBTNight: 514,173 WUA JuvBTDay: 1,328,856 WUA AduBTDay: 1,525,701 MO2 would increase WUA by between 2-5% = Minor increase	11,698 cfs (median) and 13,840 and 9,281 cfs (25 and 75%) WUA JuvBTNight: 514,245 WUA JuvBTDay: 1,328,990 WUA AduBTDay: 1,525,808. MO3 would increase WUA by between 2-5% = minor increase	13,109 cfs (median) and 15,602 and 10,362 cfs (25 and 75%) WUA JuvBTNight: 465,603 WUA JuvBTDay: 1,227,555 WUA AduBTDay: 1,441,128. MO4 would decrease WUA by between 3-5% = minor decrease	Lower usable weighted habitat may result in reduced growth and/or survival of all life stages of bull trout. Weighted usable area decreases with increasing discharge for all relationships above the maximums. Nearly all riffles, which provide the most productive benthic insect habitat, are inundated at 9 kcfs.
Food availability/off-channel inundation and connectivity is optimized at Libby Dam flow of 9 kcfs to 12 kcfs.	MEAN LIBBY DAM FLOW during bull trout minimum flow requirement period (15 May through 30 September)	NAA provides a MEAN LIBBY DAM DISCHARGE flow of 10.7 - 15.1 kcfs during bull trout minimum flow requirement period (15 May through 30 September). NAA would provide flows that are up to 26% greater than optimum flows.	10.2 - 14.9 kcfs MO1 would provide flows up to 2% less than the NAA = Negligible positive change.	9.7 - 14.5 kcfs MO2 would provide flows up to 5% less than the NAA = Minor positive change.	9.7 - 14.5 kcfs MO3 would provide flows up to 5% less than the NAA = Minor positive change.	10.8 - 16.4 kcfs MO4 would provide flows up to 10% more than the NAA = Minor negative change.	Decreased productivity would occur outside inundation optimums.
Libby Dam flow fluctuations during the winter impact benthic ecology.	Daily flow shape	NO DATA are available to assess within day variability	NA	NA	NA	NA	Current winter operations (relaxed ramping rates) allow for varial zone desiccation, re-inundation, and freezing. May impact species bioenergetics - increased metabolic activity. Winter load shaping/following is deleterious to benthic ecology.
Maximum Libby Dam flow (?20 kcfs) is needed seasonally to flush and sort fine sediments and gravels. The typical rule of thumb for channel maintenance and gravel sorting is “bankfull flow for at least 48 hours on a periodicity of 2.5 years.”	Peak (?20 kcfs) Libby Dam flow during freshet period (15 May through 15 June).	NAA provides 13 (11 to 16) days of LIBBY DAM FLOW > 20 kcfs; mean flow is 18.8 (18.2 to 20.8) kcfs peak is 24.4 (23.1 to 26.9) kcfs	12 (0 - 20) days 18.0 (16.4 - 20.5) kcfs 23.7 (23.0 - 26.9 kcfs MO1 would provide decreases between 3% and 7% in metrics that measure sediment movement - negligible decrease in delta movement.	11 (9 - 15) days 17.4 (14.5 - 20.3) kcfs 23.3 (23.0 - 27.0) kcfs MO2 would provide decreases between 5% and 15% in metrics that measure sediment movement - Minor decrease in delta movement.	11 (9 - 15) days 17.4 (14.5 - 20.3) kcfs 23.3 (23.0 - 27.0) kcfs MO3 would provide decreases between 5% and 15% in metrics that measure sediment movement - Minor decrease in delta movement.	12 (10 - 16) days 18.4 (16.6 - 20.7) kcfs 24.0 (22.8 - 27.0) kcfs MO4 would provide decreases between 2% and 7% in metrics that measure sediment movement - negligible decrease in delta movement.	Higher flows - up to 25 kcfs, for a higher duration - up to 30 days, are desired. These higher flows are insufficient to remove tributary delta aggradation that can prevent bull trout access to natal tributaries during spawning season. The peak discharge of all M0's, as well as the NAA, are insufficient to remove tributary delta aggradation that can prevent bull trout access to natal tributaries during spawning season.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Temperature Effects							
RESERVOIR TEMPERATURE influences habitat suitability, surface elevation and reservoir volume influence thermal structure of pool. Fish seek preferred temps; volume of temperature range influences amount of habitat available. Bull trout optimal growth occurs at 55.8 F. The upper incipient lethal temperature for bull trout is 69.7 F.	MEAN MONTHLY RESERVOIR TEMPERATURE influences LIBBY DAM DISCHARGE TEMPERATURE	Mean Monthly Reservoir Temperature: JAN: 40.88°F FEB: 38.97°F MAR: 38.32°F APR: 38.83°F MAY: 43.20°F JUN: 48.50°F JUL: 51.40°F AUG: 52.45°F	40.88°F 38.97°F 38.32°F 38.83°F 43.25°F 48.10°F 51.30°F 52.35°F No change from NAA	40.88°F 38.97°F 38.32°F 38.83°F 43.30°F 48.20°F 50.80°F 52.35°F No change from NAA	40.88°F 38.97°F 38.32°F 38.83°F 43.30°F 48.20°F 50.80°F 52.35°F No change from NAA	40.88°F 38.97°F 38.32°F 38.83°F 43.25°F 48.00°F 50.90°F 52.80°F change from NAA	Reservoir temperature (Dunnigan, unpublished) is determined by several variables, the most indicative of which are volume of the reservoir through the winter (as measured by minimum pool elevation in April), inflow, and air temperature. The estimated temperature differences for all M0's are very small, and are all below the optimal growth temperature and upper incipient lethal temperature during all months.
LIBBY DAM DISCHARGE TEMPERATURE is manageable seasonally when the reservoir stratifies (non-isothermic conditions) via a Selective Withdrawal system to provide normative discharge temperatures. Bull trout optimal growth occurs at 55.8 F. The upper incipient lethal temperature for bull trout is 69.7 F.	MEAN MONTHLY RESERVOIR TEMPERATURE influences MEAN MONTHLY DISCHARGE TEMPERATURE	Mean Monthly Reservoir Temperature: JAN: 40.88°F FEB: 38.97°F MAR: 38.32°F APR: 38.83°F MAY: 43.20°F JUN: 48.50°F JUL: 51.40°F AUG: 52.45°F	40.88°F 38.97°F 38.32°F 38.83°F 43.25°F 48.10°F 51.30°F 52.35°F No change from NAA	40.88°F 38.97°F 38.32°F 38.83°F 43.30°F 48.20°F 50.80°F 52.35°F No change from NAA	40.88°F 38.97°F 38.32°F 38.83°F 43.30°F 48.20°F 50.80°F 52.35°F No change from NAA	40.88°F 38.97°F 38.32°F 38.83°F 43.25°F 48.00°F 50.90°F 52.80°F No change from NAA	Selective Withdrawal system is used to provide normative discharge temperatures as reservoir forebay conditions allow. The estimated temperature differences for All M0's are very small, and are all below the optimal growth temperature and upper incipient lethal temperature during all months.
Westslope Cutthroat Trout							
Reservoir Elevation Effects							
LIBBY ELEVATION during summer months determines area of photic zone related to surface productivity.	Number of days KOOCANUSA ELEVATION is > 2450' 15 June through 15 September	NAA provides 44 days (median) (0-66 days; 25 and 75%) of KOOCANUSA ELEVATION > 2450' during the summer period of productivity (15 June - 15 September)	51 (43 - 68) MO1 provides 16% more days over 2450. The expected result would be a minor increase in productivity and food web connectivity.	46 (18 - 66) No change from the NAA	46 (18 - 66) No change from the NAA	33 (0 - 59) MO4 would result in a 25% decrease in days over 2450. Minor decrease in productivity and food web connectivity would likely negatively impact westslope trout growth and/or survival.	Higher lake elevations in the warm summer months provides a larger body of warm euphotic zone for primary production and zooplankton production. Westslope cutthroat trout food base relies on this production for food the following winter. The expected result may be increased primary and secondary production that would likely positively impact westslope cutthroat trout growth and/or survival.
MINIMUM LIBBY ELEVATION in one year influences insect larvae production the following year where lower drafts are associated with lower production the following year.	MINIMUM LIBBY ELEVATION (typically in mid-April)	NAA MINIMUM KOOCANUSA ELEVATION is 2366' (median) 2320' -2408' (25 and 75%).	2364 (2327-2406) Lower Draft by 2 foot compared to NAA - negligible change in productivity	2359 (2328-2392) Lower Draft by 7 feet compared to NAA - Minor reduction in productivity	2359 (2328-2392) Lower Draft by 7 feet compared to NAA - Minor reduction in productivity	2366 (2329-2407) No change from the NAA	Maximum elevation draft in one year affects insect larvae production the following year. Minimum elevations measure the depth of the draft and acts as a surrogate for area desiccated.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
MAXIMUM LIBBY ELEVATION (May to Sept) is positively correlated to RRT weight growth downstream of Libby Dam.	MAXIMUM LIBBY ELEVATION (typically early-August)	NAA MAXIMUM KOOCANUSA ELEVATION is 2451 median and 2449 - 2455 (25 and 75%)	2453 (2452 - 2456) MO1 would have two additional feet of elevation - Negligible change from the NAA.	2452 (2450 - 2456) MO2 would have one additional foot of elevation - Negligible change from the NAA.	2452 (2450 - 2456) MO3 would have one additional foot of elevation - Negligible change from the NAA.	2451 (2447 - 2456) No change from the NAA.	This metric did not distinguish differences in the alternatives.
MAXIMUM LIBBY ELEVATION is related to volume and surface area, and to proximity of the surface to terrestrial insect deposition - higher elevations are associated with greater terrestrial inputs.	MAXIMUM LIBBY ELEVATION (typically early-August)	NAA MAXIMUM KOOCANUSA ELEVATION is 2451 median and 2449 - 2455 (25 and 75%)	2453 (2452 - 2456) MO1 would have two additional feet of elevation leading to a minor increase in terrestrial inputs and productivity when compared to the NAA.	2452 (2450 - 2456) MO2 would have one additional foot of elevation - Negligible change from the NAA.	2452 (2450 - 2456) MO3 would have one additional foot of elevation - Negligible change from the NAA.	2451 (2447 - 2456) No change from the NAA.	MO1 would have minor increases in terrestrial insect deposition and food resources for juvenile bull trout.
Reservoir Flow Effects							
Rainbow/Redband Trout weighted useable area in the Kootenai River for juvenile and adult trout is maximized at 4,000 cfs discharge from Libby Dam. Weighted usable area decreases with increasing discharge for all relationships above the maximums.	Weighted usable area (sq. m) for juvenile and adult Rainbow/Redband trout based on the mean discharge for the period May 15 to Sept 30 for the median, 25, and 75th percentiles.	The NAA has a mean flow of 12,388 cfs (median) and flows of 14,445 and 10,301 cfs for the 25 and 27th percentiles from May 15 to Sept 30.WUA in square meters.WUA JuvRBRBT: 683,548WUA AduRBRBT: 680,501	12081 cfs (median) and 14194 and 9758 cfs (25 and 75%) WUA JuvRBRBT: 699,413 WUA AduRBRBT: 703,847MO1 would increase RBT WUA by between 2-3% = negligible increase in habitat	11700 cfs (median) and 13842 and 9281 cfs (25 and 75%) WUA JuvRBRBT: 719,103 WUA AduRBRBT: 703,847MO2 would increase RBT WUA by between 3-5% = minor increase in habitat	11698 cfs (median) and 13840and 9281 cfs (25 and 75%) WUA JuvRBRBT: 719,207 WUA AduRBRBT: 732,974MO3 would increase RBT WUA by between 5-8% = minor increase in habitat	13109 cfs (median) and 15602 and 10362 cfs (25 and 75%) WUA JuvRBRBT: 649,615 WUA AduRBRBT: 634,688MO4 would decrease RBT WUA by between 5-7% = minor decrease in habitat	Lower usable weighted habitat may result in reduced growth and/or survival of all life stages of rainbow redband trout.
LIBBY DAM FLOW fluctuations during the winter impact benthic ecology.	Daily flow shape	NO DATA are available to assess within day variability	NA	NA	NA	NA	NAA winter operations (relaxed ramping rates) allow for varial zone desiccation, re-inundation, and freezing. May impact species bioenergetics - increased metabolic activity. Winter load shaping/following is deleterious to benthic ecology. Metric not used - no data available.
SUGGEST Deleting this: MAXIMUM LIBBY DAM FLOW (> 20 kcfs) is needed seasonally to flush and sort fine sediments and gravels.	PEAK (> 20 kcfs) LIBBY DAM FLOW during FRESHET period (15 May through 15 June)	NAA provides 13 (11 - 16) days of LIBBY DAM FLOW > 20 kcfs; mean flow is 18.8 (18.2 - 20.8) kcfs peak is 24.4 (23.1 - 26.9) kcfs	12 (0 - 20) days 18.0 (16.4 - 20.5) kcfs 23.7 (23.0 - 26.9 kcfs MO1 would provide decreases between 3-7% in metrics that measure sediment movement - negligible decrease in delta movement.	11 (9 - 15) days 17.4 (14.5 - 20.3) kcfs 23.3 (23.0 - 27.0) kcfs MO2 would provide decreases between 5-15% in metrics that measure sediment movement - Minor decrease in delta movement.	11 (9 - 15) days 17.4 (14.5 - 20.3) kcfs 23.3 (23.0 - 27.0) kcfs MO3 would provide decreases between 5-15% in metrics that measure sediment movement - Minor decrease in delta movement.	12 (10 - 16) days 18.4 (16.6 - 20.7) kcfs 24.0 (22.8 - 27.0) kcfs MO4 would provide decreases between 2-7% in metrics that measure sediment movement - negligible decrease in delta movement.	Higher flows - up to 25 kcfs, for a higher duration - up to 30 days, are desired. These higher flows are insufficient to remove tributary delta aggradation that can prevent bull trout access to natal tributaries during spawning season. The peak discharge of All M0's is insufficient to remove tributary delta aggradation that can prevent bull trout access to natal tributaries during spawning season.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Temperature Effects							
RESERVOIR TEMPERATURE influences habitat suitability, surface elevation and reservoir volume influence thermal structure of pool. Fish seek preferred temps; volume of temperature range influences amount of habitat available. Rainbow and westslope cutthroat trout optimal growth occurs at 55.6°F and 56.5°F, respectively. The upper incipient lethal temperature for rainbow and westslope cutthroat trout is 75.7°F and 67.3°F, respectively.	MEAN MONTHLY RESERVOIR TEMPERATURE influences LIBBY DAM DISCHARGE TEMPERATURE	Mean Monthly Reservoir Temperature: JAN: 40.88°F FEB: 38.97°F MAR: 38.32°F APR: 38.83°F MAY: 43.20°F JUN: 48.50°F JUL: 51.40°F AUG: 52.45°F	40.88°F 38.97°F 38.32°F 38.83°F 43.25°F 48.10°F 51.30°F 52.35°F No change from NAA	40.88°F 38.97°F 38.32°F 38.83°F 43.30°F 48.20°F 50.80°F 52.35°F No change from NAA	40.88°F 38.97°F 38.32°F 38.83°F 43.30°F 48.20°F 50.80°F 52.35°F No change from NAA	40.88°F 38.97°F 38.32°F 38.83°F 43.25°F 48.00°F 50.90°F 52.80°F No change from NAA	Reservoir temperature (Dunnigan, unpublished) is determined by several variables, the most indicative of which are volume of the reservoir through the winter (as measured by minimum pool elevation in April), inflow, and air temperature. The estimated temperature differences for all M0's are very small, and are all below the optimal growth temperature and upper incipient lethal temperature during all months.
LIBBY DAM DISCHARGE TEMPERATURE is manageable seasonally (non-isothermic conditions) via a Selective Withdrawal system to provide normative discharge temperatures. Rainbow and westslope cutthroat trout optimal growth occurs at 55.6°F and 56.5°F, respectively. The upper incipient lethal temperature for rainbow and westslope cutthroat trout is 75.7 and 67.3 F, respectively.	MEAN MONTHLY RESERVOIR TEMPERATURE influences MEAN MONTHLY DISCHARGE TEMPERATURE	Mean Monthly Reservoir Temperature: JAN: 40.88°F FEB: 38.97°F MAR: 38.32°F APR: 38.83°F MAY: 43.20°F JUN: 48.50°F JUL: 51.40°F AUG: 52.45°F	40.88°F 38.97°F 38.32°F 38.83°F 43.25°F 48.10°F 51.30°F 52.35°F No change from NAA	40.88°F 38.97°F 38.32°F 38.83°F 43.30°F 48.20°F 50.80°F 52.35°F No change from NAA	40.88°F 38.97°F 38.32°F 38.83°F 43.30°F 48.20°F 50.80°F 52.35°F No change from NAA	40.88°F 38.97°F 38.32°F 38.83°F 43.25°F 48.00°F 50.90°F 52.80°F No change from NAA	Selective withdrawal system is used to provide normative discharge temperatures as reservoir forebay conditions allow. The estimated temperature differences for all M0's are very small, and are all below the optimal growth temperature and upper incipient lethal temperature during all months.

Dunnigan, unpublished

Skaar, D., J. DeShazer, L. Garrow, T. Ostrowski and B. Thornburg. 1996. Quantification of Libby Reservoir levels needed to maintain or enhance reservoir fisheries - investigation of fish entrainment through Libby Dam, 1990-1994 Final report. Project 83-467 - prepared for Bonneville Power Administration. Montana Fish, Wildlife & Parks, Kalispell, MT. 114 pp.

HUNGRY HORSE/CLARK FORK BASIN

Fish and aquatic resources in the Hungry Horse/Clark Fork basin were evaluated qualitatively. Hydrology and WQ data outputs from models were examined to predict effects using relationships between these parameters and biological responses. These relationships were guided by conceptual ecological models for species in this area and regional/local knowledge of the subteam. These relationships and the effects of the No Action Alternative were developed in a workshop in Kalispell, MT March 12-13, 2019 in Kalispell, MT. The Resident fish team subgroup for this region then met again May 30-31, 2019 in Kalispell, Montana to evaluate the effects of the Multi-Objective alternatives to these resources using the same relationships and compare these effects to the NAA. During this workshop, discussions led to the desire to do some further processing of hydrology data to estimate quantitatively the changes in euphotic zone and surface area of the reservoir at the end of each month under each alternative, as these indicate important relationships between Hungry Horse reservoir elevations and aquatic food sources, which is a driving factor for fish. Changes in surface area were also used as an information proxy to understand the magnitude of change in benthic surface available for insect production as well. Information from these tables were incorporated into the matrix and discussed with the team via follow-up conference calls and correspondence. Hydrology and water quality information used can be found in the pertinent sections of Chapter 3 or the associated technical appendices.

The fish community of Hungry Horse Reservoir is dominated by native fish such as bull trout, westslope cutthroat trout, and mountain whitefish, and the most important drivers are related to food production, which affects all fish. The team developed relationships and NAA effects for some other species in different spreadsheets, but noticed considerable overlap with bull trout. For the action alternatives the team decided to discuss analyses of all fish at the same time and these were compiled all in the bull trout tab, with notations there when a particular relationship applied to a different species differently, such as the difference in spawning run timing for tributary access affects. . Likewise, the fish resources downstream of Hungry Horse were minimally affected by changes in the alternatives and, again, the relationships apply more on a habitat scale rather than by species. Therefor, there is only one matrix for this area with discussions weighted to bull trout but covering all species. The matrix considers resources starting with Hungry Horse Reservoir and working downstream through the South Fork of the Flathead River, mainstem Flathead River, Flathead Lake, the lower Flathead River (below Flathead Lake), and the Clark Fork River. Non-native species become more prevalent in the downstream reaches of the basin.

After completing these analyses, the team received notification that there was an error in the hydrology data provided to the fish team. Without sufficient time to re-run the hydrology and adjust the analyses quantitatively, a description of the error was provided by the hydrology team and used to qualitatively adjust the conclusions in the fish analyses described in Chapter 3.5. All elevation data, euphotic zone calculations, and surface area calculations in these tables are from the original model runs. It should be noted that when Alternatives MO1 and MO3 were modeled, the initial Hungry Horse Reservoir levels at the start of each water year were

erroneously set lower than intended. A subsequent sensitivity analysis revealed that this initialization error primarily affected results in the fall and winter. This initialization error causes the Alternative MO1 results to be too low during the fall and winter. In the summary hydrograph shown above, years at the median and higher elevations should have water levels 1-3 feet higher than shown from October through May. For years with reservoir elevations lower than the median elevation, the results should be 5-10 feet higher from October through February. This initialization error had little effect downstream from Hungry Horse Dam. Hungry Horse Dam's modeled releases were up to 1 kcfs lower than they should have been, but by the time flow reaches Flathead Lake the MO1 results have little error.

As in all resources, a matrix was used to capture the environmental relationships, the metric to evaluate it, and then data, effects, and notes for each of the alternatives, including the NAA. The information in the matrix was condensed into the matrix in this section. Following the matrix, tables display the outcome of the additional euphotic zone and surface elevation information developed, including the volume and surface area, the change from NAA of each, and the percent change. These values were reported and discussed in the text of Chapter 3.5.

5342 **Table 3-69. Flathead/Clark Fork Qualitative Effects Analysis Matrix Part 1**

<table>
<tr><th>Affected Environment Important Relationships / Criteria</th><th>Environmental Consequences Metric</th><th>Environmental Consequences NAA</th><th>Environmental Consequences MO1</th><th>Environmental Consequences MO2</th><th>Environmental Consequences MO3</th><th>Environmental Consequences MO4</th><th>Notes</th></tr>
<tr><td colspan="8">Bull Trout</td></tr>
<tr><td colspan="8">Hungry Horse Reservoir</td></tr>
<tr><td>–</td><td>–</td><td>Most important relationships are related to productivity (food source for all fish in the reservoir, including bull trout). Several relationships are defined that are interrelated. Hungry Horse Reservoir has no known water quality issues. The reservoir is an oligotrophic water body with high water quality. It is located high in the watershed. Few processes are likely to influence water quality with respect to nutrients and/or sediment. These processes include: forestry operations, road building, natural disasters (e.g. forest fires) and atmospheric deposition. 2500-10000 bull trout, stable, limited harvest fishery. http://docs.streamnetlibrary.org/BPA_Fish_and_Wildlife/12659-5.pdf. Is food the limiting factor - driver is likely successful reproduction, but food availability is important in the reservoir.</td><td>Most important impacts from lower water levels at Hungry Horse from water supply measure. Half of years, Sep 30 elevation at least 4 feet lower. In 10% of years, 4 feet to 16 feet deeper draft. Sliding scale measure - driest years provides additional water supply (4 feet), sliding scale, then meet minimum flows. Lower releases most of year to support higher releases Aug and Sep.</td><td>Additional outflow for power generation results in much higher outflows in January and deeper drafts in winter (Dec to Apr); median elevations 4 feet to 8 feet lower than NAA. Sliding scale reduces occurrences of drafts to 20 feet in extremely low elevations, with some years going to somewhere between 10 feet and 20 feet instead that would have drafted clear to 20 feet under NAA. Relaxed ramping rate restrictions could result in more drastic day to day and within day fluctuations. Outflow changes promulgate downstream but attenuated as flows join Flathead River and are passed through Flathead Lake. Note: Modeling assumed flows passed through Flathead Lake, but operators could choose to store that water and release differently.</td><td>Very similar to MO1 - See Elev. Fcst_Comparisons</td><td>In drier half of years up to 10 feet to 15 feet lower Hungry Horse elevation. Average years and above are similar to MO1.</td><td>http://dnrc.mt.gov/divisions/reserved-water-rights-compact-commission/docs/cskt/2011_hhbiologicalconstraintsreport.pdf</td></tr>
<tr><td>Hungry Horse Reservoir elevations affect production of phytoplankton, zooplankton, and invertebrates that are the base of the food source for bull trout in three ways: 1) Higher lake elevations in the warm summer months provide a larger body of warm euphotic zone for primary production and zooplankton production. Lower elevations = lower production.
2) Higher elevations = more areas of benthic substrate in the zone that</td><td>Hungry Horse Reservoir elevation duration monthly: Jun, Jul, and Aug; and probability of reaching target pool elevation Jul 30.
Elev_Fcst_Comparison-2019_0408 elevation on Jun 30 average, dry, wet year types.
Rate of refill to full pool, duration at/near full before drawdown. Duration at maximum elevation.</td><td><table><tr><th colspan="2">Jun</th><th colspan="2">Jul</th></tr><tr><td>50%</td><td>3551.21</td><td>50%</td><td>3559.17</td></tr><tr><td>60%</td><td>3548.08</td><td>60%</td><td>3558.59</td></tr><tr><td>70%</td><td>3544.14</td><td>70%</td><td>3557.36</td></tr><tr><td>80%</td><td>3539.07</td><td>80%</td><td>3555.70</td></tr><tr><td>90%</td><td>3529.94</td><td>90%</td><td>3552.97</td></tr></table><table><tr><th colspan="2">Aug</th></tr><tr><td>50%</td><td>3556.21</td></tr><tr><td>60%</td><td>3555.58</td></tr><tr><td>70%</td><td>3554.68</td></tr><tr><td>80%</td><td>3552.50</td></tr><tr><td>90%</td><td>3551.019</td></tr></table>Probability of exceeding 3559 by Jul 30 = 0.75.
Jun 30 Elevation Ave: 3558.78</td><td>High years: About 4 feet lower by end of Sep Ave: About 4 feet lower by end of Sep Dry: About 1 foot lower end of Sep. Very dry (10%) 4 feet to 16 feet lower.
Probability of exceeding 3559 by Jul 30 = 0.69
Jun 30 Elev Ave: 3558.62
Jun 30 Elev Dry: 3557.15
Jun 30 Elev Wet: 3553.15
Jul 31 Elev Ave: 3558.26
Jul 31 Elev Dry: 3553.45
Jul 31 Elev Wet: 3559.11
Aug 31 Elev Ave: 3552.5
Aug 31 Elev Dry: 3546.26
Aug 31 Elev Wet: 3553.24
Through the summer, drops 4 feet lower than NAA, the body of euphotic zone for primary</td><td>Same as NAA until Nov, then deeper draft in winter, up to 10 feet lower Dec to late April. Wet and average years same as NAA; Dry years lower in Jun to Jul, higher in Aug.
Jun 30 Elev Ave: 3558.07
Jun 30 Elev Dry: 3555.18
Jun 30 Elev Wet: 3553.92
Probability of 3559 feet by Jul 31 = 67%
See elevation comparisons. Dry years - flatter slope. Ave/wet - same as NAA. Drastically reduced substrate for insect production, large bays could be dewatered. Insects that would have been overwintered for following season would be not available. These insects are important spring food</td><td>See Elev_Fcst_ Comparisons
Same as MO1. Probability of exceeding 3559 by Jul 30 = 0.75
Jun 30 Elev Ave: 3558.68
Jun 30 Elev Dry: 3556.21
Jun 30 Elev Wet: 3553.62
Same as MO1.</td><td>High years: About 4 feet lower by end of Sep
Ave: About 4 feet lower by end of Sep
Dry: About 10 feet to *15 feet lower end of Sept.
Very dry (10%) 4 feet to 16 feet lower.
Jun
50% = 3549.70 (-1.5)
60% = 3546.23 (-1.8)
70% = 3542.18 (-2.0)
80% = 3536.87 (-2.2)
90% = 3528.13 (-1.8)
Jul
50% = 3558.87 (-0.3)
60% = 3558.13 (-0.5)
70% = 3556.88 (-0.5)
80% =3554.9 (-0.8)
90% =3551.27 (-1.7)</td><td>Flathead Subbasin plan, reference section.
Wiseman et al., 2016 - Gila River report RIVBIO model (Brian e-copy)
Potential mitigation - revegetate the top 10 feet of reservoir. Experimental - planted willows, would survive submerged for 43 days (Example) create a new insect source, and security cover for fish when inundated. When above water, there are wildlife benefits and terrestrial insect production for fish. (Marotz)
Water supply modeled to all come out in Jun, Jul, Aug.
In reality would likely be delivered more spread out.</td></tr>
</table>

Affected Environment Important Relationships / Criteria	Environmental Consequences Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
supports aquatic insect production. Lower elevations reduces benthic insects. Maximum elevation draft in 1 year affects insect larvae production the following year. Shape of refill/ drawdown also affects insect production; gradual slopes maximize productivity compared to faster refill or drawdown (better to miss full than to fill quickly, “touch” full pool, then drawdown again. 3) Elevations influence availability of terrestrial insects; lower elevations provide less surface area to collect insects, and the water surface becomes further from the terrestrial vegetation at lower lake levels.		Jun 30 Elevation Dry: 3558.50 Jun 30 Elevation Wet: 3553.15 Jul 31 Elevation Ave: 3558.90 Jul 31 Elevation Dry: 3554.10 Jul 31 Elevation Wet: 3559.40 Aug 31 Elevation Ave: 3554.80 Aug 31 Elevation Dry: 3547.20 Aug 31 Elevation Wet: 3555.50 Current management is to try to reach full pool (Elevation 3560) by early summer to provide adequate primary productivity. Bull trout food base relies on this production for food the following winter. This would continue to provide an adequate food source for winter supply of zooplankton that fuels the food web. 1) Zooplankton is important winter food source. In the biologically-productive warm months, want the reservoir as full as possible. Gives large body of warm euphotic zone for primary production; zooplankton production. 2) Aquatic inverts important spring food source. Benthic substrate is important for aquatic inverts production. The deeper the max drawdown, the worse the spring food supply from benthic productivity. Benthic production occurs in a zone between area wetted long enough to produce, down to where too deep for light to penetrate. Fast filling/ drawdown retards productivity. Even at full pool, the substrate is wet but needs to stay wet 5 to 7 weeks in order to be productive - populate with plants, then inverts move in. If dewater before this process completes there is no benefit to production. 3) Terrestrial insects important summer food source. Bull trout piscivorous - on mountain whitefish, suckers,	production would be smaller through the warm summer months, and then in winter months would be up to 9 feet lower through winter months. Drastically reduced substrate for insect production, large bays could be dewatered. Insects that would have been overwintered for following season would be not available. These insects are important spring food source. Reduced benthic food production. See MO2 notes for quantification estimate method. Deeper draft increases the area that gets dewatered in most years by 4 feet in summer months and up to 16 feet in 20% of years (dry years). Effect to bull trout is indirect effect to prey base for adults (suckers, whitefish, peamouth, westslope cutthroat trout, pikeminnow). Juvenile bull trout moving into reservoir in spring, eating insects until transition to fish. The prey base impacted until that transition. Expect poorer condition and reduced populations of prey base fish and juvenile bull trout. Compared to MO2 - MO2 drops to a lower point so would kill more of the aquatic biota, but with MO1 the drawn down area would last longer (July to May).	source. Reduced benthic food production. See notes for quantification estimate method. Deeper draft increases the area that gets dewatered every year by 8 feet. Insects all desiccated when sampled in dewatered zones. 2-yr life cycle insects (big midges most valuable for fish) would be most affected because of 2-yr life cycle. Insects exist is a "bell curve" according to depth. Effect to bull trout is indirect effect to prey base for adults (suckers, whitefish, peamouth, westslope cutthroat trout, pikeminnow). Juvenile bull trout moving into reservoir in spring, eating insects until transition to fish. The prey base impacted until that transition. Expect poorer condition and reduced populations of prey base fish and juvenile bull trout. Deeper drawdown in winter/ spring dewaters larvae. Fail to refill, so less volume available for productivity. Pulled back further from the riparian vegetation don't land on the water.		Aug 50% = 3554.57 (-1.64) 60% = 3553.83 (-1.75) 70% = 3553.04 (-1.64) 80% = 3551.81 (-0.7) 90% = 3548.44 (-2.58) Probability of exceeding 3559 by Jul 30 = 0.65 Jun 30 Elev Ave: 3558.62 Jun 30 Elev Dry: 3557.15 Jun 30 Elev Wet:3553.15 Jul 31 Elev Ave: 3558.26 Jul 31 Elev Dry:3553.45 Jul 31 Elev Wet: 3559.11 Aug 31 Elev Ave: 3552.5 Aug 31 Elev Dry:3546.26 Aug 31 Elev Wet: 3553.24 Jun 30 Elev Ave: 3558.40 Jun 30 Elev Dry: 3550.19 (8.31 feet lower) Jun 30 Elev Wet: 3553.15 Wet and Average years: About 5 feet lower than NAA, and about 1 foot lower than MO1. Effects would be similar to MO1, only a little bit higher magnitude. (5 feet lower instead of 4 feet lower). Dry years: 10-foot to 15-foot drop in elevation. Decrease in warm euphotic zone and benthic substrate production. Mitigation - reshape flow regime to pay back Coulee water in McNary measure to be less detrimental. NOTE: per our notes, I have info converting surface elevation to volume and surface area. Need to chat about the findings.	Water is for industrial, municipal, and irrigation Fish eating pupae, a more gradual drawdown would provide benefit for longer, and potentially aquatic insects could move to deeper locations (larvae may Steeper slope would exacerbate this effect: Potential mitigation - fill slower, don't get as high, but better to miss full and drawdown slower. July start drafting for multipurposes plus new purpose of water supply. Up to 80% years, runs lower than NAA directly. In drier years, 80% to 90%, the sliding scale offsets some of the impact, but beyond 90% driest years the impact shows again. In most years, recover that storage in refill, but in drier years may miss full the following year more often. Ending water year lower results in drafting further to support the same minimum flows. End up deeper in the following spring. Eric - modeling did adjust to capture carryover effect in exceedance graphs. Use "Elevation Duration Monthly tab" Mitigation thoughts - Subimpoundments in headwaters of reservoirs (Palisades) create berms to hold water longer and revegetation (issues - habitat for nonnative fish, build below full pool so water floods over them, with no egress) Install woody debris reefs to provide habitat for aquatic inverts. Mitigation ideas? Can create more surface area with submerged structures, but wary

<table>
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<tr><td></td><td></td><td>minnows, etc. Prey fish all rely on the food web relationships described above.</td><td></td><td></td><td></td><td></td><td>of public safety issues. Or sink Christmas trees.
Manage (reduce) introgression of rainbow/westslope cutthroat trout; reduce overlap of spp. in Flathead River. Opportunities to expand westslope cutthroat trout populations in secure refugia (currently have non-natives)</td></tr>
<tr><td>Follow-up quantification of food production analyses. Notes of 7/2/19. Not a separate analyses, but puts some quantification to the analyses in row above.
End of month elevations (from elevation comparison tool) in wet, dry, and average years were converted to volume, then the volume of the non-productive deep part of the reservoir subtracted (see NAA notes).
Note: Euphotic zone only refers to the productivity in summer part of the relationships described in Row 8. Insect production and surface area for terrestrial production captured in next 2 rows.</td><td>Euphotic zone</td><td>Volume of euphotic zone in acre-feet:<table><tr><th>NAA Wet Year</th><th>NAA Dry Year</th><th>NAA Avg Year</th><th>Month</th></tr><tr><td>510997</td><td>635389</td><td>607725</td><td>May</td></tr><tr><td>645447</td><td>662074</td><td>662913</td><td>Jun</td></tr><tr><td>1057686</td><td>1030354</td><td>1055107</td><td>Jul</td></tr><tr><td>1376345</td><td>1316650</td><td>1371494</td><td>Aug</td></tr><tr><td>1489407</td><td>1408156</td><td>1489248</td><td>Sep</td></tr></table>Winter food – zooplankton is primary food – mostly produced the spring before.
Spring – dipterans – primary food
Summer – low nutrient so turn to terrestrials, 2 fly, 2 don’t (leafhoppers, coleopterans beetles). Flies, bees, wasps, still able to get to water surface.
Fall – switch back to aquatic insects and zooplankton.
Euphotic zone by month:
Jun: 30 feet
Jul: 50 feet
Aug: 70 feet
Sep: 80 feet
To calculate change in euphotic zone, convert elevation NAA to volume; then elevation 30 feet lower to volume and subtract to estimate euphotic zone for NAA. Do the same for MO1 through 4 and compare.</td><td>Change in volume of euphotic zone, compared to NAA. Quantification to inform effects.<table><tr><th></th><th>Wet</th><th>Dry</th><th>Avg</th></tr><tr><td>May</td><td>0%</td><td>-3%</td><td>-1%</td></tr><tr><td>Jun</td><td>0%</td><td>-1%</td><td>0%</td></tr><tr><td>Jul</td><td>0%</td><td>0%</td><td>0%</td></tr><tr><td>Aug</td><td>-1%</td><td>-1%</td><td>-1%</td></tr><tr><td>Sep</td><td>-2%</td><td>-1%</td><td>-2%</td></tr></table></td><td>Change in volume of euphotic zone, compared to NAA. Quantification to inform Row 9 effects.<table><tr><th></th><th>Wet</th><th>Dry</th><th>Avg</th></tr><tr><td>May</td><td>0%</td><td>-3%</td><td>-1%</td></tr><tr><td>Jun</td><td>0%</td><td>-1%</td><td>0%</td></tr><tr><td>Jul</td><td>0%</td><td>0%</td><td>0%</td></tr><tr><td>Aug</td><td>-1%</td><td>-1%</td><td>-1%</td></tr><tr><td>Sep</td><td>-2%</td><td>-1%</td><td>-2%</td></tr></table></td><td>Change in volume of euphotic zone, compared to NAA.<table><tr><th></th><th>Wet</th><th>Dry</th><th>Avg</th></tr><tr><td>May</td><td>0%</td><td>-3%</td><td>-1%</td></tr><tr><td>Jun</td><td>0%</td><td>-1%</td><td>0%</td></tr><tr><td>Jul</td><td>0%</td><td>0%</td><td>0%</td></tr><tr><td>Aug</td><td>-1%</td><td>-1%</td><td>-1%</td></tr><tr><td>Sep</td><td>-2%</td><td>-1%</td><td>-2%</td></tr></table></td><td>Change in volume of euphotic zone, compared to NAA. Quantification to inform effects.<table><tr><th></th><th>Wet</th><th>Dry</th><th>Avg</th></tr><tr><td>May</td><td>0%</td><td>-3%</td><td>-1%</td></tr><tr><td>Jun</td><td>0%</td><td>-4%</td><td>0%</td></tr><tr><td>Jul</td><td>0%</td><td>-4%</td><td>-1%</td></tr><tr><td>Aug</td><td>-1%</td><td>-5%</td><td>-2%</td></tr><tr><td>Sep</td><td>-2%</td><td>-7%</td><td>-3%</td></tr></table></td><td>Use volume to estimate euphotic zone loss. (Zooplankton - important for prey species and juvenile bull trout). May reports have isopleth diagrams showing how thick the thermocline is. Estimate June (with selective withdrawal starts) about 20 feet thick, Jul about 30 feet, Aug about 50 feet, Sep (prior to turnover) about 65 feet thick.
Substrate for benthic production (important all year, but the most important food in spring) use elevation to surface area, have to assume continuous even slope, for an index of substrate habitat lost.
Terrestrial insect deposition - proportional to surface area lost for all 4 insect orders. Two of the orders don't fly so lose more due to being further from the surface elevations. Coleopterans (beetles) and homopterans (leafhoppers). Lose contribution to fish food supply because fall close to shoreline vegetation (don't fly). Hymenopterans (very important summer food source) and hemipterans fly well so don't have that effect but rather are proportional to surface area. Coleopterans are main food supply during summer.</td></tr>
<tr><td>Follow-up quantification of surface area available for terrestrial insect feeding. Elevations at the</td><td>–</td><td>NAA: Hungry Horse Surface Area (Acres)</td><td><table><tr><th>MO1</th><th></th><th></th><th></th></tr><tr><td>Month</td><td>Wet</td><td>Dry</td><td>Avg</td></tr><tr><td>Oct</td><td>-2%</td><td>-3%</td><td>-3%</td></tr></table></td><td><table><tr><th>MO2</th><th></th><th></th><th></th></tr><tr><td>Mth</td><td>Wet</td><td>Dry</td><td>Avg</td></tr><tr><td>Oct</td><td>2%</td><td>3%</td><td>3%</td></tr></table></td><td><table><tr><th>MO3</th><th></th><th></th><th></th></tr><tr><td>Mth</td><td>Wet</td><td>Dry</td><td>Avg</td></tr><tr><td>Oct</td><td>-2%</td><td>-4%</td><td>-3%</td></tr></table></td><td><table><tr><th>MO4</th><th></th><th></th><th></th></tr><tr><td>Mth</td><td>Wet</td><td>Dry</td><td>Avg</td></tr><tr><td>Oct</td><td>0%</td><td>0%</td><td>0%</td></tr></table></td><td>Follow-up quantification of food production analyses. Notes of 7/2/19.</td></tr>
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<tr>
<td>end of each month (from the elevation comparison tool) in wet, dry, and average year types were converted to surface acres using conversion tables provided by MFWP.</td>
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<table>
<tr><th>Month</th><th>Wet</th><th>Dry</th><th>Aug</th></tr>
<tr><td>Oct</td><td>22345</td><td>22345</td><td>22448</td></tr>
<tr><td>Nov</td><td>22038</td><td>21833</td><td>22345</td></tr>
<tr><td>Dec</td><td>21935</td><td>21221</td><td>22038</td></tr>
<tr><td>Jan</td><td>21119</td><td>20611</td><td>21527</td></tr>
<tr><td>Feb</td><td>19913</td><td>20113</td><td>20812</td></tr>
<tr><td>Mar</td><td>17280</td><td>19814</td><td>20212</td></tr>
<tr><td>Apr</td><td>152123</td><td>20511</td><td>19913</td></tr>
<tr><td>May</td><td>18754</td><td>22652</td><td>21731</td></tr>
<tr><td>Jun</td><td>23072</td><td>23602</td><td>23602</td></tr>
<tr><td>Jul</td><td>23707</td><td>23178</td><td>23602</td></tr>
<tr><td>Aug</td><td>23284</td><td>22448</td><td>23178</td></tr>
<tr><td>Sep</td><td>22755</td><td>21731</td><td>22755</td></tr>
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<tr><td>Nov</td><td>-3%</td><td>-3%</td><td>-4%</td></tr>
<tr><td>Dec</td><td>-4%</td><td>-2%</td><td>-4%</td></tr>
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<tr><td>May</td><td>-2%</td><td>-1%</td><td>0%</td></tr>
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<tr><td>May</td><td>3%</td><td>1%</td><td>0%</td></tr>
<tr><td>Jun</td><td>0%</td><td>0%</td><td>0%</td></tr>
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<tr><td>Sep</td><td>0%</td><td>-4%</td><td>0%</td></tr>
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<td>Three lobes of reservoir different shapes.
Emery (Main lobe, towards dam)
Murray
Sulivan
Not able to do separate surface area analyses to further inform insect production in the time available.</td>
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<tr>
<td>Increased outflows can increase the entrainment loss of zooplankton. Changes in lake levels and selective withdrawal locations could exacerbate this issue.</td>
<td>Hungry Horse outflows (mean monthly outflows) and qualitative assessment of stratification and elevation changes.</td>
<td>Average Monthly Outflow
(25%, 50%, 75%)
Oct: 2242, 1934, 1386
Nov: 2353, 1979, 1426
Dec: 2731, 2425, 2134
Jan: 3110, 2625, 2340
Feb: 3997, 2745, 2418
Mar: 5651, 2715, 2249
Apr: 8142, 5433, 3147
May: 7017, 5655, 4062
Jun: 6051, 4257, 3160
Jul: 4170, 3400, 2592
Aug: 3083, 2680, 2389
Sep: 3082, 2680, 2393
Zooplankton would continue to be entrained into the South Fork Flathead River from Hungry Horse Reservoir. The zooplankton enhances food supply in the South Fork Flathead River and along the near bank of the Flathead River, but decreases food supply for fish in Hungry Horse Reservoir. Zooplankton entrainment moves through South Fork Flathead, also stays along one bank, mixes about Teakettle.</td>
<td>Percent change from change doc.
(25%, Median, 75%)
Oct: Same as NAA
Nov: -1%, -6%, -14%
Dec: -4%, -6%, -10%
Jan: -12%, -3%, -7%
Feb: -21%, --4%, -5%
Mar: -12%, -6%, -3%
Apr: -5%, -13%, -17%
May: -4%, -6%, -9%
Jun: -7%, -8%, -11%
Jul: +1%, +1%, +9%
Aug Higher: 17%, 21%, 19%
Sep Higher: 17%, 21%, 18%
Entrainment/outflow decreased in winter months, and typically spread equally, so correlate directly to outflows. In summer months, zooplankton more susceptible to entrainment because they are concentrated at withdrawal location, and more outflow would result in increased entrainment of zooplankton. Aug and Sep, increased entrainment reduces food source for bull trout prey base and juveniles while they are staging for migration. Increased zooplankton entrainment could help South Fork Flathead. Mitigation: restore operation of slide gates; allows to</td>
<td>Increased outflows in Jan/Feb over 100% increase in median years. 6,000 to 6,100 in MO1
Oct: -5%, -6%, -10%
Nov: -1%, -2%, 0%
Dec: 0%, -1%, -1%
Jan Higher: 179%, 108%, 15%
Feb Higher: 50%, 2%, -1%
Mar: -8%, -8%, -8%
Apr: -17%, -17%, -12%
May: -1%, -2%, +3%
Jun: -25%, -37%, -50%
Jul: -3%, -3%, 10%
Aug Higher: 17%, 21%, 19%
Sep Higher: 17%, 21%, 18%
Note: these are incorrect!
Zooplankton would be decreased in correlation to outflow changes in winter months and in Aug/Sept. All are important months for bull trout FMO. Expect decreased food supply for fish; roughly double the amount of zooplankton lost to entrainment. Zooplankton are winter food supply for fish. Bull trout are piscivorous, juveniles directly affected by zoo loss; adult bull trout indirectly due to reduction in food supply for prey species. Entrainment would be less in Mar-June.</td>
<td>Oct: -5%, -7%, -12%
Nov: -2%,-6%,-16%
Dec: -6%, -6%, -16%
Jan: -12%, -3%, -8%
Feb: -23%, -5%, -6%
Mar: -15%, -7%, -5%
Apr: -4%, -19%, -20%
May: -4%, -8%, -12%
Jun: -7%, -8%, -11%
Jul: +2%, +1%, +9%
Aug: Higher 17%, 21%, 18%
Sep: Higher 17%, 21%, 19%
Similar to MO1</td>
<td>Change from NAA
(25%, 50%, 75%)
Oct: -4%, -6%, -10%
Nov: -1%,-6%,-14%
Dec: -5%, -6%, -12%
Jan: -12%, -3%, -7%
Feb: -22%, -4%, -5%
Mar: -14%, -7%, -4%
Apr: -5%, -15%, -18%
May: -4%, -6%, -8%
Jun: -3%, -5%, -6%
Jul: Higher +8%, +11%, +17%
Aug: Higher 36%, 37%, 35%
Sep: Higher 36%, 37%, 35%
October through June is similar to MO1 and MO3. July, Aug, and Sept much higher; expect entrainment of zooplankton and reduced food for fish, similar to MO1 but in higher magnitude.</td>
<td>NA</td>
</tr>
</table>

Affected Environment Important Relationships / Criteria	Environmental Consequences Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
			mix water both warmer and colder of target temp and mix them rather than taking directly from the target temp where the plankton are concentrated. Temperature gauge array on face of the dam to determine where target temperature is. NOTE: Zooplankton entrainment study - Cavigle et al., 1998 (Pam has)				
Increased outflows can increase entrainment of bull trout and other fish.	Hungry Horse outflows, mean monthly in all months, 25%, 50%, and 75% exceedances. See outflow comparison to visually compare alternatives.	See above. Some level of bull trout entrainment would probably occur, though it is not known how much or from which outlets. Although there may be entrainment occurring, no data or studies to determine how much or at what flows/outlets. It is not known to affect the South Fork populations in the reservoir and tributaries. Possible scenarios - concentration of food sources near the outlet could make them more susceptible. Shape of dam - most species immersal (littoral) and the intakes are out to the sides. If any alternatives alter the thermal structure so it concentrates bull trout near the outlets it could be an issue. Vertical sonar indicated no targets near outlets for selective withdrawal. Bull trout and Northern pikeminnow were only species found at great depth (>100 feet approximately), so more susceptible to entrainment. When isothermal (turns over) fish spread out, selective withdrawal only when stratified. When bull trout go deep, they could be more susceptible to entrainment during stratification.	See zooplankton entrainment relationship above. Increased outflows July, Aug, Sep. Entrainment expected to increase with higher outflows. Water withdrawal - June - by surface (20 feet or so), then gradually deeper through Jul. Aug/Sept start to go deeper to get target temps, fish are in the strata where being outflows. Bull trout and pikeminnow more susceptible at late summer, when outflows increase by about 20%. Entrainment rates not known, but would increase by about 20% or more.	See outflows from Hungry Horse. Expect higher entrainment of fish in winter months. Bull trout are more likely to be in the reservoir in these months, but may be spread throughout the reservoir rather than concentrated at the depths near the outlets.	Same as MO1.	See outflows from South Fork Flathead section. 37% higher in Aug/Sep. Concentration of littoral zone closer to penstocks would increase entrainment risk. 37% more outflow would increase entrainment. Relationship would be more than direct correlation because of increased risk. Bull trout and pikeminnow more susceptible because they are found deeper where withdrawals would be from.	Westslope cutthroat trout – high densities below Hungry Horse. Could stray to somewhere else to spawn or lost from population. High susceptibility to entrainment because taking water from zone where they occupy. Other native fish – suckers, pikeminnow higher subject to entrainment because they hang out by the face of the dam. Pikeminnow and bull trout occupy deep strata. Suckers are also right by surface. Water withdrawal – Jun – by surface (20 feet or so), then gradually deeper through Jul. Aug/Sep start to go deeper to get target temperatures, fish are in the strata where being outflows. Mitigation – entrainment studies to determine if an issue, mitigate commensurate with effect.
Elevation can influence exposure to angling exploitation and predation for bull trout where tributaries enter the reservoir.	Hungry Horse elevation Bull trout: Jul to Oct. Westslope cutthroat trout and other spring spawn: Apr to Jun.	If full in summer, not as much issue, with current draft in summer increases exposure in bays where tributaries enter reservoir. Years with 20-foot drafts and don't reach full (overestimate inflow forecast) is when this is an issue.	Visually compared: Wet, dry, ave all similar pattern. Use median end of month elevations. Jul: Aug: 3552 (-3 feet) Sep: 3546 (-4 feet)	MO2 similar to NAA in Jul/Aug. When bull trout staging to migrate upstream to tributaries, the elevation would be similar to NAA.	–	Dry years, Sep elevation 3429.5.	Varial zone in deeper drafts topography unknown. Delta aggradation likely has built up deltas. Potential mitigation – research bathymetry of tributary zones; identify potential channel

Affected Environment Important Relationships / Criteria	Environmental Consequences Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
			More exposure to predation/angling in Aug for upstream migrations. In late Sept through Oct as adults migrate back into reservoir there would be more exposure. Likely moving at night. More varial zone to pass through to get to reservoir pool. Tributary delta underwater now is not known, but if has sedimented up there could be full blockages of tributaries; preventing both ingress and egress.				reconstruction and cover. (See Deadwood examples for lessons learned.) Large woody debris in bays to provide cover. Modernize reservoir model HRMOD with updated bathymetry, translate into modern code – to evaluate specifically where effects happen, helps fine-tune operations decisions.
Access to spawning areas can be affected by reservoir levels. At NAA elevations, bull trout (and other species) typically have access. At lower elevations access to spawning tributaries could become problematic. NOTE: more applicable to westslope cutthroat trout.	Median end of month elevation Bull trout: Aug to Sep. Westslope cutthroat trout and others: Apr to Jun.	Median End of Month Elevation: Aug: 3555 Sep: 3550 Apr: 3520 May: 3539 Jun: 3558 Changes in reservoir operations implemented in 2009 have reduced water level fluctuation during the summer and fall, which overlaps with the primary period when bull trout are migrating to spawning and overwintering habitats in tributaries. (2016 BA). The NAA would continue to provide access to spawning tributaries.	Aug: 3552 (-3 feet) Sep: 3546 (-4 feet) Apr: 3515 (-5 feet) May: 3536 (-3 feet) Jun: 3558 (similar to NAA) See above notes. Westslope cutthroat trout: Spawning, entering in April, and leaving through late June. Lower elevations through Apr and May, by Jun 1 back up to near NAA. More exposure in bays to predation/angling. Tributaries on descending limb on June as westslope cutthroat trout coming	Aug: 3555 (0) Sep: 3550 (0) Apr: 3515 (-5 feet) May: 3536 (-3 feet) Jun: 3557 (-1 foot) No effect.	Aug: 3552 (-3 feet) Sep: 3546 (-4 feet) Apr: 3515 (-5 feet) May: 3536 (-3 feet) Jun: 3558 (similar to NAA) All same as MO1.	Aug: 3551 (-4 feet) Sep: 3545 (-5 feet) Apr: 3515 (-5 feet) May: 3535 (-4 feet) Jun: 3556 (-2 feet)	Hungry Horse mitigation and implementation plans. Brian provide e-copy. Mitigation: passage improvements. Example: McInernie culver, others? Look for undersized culverts and improve them. Possibly replace with arch culverts or bridges. Continue to restore and protect genetic diversity in native spp. Through funding continued conservation aquaculture, etc. Sekokini springs facility (genetic conservation facility - current mitigation for HH) Mitigate for losses to westslope cutthroat trout. (hybridization, etc., issues, or just population losses).
Water temperatures affect habitat suitability. Surface elevation affects thermal structure of pool; fish seek preferred temperatures; volume of temperature range affects amount of habitat available.	Hungry Horse elevations; mid-Jun through Sep, qualitative from water quality team.	Water temperatures in reservoir are appropriate for bull trout. Spring food source mainly affected (in summer, switch to terrestrials).	Similar to NAA (from water quality presentation).	No change expected.	No change.	No change from NAA.	NA.

Affected Environment Important Relationships / Criteria	Environmental Consequences Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
South Fork Flathead River below Hungry Horse							
–	–	Potentially migratory/overwintering habitat only/Transitional habitat only. No spawning within the mainstem South Fork below Hungry Horse and no spawning tributaries in that reach. CH is not designated below the dam (see CH Unit 31). With selective withdrawal temps that are more conducive; we see some bull trout juveniles and adults in river. Don't know if entrained from Hungry Horse or from main Flathead. Probably Flathead - when stop selective withdrawal most move back out to the main Flathead.	–	–	–	–	–
Water volume/flow affects available habitat? Minimum in-stream flows 400 cfs to 900 cfs on sliding scale based on water availability. Most critical to meet South Fork minimums during spring runoff (otherwise are met automatically to provide to Columbia Falls).	Flows – water volume during late summer.	See outflow comparison. Bull trout would likely use the river below Hungry Horse during what months? Oct through Jul? Year-round? They are just visitors here. Typically release > minimum in South Fork Flathead to meet Columbia Falls minimums. Exception in flood emergency, can reduce to spin/no-load flows of 1 turbine.	Lower flows in Apr-Jun in average years Lower flows Feb-Apr in wet years Lower flows in Apr in dry years 500 (11%) cfs higher than NAA in Jun to Aug MO1: 4992 NAA: 4482 Higher flows in the summer would be beneficial, more wetted perimeter and invert production, if the flows are stable. Would be keeping shoreline wet longer that was already wet; good for invert production. However, would likely reduce availability of suitable habitat for bull trout due to increased velocities. Lower outflows from Hungry Horse in Apr to Jun result in very minimal change in Flathead River, because still release to meet minimum in-stream flows.	Dry - much higher in May, much lower in Jun, slightly lower through Jul to Sep. (900 cfs minimum flows through much of Jun. Ave - much lower early May, higher late May, lower Jun Wet - Much higher Jan to Feb, much lower early May, higher late May, lower Jun Jan flows: More fluctuations between high flows and low flows would disrupt the production of aquatic inverts every time flows are increased for a time and then dropped again. Drops in Jan to Feb, Apr to May, May to Jun, Jun to Jul. Much higher flows in late May would likely push out juvenile forage fish, and result in less habitat available for bull trout and westslope cutthroat trout.	Similar to MO1.	Dry – Jul drops steeply from NAA, Jul-Sep higher Ave – Jul-Sep about 500 cfs higher than NAA. Wet – same as MO1, lower Feb-Apr, higher Jul-Sep Jul +11%, +400 cfs Aug +37%, +1000 cfs Sep +37%, +1000 cfs Wet/Ave similar to MO1, slightly higher magnitude. Dry year - steep dip in mid-Jun would "reset" the bio productivity in Jun as the South Fork Flathead River would drop. It would take until (60 to 90 days) Aug to reset the biota and recover to be food source for fish. By then, the time period for fish growth would be almost over. In summer months, South Fork effects: departs further from normative flows, reduces amount of low velocity habitat available. IFIM shows reduction of habitat due to velocity. Suckers - juveniles in August, flushed downstream, reduce bull trout food source. Summer in riffles is young-of-year or yearling	Mitigation: Didymo research - reducing didymo, it displaces aquatic inverts. Reducing would increase food supply for fish. Create back-channel habitat for juvenile bull trout, create trout rearing habitat. Creston National Fish Hatchery - funding for bull trout conservation (Hungry Horse mitigation in NAA?). Public interest in species - opportunities to increase awareness and allow bull trout harvestable populations. Redirect harvest - grow and take fisheries for cutthroat in small lakes in area. Mitigation - smooth out the drop in June, fail to refill but would be better to not drop flows. Avoid short-term flow reductions to avoid dewatering benthos.

Affected Environment Important Relationships / Criteria	Environmental Consequences Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
						mountain whitefish; these could get flushed out. Riffle habitat is important.	
Within day fluctuations in the river and day to day. Short-term flow reduction to productivity. Takes time after coming back up for productivity to return.	Review measures in alternatives to detect if any increase in fluctuations would be expected. Daily discharge data, Jun to Sep.	Flow gauge data; and examine measures. Food resources are still impacted by day to day and within-day fluctuations.	Similar to NAA.	Ramping rates for safety would remove ramping rate restrictions put in place to protect fish. Treaty has good qualitative discussion of ramping effects. Additional fluctuations would decrease food production.	Same as MO2.	Same as NAA.	–
Water temperatures affect habitat suitability and competition with lake trout and northern pm. Selective withdrawal restores temperature regime to near-natural seasonal temperatures. This benefits growth potential and food production. Designed to operate at a specific range of elevations.	See above. Ability to operate selective withdrawal.	Not readily available - but through agreements water temperature is kept between 10°C and 15°C during SWS operations - suitable for BT and other native fish and similar to SF and NF flows. Difficult to meet temp targets until mid-summer in high flow years. Low flow years easier to meet temperature targets sooner. Typically release > minimum in South Fork Flathead to meet Columbia Falls minimums. Exception in flood emergency, can reduce to spin/no-load flows of 1 turbine.	From water quality presentation – all elevations within ability to operate. No change to temperature expected. Same as NAA.	Increased flows in Jan. Likely to warm the South Fork in the winter.	Same as MO1.	No change.	Design specifications for selective withdrawal range of operations. Dennis Christenson publications. All alternatives will continue to use the SWS, which can only operate until late fall/early winter. Lake trout used to inhabit South Fork Flathead, when water temperature reaches 14°C the lake trout move back out. Natural temperature regime is conducive to native fish.
Flathead River (South Fork Confluence to Flathead Lake)							
–	–	From South Fork confluence to mouth is 47 miles of habitat, but up to about 20 miles is controlled by lake effect (Flathead Lake). Relationships below can influence Flathead River conditions that could affect the balance of native/non-native spp. Conditions for invasive non-native fish; they are more tolerant of degraded water quality than bull trout. Could be indirect effect if skews conditions towards non-natives.	–	–	–	–	–

Affected Environment Important Relationships / Criteria	Environmental Consequences Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Flows in summer affect availability of suitable habitat (IFIM). Higher than normative summer flows can create velocities too high for suitable habitat.	Hungry Horse outflows and Columbia Falls elevations.	Summer flow augmentation creates higher summer flows leads to reduction in juvenile and adult bull trout habitat (also westslope cutthroat trout). Winter: bull trout in deep at day, then into shallows at night to feed. Westslope cutthroat trout don't do diel movement likely bull trout do. Move with insect hatches.	Similar to NAA (just slightly higher in Aug, otherwise very similar).	Same as NAA.	Same as MO1.	–	–
Winter flows currently higher than natural; higher winter flows affect reestablishment of riparian vegetation leads to less shoreline habitat for all fish. Winter flows – ice formation…lower river freezes now. 39°F to 41°F water releases from Hungry Horse. Under-ice refugia for bull trout.	Hungry Horse outflows.	Winter flows about 2,100 cfs to 2,700 cfs.	Wet years, lower flows in Feb.	Higher winter flows. High winter flows could limit cottonwood regeneration if Jan flows scour, but observed that the Jan increase would be below the elevation where cottonwoods would be establishing.	–	–	–
Decreased spring runoff peak leads to less frequent channel maintenance flows from South Fork Flathead. Also important for riparian recruitment. Cottonwood recruitment in lake-influenced portion of the river.	Hungry Horse outflows	See flow comparison to determine need for additional analyses. Peak about 30,250. Woody material and gravel recruitment would continue to be impeded by Hungry Horse Dam; downstream effects - minor effect to bull trout but maybe for other resident fish. Interstitial spaces for inverts (benthic production)	Same as NAA.	Slightly higher flow peak in May; at Columbia Falls - 32,954 peak MO2, compared to 30,248 peak in NAA (about 2700 cfs or 8% higher) Higher than NAA peak flows could provide better channel maintenance.	–	–	–
Temperature effects. Temperature benefits of selective withdrawal in summer, but not in winter when South Fork contribution to flow is disproportionately high.	Hungry Horse outflows	See outflow comparison. Current contribution of South Fork flows results in some warming in winter.	Slightly lower outflows in winter, with less temperature influence.	Increased South Fork flows contribution in winter could warm the Flathead River. Predominant trout is rainbow hybrid. Could increase productivity and metabolism of resident fish disproportionately to migratory native bull trout and westslope cutthroat trout. Under NAA, South Fork is about 60% of flow, and 8-10°F Flathead flows. MO2 would increase South Fork contribution; warming the Flathead River. Example: stoneflies emerge too soon when freezing out.	–	–	–

Affected Environment Important Relationships / Criteria	Environmental Consequences Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
TDG – High TDG levels can cause health effects to fish.	–	TDG at South Fork Flathead typically tops out at 117%, downstream stays near bank, and mixes about Teakettle Bridge. Affects habitat suitability for bull trout. Spring spill would continue, continued TDG elevated to up to about 117%.	No change. Same as NAA.	Reduced TDG. See water quality presentation. No change from NAA to fish.	–	–	–
Potential increase of effect of lake erosion at top of Flathead Lake could be affected by Hungry Horse outflows. Negligible water quality effects, but look at outflows changes to water quality.	Flathead River 96.816, 111.984, and 120.403.	See hydrographs. Upper area of lake where river meets. Bull trout, subadults and adults hang out there. Northern pike and bass. Sloughs and lower river could be transitory for lake trout.	Same as NAA.	Jan timing would not affect erosion. As modeled, no effects. Could potentially see changes in lake elevations if SKQ operations don't pass through flows as modeled.	–	–	–
Flathead Lake/Lower Flathead River							
–	–	Live in Flathead Lake, migrate to tributaries of North Fork and Middle Fork Flathead "and occasionally in SF". Early summer from lake into river staging areas; into spawning tributaries in Aug, spawn Sep, then back to Flathead Lake (fluvial), or Flathead River (adfluvial). 4 to 5 years in lake, stage and spawn in tributaries to Flathead River upstream of lake, most go back to lake and some in river. Mostly 3- to 4-year-olds.	–	–	–	–	–
Operations of SKQ could change in relation to different inflow regimes. Changes in winter flows could affect rearing fish in lower Flathead River below SKQ.	SKQ outflows	See summary hydrograph. Stable winter base flows, about 7,700 cfs in Jan. Under NAA, spring flows are greatly diminished. Cumulative effects: Up to 90K out of Hungry Horse for water supply measure may decrease diversions in tributary streams. Providing this water will help restore more normative flows in those tributaries for huge benefits in tributaries. CSKT water compact. Not a direct or indirect effect. Check with Jen for water supply language. Note: Pike currently are near atretic when lake levels come up far enough for them to get into	Not biologically noticeable, happens in high flows. Potential - smallmouth bass spawning time. Modeled that all inflows passed through in outflows, but in real operations some inflows could be captured and released differently. If operated as modeled, no effect.	Higher late May, lower Jun Higher Jan 3400 cfs higher at base flow conditions.) 10%, 9% lower outflows (SKQ) in May and Jun. Increased Jan flows: Stress from flow changes would cause fish movement, they would move into newly flooded shallows that would not have food available. Negatively affect fish, primarily juveniles. Need appropriate ramping rates on ramping down. When flows come back to base in Feb, not as much of an effect, but stressed from displacement. Fish in lower Flathead River, flows reduced by 9% to 10% likely not	Same as MO1.	Aug:+12% Sept: +7% SKQ operations: would ops change with increased inflows in summer. Assume no change in operations. May actually mimic more natural hydrograph in MO4 (higher summer, lower winter).	Hungry Horse: Assume same operations of SKQ, if more summer inflow causes them to change operations with more water for power generation it could cause some changes we'd need to look at. Check also - flood stage change at Columbia Falls gauge. Assumes ramping rates at SKQ still apply. Likely no effects to thermodynamics in Flathead Lake, volume is large, and time of year (cold water to cold water). Likely no effect to shoreline erosion, water. Potential effect to riparian regeneration? If flows up for a month, could get hanging ice,

Affected Environment Important Relationships / Criteria	Environmental Consequences Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		bays and spawn. Any delay in lake refill could reduce spawning success for pike.		biologically noticeable. More dominated by non-natives, but bull trout and westslope cutthroat trout are there.			used to do peaking; the up and down freezing over shorter period caused ice stacking that damaged riparian vegetation. Not likely in this case. Cottonwood regeneration issue - already happens under NAA. SKQ already operated higher in winter, additional flow could exacerbate the issue. (note for cumulative effects). Already altered hydrograph, native fish likely cue on the tributary hydrograph (not affected by the alternative).
Entrainment through SKQ Dam? Factors affecting? Effect to Flathead Lake populations? No data on entrainment, but assume fairly insignificant.	Flows/discharge	Bull trout in Flathead Lake are likely entrained through Kerr Dam or migrate up from Clark Fork. Warmest water in lake in summer goes in, warmest water out SKQ, but no changes to elevations or SKQ operations; should not change. Could be mixed age populations in winter. USFWS concerns about irrigation pump in forebay of dam.	Slightly less outflow in May/Jun. Likely no fish in area of dam at this time. No effect.	Higher late May, lower Jun Higher Jan (3400 cfs higher in Jan) Fish would be in the area near the dam in Jan. Temps favorable. Entrainment would expect to increase with higher outflows. If entrained, lost from population and would not be a part of any other population. Lost from Middle Fork and North Fork Flathead (tributary populations). Lower outflows in May/Jun would be when bull trout and westslope cutthroat trout are not in the area of the dam.	Same as MO1.	Same as MO1. Potentially increased entrainment of temp tolerant fish (smallmouth bass, pike, etc.) Only 14.5 kcfs is turbine, the rest in spill. Expect increased spill, surface. May further increase habitat for non-native fish.	Bull trout not there. Bottom lobe near the outlet is shallow, keeps too warm in summer and fall, but in Jan they could get down towards the dam.
Mysis – supports lake trout populations. Do not expect important relationship here, but think through Hungry Horse outflows.	Hungry Horse outflows	NA	NA	NA	NA	NA	NOTE: No change in alternatives. Noted here that the team considered it.
Temperature in Flathead Lake? Do not expect temperature changes due to operations. Add basic temperature baseline info.	Inflow volume, temperature from water quality.	No temperature of North and Middle Fork, have selective withdrawal on South Fork, so only temperature difference would come from volume changes. Expect very minor. Diluted by Stillwater, Swan, etc. Temps in Flathead Lake support bull trout FMO.	Same as NAA.	Same as NAA.	Same as NAA.	Same as NAA.	NA

Affected Environment Important Relationships / Criteria	Environmental Consequences Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Clark Fork River							
–	–	Fragmentation by Clark Fork hydro dams results in isolated populations and reservoir environments favor non-native species. Less than 100 spawning adult population in Jocko. Mission Creek used as migratory corridor. Bull trout passage improvements at Cabinet Gorge are underway (currently trap and haul, planned passage), and there is passage at Thompson Falls.	–	–	–	–	–
Flows can affect spawning habitat for smallmouth and pike. Increased flows in summer could increase spawning habitat. Lower summer flows decrease spawning habitat.	Flathead River 11.506, any Clark Fork near Plains.	Higher summer flows could increase spawning habitat for non-natives. Below Thompson Falls in Lake Pend Oreille influenced.	Same as NAA.	See above for changes. Higher Jan, lower May/Jun. Likely no effect to non-native predators.	Same as NAA.	Higher summer flows could increase pike, smallmouth habitat. Favor non-native fish.	NA
Flows affect downstream flushing of northern pike and walleye from Noxon and Cabinet Gorge reservoirs.	Clark Fork 31.41	NAA would continue some level of flushing pike and walleye downstream. Analyze any increases in flow.	Similar to NAA	Slightly lower May/Jun. Likely no effects from higher winter flows; potentially slightly less flushing in spring flows if lower May/June. Fry and Juveniles get flushed with spring pulses. Cabinet Gorge and Noxon both ice over, wouldn't expect any flushing.	Similar to NAA.	Aug +12% Sept +7% Any increase could pass more fish, expect some increase in entrainment. The bigger issue is big spring flows when they've seen increase in pike - juveniles get flushed. This increase in later summer flows likely not a big increase in juvenile flushing.	N/A
Effects to trap and transport at Cabinet Gorge.	Clark Fork 31.41	See Summary hydrograph at Clark Fork 31.41	Slight difference in Dec in 1%, otherwise similar to NAA.	Winter Flow changes attenuated to less than 2 inches at this gauge.	Similar to NAA.	0.3 to 0.5 feet lower than NAA in Mar/Apr. Water surface elevations increases in Aug, Sep. About 4 feet higher. Lower elevations in Mar/Apr reduce pike spawning success in lower Flathead.	N/A

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5344 **Table 3-70. Flathead/Clark Fork Qualitative Effects Analysis Matrix Part 2**

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences H&H and Water Quality Outputs	Environmental Consequences Effects to Resource NAA	Environmental Consequences Notes	Citations
Westslope Cutthroat Trout					
Hungry Horse Reservoir					
Tributary Access/Varial Zone	Water surface elevation at forebay.	Water surface elevation during winter/spring? Not sure when they move out of the reservoir.	–	No issues for bull trout same for westslope cutthroat trout? "The South Fork represents the largest connected population of migratory, genetically unaltered westslope cutthroat trout left in the United States." Since they move out, probably during refill operations, I would think reservoir elevations would be okay.	file://C:/Users/pdruliner/Downloads/02_SouthForkFlatheadRiver.pdf
Entrainment	Unknown	Unknown	–	Probably not an issue given the statement above.	–
Competition	Chance of full pool lake elevation in Jul.	Full pool is 3560|Hungry Horse elevation duration monthly | For Jul|50% = 3559.17|60% = 3558.59|70% = 3557.36|80% = 3557.70|90% = 3552.97	Current management is to try to reach full pool (Elevation 3560?) by early summer to provide adequate primary productivity. There would be a 50% chance of elevations being within about a foot of reaching full pool and remaining there for the month of July, a 60% chance of exceeding 3558.7 feet, at 70% chance of exceeding 3557.4, an 80% chance of exceeding 3555.7 feet and a 90% chance of exceeding 3553 feet. This would continue to provide an adequate food source for winter supply of zooplankton that fuels the food web.	Our operations are not going to influence competition for NAA.	–
Spawning Areas	–	–	–	No spawning in reservoir.	–
Migration/Barriers	–	–	–	Other than the dam, likely none.	–
Water Temperature	–	–	–	No known issues.	–
Food/Productivity of Reservoir	–	–	–	Lake bull trout, probably fine.	–
Elevation can influence exposure to angling exploitation and predation by bull trout on westslope cutthroat trout. If full in summer, not as much issue with current draft in summer increases exposure in bays where tributaries enter reservoir.	Reservoir draft in spring; change in elevation from full pool.	About 10-foot drop (3560 to 3550).|Jul 1: 3560 feet|Sep 30: 3540 feet	–	Years with 20-foot drafts and do not reach full (overestimate inflow forecast) is when this is an issue.	–
Access to spawning areas can be affected by spring reservoir levels. At elevation XX (Brian provide), access to spawning tributaries is cut off.	Percent exceedance Hungry Horse elevation at or above XX during mid-Apr to end of Jun.	–	Lake levels would continue to provide access to spawning tributaries.	Spawn in tributaries above Hungry Horse and the South Fork Flathead upstream of reservoir. Tributaries have been "fixed," with culvert replacements or baffles: improved passage. Westslope cutthroat trout spawn in numerous tributaries above Hungry Horse Reservoir.	–
Water temperatures affect habitat suitability – surface elevation affects thermal structure of pool; fish seek preferred temperatures; volume of	Hungry Horse elevations; mid Jun through Sep.	–	–	Applies the same as bull trout.	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences H&H and Water Quality Outputs	Environmental Consequences Effects to Resource NAA	Environmental Consequences Notes	Citations
temperature range affects amount of habitat available.					
Loss due to entrainment? Could be increased entrainment if outflow is increased.	Outflows	–	NAA: Entrainment is not a problem and not expected to be (see notes)	Although there may be entrainment occurring, no data or studies to determine how much or at what flows/outlets. It is not known to affect the South Fork populations in the reservoir and tributaries. Possible scenarios – concentration of food sources near the outlet could make them more susceptible. Shape of dam – most species immersal (littoral) and the intakes are out to the sides. If any alternatives alter the thermal structure so it concentrates westslope cutthroat trout near the outlets, it could be an issue. Vertical sonar indicated no targets near outlets for selective withdrawal. When entrainment does occur, it is relative to discharge volume and depth of withdrawal. Westslope cutthroat trout did not go to depth like bull trout (Montana Fish, Wildlife, and Parks, unpublished data), so not as susceptible to predation.	Cavigli reports for zooplankton entrainment.
Zooplankton entrainment was considered, not an issue. Selective withdrawal can increase zooplankton entrainment. Changes in lake levels could exacerbate this issue.	–	–	–	Zooplankton cells become denser with less volume, so less volume could result in increased entrainment of zooplankton and reduced food supply in Hungry Horse.	See BPA reports.
Maximum elevation draft in one year affects insect larvae production the following year.	Maximum drawdown – typically in mid-Apr.	Median 3520 feet.	–	The deeper the maximum drawdown, the worse the spring food supply from benthic productivity.	–
Maximum lake elevation.	Maximum lake elevation.	–	Current management try to reach full pool.	Biologically productive warm months, want the reservoir as full as possible. Gives large body of warm euphotic zone for primary production. Zooplankton production (for winter food), summer food is terrestrial insect.	–
Shape of refill/drawdown. Gradual slopes maximize productivity (even if fail to fill) compared to fast refill or drawdown just to "touch" full.	Rate of refill to full pool, duration at/near full before drawdown. Duration at maximum elevation.	–	–	Fast filling/drawdown retards productivity. Even at full pool, the substrate is wet but needs to wet 5 to 7 weeks in order to be productive – populate with plans, then inverts move in. If dewater before this process completes, there is no benefit to production.	–
South Fork below Hungry Horse					
Tributary access/varial zone/for spawning	Outflow/discharge	H&H winter-summer hydrographs?	Probably little	Is this a known concern from MFWP?	
Entrainment	–	–	–	Same as bull trout – unknown degree.	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences H&H and Water Quality Outputs	Environmental Consequences Effects to Resource NAA	Environmental Consequences Notes	Citations
Competition	Water temperature	–	–	SWS has positive effect of limiting numbers of lake trout.	–
Migration Barriers	–	–	–	NA?	–
Water temperature	–	–	–	Okay with SWS	–
TDG	–	–	–	–	–
Water Quality/didymo	–	–	–	–	–
Food/Productivity of River	–	–	–	–	–
South Fork Flathead River below Hungry Horse					
–	–	–	–	South Fork Flathead River use by westslope cutthroat trout – densities in South Fork Flathead River are high, most likely come up from Flathead River and return there when temperature control are not operating.	–
Ramping rates affect fish below Hungry Horse and cause westslope cutthroat trout to leave (BPA report, Matt send…2004-05?) displacement by operations with substantial fluctuations is flow. (Not an issue with NAA.)	Hungry Horse outflows; day-to-day fluctuations, percent change from day to day or week to week.	–	NAA operations are designed to avoid this issue.	Show examples of when fluctuations affect fish.	–
Within day fluctuations in the river and day to day. Short-term flow reduction to productivity; takes time after coming back up for productivity to return.	Review measures in alternatives to detect if any increase in fluctuations would be expected. Daily discharge data, Jun to Sep.	Flow gauge data; and examine measures.	Food resources are still impacted by day-to-day and within-day fluctuations.	–	–
Westslope cutthroat trout entrained through Hungry Horse – affected by spill? How? See notes.	We do not know at what flows bull trout are entrained or to what extent – or at what elevation.	–	Any entrainment currently occurring will continue – it has not been identified as a huge issue by USFWS.	Spill occurs in high flow years during spring and early summer. Spillway at Hungry Horse is a glory hole, do not know what is entrained there, or in deep outlet tubes. Spilled water shoots against bedrock, likely no fish survival in entrained in spill.	–
Do we care about didymo? Didymo is present in the South Fork Flathead River, and can cause concerns for native fish by displacing native insects (food source). Community structure – more chironomids. Sloughs, then starts growing again. Can be extensive, but do not know relationships?	–	–	–	Have tried flushing flows. Just flushes the thalweg, not pools or shorelines. Some disturbance has been considered, but not supported by data – just hypotheses.	–
TDG effects. Assume flow > turbine capacity is spill. Likely minimal effect, but increased duration of exposures.	Look at frequency of spill to quality. Detect > TDG potential.	Not readily available, but can use the curves/models developed by Mary Melama and Clyde Lay for the spill test BA and for the Hungry Horse Modernization BA.	See above – elevated above 110 during late spring and early summer during high spill events when spill must occur beyond what the turbines can use. Configurations and operations minimize TDG effects.	Highest TDG has been around 117 (can look at Hungry Horse BA for TDG) – very dependent on air/water temperatures and barometric pressure. Assume any fish in the river is affected downstream to XXX (see Hungry Horse Modernization BA). Downstream gas effects go to Columbia Falls – mixes right above Teakettle Bridge. Have been spilling more with turbines out.	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences H&H and Water Quality Outputs	Environmental Consequences Effects to Resource NAA	Environmental Consequences Notes	Citations
Selective withdrawal restores temperature regime to near-natural seasonal temps. This benefits growth potential and food production. Designed to operate at a specific range of elevations.	Ability to operate selective withdrawal.	–	–	Lake trout used to inhabit South Fork Flathead, when water temperature reaches 14°C the lake trout move back out. Natural temperature regime conducive to native fish.	Design specifications for selective withdrawal range of operations. Dennis Christenson publications – Brian send.
Water temperatures affect habitat suitability and competition with lake trout and northern pikeminnow.	See above.	Not readily available but, through agreements, water temperature is kept between 10°C and 15°C during SWS operations. Suitable for bull trout and other native fish, and similar to South Fork and North Fork flows.	–	All alternatives will continue to use the SWS, which can only operate until late fall/early winter.	–
Is water volume/flow a concern – available habitat? (See below.)	Flows – water volume during late summer.	–	–	Bull trout would likely use the river below Hungry Horse during what months? Oct through Jul? Year-round? They are just visitors here.	–
Minimum in-stream flows 400 cfs to 900 cfs on sliding scale, based on water availability. Most critical to meet South Fork minimums during spring runoff (otherwise are met automatically to provide to Columbia Falls).	–	–	–	–	–
–	Hungry Horse outflows – ability to meet in-stream flows in spring	–	–	Typically release > minimum in South Fork Flathead to meet Columbia Falls minimum. Exception in flood emergency, can reduce to spin/no-load flows of 1 turbine.	–
Use by Flathead River fish. How affected? Important?	–	–	–	Note: AE says no documentation of spawning in one paragraph, but "occasionally in the South Fork Flathead River" in next paragraph. Help? (Pam: no spawning tributaries below Hungry Horse to the confluence). Workshop – no, no spawning fix in AF.	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences H&H and Water Quality Outputs	Environmental Consequences Effects to Resource NAA	Environmental Consequences Notes	Citations
Native Fish Community					
Hungry Horse Reservoir					
Hungry Horse Reservoir primarily native fish community (westslope cutthroat trout, mountain whitefish, bull trout) isolated by Hungry Horse Dam from non-native species downstream. Only non-native is Arctic grayling.	–	–	–	Notes from Subbasin Assessment (year 2004): Unnaturally high flows during summer and winter negatively impact resident fish. Summer flow augmentation causes reservoirs to be drafted during the biologically productive summer months. This impacts productivity in the reservoirs. Drafting the reservoirs too hard prior to receiving the Jan 1 inflow forecast places the reservoirs at a disadvantage for reservoir refill. This is especially important during less-than-average water years. Flow fluctuations caused by power, flood control, or fish flows create a wide varial zone in the river, which becomes biologically unproductive.	–
Mountain whitefish migrate up system to spawn – same as westslope cutthroat trout issues.	–	–	–	The planned reservoir refill date in the NOAA Fisheries BiOp of Jun 30 will cause the dam to spill in roughly the highest 30% of water years. This is because inflows remain above turbine capacity into Jul on high years. That means the reservoirs fill and have no remaining capacity to control spill, which causes gas supersaturation problems.	–
Northern pikeminnow, largescale and longnose suckers, sculpins – mostly tributary production.	–	–	–	Flow fluctuations caused by power, flood control, or fish flows cause sediments to build up in river cobbles. Before dams were built, these sediments normally deposited themselves in floodplain zones that provided the seedbeds necessary for the establishment of willow, cottonwood, and other riparian plant communities. Young cottonwood stands are needed to replace mature stands being lost to natural stand aging, as well as adverse human activities such as hardwood logging and land clearing.	–
Northern pikeminnow predation in shallow water, suspect spawning. Dewatering of bays in early summer could affect spawning success by dewatering.	–	–	–	–	–
Varial zones drawdown during migration periods can increase exposure of native fish to predation (birds, mammals, etc.).	Hungry Horse elevations, Apr to Jul.	–	–	Adults upstream: May to Jun	–
Emigration juveniles: Jun to Jul	–	–	–	–	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences H&H and Water Quality Outputs	Environmental Consequences Effects to Resource NAA	Environmental Consequences Notes	Citations
South Fork Flathead River below Hungry Horse					
Temperature control operations control lake trout interactions.	–	–	–	Can come up in late fall and winter. In Jul, when native fish coming out of natal tributaries, lake trout have moved out due to temperature control.	–
Unnaturally high flows in summer.	–	–	–	–	–
Altered hydrograph that impacts riparian vegetation.	–	–	–	–	–
Flood control or fish flows that affect sediment/deposition and transport.	–	–	–	–	–
TDG	–	–	–	–	–
Competition with non-native (lake trout)	–	–	–	–	–
Water temperatures	–	–	–	–	–
Flathead River – same relationships as South Fork, just attenuated by downstream and addition of flathead flows.	–	–	–	Pygmy whitefish in Flathead River may make a spawning run	–
Flathead Lake (see bull trout section)					
Anything in operations that impacts productivity?	–	–	–	–	–
Temperature?	–	–	–	–	–
Shrimpies	–	–	–	–	–
Competition with non-native (lake trout) – Clark Fork	Clark Fork	–	–	Temperature and flow effects may tip the scales towards non-native populations from the reservoir.	–
Game Fish					
Flathead Lake (important game fish are westslope cutthroat trout and bull trout – covered in their own sections)	–	–	–	–	–
–	Flathead River 79.431 and/or 96.816	–	–	Potential temperature or lake level effects. Very low chance of any effects due to project operations, but look at Hungry Horse Dam in Flathead Lake for an potential effects.	–
Perch – spawning, aquatic vegetation, changing elevations? Likely not enough to make any change, dewater eggs, etc., not an issue.	–	–	–	–	–
Lake whitefish – dependent on good perch spawn.	–	–	–	–	–
Smallmouth Bass	–	–	–	–	–
Lake trout	–	–	–	–	–
Northern Pike	–	–	–	–	–
Potentially, walleye	–	–	–	–	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences H&H and Water Quality Outputs	Environmental Consequences Effects to Resource NAA	Environmental Consequences Notes	Citations
Kokanee					
Flathead Lake					
In Flathead Lake, there used to be kokanee, but this collapsed due to mysis and lake trout interactions.	Flathead River 79.431 and/or 96.816.				

The table of end of month elevations was summarized from outputs of the hydrology modeling. This information was used in qualitative discussions, as well as an input to figuring the end of month euphotic zone and surface area.

Table 3-71. End of Month Elevations (ft) of Hungry Horse Reservoir

Month	NAA Wet	NAA Dry	NAA Avg	MO1 Wet	MO1 Dry	MO1 Avg	MO2 Wet	MO2 Dry	MO2 Avg	MO3 Wet	MO3 Dry	MO3 Avg	MO4 Wet	MO4 Dry	MO4Avg
October	3546	3546	3547	3542	3541	3541	3546	3546	3547	3541	3538	3541	3541	3538	3541
November	3544	3541	3546	3538	3536	3538	3544	3542	3546	3538	3535	3538	3538	3535	3538
December	3542	3536	3544	3534	3531	3536	3542	3536	3544	3533	3531	3534	3533	3531	3535
January	3534	3530	3538	3531	3525	3532	3527	3530	3528	3529	3524	3530	3531	3524	3530
February	3522	3524	3531	3519	3519	3526	3508	3524	3521	3519	3518	3526	3519	3518	3526
March	3498	3522	3526	3497	3514	3521	3486	3521	3516	3497	3514	3520	3497	3514	3520
April	3477	3528	3522	3477	3521	3519	3473	3528	3516	3478	3520	3518	3477	3520	3518
May	3511	3550	3541	3511	3545	3539	3507	3542	3538	3511	3544	3539	3511	3544	3538
June	3553	3559	3559	3553	3557	3559	3554	3555	3558	3554	3556	3559	3553	3550	3558
July	3559	3554	3559	3559	3553	3558	3560	3554	3559	3559	3553	3558	3559	3547	3557
August	3555	3547	3555	3553	3546	3552	3556	3549	3555	3553	3546	3552	3553	3539	3551
September	3550	3540	3550	3546	3539	3546	3550	3544	3550	3546	3539	3546	3546	3530	3546

To calculate euphotic zone, the team first found the total volume of the reservoir at the end of each month using known volumes at elevations for Hungry Horse Reservoir. The depth of productive zone was calculated by finding the total reservoir volume at the end of each month from the previous calculation and subtracting the volume of non-productive depth. The depth of the euphotic zone varies by month, getting deeper through the summer months; the following depths were used in calculations:

- May: 30 feet
- June: 30 feet
- July: 50 feet
- August: 70 feet
- September: 80 feet

Table 3-72. End of Month Euphotic Zone (Acre-Feet)

Month	NAA Wet	NAA Dry	NAA Avg	MO1 Wet	MO1 Dry	MO1 Avg	MO2 Wet	MO2 Dry	MO2 Avg	MO3 Wet	MO3 Dry	MO3 Avg	MO4 Wet	MO4 Dry	MO4 Avg
October	1456748	1456829	1464916	1420897	1413025	1416882	1457316	1456829	1467252	1416547	1391075	1414284	1416547	1390064	1414284
November	617552	609341	624264	599096	592718	600836	618031	612035	624264	598916	590271	600235	598916	590271	599965
December	612005	592386	616531	588547	578843	592869	613023	592266	617011	585452	578504	588819	585816	578504	591572
January	588335	574386	600356	578411	558132	580288	564744	574510	570309	573700	557161	576495	577578	557161	576372
February	549502	557698	579704	540009	538194	562007	500826	557430	546977	538997	535164	561579	538229	535303	561612

Month	NAA Wet	NAA Dry	NAA Avg	MO1 Wet	MO1 Dry	MO1 Avg	MO2 Wet	MO2 Dry	MO2 Avg	MO3 Wet	MO3 Dry	MO3 Avg	MO4 Wet	MO4 Dry	MO4 Avg
March	472877	548639	561052	471344	522332	544230	438764	545518	527017	471400	520616	543952	471037	520885	543116
April	411772	569929	549812	412334	546700	537252	397605	569897	529385	413084	543917	536451	412334	543917	535686
May	510997	635389	607725	511157	619474	602304	498724	611766	598556	513272	618512	602036	511190	617821	600596
June	645447	662074	662913	645478	657843	662447	647851	651718	660706	646894	654918	662602	645478	636425	661733
July	1057686	1030354	1055107	1056069	1027234	1051713	1059048	1027593	1056170	1056271	1026671	1051814	1056018	991584	1047599
August	1376345	1316650	1371494	1360008	1309545	1354349	1377094	1327884	1372238	1360008	1308624	1354422	1359787	1256439	1341887
September	1489407	1408156	1489248	1457154	1396713	1456991	1489487	1437925	1489327	1457154	1395537	1456991	1457154	1249532	1452356

5357 **Table 3-73. End of month Surface Area Table**

Month	NAA Wet	NAA Dry	NAA Avg	MO1 Wet	MO1 Dry	MO1 Avg	MO2 Wet	MO2 Dry	MO2 Avg	MO3 Wet	MO3 Dry	MO3 Avg	MO4 Wet	MO4 Dry	MO4 Avg
October	22345	22345	22448	21936	21833	21833	22345	22345	22448	21833	21527	21833	21833	21527	21833
November	22140	21833	22345	21527	21322	21527	22140	21935	22345	21527	21220	21527	21527	21220	21527
December	21935	21322	22140	21119	20812	21322	21935	21322	22140	21017	20812	21119	21017	20812	21221
January	21119	20710	21527	20812	19522	20812	20312	20710	20511	20611	20113	20710	20812	20113	20710
February	19913	20113	20812	19618	19522	20212	18409	20113	19814	19618	19426	20212	19522	19522	20212
March	17388	19913	20212	17280	19138	19714	16126	19714	19234	17280	19042	19714	17280	19042	19714
April	15213	20511	19913	15213	19814	19522	14674	20511	19330	15213	19714	19522	15213	19714	19522
May	18754	22652	21833	18754	22140	21527	18294	21935	21527	18850	22140	21527	18754	22140	21527
June	23072	23602	23602	23072	23496	23602	23072	23284	23602	23072	23390	23602	23072	22755	23602
July	23707	23178	23602	23707	23072	23602	23707	23072	23707	23707	23072	23602	23707	22345	23496
August	23284	22448	23178	23072	22345	22967	23284	22550	23178	23072	22345	22967	23072	21527	22755
September	22755	21731	22755	22345	21527	22345	22755	22140	22755	22345	21527	22345	22345	20710	22243

5358 **PEND OREILLE**

5359 **Table 3-74. Columbia River Pend Oreille Regional Qualitative Effects Analysis Matrix**

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Lake Pend Oreille Bull Trout							
Temperatures over 15°C are limiting to bull trout distributions.	Temperatures in FMO habitat from November through June.	Nov through Jun (when bull trout are present) surface temperatures range from 4°C to 15°C, while deepwater (>20 meters) temperatures rarely exceed 15°C. Cold water habitats occur year round, while surface water temperatures from Jun through Oct may be too warm for bull trout. Under the NAA, Lake Pend Oreille deepwater temperatures are suitable for bull trout year round, while shallow water supports bull trout from Nov through Jun.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA. There are no changes to operations expected at Albeni Falls Dam for median and high water years under MO4. For the drier 40 percent of years, Lake Pend Oreille will be around 2.5 feet lower in the summer due to higher outflows from Albeni Falls Dam. Due to this change, it is possible that higher summer flows might increase or decrease the temperature (±0.9°F to 1.8°F) in the Pend Oreille River, depending on flow and weather conditions.	Surface water releases from Albeni Falls Dam exceed 20°C (68°F) from early Jul through late Sep. Any fish entrained will be lost to the system. USFWS 2015, Water Quality Appendix 7-3.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Entrainment – increased flows could increase bull trout entrainment through Albeni Falls Dam.	Albeni Falls outflow from Mar through Jun.	Entrainment most common in Mar through June when flows are high. Mean flows in Mar through Jun = 37,815 cfs Under current conditions, an unknown number of bull trout are entrained through Albeni Falls Dam and lost to the system. Under the NAA, this is likely to continue.	No difference from NAA. Hydrograph from MO1 overlays NAA hydrograph. Mean flows from Mar through Jun = 37,329 cfs (-486 ~ 1.3%).	Slightly lower flows in Mar through Jun would decrease risk of entrainment for MO2 compared to NAA. Mean flows from Mar through Jun = 36,912 cfs (-903 ~ 2.4%).	No difference from NAA. Hydrograph from MO3 nearly overlays NAA hydrograph. Mean flows from Mar through Jun = 37,257 cfs (-558 ~ 1.5%).	No difference from NAA. Hydrograph from MO3 nearly overlays the NAA hydrograph. Mean flows from Mar through Jun = 37,447 cfs (-118 ~ 0.3%).	Bull trout are likely headed downstream for winter migrations naturally in Oct and Nov. Electroshocking surveys used to capture bull trout that have been entrained through Albeni Falls Dam, but capture efficiency is very low. These data are only good for presence/ absence of bull trout. May affect Priest River fish that head downstream and are lost. Most within Lake Pend Oreille are large enough populations, but probably without large genetic effects. If fish trap and haul is completed at Albeni Falls Dam, potential to reduce entrainment. Kalispel Tribe and EWU may have numbers. Corps, 2018. Normandeau, 2014.
Bull trout need robust kokanee populations for adequate forage. (See kokanee for effects).	Kokanee numbers.	Kokanee increased from ~100 adult fish/ha in 2008 to 377 adults/ha in 2016. Under current conditions, kokanee will continue to provide a good forage base for adult bull trout.	Status of the kokanee population in the future is unknown. There appears to be no difference between MO1 and NAA that would change the future of the kokanee population.	Status of the kokanee population in the future is unknown. There appears to be no difference between MO2 and NAA that would change the future of the kokanee population.	Status of the kokanee population in the future is unknown. There appears to be no difference between MO3 and NAA that would change the future of the kokanee population.	Status of the kokanee population in the future is unknown. There appears to be no difference between MO4 and NAA that would change the future of the kokanee population.	Current operations are good for kokanee populations ~ good for bull trout. This metric does not appear to detect any differences in the alternative. Andy Dux, 2019.
Albeni Falls operations affect sedimentation and erosion from lake shorelines. Could indirectly affect bull trout access to tributary mouths due to sedimentation.	Lake elevations in Sep affect tributary access, and amount of fluctuations.	Lowest elevations (2051) are reached in mid-Nov. Elevations go back up starting in early Apr, and reach full pool on Jul 1. During upstream migrations (May through Sep), water elevations are rising or full (2062). In dry years, there are some sites that may have issues (e.g., Johnson Creek at Clark Fork Delta). Current operations rarely affect tributary access during spring and summer. Operations would continue to provide access to most tributaries under current conditions.	No difference from NAA. Mean elevation in Sep is 2061.6.	No difference from NAA. Mean elevation in Sep is 2061.6.	No difference from NAA. Mean elevation in Sep is 2061.6.	In dry years, MO4 would not reach full pool. Mean elevation in September = 2059.7 ~ 2 feet lower than NAA. On dry years, access to spawning streams may be more limited under MO4 than the NAA.	Indirect effect on bull trout habitat, may alter tributary mouth habitats. Bull trout move into tributaries when lake levels are high during May and June. Gold and Granite Creeks may be more impacted as fish move into these tributaries later in the year. Would drawdown in late September affect access? Future alternatives may change that? Check lake elevations in MOs. Corps, 2018.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Large woody debris are not currently allowed to enter Lake Pend Oreille (boating safety). This habitat is essential to bull trout in stream settings.	Shoreline habitat and woody debris.	A log boom diverts the debris from entering the lake. These are piled on shore. Does this affect topography and shoreline habitat? The loss of woody debris along the shoreline is not likely to negatively impact bull trout, because these were historically found in shallow warm water used only seasonally.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Bull trout need cold water. The debris historically settled out in shallow water habitats not likely to be used by bull trout. Warmer surface temperatures at these sites would benefit warm water species and not bull trout. Important in streams not so much in lakes.
Flexible winter power operations result in changing lake elevations in the winter. Greater range of elevations in winter for power production flexibility allows 5-foot operating range (from 2051 to 2056) – may increase erosion rates.	Nov to Mar lake elevations.	See Albeni Falls operations above. In median years, the models do not project elevation fluctuations. Current operations are not likely to directly adversely affect bull trout. However, winter fluctuations are likely to increase erosion of lake bed at lower elevations ~ 2051 to 2056 and may impact forage fish production.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Outmigration of subadults from Priest River in winter could move downstream and be entrained. Cutthroat trout have been entrained (Fred), could also happen to bull trout. No data are available for fluctuations in the MOs – this metric is not useful in selecting an alternative. Corps and BPA, 2011.
Cabinet Gorge blocked upstream migration of bull trout in 1953. May have lost much of the genetics for that population. Some passage was recently restored through temporary trap and haul (2001). To be replaced by permanent structure in 2018.	Numbers of bull trout passing Cabinet Gorge.	35 bull trout per year are hauled above Cabinet Gorge Dam. See Avista Contacts. Under current conditions, bull trout will continue to have passage above Cabinet Gorge Dam.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Cabinet Gorge efforts for passage, Lake Pend Oreille bull trout historically ran up the Clark Fork River. Cabinet Gorge blocked those runs, but now there is passage again. Annual reports show numbers/percent of fish from upstream populations. This metric is not useful in selecting an alternative as none of the alternatives change access to upstream habitats.
Predation and competition from walleye populations my limit bull trout populations. Walleye forage on kokanee populations. In addition, operations may favor walleye and other warmwater fish during the time that bull trout subadults are migrating downstream into Pend Oreille River through river lake interface. Bull trout can enter the lake until July, when temperatures are too warm.	Walleye populations	Walleye populations are expanding rapidly. From 2011 to 2017, relative abundance doubled every 3 years (citation). Relative abundance numbers (2017 report – Matt). Under current conditions, walleye populations are expected to expand and compete with and prey on adult and subadult bull trout respectively.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Walleye trend increasing, affects bull trout. 2011 to 2017 relative abundance doubled every 3 years. Been at low level for a time, but increasing trend now; in-lake recruitment. Also increasing below Albeni Falls. Entrainment from upriver – suspect with commensurate increase in downstream populations.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Northern pike – predation on bull trout and competition for kokanee.	Northern pike consumption. Metric does not change between alternatives.	Studies in Montana show that northern pike eat bull trout. Bull trout and westslope cutthroat are around 5% of the diet in upriver sites. Northern pike numbers are low and future populations are currently undetermined at this time in Lake Pend Oreille. While northern pike do eat bull trout, their numbers are low in Lake Pend Oreille, and any effect is undetermined.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Pike are present. Rocky Mountain Research station is looking at pike distribution patterns. Entrainment from upstream and in-lake recruitments. Muhlfeld, 2008.
Lake trout compete with bull trout – primarily for kokanee. This predation is not directly affected by project operations, but is included for context.	Lake trout populations	Lake trout harvest also resulted in over 14,000 bull trout being harvested, so it was hard to estimate the benefit from lake trout suppression efforts. Lake trout catch rates are down, kokanee numbers are up (100 to 377 fish/ha), and bull trout redd counts are down. Under the NAA, competition with lake trout will continue at reduced levels and bull trout are likely to persist in Lake Pend Oreille.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Lake trout suppression program 2006 to 2016 – published 2019. Successful in removing lake trout, but bull trout populations still low. Adult kokanee populations increased from 100 fish/ha to 377 fish/ha. Historically negative affected kokanee with dam ops., link to lake trout suppression. Abundance modeling currently showing growth of bull trout populations (Matt). Andy Dux, 2019.
Downstream of Albeni Falls Dam							
Bull trout are scarce below the dam due to habitat limitations in temperature.							
Albeni Falls blocks upstream migration back into the system where temperatures allow survival. Fish entrained into the river below Albeni Falls Dam are lost when temperatures increase in summer. Entrainment is likely highest during spring migration when bull trout are moving and flows are highest.	Entrainment and river water temperature.	Entrainment most common March to June when flows are high. Temperatures over 15°C limit movement, over 20°C can be lethal. River temperatures reach 15°C in June and lethal temperatures in July. Under current conditions, an unknown numbers of bull trout are entrained through Albeni Falls Dam and lost to the system. Under the NAA, this is likely to continue.	No difference from NAA.	No difference from NAA.	No difference NAA.	No difference from NAA.	Very few captured trace back to Lake Pend Oreille tributaries. Reintroduction efforts. Recovery efforts, FERC relicensing. There is now passage at Box Canyon. Corps, 2018.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Northern pike predation. Below Albeni Falls Dam, northern pike have expanded and are apex predators in this system.	Numbers of bull trout entrained into lower river – numbers of northern pike.	Unknown numbers of bull trout are entrained. Pike numbers have increased and are being suppressed (over 17,000 removed since 2012 ~ 90% reduction). Under current conditions, an unknown number of bull trout will continue to be entrained and some may be consumed by northern pike. Not likely to affect as these fish are lost to the lake.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Pike are a big deal below Albeni Falls. Suppression of pike occurring in Box Canyon Reservoir since 2012. These fish experienced exponential growth up to when suppression efforts began. Also began suppression efforts at Boundary Dam.
Temperatures in the lower Pend Oreille River – bull trout may not survive below Albeni Falls Dam during high summer temperatures from June through October. May be thermal refuges in the system.	Water temperature in Pend Oreille River.	Temperature profiles from WQ Appendix show that temperatures between June and October are likely to hit for bull trout in the river section of the lake. Temperatures reach 15°C in June and lethal temperatures by July. Surrogate temperatures from Lake Pend Oreille. Under current conditions, unknown numbers of bull trout are entrained through Albeni Falls Dam and lost to the system. Under the NAA, this is likely to continue.	–	–	–	On dry years, the lake may be as much as 2.5 feet lower for MO4 compared to NAA. Lower water will likely be associated with higher water temperatures. Under MO4, on dry water years, elevated temperatures may exacerbate the current conditions.	LPR river arm near the dam does not stratify so temperatures get hot in the summer before leaving the lake. Water Quality Appendix 7-3.
Walleye expanded in Box Canyon and Boundary Reservoirs, and expected to continue to rise.	Walleye populations	Unknown number of bull trout are entrained. Walleye numbers are expected to rise in Box Canyon and Boundary Reservoirs.	–	–	–	–	–
Unknown number of bull trout will continue to be entrained and some may be consumed by walleye. Not likely to affect.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	This is not likely a driving factor as bull trout cannot survive well in this reach regardless of predator numbers. While numbers of walleye are increasing, they are still relatively low.	–	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Potential indirect effects: Brook trout populations in tributaries could hybridize with bull trout.	Extent of brook trout populations.	Limited brook trout populations in the mainstem habitats. Brook trout locations unrelated to project operations. Brook trout hybridization with bull trout is not likely to be impacted by any of the project alternatives.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	–
Westslope Cutthroat Trout							
Upstream tributary access was blocked in 1953 when Cabinet Gorge Dam was completed. Loss of genetics and habitat. Access was restored in 2016 when limited numbers of westslope cutthroat trout were transported.	Access – number of westslope cutthroat trout passing Cabinet Gorge.	Need number of westslope cutthroat trout allowed upstream of Cabinet Gorge Dam. 40 transported in 2016 and 41 in 2017. Avista, 2017. Unknown numbers of westslope cutthroat trout will continue to gain passage above Cabinet Gorge Dam.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Tributary access was blocked completely. Trap and haul started 2016 (NAA).
Entrainment: Cutthroat trout can be entrained through Albeni Falls, isolated from habitat. Priest River fish overshooting and getting entrained. Westslope cutthroat trout are cued to spawn when water temperatures reach ~ 10°C (Liknes and Graham, 1988) or about May in LPR.	Numbers of westslope cutthroat trout entrained in May and June during migration. Flows in May and June.	Reports of more westslope cutthroat trout from bull trout below Albeni Falls Dam. Genetic map created for identifying fish that should pass. Highest entrainment likely during spring high spill season. Mean flow = 54,442 cfs. Albeni Falls Dam will continue to entrain unknown numbers of westslope cutthroat trout into the Pend Oreille River.	Mean flow = 53,776 cfs. No difference from NAA.	Mean flow = 52,965 cfs ~ 2.7% less flow. No difference from NAA.	Mean flow = 53,705 cfs. No difference from NAA.	No difference from NAA.	Cutthroat found relatively often below Albeni Falls come down out of the lake and don't go up the Priest River system. Genetics work shows Priest origins of entrained fish. Same effect as bull trout. Liknes and Graham, 1988.
River below Albeni Falls Dam							
Walleye expansion in Box Canyon and Boundary Reservoirs expected to forage on and compete with westslope cutthroat trout. Walleye numbers are expected to continue to rise.	Walleye population numbers.	Walleye numbers are expected to rise in Box Canyon and Boundary Reservoirs. Cutthroat in Pend Oreille River are susceptible to predation. Walleye will consume and unknown number of westslope cutthroat trout in the Pend Oreille River.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	This is not likely a driving factor as westslope cutthroat trout cannot survive well in this reach, regardless of predator numbers. While numbers of walleye are increasing, they are still relatively low.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Northern pike predation. Below Albeni Falls Dam, northern pike have expanded and are apex predators in this system.	Numbers of northern pike.	Pike numbers have increased and are being suppressed (over 17,000 removed since 2012 ~ 90% reduction). Cutthroat in the Pend Oreille River are susceptible to predation. Northern pike will consume and unknown numbers of westslope cutthroat trout in the Pend Oreille River.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Pike are a big deal below Albeni Falls. Suppression of pike occurring in Box Canyon Reservoir since 2012, exponential growth up to suppression efforts. Also began suppression efforts at Boundary Dam. This is not likely a driving factor as westslope cutthroat trout cannot survive well in this reach regardless of predator numbers.
Temperatures in lower Pend Oreille River – westslope cutthroat trout may not survive below Albeni Falls Dam during high summer temps (Bear et al., 2007) from June through October. Temperatures over 18°C are limiting for westslope cutthroat trout. Upper lethal temperature is ~20°C. Thermal refuges may be present.	Water temperature in the Pend Oreille River over 18°C.	Temperature profiles from WQ Appendix show that temperatures between June and October are likely too hot for westslope cutthroat trout in the river section of the lake and downstream. Temperatures reach 15°C in June and lethal temperatures by July. Under current conditions in unknown numbers of westslope cutthroat trout are entrained through Albeni Fall Dam and likely lost to the system. Under the NAA, this is likely to continue.	No difference from NAA.	No difference from NAA.	No difference from NAA.	On dry years, the lake may be as much as 2.5 feet lower for MO4 compared to the NAA. Lower water will likely be associated with higher water temperatures. Under MO4, on dry water years, elevated temperatures may exacerbate the current conditions.	The Lake Pend Oreille river arm near the dam does not stratify, so temperatures get hot in the summer before leaving the lake. Resident populations in the tributaries; historically was fluvial or adfluvial component. Now too warm in the summer. No passage to get to thermal refuge in Lake Pend Oreille. Water Quality Appendix 7-3. Bear et al., 2007.
Kokanee							
Kokanee are main forage item for predator fish in Lake Pend Oreille. There are two strains of kokanee – early tributary spawners and late lakeshore spawners. Hatchery programs are used to increase numbers.	–	No relationship. Just species facts.	–	–	–	–	No relationship, just facts about the kokanee populations.
Effect of water level fluctuations on kokanee egg incubation, water level drawdowns during, or shortly after spawning would negatively impact kokanee populations. This metric does not appear to separate the alternatives – suggest deleting.	Pool elevation (Nov to May).	Pool elevations rise from 2052 to 2055 between Nov and May on an average year. Current lake operations do not negatively impact kokanee spawning or egg incubation.	Pool elevations are similar to NAA – no difference from NAA.	Pool elevations are similar to NAA – no difference from NAA.	Pool elevations are similar to NAA – no difference from NAA.	Pool elevations are similar to NAA – during this time, no difference from NAA.	Tried winter elevation changes in tests, did not find a better operation for kokanee. Current lake level management does not negatively affect kokanee. Gets lake levels down before kokanee spawn and, once they spawn, they are wetted. Whitlock et al., 2015a and b, and 2018.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Flexible winter power operations results in changing lake elevations in the winter. Greater range of elevations (2051 to 2056) in winter, may increase erosion rates during kokanee spawning.	Pool elevation in winter months.	Current modeling from H&H cannot show power peaking operations. Current lake operations do not negatively impact kokanee spawning or egg incubation.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Power peaking operations raise and lower water elevations during winter. Can cause erosion of spawning habitats? No evidence this is causing problems.
Kokanee exploitation – relationship to water elevation.	Angler access and exploitation.	Anglers have access except in low water years when access could be limited on dry years. Under the NAA, kokanee exploitation, as measured by angler access will not limit kokanee populations.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Water elevations during summer months will be ~2.5 feet lower on driest years. Will this impact angler access? In low water years, access will not be limited. MO4 will not refill on driest years – will be left 2.5 feet below full pool.	The exploitation rate of age-2 kokanee is estimated to be approximately 1.4%; of age-3 kokanee, approximately 11%; and of age-4 kokanee, approximately 25%. Harvest limit is 15 fish a day, not thought to be a driving factor. Operations can affect access to lake in winter months (boat ramps), but there are few anglers during that time period. Not affected by operations except in winter when low water levels limit access – low fishing pressure. Corps, 1998 EIS.
Continuing to manage predation is key. Large numbers of predators control kokanee populations (lake trout, Gerard rainbow trout, and walleye).	Predator numbers.	Walleye populations are increasing, while lake trout have been reduced. Rainbow trout are constant. Predator populations appear to be the primary driver for kokanee populations in Lake Pend Oreille. Kokanee are expected to provide a fishery and forage for predators including bull trout in future years.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Walleye numbers have increased in recent years. Appears some threshold has been exceeded. Lake and mysis shrimp are controlling factors for kokanee populations in Lake Pend Oreille. Mysis compete for food resources and lake trout (other predators as well) consume kokanee. Corsi et al., 2019.
Mysis control carrying capacity for kokanee. Predators control kokanee populations.	Mysis and predator numbers.	–	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Operations don't affect mysis populations reduce spawning success or productivity of the kokanee population, while high predator populations (lake trout) correspond to reduced kokanee numbers and biomass. Corsi et al., 2019.
Entrainment – kokanee entrained through Albeni Falls Dam, high flows associated with entrainment.	Kokanee numbers entrained flows in May and June.	–	Mean flow = 53,776 cfs. No differences from NAA.	Mean flow = 52,965 cfs ~ 2.7% less flow. May be slight reduction in risk of entrainment under MO2.	Mean flow = 53,705 cfs. No difference from NAA.	Mean flow = 53,992 cfs. No difference from NAA.	Entrainment not likely limiting kokanee in Lake Pend Oreille. Assume entrainment occurring in high water events – Bill (personal communication) has seen kokanee in Box Canyon and Boundary Reservoirs following high flow events.
Below Albeni Falls, kokanee not a significant part of fishery.		No effect.	No effect.	No effect.	No effect.	No effect.	Kokanee are not a significant part of the fish community below Albeni Falls Dam.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Northern Pikeminnow							
Pikeminnow are part of native fish tab – they are a minor player here, but part of the native fish.							
Walleye							
Walleye populations expanding in Lake Pend Oreille. They hang out in habitats submerged in summertime. Pend River. They also hang out at tributary mouths and forage on outmigrating kokanee, westslope cutthroat trout, and bull trout.	Not a metric, but a statement of current condition.	–	–	–	–	–	–
Spawn in spring beginning at ~ 4°C over benthic habitats less than 10 feet deep. Spawning in April and May.	Quality of shoreline habitat available. Temperatures in spring.	Water temperatures are as low as 3°C in Feb and reach 4°C in Mar, 8°C in Apr, and 12°C in May. Cobble and gravel slopes are available in much of the lake. Unknown impact on walleye spawning. Elevated stable water levels may improve summer habitat for walleye.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Spawning in river deltas and backwaters (Pack River and Clark Fork). Water Quality Appendix 7-3.
Fry are pelagic and feed on zooplankton. Lower plankton numbers lead to reduced fry survival.	Productivity.	Lake Pend Oreille is classified as oligotrophic to mesotrophic (low to moderate productivity). Currently plankton numbers do not appear to be limiting for walleye fry.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Recent increases in walleye populations is evidence that there are not limitations to fry survival. Moderate numbers of phytoplankton were sampled with increases in the last 8 years. Water Quality Appendix 7-3.
Stable water level is critical for walleye spawning success. Drawdowns during spawn would leave eggs and larvae dry.	Reservoir levels mid-Mar to mid-May.	Water elevations under NAA start a 2051 and go up to 2059 by the end of spawning and incubation. Winter operations can fluctuate as much as 5 feet during early Mar and may impact a small portion of the walleye spawn. Unknown impact on walleye spawning.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Current hydrograph supports spawning and recruitment. Walleye spawn when lake is filling, so eggs and larvae should stay submerged. Spawning in Lake Pend Oreille occurs in Pack River delta area, and Clark Fork River delta. Caught ripe males at Sandpoint. Water Quality Appendix 7-3.
Smallmouth Bass							
Smallmouth in Lake Pend Oreille is a popular fishery, and impacts to other fish are probably very minor. Suggest the team consider in the gamefish tab.	Not a metric, but a statement of current condition.	–	–	–	–	–	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Temperature effects to spawning – smallmouth bass spawning initiated at ~ 13°C.	Lake temperature from mid-May through Jun.	Lake Pend Oreille reaches 13°C at about mid-May. The lake currently provides water temperatures that support smallmouth bass spawning. No effect.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Smallmouth may nest more than once if temperatures drop after the first attempt. Edwards et al., 1983.
Pool elevation effects on spawning habitat availability – water fluctuations during spawning and egg incubation can reduce recruitment – water levels drop and dry up nests.	Lake elevation mid-May through Jun.	Water elevation increases from 2057 to 2062 during this time period. Lake elevations will not negatively impact smallmouth bass spawning or egg development. No effect.	No difference from NAA.	No difference from NAA.	No difference from NAA.	On dry years, under MO4 Lake Pend Oreille may be as much as 2.5 feet lower in Jun through Jul compared to NAA. However, the team does not anticipate water level fluctuations that would desiccate smallmouth bass nests during this time. No effect on smallmouth bass nests.	Edwards et al., 1983.
Temperature effects on egg development – require temperatures from 13°C to 25°C for normal growth.	Water temperature from mid-May through Jul	Lake Pend Oreille reaches 13°C about mid-May, 17°C by mid-Jun, and over 20°C in Jul. The lake currently provides water temperatures that support smallmouth bass embryo development. No effect.	No difference from NAA.	No difference from NAA.	No difference from NAA.	On dry years, under MO4 Lake Pend Oreille may be as much as 2.5 feet lower in Jun through Jul compared to NAA. However, the team does not anticipate changes in water temperature in the lake. We would expect higher water temperatures downstream of Lake Pend Oreille in the Pend Oreille River.	Edwards et al., 1983.
Pool elevation effects on fingerling survival (mean elevation May through Oct).	Reservoir elevation May through Oct (Edwards et al., 1983).	Lake Pend Oreille water levels are generally raised from May to Jul and then held constant until Sep and drop rapidly until Nov. The lake water levels under NAA may negatively impact smallmouth bass fry or fingerling at the end of rearing in Sep and Oct by forcing them to leave nesting and rearing areas.	No difference from NAA.	No difference from NAA.	No difference from NAA.	On dry years, under MO4 Lake Pend Oreille may be as much as 2.5 lower in Jun through Sep compared to the NAA, but would hold these lower water levels stable for 1 month longer. Stable is better for nesting smallmouth bass and expect reduction in risk of displacement for smallmouth bass in MO4.	Edwards et al., 1983.
Downstream – long-time resident fishery, numbers have increased in Box Canyon. Important component of the fishery.	Not a metric, but a statement of current condition.	–	–	–	–	–	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Northern Pike							
Upstream of Albeni Falls							
Pool elevations can affect pike habitat availability. Lake bathymetry would provide very little habitat without the lake level up to inundate slough and inlet areas. Northern pike are seen at Clark Fork delta and slough habitats. Seem increasingly in creel.	Lake elevations from May through Oct.	Lake Pend Oreille water levels are generally raised from May to Jul and then held constant until Sep and drop rapidly through Oct. Current operations maintain lake levels that support spawning/rearing habitat until for northern pike.	No difference from NAA.	No difference from NAA.	No difference from NAA.	On dry years, under MO4 Lake Pend Oreille may be as much as 2.5 feet lower in Jun through Sep compared to NAA. Under these conditions, the team expects there to be a decrease in suitable habitat for northern pikeminnow.	In Clark Fork River above lake, expanding. Pike are present, Rocky Mountain Research station looking at pike distribution patterns. Entrainment from upstream and in-lake recruitments. Carim, 2019.
Flow regime could affect entrainment rates into Lake Pend Oreille from Clark Fork River. High flow rates could move fish from Noxon Rapids and Cabinet Gorge Dams.	Flows from Cabinet Gorge Dam during spring freshet (May and June).	High flow in May and Jun. Higher flows result in increased risk of entrainment. Median flow = 48,392 cfs. Entrainment most common May to Jun when flows are high.	Median flow = 47,818 cfs ~ 1.2%. No difference from NAA.	Median flow = 47,296 cfs ~ 2.4%. May be slight reduction in risk of entrainment under MO2.	Median flow = 47,727 cfs ~ 1.4%. No difference from NAA.	Median flow = 47,858 cfs ~ 1.1%. No difference from NAA.	Need more information about this relationship and citations.
Downstream of Albeni Falls							
Northern pike suppression program POR-program uses netting and angling to remove non-native northern pike.	Northern pike removal.	Current northern pike suppression has removed 17,193 northern pike from 2012 through 2018. Catch rates have dropped dramatically in recent years. Current management is single greatest effect to northern pike populations. Program will continue to suppress northern pike populations.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Need removal numbers or rates.
Native Fish Community							
Pikeminnow are part of native fish tab – they are a minor player here, but part of the native fish community. Not a relationship – just a statement of current conditions.	Northern pikeminnow numbers.	Reduced numbers of northern pikeminnow.	No difference from NAA.	No difference from NAA.	No difference from NAA.	–	Because northern pike minnow are not a decision driver in this basin they will not be discussed further.
Mountain whitefish – Flows in winter spawning season could affect spawning below Albeni Falls Dam. Dewatering eggs could be an issue.	Outflows at Albeni Falls during spawning and incubation (Oct to Apr 15).	Mean flows drop from ~24 kcfs in Oct to 19 kcfs in Nov and 14 kcfs in Dec when eggs are still in the nest incubating (reduction in flow of 42%). Under the NAA mountain whitefish eggs will be dewatered below Albeni Falls Dam.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Spawn in tailraces of Albeni Falls, Box Canyon, and Boundary Dams. Oct to Nov. Hatch out between Dec and Jan. Broadcast spawn, gravel/cobble, and adhesive eggs.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Predation from non-native predators impact native species (sucker and minnow – see effects to kokanee).	Predator numbers.	Additional non-native predators include walleye, smallmouth bass, northern pikeminnow, and lake trout. Increased number of non-native predators is likely to alter native fish community.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	–
Invasive milfoil alters native species habitats. Lake elevation fluctuations can lead to milfoil reductions.	Milfoil expansion – pool elevation fluctuations at Lake Pend Oreille.	Milfoil in the Pend Oreille River in 1982. Annual pool elevations will fluctuate 11 feet at Lake Pend Oreille with peak elevations in the summer of 2062 to a low in winter of 2051. Pool fluctuations of 11 feet will limit expansion of milfoil in shallow water (top 11 feet) of Lake Pend Oreille. Expansion may occur outside this band. Limitation of northern pike and yellow perch habitat.	No difference from NAA.	No difference from NAA.	No difference from NAA.	On dry years, Lake Pend Oreille will not reach full pool ~ 2.5 feet below full. This will not change the effect to milfoil. Still reduced expansion in top 11 feet of reservoir.	Milfoil invasion likely caused and/or exacerbated by dams.
Game Fish **Largemouth Bass, Yellow Perch, and CRP**							
Warmwater fish spawning/incubation and water elevation – water level fluctuations, especially dramatic drops will lead to desiccation of eggs or fry. Water level for Jun and Jul.	Water elevations (Jun and Jul).	Water elevations in Lake Pend Oreille are rising slightly or held constant in Jun and Jul. Water elevations will continue to support warmwater game fish spawning and incubation. No effect.	No difference from NAA.	No difference from NAA.	No difference from NAA.	On dry years, water levels will not reach full pool under MO4, but will be up to 2.5 feet below full pool. No fluctuations are anticipated during the spawning and incubation period of warmwater game fish.	–
Winter drawdown of the lake interrupts juvenile rearing and may reduce numbers of non-native species like tench, largemouth bass, pumpkinseed, and black crappie compared to the population size that would exist if there was no winter drawdown of the Pend Oreille River above Albeni Falls Dam (Joe Dupont and Dave Bennett, 1983).	Water elevations from Oct through May at all three waters.	–	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Gerrard (Kamloops) rainbow trout are an important trophy sportfishery at PDR Basin. Suggest using the same relationships as for bull trout and kokanee.	Kokanee numbers.	–	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Kokanee populations are key prey item for this predator species. Potentially tributary mouth issues – spawn in spring on rising hydrographs. Spring fishery in Clark Fork and Pack Rivers. Current operations appear to support populations. See Affected Environment for discussion. Natural reproduction is good. Andy Dux, 2019.
Below Albeni Falls Dam – mostly warmwater species, including bass and panfish. There are increasing numbers of walleye.	Water temperatures below Lake Pend Oreille.	–	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Walleye expansion commensurate with Lake Pend Oreille increases.
Brown trout population in Box Canyon and Boundary Reservoirs, most temperatures tolerant of salmonids, but still limited by temperatures.	Summer temperatures (Jun to Sep).	Temperatures go from 16°C in Jun to 24°C in Jul and Aug, then back to around 15°C in Sep. Summer water temperatures below Albeni Falls Dam will continue to be limiting for coldwater fish species in the NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Water Quality Appendix 7-3. Raleigh et al., 1986.
Notes on burbot. Not on the species list for this area, but checking around there are a couple of burbot populations in lakes in the basin, draining in to the Pend Oreille River below Albeni Falls Dam, but they were introduced. Genetically linked to Kootenai stock. Not in scope of EIS.	–	–	–	–	–	–	–

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3.8.2 Region B

3.8.2.1 Lake Roosevelt/Columbia River from Canadian Border to Chief Joseph Dam

Fish and aquatic resources in this basin were evaluated qualitatively. Hydrology and WQ data outputs from models were examined to predict effects using relationships between these parameters and biological responses. These relationships were guided by conceptual ecological models for species in this area and regional/local knowledge of the subteam. These relationships and the effects were developed in a series of workshops in Spokane, WA as well as followup conference calls and other collaboration. Retention time was found to be an important relationship to many resources in Lake Roosevelt, so additional processing of hydrology data was requested to provide this metric. Tables and a hydrograph illustrating how retention time would change under each alternative are provided here. Although the entrainment and growth relationships apply to many species in the reservoir, much of the existing literature focuses on kokanee, so the retention time analyses is documented in the kokanee spreadsheet and referenced in other species where applicable. Another data need was to understand how water quality may change in specific locations where there are net pens for mitigation fish rearing. The water quality team provided additional analyses and tables showing that data are also provided in this appendix.

Table 3-75. Columbia River, Canadian Border to Chief Joseph Dam, Qualitative Effects Analysis Matrix

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Bull Trout							
Use of Columbia River Reach as Feeding, Migratory, and Overwintering (FMO) Habitat Key issues: Very few. FMO only, isolated from spawning habitat. Temperatures and flows could slightly affect distribution, timing through entrainment, and flushing downstream into FDR and entrainment into Lake Rufus Woods. Bull trout prey base could be affected by productivity influenced by retention time of water in the reservoir.							
Temperatures greater than 18°C result in stress; mainstem in FMO habitat only. Bull trout leave when temperatures get higher.	Temperatures: Mainstem Columbia and Lake Roosevelt	Temperatures continue to support the few bull trout that use this reach.	No change in temperatures.	Same as NAA.	Same as NAA.	Same as NAA.	Max about 18°C is within criteria for bull trout.

<table>
<tr><th>Affected Environment Important Relationships/Criteria</th><th>Metric</th><th>Environmental Consequences NAA</th><th>Environmental Consequences MO1</th><th>Environmental Consequences MO2</th><th>Environmental Consequences MO3</th><th>Environmental Consequences MO4</th><th>Notes</th></tr>
<tr>
<td>High flows in spring during high flow years result in increased flow (spring) could increase recruitment from river reach into FDR.</td>
<td>GC inflow peak and duration</td>
<td><table><tr><th></th><th>1%</th><th>25%</th><th>50</th></tr><tr><td>May</td><td>256775</td><td>84479</td><td>15</td></tr><tr><td>Jun</td><td>323726</td><td>16408</td><td>17</td></tr><tr><td>Comb:</td><td>290250</td><td>200443</td><td>16</td></tr><tr><td>Peak:</td><td>359328</td><td>244681</td><td>20</td></tr></table>High flow years would continue to potentially flush to FDR in high water events. Could be increased entrainment into Lake Rufus Woods.</td>
<td><table><tr><th></th><th>1%</th><th>25%</th><th>50%</th></tr><tr><td>May</td><td>254999</td><td>180432</td><td>1483</td></tr><tr><td>Jun</td><td>320853</td><td>212547</td><td>1756</td></tr><tr><td>Comb:</td><td>287926</td><td>196490</td><td>1619</td></tr><tr><td>cfs chg:</td><td>-2324</td><td>-3954</td><td>-480</td></tr><tr><td>Pct chg:</td><td>-0.8%</td><td>-2.0%</td><td>-2.9</td></tr><tr><td>Peak:</td><td>356197</td><td>240864</td><td>2036</td></tr><tr><td>Peak chg:</td><td>-3131</td><td>-3817</td><td>-458</td></tr><tr><td>Pct chg:</td><td>-0.8%</td><td>-1.6%</td><td>-2.2</td></tr></table>No change in duration.
Negligible effect to flushing bull trout into the reservoir.</td>
<td>Similar to MO1.
Negligible effect to flushing bull trout into the reservoir.</td>
<td>Similar to MO1.
Negligible effect to flushing bull trout into the reservoir.</td>
<td><table><tr><th></th><th>25%</th><th>50%</th><th>75%</th></tr><tr><td>May Mean Mon</td><td>180309</td><td>148055</td><td>124</td></tr><tr><td>Jun Mean Mon</td><td>213188</td><td>176495</td><td>138</td></tr><tr><td>*Ave May / Jun</td><td>196750</td><td>162275</td><td>131</td></tr><tr><td>cfs chg</td><td>-3995</td><td>-4520</td><td>-41</td></tr><tr><td>Pct chg</td><td>-1.8%</td><td>-2.7%</td><td>-3.0</td></tr></table><table><tr><th></th><th>1%</th><th>25%</th><th>50%</th></tr><tr><td>Peak</td><td>356331</td><td>240342</td><td>203</td></tr><tr><td>Peak Chg</td><td>-2997</td><td>-4339</td><td>458</td></tr><tr><td>Pct chg</td><td>-0.8%</td><td>-1.7%</td><td>-2.2</td></tr></table>No change in duration.
Negligible effect to flushing bull trout into the reservoir.</td>
<td>After 97 high flow, started seeing some bull trout in reservoir.
CHJ kokanee enhancement project. Lake Roosevelt data collection project. (BPA projects), unpublished data. (1990 to 2000 era).
*Note: MO1 and MO4 workshop did not have wet/dry/ave hydrographs, so used calculation of HH data. MO2/MO3 workshop was later in process and hydrographs were available to visualize alternative compared to NAA without having to do calculations. In MO1 to MO4, should not have averaged monthly means, but the conclusion is the same.</td>
</tr>
<tr>
<td>Water quality/sediment effects: Increased reservoir fluctuations could increase redox of mercury. Contaminants could affect bull trout adults, bioaccumulation (top predator).</td>
<td>Reservoir fluctuation events, elevation profiles</td>
<td>Current rates of redox events would continue; baseline rate of bioaccumulation.</td>
<td>Pool elevations are generally lower Dec to Feb, but does not appear to have additional fluctuation events at the 25/50/75 percentile; potentially more fluctuations in extreme conditions (1%).
Lower elevations in Dec to Mar could increase potential for exposure, but fluctuations (daily) would be similar to NAA. Likely no measurable effect to bull trout. About 5 feet more increased sediment exposed could increase mercury in the system in fall.
All MO Alts: 1,2,4 - winter frm = more risk in Dec and Jan.</td>
<td>Similar to MO1.
MO2 - deeper draft in Jan
All earlier draft (.8SRD) Jan/Feb in wet years, MO2 - Sep lower
All MO Alts: 1,2,4 - winter frm = more risk in Dec and Jan</td>
<td>Same as NAA.
MO3 - slightly reduced risk in Jan (less draft)</td>
<td>Dry years: More variability than NAA, also deeper draft. Dry years have highest potential for effects, drawdowns up to 22 feet from NAA.
All MO Alts: 1, 2, 4 - winter frm = more risk in Dec and Jan
Mitigation: Do follow-up mercury analysis (fish tissues) to update human health advisory. Current advisory may become outdated if changes in redox events. Fish with highest risk are walleye, pike. If high risk to human health - provide replacement species for harvest. (move this from bull trout tab to other spp.)</td>
<td>See meeting notes from WQ to determine mechanism for redox events. See Elevation profiles.
Drawdown at forebay results in exposure of upper reservoir exposed shoreline extent. Look at March-May.
Ongoing tissue monitoring - tie to mercury methylation. Increased mercury methylation and bioaccumulation (see Willacker 2016, Reservoirs and Water Management Influence Fish Mercury Concentrations in the Western United States and Canada).
Relationship is from literature,
Likely more concentrations in lower parts; but with mercury it may not necessarily be the case, in water.
Juvenile more susceptible? Timing - in December less actively feeding.
Inundation in Jan to March, could introduce mercury into the food web.
Willacker, 2016
Eagles-Smith, 2016</td>
</tr>
</table>

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Lake Roosevelt Operations effects on bull trout as FMO							
Lake Roosevelt temperatures.	Lake Roosevelt Temperatures – 5-year water quality in the reservoir.	–	Negligible change to temperatures in 5-year reservoir results.	Likely same as NAA.	Likely same as NAA.	Likely same as NAA.	Temps may get too warm, very few bull trout in FDR, can move to cool areas, DO stays good. If in Spokane arm, may move out if DO/temperatures limit. See kokanee page….determining model result of less stratification reducing cold-water refugia. Volume-weighted temp at Kettle Falls. Note - not relevant to bull trout necessarily, but general... Temps using volume-weighted averages. Near dam temps may be more difference. Anoxia does occur upstream of Spokane arm, model vertical profile. Spokane has DO data. Can provide DO profiles in Spokane arm to see if model captures biological implications.
Lake Roosevelt prey base.	Prey population effects – primarily entrainment.	–	See kokanee tab.	See kokanee tab.	See kokanee tab.	See kokanee tab.	Retention time relationship to kokanee entrainment applies to bull trout as well. As forage fish are concentrated more towards the dam, bull trout would be too.
High flow – higher entrainment out of FDR, moves bull trout downstream, eventual fate not known. Mortality may move on downstream to other areas.	GC outflow.	–	Dec outflows 2%-6% higher Apr-Sept 2%-5% lower Average of mean monthly flows = 106258, -1.8% Generally the same or slightly higher in Oct/Nov, 2-8% higher in Dec/Jan, 2-5% lower in Mar-Apr. Increased median outflows in December = 100,525. Likely immeasurable change, increased outflows could potentially increase entrainment risk in December and decrease risk in Mar-Apr/December outflows, Most bull trout in upriver? But some near Sanpoil, potential for bull trout near dam.	Nov, Dec higher outflows (Nov 2%-5% and Dec 8%-15% higher). Sept. 4% higher. Oct. 8%-9% lower. Mar-May slightly lower, Jun-Aug similar to NAA. Higher outflows in Nov, Dec, and Feb could increase entrainment out of FDR.	–	Average of mean monthly flows = 106258, -1.8% Generally - slightly lower in July/Aug, 3% to 17% lower in Sept to Oct, slightly higher (0% to 3%) in Dec/Jan, (0% to 9%) lower in Feb to Apr, mixed in May to Jun (higher in low water conditions, lower in high water conditions). Increased outflows in dry years in Jan and May could increase entrainment risk. Bull trout prey species typcially moving towards the dam to follow zooplankton, bull trout follow this food sources and become more susceptible to entrainment, and higher flows increases entrainment risk as well. High fluctuations in Nov to Jan - could smooth those out?	Beeman et al., 2003, LeClaire, 2000 Entrainment in high flow years. When catch some in one year, typically don't catch any the following 2 years. Entrainment out of drum gates not by composition. (For rainbow, when elevation drops below 1260, entrainment increases)
Lake Rufus Woods as FMO – negligible. Did not analyze effects to bull trout in Lake Rufus Woods.	–	–	–	–	–	–	–

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
White Sturgeon							
Recruitment as a function of flow >200 kcfs, at 14°C for 3 to 4 weeks in late Jun/beginning of Jul, coupled with lower reservoir elevations low enough to provide riverine stretch.	GC Elevation, Columbia at Border flow – number of days exceeding 200 kcfs, Jun 15 to Jul 31. Temperature at border.	Apply to No Action alternative HH and water quality outputs to determine how many out of POR would provide these conditions. Days exceeding 200 kcfs Jun 15 to Jul 31 1% = 43 days 25% = 8 days 50% = 0 70.1% chance exceedance 200 kcfs Apr 1 to Jul 31. Discharge duration: About 36% of the time June discharge exceeds 200 kcfs; about 10% July. Conditions typically not conducive to successful recruitment except in very few water years. In 3 years since 1995.	Days exceeding 200kcfs 1% = 42 days 25% = 3 days 50% = 0 days 53% chance exceed 200kcfs Apr 1 to Jul 31 Discharge duration - about 25% of the time exceeds 200 kcfs in Jun, about 8% in Jul. About 2% lower discharge duration, about 5% lower chance of exceeding this discharge in Jun/Jul, and one or two fewer days where discharge exceeds 200 kcfs. This would be a small decrease in potential recruitment window for white sturgeon.	June 15-July 31 flows are similar to MO1 Days exceeding 200 Kcfs 1% = 43 25% = 2 50% = 0 52% chance exceedance Apr1-Jul31 Same as MO1	Same as MO1 and MO2, slight decrease from NAA, likely imperceptible.	Days exceeding 200kcfs 1% = 42 days 25% = 4 days 50% = 0 days 53% chance exceeding 200kcfs April 1-July 31 Discharge duration - about 25% of the time exceeds 200kcfs June, About 8% in July. Same as MO1 in high and average years. Increased flows compared to NAA in low water years, but no change to sturgeon recruitment. Low years don't get enough flow in any scenario for recruitment.	Sturgeon annual reports (Colville and McLellelan and Howell). Use mid-June ok because temps likely don't meet criteria until about then. Flows used to get there more often until mid-60's, but modeling incorporates today's configuration (operating rules) on past hydrology record. Spokane 1995-02700 96-97, 2011 had recruitment documented. High water years get some recruitment. Successful spawning, YOY every year, but fail after larval stage. Potential mitigation for any sturgeon recruitment failure: larval transport, capture wild-caught larvae and transport to habitats in reservoir (skip over the transition zone, hypothesis of issues there = contaminants, predation, etc.).
Reservoir elevations lower, in late Jun to early Jul increases chances of recruitment.	GC Elevation, Jun 30 and Jul15 elev. In high water years	Jun 30 = 1285.2 July 15 = 1289.5 Reservoir influence above China Bend at full pool. Compare where river conditions transition to reservoir. Sturgeon survival model looked at 1210-1290. Drawdown to Kettle area would increase recruitment.	Generally 0.0 to 0.3 feet lower in June and July at most exceedances. Jun 30 = 1285.1 Jul 15 = 1289.5 Slightly lower or no change in most conditions. Potentially increased riverine habitat to offset decrease in flow from first relationship. Most substantial change (decrease of 1.3 and 3.8 feet, is in 98 and 99 percentile exceedances, respectively (already low conditions).	Jun 30 = 1285.3 (+0.2') Jul 15 = 1289.5 Same as NAA	Jun 30 = 1285.1 Jul 15 = 1289.5 Same as NAA	Ave and wet years: Jun 30 = 1285.1 Jul 15 = 1289.5 Dry years: median in dry years about 22 feet lower from comparison plots) 40% of years, 5 feet lower than NAA 30% 15' lower 20% 24' lower (from exceedance curves) Lower lake levels when already low conditions. Any benefit? Slightly lower at the higher exceedances would be benefit for sturgeon. In dry years, lower elevations potentially improves conditions, by providing additional length of riverine habitat for larval dispersal and increases probability for recruitment, but unlikely to have flows to provide any spawning/recruitment.	Use 80 year set, wet/ave/dry years of flow data overlaid with elevation data. Assume temp is the same. CCT has sturgeon recruitment and hydrology modeling report. Sturgeon go to same spot for spawning. Same temps at boundary. H&H? To figure additional river miles; is there a lag between dry year elevations and wet year inflows? A: No, GC resets.

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Productivity/food effects on larvae – unknown (see flow correlation). See kokanee tab for food web, productivity effects. Note: indirect relationship to phytoplankton/zooplankton and food likely not limiting.	Retention time related to entrainment of food organisms	See kokanee tab. Larval sturgeon likely feeding on benthic organisms. Potential indirect relationship to retention time - zooplankton – filter feeding benthos; food likely not limiting.	Retention time - see Kokanee. Minor changes in flow, likely no effect.	Retention time - see Kokanee. Likely not affecting sturgeon - see notes.	Retention time - see Kokanee. Likely not affecting sturgeon - see notes	See kokanee tab. Retention time - see Kokanee Likely a minor effect on sturgeon, they are in part of reservoir where not a lot of zooplankton, not pelagic like kokanee. Food limitation Is not the concern for sturgeon. Also, the contamination, predation, and lack of riverine habitat to recruit.	See retention time discussion in kokanee? Relative to white sturgeon - same source? Is the same relationship of reservoir rearing below? Or different nuance in river? Larvae are in system in mid-July, then removed for hatchery program. Ones left in the system likely do not survive. Sturgeon are all up in upper Region, inflows not changing enough to affect food dynamics.
Predation (smallmouth bass/walleye) on larval sturgeon. Reservoir conditions favor predators; see predator; inflows can flush larvae into reservoir conditions.	–	See smallmouth bass and walleye tabs.	Flows similar to NAA, slightly lower. Slightly lower inflows, potentially lower risk of moving larvae down.	See smallmouth bass and walleye tabs.	–	See smallmouth bass and walleye tabs. Dry years, longer reaches of riverine habitat, less predation risk, predators would move to reservoir.	Slight change to inflows, unlikely to see biological effect. See smallmouth bass and walleye tabs. Predation is a suspected limiting factor for sturgeon.
Contaminants: Closer to Canadian border, increased copper. Copper has sublethal effects on sturgeon swimming behavior, feeding, predator avoidance, etc. Higher flows move larvae further downstream and into lower copper concentrations. Cadmium is more widely dispersed.	Flow at border	Flows at current level would continue to mobilize contaminants further downstream at the rate similar to in the past.	Slightly lower in Dec, slightly higher in Jan/Feb. Potential increase in movement of contaminants from above Kettle Falls area into the mid and lower River.	Inflows slightly higher in Nov/Dec. Same as MO1, slightly higher magnitude.	Same as MO2.	June/July inflows higher in low water years (McNary measure triggered). More potential for moving larvae down, but in low water years (when measure is triggered), there are likely no larvae there. Contaminants could be mobilized downstream more than in the NAA, but no effect to sturgeon.	Additional flows could move larvae out, but could also increase transport of contaminants further down too. Slight changes to inflows among alternatives.
Subyearlings (hatchery) through adults reach very high survival once around 200 g (about 12 inches). Reservoir conditions provide adequate rearing conditions.		Reservoir would continue to provide good conditions for growth and survival of sub-yearling through adult life stages.	NA	See change descriptions, see any effects to subyearlings? No change.	See change comparison, see any effects to subyearlings? No change.	See change comparison. Potential change in reservoir v. riverine conditions, but likely would not change suitability for sturgeon grown and survival after they reach about 200g.	Note: effects not noted, but keep this row for notes. Talk through reservoir spp. Any effects to conditions for reservoir rearing for subyearlings to adults?
Temperatures – adults require 12°C to 14°C.	Reservoir temp	No change in any alts noted.	No change in MO1 data. Same as NAA.	Same as NAA.	Same as NAA.	Same as NAA.	Hanson et al., 1992. No change to temp in any alts. Keep this row for notes.
Contaminants: Adults feed in reservoir and may bioaccumulate mercury (see bull trout page). Keep this line for notes only specific to sturgeon.		See bull trout tab.	See bull trout tab.	See bull trout tab.	See bull trout tab.	See bull trout tab. Higher variability and deeper draft could increase redox events.	Fishery 38 inches to 62 inches for tribes and 54 inches to 62 inches for state anglers. Hatchery fish, were stocked as subyearlings, growth to "take" size would be about 10 years in mercury exposure.
Burbot							
Columbia River							
Columbia River elevations relate to depth needed to support	Water surface elevations; Feb to Mar drops in	River conditions under the NAA provide adequate depth for burbot.	March about 2 feet to 3 feet lower than NAA. Potential reduced habitat and increased	MO2 wet years, draw down lower and a little faster (5 feet lower on Mar 1). Potential	Same as NAA.	Same as MO1.	See profiles map - determine best cross section to look at. Reach 720.431. NOTE: need drop in Feb to Mar data.

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
burbot, and drops in river stage in Feb to Mar can dewater eggs.	elevation at RM 720.431.		stranding of eggs compared to NAA.	reduced habitat and increased stranding of eggs compared to NAA. Slightly higher magnitude than MO1.			
Cold temperatures (see kokanee page for potential change in reservoir stratification), likely modeling artifact.	Temperature in river	See kokanee tab, line 11.	No change in river. Reservoir? See kokanee tab, line 11.	See kokanee tab, line 11.	See kokanee tab, line 11.	See kokanee tab, line 11.	No change expected from any alts. Bonar et al., 2000
Velocities in river can affect suitability for burbot spawning (need slower velocities in winter).	GC Inflows Dec-Mar	See notes.	See notes.	See notes.	See notes.	See notes.	No velocity data; no notable changes expected in inflows that would change velocities that would be biologically notable. Retain line for records. Bonar et al., 2000.
Lake Roosevelt							
Drawdowns in Lake Roosevelt elevations in winter/early spring can dewater eggs.	Use elevation comparison, visualize and estimate drop from Dec to end of Mar.	Reservoir elevations comparison. Ave years about 20-foot drop from Feb 1 to end of Mar. Dry years, only about 3-foot drop while in gravel. Wet, dry years - 30-foot drop in Mar. Reservoir spawners likely high loss of eggs; river spawners not as affected.	Deeper drawdowns Dec to Mar. See elevation comparisons. Dec to Mar drawdowns could potentially dewater eggs. Rate of change of reservoir elevations is the same. Habitat use not well-known, but Dec to Mar drawdown would decrease availability of habitat overall. Slightly less steep drawdown would decrease (slightly) risk of dewatering. In terms of slope, could be beneficial; terms of habitat, it's a data gap.	Deeper and steeper drawdowns than MO1 Similar effect to MO1 with higher magnitude in dry years.	Same as NAA	About 10-foot deeper drawdowns in Dec to Feb or Mar. Likely to strand/ desiccate more eggs in dry years than NAA. Wet and average years continue to experience high loss of eggs similar to NAA. Early spawners affected by additional drop in Jan.	Spawn near Colville River on shorelines, winter Feb to Mar, FRM year, drafting a lot increases chance of this effect. Juveniles hatch, feed on zooplankton, exacerbates effects. Very shallow spawners, any drawdown in Feb to Mar timeframe can desiccate eggs. Lower surface elevations from wildlife map. Look at summary hydrographs for drawdown events.
Retention time affects direct entrainment of burbot. Food availability prey base for juveniles, food source is pushed further down-reservoir by flows. Burbot follow the food source and can become more susceptible to entrainment.	Retention time, see kokanee tab	See kokanee tab.	See kokanee tab. Slightly lower retention times (2-3 days) in Dec-Mar could increase risk of burbot entrainment. See also kokanee tab.	See kokanee tab. Lower retention times (up to 6 days) in Dec to Mar could increase entrainment risk for burbot during spawning season.	See kokanee tab Similar to NAA; slight increase in retention time potentially increases food and lessens potential entrainment.	See kokanee tab.	Pelagic species; (link to other pelagic species). Decreasing retention time leads to increasing entrainment. Retention time metric, how calculate? Flow routing could affect how fast zooplankton get pushed out, but use retention time. Retention time is of inflow/outflow. See notes on retention time, developed by H&H.
Retention time of water through the reservoir effects food availability and location. Higher retention time = more food and more widely dispersed. Lower retention time = less food available and higher concentrations of zooplankton further down-reservoir.	See above.	See kokanee tab.	See kokanee tab. Slightly lower retention times (2 to 3 days) in Dec-Mar could reduce food supply for burbot during spawning season.	See kokanee tab. Lower retention times (up to 6 days) in Dec to Mar could reduce food supply for burbot during spawning season.	See kokanee tab. Similar to NAA; slight increase in retention time potentially increases food.	See kokanee tab	Plankton size - larger plankton vs smaller smaller. Larger-bodied daphnia have longer generation times (higher flows-source popn move further downstream), longer retention time allows more to mature before washing out of reservoir. May shift the prey availability from larger to smaller plankton, potentially exacerbating the entrainment issue. Winter spawning season critical time for feeding?

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Kokanee							
Retention time and Food Supply: Retention time of water through the reservoir effects food availability and location. Higher retention time = more food and more widely dispersed. Lower retention time = less food available and higher concentrations of zooplankton further down-reservoir.	Retention time-year round	See RT file. Generally 40 to 50 days in winter/spring, downs to 21 days by June, gradual increase over summer to 45 days end of Aug. Sept and Oct 60 to 80 days. The NAA regime of retention time supports the current fish community. Kokanee, redband rainbow trout, juvenile burbot, larval sturgeon, and many prey species rely directly. Bull trout indirectly.	See graph Oct to Nov: = NAA Dec Ave: 45 Dec (-7%) Jan: 2 to 4 days <NAA (-7% to 10%) Feb: Wet and Dry 2 to 3 days <NAA, Ave: = -4% to 5% Mar: Wet 1day <NAA, Dry 1day >NAA, Ave: = Apr to Sep: Similar to NAA Losses in primary/secondary production, source populations get moved downstream, draws fish closer to the dam outlets. (Dec. FRM measure) Lesser retention times are not as critical because RT is higher (lower percentage change). Some loss of food supply. Increased outflows starting in Dec, increased drawdown.	Similar to MO1: Oct-Nov: = NAA Dec: Ave: 42 days, 6d <NAA (MO1 was 2 to 4 days <NAA) -14% Jan: 2 to 4 days <NAA (-7% to 10%) Feb: Wet and Dry 2 to 3 days <NAA, Ave: = Mar: Wet 1 day <NAA, Dry 1 day >NAA, Ave: = Apr to Aug: Similar to NAA except May 1 to 15: 3 days >NAA Sep: 3 days <NAA Similar to MO1 but larger magnitude of effect in Dec. 13% decrease in retention time. Decrease in food source in winter. Increased in summer (2% to 6% higher). Deeper draft for hydropower would be a larger magnitude of impact. Retention time, elevations, outflows effects are masked by winter FRM measure in this case.	Similar to MO1 except 2 to 3 days >NAA in Jan. Average years (MO1 is <NAA in Jan). Similar to MO1, but slightly less effect in Jan. Note: Change is in Jan and NAA is about 45 days, is 2 to 3 days either way make a difference?	Average and Wet Years: Same as NAA except: 2 to 4 days <NAA in Dec-Jan and mid-Jun through Aug. Dry: 5 to 8 days <NAA in May to Aug, as low as 25 days for much of May; about 5 days >NAA in Sep; Dec and Jan up to 8 days <NAA, as low as 40 days in Dec and Jan. Median and below water years would see retention time reduced, leading to reduced food availability. Likely affect growth in kokanee negatively. Would result in smaller plankton. Shift to smaller plankton size would decrease food value for kokanee (they feed on larger ones). Drawdowns for longer periods, larger relative volumes of water are going to be warm, ex: in tributaries such as Spokane arm, effect to juvenile fish that use these habitats. In MO4, Sept and Oct retention time is higher than NAA, slighlty positive effect on retaining fall and winter food source. The dry year scenario is more likely to be more frequent in the future due to climate change. (Modeled as outliers but likely to become more frequent.) Fall flows/lower retention time flushes out winter food supply. Elevation also important for spawning. Temperature discussion, temperatures do not get too warm for kokanee now, but would reduce retention time lead to temp issues? Spikes in retention time in model in 95 percentile are likely indicative of reaching draft	See workshop notes. LeClaire 2000. Bret to send. Baldwin and Polacek 2002- evaluating limiting factors. Plankton size - larger plankton vs smaller. Larger-bodied daphnia have longer generation times (higher flows-source popn move further downstream), longer retention time allows more to mature before washing out of reservoir. May shift the prey availability from larger to smaller plankton. Potentially exacerbating the entrainment issue. Adult kokanee looking for one thing, juveniles another. Kokanee are size selective on plankton. Fall zooplankton ds, but kokanee probably dispersing to spawning habitats. Team: Is change in RT more important when RT is already low? Is a percentage change meaningful? Yes, use percent change. Difference less critical at higher rt. Are there other factors that make difference in importance of retention time? Hatchery or wild? Most kokanee are wild, but there is a hatchery component. Ecosystem benefits for wild would be same for hatchery except for spawning considerations.

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
						target in Oct then shutting down outflows.	
Retention time and Entrainment: Decreased Retention time and increased outflows tend to move the concentration of plankton nearer to the outlets. Kokanee follow the food source and become more susceptible to entrainment. Note - several factors increase risk: elevation, retention time, and habitat use.	Retention time and outflows	See RT file, and summarized above. 10-13% of pelagic fish lost each month to entrainment. Kokanee follow the food source and concentrate in the lower reservoir where they are more susceptible to entrainment, lost from FDR population. Over 400,000 average entrained fish per year, (LeClaire, 2000), 30% to 50% kokanee, primarily wild. Redband rainbox second most.	See Row 7 for RT Monthly Average. Potentially increased entrainment in Dec-Jan, Feb. and April. See notes on elevation. Drawdown initiated sooner in Dec, 7% to 10% decreased retention time could prolong the time period when fish are more susceptible to entrainment. Potentially increase entrainment 7% to 10%, Earlier draft would increase entrainment. Flat spot measure, in 5% to 6% of years the elevations would be up to 8 feet lower than NAA in April. Could increase entrainment risk to kokanee. Flat spot measure, in 5% to 6% of years the elevations would be up to 8 feet lower than NAA in April. Could increase entrainment risk. . Winter space masks 0.8 feet per day drat rate in wetter years. Already lower in Jan from winter space, so don't see draft rate impacts on outflow/elevations. Without winter space, .8SRD would draft earlier (Jan and Feb), compared to March/Apr in NAA.	See Row 7 for RT Monthly Ave. Same as MO1, but larger magnitude of effect in Dec.	See Row 7 for RT Monthly Ave. Entrainment similar to NAA, potentially less entrainment than NAA in Jan.	See Row 7 for RT Monthly Ave. and see also game fish tab for discussion on retention time/entrainment. Decreased retention time in Dec-Jan would increase kokanee entrainment. Elevation also exacerbates entrainment. Decreased retention time would concentrate kokanee near the dam, and elevation. Dry years increased entrainment in summer. Increased outflows in winter months would be more susceptible to entrainment, because they follow the food source. Plankton food source pushed downward to nearer the outlets. Retention time would decrease correspondingly. Mitigation - fish collection system near forebay of GC to trap, sort, and transport native spp. Elevations below 1260 causes increased entrainment. 400,000 fish annually or more. Daphnia source entrained.	Entrainment accounts for up to 30% total limnetic fishes (study on hatchery fish limiting factors) Baldwin - correlated inflow to entrainment rates. Powerhouse intakes are near regulating outlets, does reservoir elevations coinciding with times of short retention times affect entrainment rates (i.e., kokanee at a certain point in the water column, where they are can be affected by lake elevations). See game fish tab: elevation affects correlation for net pen fish.
Elevations lower than 1283 can result in reduced access to tributary habitat compared to the NAA.	Reservoir elevation	All water years meet 1283 by 9/30. Access issues would remain as in past. Historical target, there could be issues under the NAA but not known.	See Elevation Forecast Comparisons All water years above 1283 feet by 9/30. Same as NAA.	Wet and average years above 1283 feet by 9/30. Dry years only to 1279 feet by 9/30. Potentially access issues in dry years.	All water years reach 1283 feet by 9/30. Same as NAA.	In wet years, both NAA and MO4 are typically above 1283 feet in Sep through Jan. In median water years and below. MO4 drops below 1283 feet (20 feet below) about Dec. 1 and stays below through Jan. Tributary access would be impeded by drops in reservoir elevation in December; predation (avian) risk could increase and volitional migration time could increase. Increased exposure to varial zone issues. Similar to MO2, but higher magnitude.	1283 feet is an operational metric. By Sep 30 at 1283. Sep is peak run for kokanee/native fish. Small part of population uses tributaries; more relative to rainbow. Kokanee are primarily shoreline, but redband are tributaries only, so redband would be more affected by this effect. Keep this relationship for kokanee, but is not a high magnitude. Only applies to the portion that use the tributaries. Mitigation: study access to tributaries. Survey elevations, determine if access impeded, varial zone issues, etc. Identify and resolve where effects are determined.

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
						See also redband tab, same relationship.	
If reservoir levels decrease after spawning, eggs can be desiccated.	GC elevation Sep to Feb. Elev_Fcst_ comparisons, see figure below.	Wet - steady or rising Sept to Feb, drop to 1267 feet in March. Average: 1288 feet (Jan 1) to 1285 feet (Feb 1), 3-foot drop (steady Sept 30 to Jan 1), 18-foot drop Feb 1 to 28 to 1267 feet. Dry: Drops from 1288 feet (mid-Nov) to 1281 feet (Feb 1). 7-foot drop, but then rising in Feb 1 to 28. Wet years: Reservoir elevations typically rise gradually after kokanee spawn ok, until Feb when drops 20'. Ave years: 3-foot drop could desiccate eggs in shallow spawners, fry also stay in gravels and could get stranded. Dry: same issue, more kokanee affected; likely direct relationship to drop.	Wet: 1288 feet (Dec 1) to 1278.5 feet (Feb 1), 9.5-foot drop, compared to no drop in NAA. Ave: 1288 feet (Dec 1) to 1282 feet (Feb 1) 6-foot drop compared to 3-foot drop in NAA, and drops 1 month earlier Dry: Drops from 1288 feet (mid-Nov) to 1276 feet (Feb 1). 12-foot drop, 5 feet more than NAA. Wet years: 9.5 feet more drop Ave: earlier timing of drawdown would put more kokanee at risk (none hatched out yet); Dry: Follow the data.	All water years drop 1288 feet (Dec 1) to 1279.5 feet (Feb 1), 8.5-foot drop compared to no drop in wet, 3-foot drop to 7-foot drop in dry years in NAA. All years effect would be similar to MO1. but with different magnitude (figure % change to show relative) In dry years; kokanee would likely spawn at lower elevations than under average and wet; so the following drop in December would not affect those eggs until it drops below 1279 feet.	Wet and Ave years: steady or rising Sep 30 to Feb. 1. Note - flat spot holds ave a little higher longer to keep from dropping until after Feb. 1, as compared to NAA. Dry: Drop 1288 feet (Dec 1) to 1284.75 feet (Feb. 1). 3.25-foot drop; 3.75-foot less drop than NAA Average water years would be slightly better than NAA because flat spot would avoid the drop that happens in Jan-Feb under NAA, but short-term drops could cause some desiccation of eggs. Otherwise very similar to NAA. Note a little dip in the hydrograph in Dec; may be modeling artifact, but could dry some eggs for a short period then back up. Reason for short-term dips? Could be power production or chum flows.	Wet: 1286 to 1281 in early Oct, then up to 1286, Nov 1288 to 1286 and back up; late Dec down to 1281. Ave: Down to 1278' (Feb 1) (note dips in hydrograph each month) Dry: 1288' down to 1272 (late Jan). The drawdown in Dec-Feb would dessicate any kokanee redds along the shorelines in L. Roosevelt. Note: extreme drawdowns may not have straight 1:1 effect, could be lesser. See notes. To quantify effect: look at relationship of elevation to storage. H&H has storage. Compare to NAA. Also, see if GIS can analyze using bathymetry. Reply: no time to try quantification for draft. Qualitative only for now.	Kokanee in L. Roosevelt suggests shoreline spawning. Spawn Sept. 15-Oct 15, : Eggs incubate through Feb. Need temp units (degree days) to hatch; interactions with water temp. Depth of kokanee spawning not known in L. Roosevelt. Discussion: in Coeur d'Alene known to spawn deep, but in other places they spawn near the surface. Early spawners deposit eggs when reservoir is lower so fewer of those fish would be affected (deposition at lower level). Mitigation: Reduce water supply; determine magnitude of effect, improve mainstem spawning habitat - supplement substrate, reconnect off-channel habitats, etc., Increase habitat at lower elevations so more kokanee spawn at levels that don't get dewatered. Important to kokanee; applies to redband but only to portion that uses tributaries, but also changes alluvial fan habitat availability. Would need surveys for spawning depths to know magnitude of impact. For comparison, assuming 1:1 relationship between feet elevation change and eggs/fry desiccated. (Mitigation)
Temperature in the reservoir - kokanee are sensitive to temps. Note: Greyed this relationship because still investigating whether modeled results are real or a modeling artifact (suspected). Timing may not be able to determine until after draft.	See temperature stratification results	Found at depths below 120 meters to find temperature tolerance. Habitat suitability is function of temp and DO, but for the most part the DO is ok, not stratified. There is an area of Spokane arm that gets low DO. Kokanee about 62°F	Check out NAA - all four MOs appear to cause less stratification and the effect described. Determine mechanism (Eric and Sue) Thoughts - model may have pulled more through the lowest outlets and causing modeled change in stratification that wouldn't really happen? Main reservoir DO likely stays ok, but in the lower portions of the reservoir the model showed decreased stratification that could cause the temps at depth to increase up to 7°F compared to NAA in summer. Reduced	Later in the year DO declines. Higher up in water column in the Spokane arm (still about 5 mg/l, but may be an issue). Spokane arm would have decreased habitat suitability due to low DO. Midsummer anoxic DO from below/temp squeeze from above. Main reservoir DO likely stays ok, but in lower portions of the reservoir model showed less stratification that could cause temps to increase up to 7°F at depths of 100 to 120 m (approx), compared to NAA in summer. Reduced thermal refuge in	Main reservoir DO likely stays ok, but in the lower portions of the reservoir the model showed decreased stratification that could cause the temps at depth to increase up to 7°F compared to NAA in summer. Reduced thermal refuge area in summer habitat. Fish likely get more stress, more disease, may congregate in groundwater upwelling; may become more susceptible to entrainment if they move further downstream.	Later in the year start to decline DO higher up in the water column in the Spokane arm (still about 5 mg/l, but may be an issue). Reservoirs lower in Jun/Jul/Aug/Sep would result in less habitat available to kokanee. Increased thermal stress in habitats, increased disease,	See BPA report, Project 1995-011-00 Kokanee most sensitive; maybe lake whitefish (non-native), mountain whitefish If powerhouses are releasing from deep, and kokanee are oriented nearer to these powerhouses due to the thermal requirement described…they would be more susceptible to entrainment.

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
			thermal refuge area in summer habitat. Fish likely get more stress, more disease, may congregate in groundwater upwelling; may become more susceptible to entrainment if they move further downstream. Mitigation: Don't know causation - can't develop mitigation without knowing. Habitat improvements to decrease temps in other areas of reservoir?	summer habitat. Fish likely get more stress and disease, may congregate in groundwater upwelling; become susceptible to entrainment if they move further downstream.			
Rufus Woods - not great habitat for kokanee, mostly FDR entrained.							
Redband Rainbow Trout							
Elevations lower than 1283 feet can result in reduced access to tributary habitat. Becomes an issue for fall run rainbow. Note: See kokanee tab for analyses of MOs, this line for notes of anything specific to redband rainbow trout only.		See kokanee tab.	See kokanee tab.	See kokanee tab.	See kokanee tab.	See kokanee tab.	Check Dmitri on Deadwood reservoir reports. And Pat Monk at Kechelus and Kachees. 1283 feet is an operational metric. By Sep 30 at 1283 feet. Sep is peak run for kokanee/native fish.
Reservoir drawdowns increases susceptibility to predation of adults and juveniles moving from reservoir into tributaries (Feb-Apr) (h:) and outmigrating (typically with freshet, but outmigrate all year)Note: See kokanee tab for analyses of MO's, this line for notes of anything specific to redband rainbow trout only.	GC Elevation	See kokanee tab.	See kokanee tab.	See kokanee tab.	See kokanee tab.	Dry years - elevations lower than NAA, more susceptible to predation in Feb through May. Dry years have potential thermal issues. MO4 down to 1255, would have higher temps in reservoir. If higher tributary temperatures, they have to go through 20 vertical feet of drawdown zone to get to cooler reservoir temps. Fall run rainbow likely to fail. Near surface water likely unusable by salmonids. Also see kokanee tab.	Moving in typically in high flows that provide some cover, but reservoir can increase that predation rate. Important spawning tributaries - Sanpoil, blue Creek, Alder, Hall Creek, Nez Perce, Onion, Big Sheep, Deep Creek. Higher tributaries more susceptible to this effect because a smaller change in elevation would result in a larger area of exposure. Note recreational impact to tribe campground.
Transboundary reach mainstem river spawning. Drops in elevation Sept- Feb can strand eggs.	Stage at 720, 739	Stage at 739 (by border) 25 percentile. Stable. Median and above: End of Sep 1292, then increasing or stable until Jan 1, the time would drop from 1290 feet to about 1289 feet by the end of Feb. See hydrograph below.	25 percentile. Stable. Median and above. End of Sep 1292, Increasing or stable until Dec 1. Drops to 1292 feet by mid-Dec then down to 1289 feet by end of Feb. See graph below. Note: the elevations here are median, the 75% are similar pattern but	Similar to MO1 except starts lower at about 1290 feet Oct. 1, and slightly less steep drop in Dec. Jan to Feb same as NAA. Similar to MO1, but potentially less eggs affected due to lower starting location (fewer eggs	Same as NAA.	More variable hydrograph during spawning time period. See hydrograph. Lower stages for spawning could change distribution of spawning habitat, and variability could result in multiple spawning events being desiccated. Varial	WDFW Joint stock assessment annual reports. BPA. Chuck Lee author. Or Kalispel project on Cbfish. Project #1997-004-00 Mainstem spawning - inundated alluvial fans of reservoir and transboundary reach.

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		Eggs could be dewatered in 75% of years, from elevation 1292 early in Feb to 1289 by end of Feb. Any eggs in the upper 3 feet of river could be dewatered if they were still in gravels after the first week of Feb. Later spawners would be more affected if they deposited eggs above 1292 feet while still rising in October.	start slightly lower, and characterization of the effect is the same. Compared to NAA, the drop in elevation starts sooner, so a higher proportion of eggs would be affected. Steep drop in early Dec: any eggs deposited from 1292 feet to 1294 feet would be dewatered (only became available in mid-Dec, no time to emerge). Any eggs deposited from 1289 feet to 1292 feet that have not emerged by early Feb would be desiccated. About 2 feet lower than MO1 and about 4 feet lower than NAA.	likely in the zone that becomes dewatered.)		zone effects likely to occur, and more eggs desiccated than NAA. Lower stages for spawning could change distribution of spawning habitat. Varial zone effects.	NOTE: Descriptions in "Data" columns refer to the transboundary elevation data (739.939), but the patterns are similar at 720.431. Both are displayed below and the filter button can be used to look at lines in any combination desired.
Fragmentation isolates populations, limits ability to express or complete all life history strategies. Fish attempt to migrate downstream and are then blocked from getting back to FDR. No change to this from any alternative.	–	Outmigrating redband, go below the dam and don't make it back up. Have detected as far downstream as East Sand Island. Fragmentation effects would continue.	Same as NAA.	Same as NAA.	Same as NAA.	Same as NAA.	McLellan, or unpublished data. Redband RM&E project annual report. PTAGIS data.
Northern Pikeminnow							
Drawdowns in spring can strand adult pike.	–	Level Oct to Jan, then decrease smoothly to mid-Mar, level to mid-Apr, decrease more to May, then initiate refill straight up to Jul fill. Springtime, water low, shorelines get vegetated, then levels come up and inundate the vegetation, pike spawn. Backwater habitats provide pike. They can wait for good conditions to spawn.	See graph - more variation in spring (up Mar 1 then dewater, but could be a modeling artifact. Potentially strand more pike in Dry years (20% of years) if spawning habitat is inundated and then dewatered again. Not Singers Bay because at lower elevation, but could be other bays/backwaters that inundate then dewater. Wet and average years same as NAA.	Same as MO1.	Same as NAA.	Similar to MO1; same pattern at slightly different elevation.	Personal communication, Bret Nine (unpublished data documented pike stranding event in Singers Bay). Elevation 1253 dries out Singers Bay, stranding adult pike (personal communication, Bret Nine), but no difference between alternatives noted. Pike are very adaptive and opportunistic; they will wait for conditions to spawn so minor changes in elevations or timing would not affect their spawning success. Subsequent note: Originally said no differences noted, but after H&H data visualized, potential stranding in MO1, 2, and 4 in Dry years possible.
Residence time - see kokanee tab, influences entrainment, may increase rate of dispersal downstream; hastens rate of invasion.	Outflows and retention time.	See kokanee tab for RT. Pike established and increasing in the reservoir. Juveniles likely being entrained and invading further downstream.	Increased outflows in Dec, 3% to 5% less in May to Sep. See also kokanee tab for RT data. Dec difference - not likely to be in that area in Dec. Slight	1% to 6% lower Mar-Jul. Dec. up to 13% higher. Adult Pike not likely there at that time, but juveniles could be entrained. Walleye are there all the time, likely to increase entrainment in Dec. Slight decrease in risk March-July. SMB, pikeminnow all	Same as MO1.	Dry year increased outflows in May-Jul increases entrainment risk. See kokanee for retention time data. May, June, July, Aug RT 21% to 29% faster than NAA. Dry years increased outflows in summer. Wet/Ave years similar to MO1. Dry years: Decreased	LeClaire (2000), documented the zooplankton and kokanee. Juvenile pike in system now. Any MOs that decrease retention time. Lower reservoir elevation, more likely to moving downstream, pike more shoreline, but up to 80 feet noted.

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
			decrease in entrainment risk in May to Sep.	similar risk. See also kokanee tab for RT data.		retention time (21% to 29% faster) and, increased outflows may increase rate of dispersal downstream in dry years. Summertime is when juvenile pike would be foraging and more susceptible to entrainment.	
Spring ops impede boat launches; impede suppression efforts.	–	Wet years: Apr 15.	–	–	–	–	–
Ave and Dry years begin refill at 1245 feet, ramps don't go out of the water. Would continue to net and remove pike at current level of effort.	Exceedance plots: 99% exceedance plot reaches 1235 feet in mid-Mar, 2 weeks earlier than NAA (Apr 1), 75% exceedance is similar to NAA. Median of low water years (lowest 20%) is Apr 15 (NAA is Apr 8) so one week sooner than NAA. Elevation comparisons: 1235 feet by Apr 9, 6 days sooner. One to two weeks less time to do pike suppression efforts. See notes for numeration.	Same as MO1	Same as NAA.	NA	Unpublished data, Colville Tribe 60 nets removed 107 pike in one week by 1 crew. Note - would normally have 3 crews at that time. Mitigation: extend boat ramps to ensure year-round access at lower elevations. Mitigation - Block nets. Mitigation: increase non-native predator control efforts	–	–
Game Fish							
Migratory Fishery – Rainbow Trout							
Similar impacts as redband and kokanee, except no spawning impacts.	–	–	See kokanee tab	See kokanee tab	See kokanee tab	See kokanee tab	–
Reservoir elevation can affect water quality in the location of the net pens.	Surface DO and temperature at locations, May 15 to Jun 15.	See Mitigation Fishery Water Quality summary. Temp, DO at locations can affect the fish prior to release or force early release. Disease and WQ issues.	Similar to NAA.	Similar to NAA.	Similar to NAA.	Two Rivers location, up Spokane arm, warmer in June (check data). Keller (closest to dam) - Ave years, very small changes; but	Drawdown affects to net pens. Surface temps and TDG at net pen locations, Expect more impacts in Spokane arm locations? See Mitigation Fishery Location water quality summary.

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
						see changes in stratification with increase in temperature, potentially allows cooler water to spread to surface; slight decrease in surface (applies to all MOs). All four MOs show a warmer than NAA in the fall in all years except LF/HT, difficult to figure causation - looks like decreasing stratification, maybe pulling only out of deep?	MO2 and MO4 potentially higher percentage of habitat in Spokane Arm with low DO, thereby reducing habitat. Causation not determined; may be modeling error.
Reservoir elevations control how far the lake backs up into the Spokane arm, affecting the depth and therefor the rate of water freezing. Lower elevations can cause earlier freezing and early release of net pens when they do not survive as well.	Reservoir elevation -	Have not seen in past operations, would not freeze.	No effects	NO Effect	No effects	6 feet to 8 feet lower in Dec/Jan	Lower reservoir elevations could increase freezing, would have to move fish out sooner. Net pens, entry fish go into pens in Fall and rear into spring; Net pens are just around corner from reservoir, don't think freezing would be an issue.
Date of refill could put releases into a time where multiple other stressors have made released fish more susceptible to mortality from TDG, temps, etc.	Initiation of refill	–	–	–	–	–	–
Retention time	Get current initiation of refill date. Refill begins early May	Same as NAA	Same as NAA	Same as NAA	Refill initiates 2nd week of June in dry years. Ave years = similar to NAA Wet years, 2 weeks earlier in NAA. Delay of refill initiation in dry years would result in releasing hatchery fish up to 4-6 weeks later, where they would likely encounter more stressful rearing conditions (higher temps and potentially TDG). Or, if released prior to initiation of refill, they would be more susceptible to entrainment. Conditions in dry years likely to be already stressful to fish, further exacerbated by delay of release. IN wet years, the earlier release could be reduced TDG and temp stress (likely experience higher TDG but lower thermal stress.	Target releases to initiation of refill date. Date of refill could change with alternatives.	–

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Deeper drawdown impacts mitigation fishery… Lower retention time can increase susceptibility to entrainment in the weeks post-release. (As compared to general entrainment risk discussed in kokanee tab.)	See retention time graphs, similar to kokanee tab. June 1 RT	June 1 RT: (Ave, Wet, Dry) = 21 days, 16 days, 34 days. Fish released at initiation of refill, about early May.	June 1 RT: (Ave, Wet, Dry) = 21 days, 16 days, 35 days. Same as NAA.	June 1 RT: (Ave, Wet, Dry) = 21 days, 16 days, 35 days. Similar to NAA. 1 day higher RT.	June 1 RT: (Ave, Wet, Dry)= 22d, 16d, 35d Same as NAA. Or slightly less risk. 1 day higher retention time.	Keller Location: Ave Years; Similar or slight increase in retention time, slightly cooler at surface Dry Years: Decrease of 9 days average in May-Jun period in lower flow years (missing full pool), no change to temps/TDG. June 1 RT: (Ave, Wet, Dry) = 21 days, 16 days, 25 days Water quality would not change operation of net pens, but would expect greater entrainment of mitigation fish in dry water years. 10 days shorter retention time; 40% lower, much higher entrainment risk. Deep water cold refugia is impacted, but not seeing much change at surface. McNary measure triggers in low flow years, but it is gradational of how much is needed, so 2013 likely providing less storage water (not much change in retention time; 2015 probably shows using full 2 MAF. RT note: 40% lower RT. Not known if RT to recruitment to tag recovery is linear relationship, but definitely much higher risk of entrainment loss.	Retention time 4 weeks post-release correlated with tag returns when reservoir elevations below 1250' elevation. This occurs in wet and average years in all MO's, and Dry year MO4 (see summary elevation comparisons).
Fishery community - component of the fishery -	–	Note: Walleye, smallmouth bass, pikeminnow, etc., are generalists and favored by reservoir environments. Changes in reservoir operations unlikely to affect populations. See kokanee tab for food web/productivity that fuels these populations. Similar relationships, but relative to prey fish. Changes in entrainment risk could increase their populations downstream. See pike tab. Walleye Spawning Spokane Arm - move in Feb, spawn in April. Very successful spawners, entrainment moves them	–	–	–	–	Spokane arm - perch comprised 91% of juvenile fish in 2017 (Spokane 2017 annual report), FDR overall Fish caught by anglers (2015-2017): 150,000 hatchery rainbow trout 260,000 walleye 59,000 smallmouth bass Wild rainbow 15,000 Wild kokanee 16,000

Affected Environment Important Relationships/Criteria	Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		through, LRW, down to mid-C and beyond. Spokane arm shifted almost entirely to non-native game fish, mostly perch. Walleye negatively impacted by anything that lowers productivity (most walleye captured are low condition, probably food-limited).					
TDG effects net pen fish in Lake Rufus Woods.	–	Net pens in L. Rufus Woods, as TDG increases have to release them into the lake rather than out to tributaries throughout the reservation for resources. Don't know survival of net pen fish, or impact on releasing them there. (Commercial net pen fish have very high mortality). May be able to release more fish into the tributaries to serve as resource.	TDG lower than NAA.	–	–	–	Increased flows increase TDG. Elevation below 1265 with high outflows increases TDG. Maintenance measure should increase TDG, but other measures reduce outflows during those periods so overall TDG is lower in all alts. Could impact resident fish.
Lake Rufus Woods rainbow trout, walleye, native fish (prey) bluegill,	–	Entrainment - flows affect entrainment but don't have it quantified. Could also be similar effect entraining food similar to kokanee tab in Lake Roosevelt. Fish typically spawn on shorelines. Few tributaries. Lake elevations typically stable during day but wide fluctuations at night.	–	–	–	–	–

Baldwin and Polacek, 2002
Beeman et al., 2003
Bonar et al., 2000
Eagles-Smith, 2016
Hansen et al., 1992
LeClaire, 2000
Nine, Bret. Personal communication.
Willacker, 2016

5399 **Table 3-76. Average monthly retention time for each alternative including change from NAA**
5400 **and percent change.**

Month	Average Retention Time	Average Change	Average Percent Change	Average Dry Retention Time	Dry Change	Percent Dry Change	Average Wet Retention Time	Wet Change	Percent Wet Change
MO1									
October	73.8	0.1	0%	75.8	-0.3	0%	72.5	-0.1	0%
November	51.6	-0.4	-1%	53.0	-0.1	0%	51.1	-0.4	-1%
December	45.0	-2.7	-6%	47.7	-3.5	-7%	43.0	-2.4	-6%
January	41.1	-2.2	-5%	47.1	-3.3	-7%	34.5	-1.9	-6%
February	33.8	-0.2	-1%	45.8	-3.1	-7%	25.4	-2.4	-9%
March	39.2	0.1	0%	60.3	1.8	3%	24.1	-2.1	-9%
April	34.5	-0.1	0%	52.8	0.3	1%	19.6	-1.0	-5%
May	23.7	0.5	2%	35.4	1.4	4%	14.6	-0.5	-3%
June	26.8	0.1	0%	38.3	0.7	2%	20.1	0.2	1%
July	33.0	-0.1	0%	46.1	-0.4	-1%	27.2	0.1	0%
August	41.3	0.0	0%	44.9	0.4	1%	34.3	0.3	1%
September	65.3	0.0	0%	64.4	0.6	1%	59.8	0.2	0%
MO2									
October	81.3	7.6	9%	83.2	7.1	9%	79.7	7.2	9%
November	50.3	-1.6	-3%	52.1	-0.9	-2%	9.0	-2.6	-5%
December	42.2	-5.5	-13%	45.5	-5.6	-12%	40.5	-4.9	-12%
January	41.9	-1.4	-3%	46.3	-4.1	-9%	35.2	-1.2	-3%
February	33.7	-0.3	-1%	46.2	-2.7	-6%	23.9	-3.9	-16%
March	40.3	1.2	3%	61.8	3.2	5%	24.7	-1.5	-6%
April	35.2	0.7	2%	54.0	1.5	3%	19.8	-0.7	-4%
May	24.0	0.8	3%	35.8	1.8	5%	14.8	-0.2	-2%
June	27.0	0.4	1%	38.7	1.1	3%	20.1	0.2	1%
July	33.2	0.1	0%	47.3	0.9	2%	27.2	0.1	0%
August	41.4	0.1	0%	45.8	1.2	3%	34.3	0.3	1%
September	62.4	-2.8	-5%	59.0	-4.7	-8%	58.4	-1.2	-2%
MO3									
October	79.2	5.5	7%	81.2	5.1	6%	77.7	5.1	7%
November	50.4	-1.5	-3%	52.2	-0.9	-2%	49.3	-2.3	-5%
December	46.4	-1.3	-3%	49.5	-1.7	-3%	44.6	-0.8	-2%
January	45.7	2.4	5%	49.1	-1.3	-3%	39.9	3.4	9%
February	34.1	0.1	0%	48.7	-0.1	0%	27.1	-0.6	-2%
March	39.4	0.4	1%	59.0	0.5	1%	25.6	-0.6	-2%
April	34.6	0.0	0%	51.9	-0.5	-1%	20.3	-0.2	-1%
May	23.8	0.6	3%	35.7	1.7	5%	15.0	-0.1	-1%
June	26.8	0.2	1%	38.8	1.2	3%	20.0	0.1	0%
July	33.1	0.0	0%	47.3	0.9	2%	27.1	0.0	0%
August	41.4	0.1	0%	45.8	1.3	3%	34.2	0.3	1%

Month	Average Retention Time	Average Change	Average Percent Change	Average Dry Retention Time	Dry Change	Percent Dry Change	Average Wet Retention Time	Wet Change	Percent Wet Change
September	65.4	0.1	0%	65.0	1.3	2%	59.8	0.2	0%
MO4									
October	82.1	8.4	10%	84.2	8.1	10%	80.0	7.4	9%
November	51.6	-0.3	-1%	52.8	-0.2	0%	51.1	-0.4	-1%
December	45.0	-2.7	-6%	47.8	-3.4	-7%	43.5	-2.0	-5%
January	40.1	-3.2	-8%	44.6	-5.8	-13%	35.7	-0.8	-2%
February	33.8	-0.2	-1%	45.5	-3.4	-7%	25.5	-2.2	-9%
March	39.2	0.1	0%	63.1	4.6	7%	24.3	-1.8	-7%
April	34.7	0.1	0%	53.3	0.8	2%	19.6	-0.9	-5%
May	22.5	-0.7	-3%	26.8	-7.2	-27%	14.7	-0.4	-3%
June	25.0	-1.6	-7%	29.4	-8.2	-28%	20.0	0.1	1%
July	30.3	-2.8	-9%	38.4	-8.0	-21%	27.1	0.0	0%
August	38.8	-2.5	-7%	39.9	-4.6	-12%	34.2	0.3	1%
September	66.3	1.0	1%	67.1	3.4	5%	59.8	0.1	0%

5401 **Table 3-77. Average monthly retention time for the NAA by water year.**

Month	Average Retention Average	Dry Retention Time	Average Wet Retention Time
October	73.7	76.1	72.6
November	51.9	53.1	51.5
December	47.7	51.2	45.4
January	43.3	50.4	36.4
February	34.0	48.9	27.7
March	39.0	58.5	26.2
April	34.6	52.4	20.5
May	23.2	34.0	15.1
June	26.7	37.6	19.9
July	33.1	46.4	27.1
August	41.3	44.5	33.9
September	65.3	63.8	59.6

5402

5403 **Table 3-78. Change in Temperature and Total Dissolved Gas at Select Net Pen Locations in Lake Roosevelt for Each Alternative in Representative Water Years.**

Δ from NAA	2011 TDG	2011 Temperature	2012 TDG	2012 Temperature	2013 TDG	2013 Temperature	2014 TDG	2014 Temperature	2015 TDG	2015 Temperature
MO1										
RT (Days	-0.5	4.8	0.0	0.3	1.8					
Sherman Creek Seg-153	0.0	0.0	-0.7	0.0	0.0	0.0	-0.1	0.0	0.1	0.2
Hall Creek Seg-186	0.3	-0.1	-1.0	0.2	1.4	-0.3	-0.1	0.0	1.3	0.7
Hunters Seg-213	0.1	0.0	-1.4	0.3	1.7	-0.8	-0.2	0.0	1.1	1.0
Seven Bays Seg-253	0.5	-0.1	-1.6	0.5	1.6	-0.5	-0.5	0.2	1.1	0.9
Lincoln Seg-259	0.4	-0.1	-0.8	0.3	1.1	-0.4	-0.5	0.1	1.0	0.9
Keller Seg-291	0.3	-0.1	-1.9	0.7	1.7	-0.6	-0.7	0.3	0.8	0.7
Two Rivers Seg-542	0.0	0.0	0.4	0.0	1.2	-0.5	0.0	0.1	0.9	0.6
MO2										
RT (Days	-0.4	4.7	0.0	0.5	2.0					
Sherman Creek Seg-153	0.0	0.0	-0.7	0.0	0.2	-0.1	-0.2	0.0	0.7	0.0
Hall Creek Seg-186	0.4	-0.1	-1.1	0.2	1.7	-0.4	-0.1	0.0	1.4	0.8
Hunters Seg-213	0.1	0.0	-1.4	0.3	2.0	-0.9	-0.4	0.1	1.2	1.1
Seven Bays Seg-253	0.5	-0.1	-1.6	0.5	2.1	-0.7	-0.6	0.2	1.3	1.0
Lincoln Seg-259	0.3	-0.1	-0.8	0.3	1.5	-0.5	-0.7	0.2	1.2	1.0
Keller Seg-291	0.3	-0.1	-1.9	0.7	2.0	-0.6	-1.1	0.4	0.9	1.0
Two Rivers Seg-542	0.0	0.0	0.4	0.0	1.4	-0.5	0.1	0.1	0.7	0.6
MO3										
RT (Days	-0.1	5.0	0.0	0.5	1.9					
Sherman Creek Seg-153	0.0	0.0	-0.8	0.1	0.0	0.0	-0.2	0.0	0.1	0.2
Hall Creek Seg-186	0.0	0.0	-2.6	0.5	-0.3	0.0	-0.1	0.0	1.2	0.7
Hunters Seg-213	-0.2	0.1	-3.3	0.7	-0.4	0.2	-0.3	0.1	1.1	0.9
Seven Bays Seg-253	-0.4	0.2	-3.3	1.2	-0.4	0.3	-0.6	0.2	1.1	0.9
Lincoln Seg-259	-0.4	0.1	-2.5	0.9	-0.3	0.1	-0.6	0.2	1.0	0.8
Keller Seg-291	-0.5	0.2	-3.2	1.1	-0.7	0.3	-0.9	0.4	0.7	0.7
Two Rivers Seg-542	0.0	0.1	0.0	0.5	-0.2	0.1	0.1	0.0	0.9	0.7
MO4										
RT (Days	-0.5	4.8	-1.4	0.5	-8.8					
Sherman Creek Seg-153	0.0	0.0	-0.7	0.0	0.2	-0.1	-0.2	-0.1	0.7	0.0
Hall Creek Seg-186	0.4	-0.1	-1.1	0.2	1.7	-0.4	-0.1	-0.2	1.4	0.8
Hunters Seg-213	0.1	0.0	-1.4	0.3	2.0	-0.9	-0.4	0.1	1.2	1.1
Seven Bays Seg-253	0.5	-0.1	-1.6	0.5	2.1	-0.7	-0.6	0.1	1.3	1.0
Lincoln Seg-259	0.3	-0.1	-0.8	0.3	1.5	-0.5	-0.7	0.1	1.2	1.0
Keller Seg-291	0.3	-0.1	-1.9	0.7	2.0	-0.6	-1.1	0.0	0.9	1.0
Two Rivers Seg-542	0.0	0.0	0.4	0.0	1.4	-0.5	0.1	-0.1	0.7	0.6

5404 Note: None of these locations were calibration points in the model, and none of the temperature or TDG changes noted in the table represent change outside of the modeling error range. Retention time was included in this table as a preliminary exercise for team
5405 discussion purposes; retention time data used in analyses is presented separately.

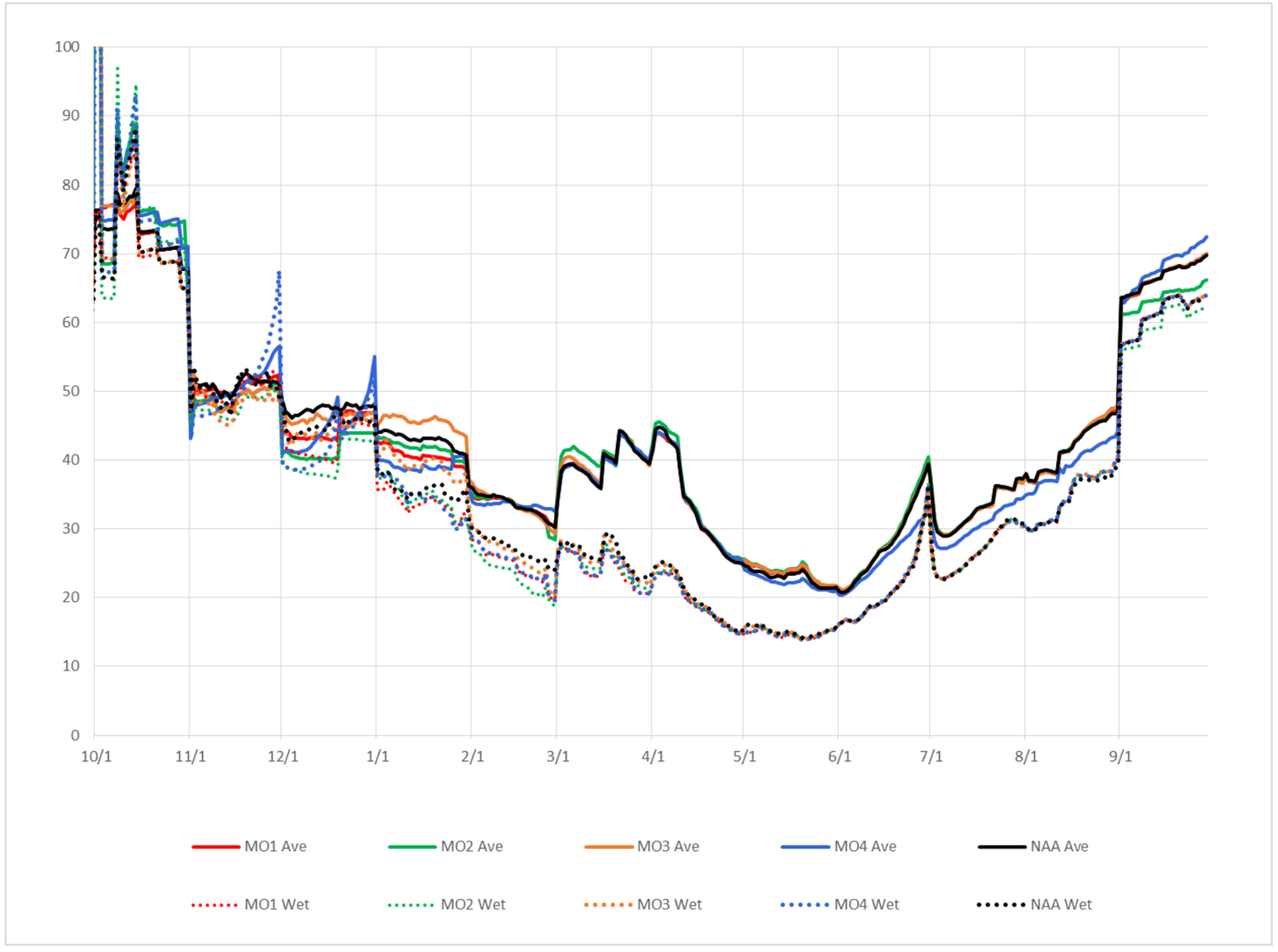

Figure 3-1. Summary hydrograph showing median retention time throughout the water year in wet and average water years.

3.8.3 Chief Joseph Dam to McNary Dam

Table 3-79. Columbia River Resident Fish Qualitative Effects Analysis Matrix

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Bull Trout							
Chief Joseph Dam to Priest Rapids Dam							
Cold water required. Prefer temperatures less than 15°C can limit distribution.	Temperatures in FMO habitat – percent of days of 15°C – Oct to Jul	Under the NAA, temperatures would support FMO habitat from Oct through Jul (when bull trout are present). CHJ = 18.9% of days over 15°C; high = 19.0°C PRD = 21.1% of days over 15°C; high = 21.6°C MCN = 25.4% of days over 15°C; high = 23.7°C Under the NAA, temperatures will support bull trout from mid-Oct through mid-Jun. Bull trout are found at several dams during Jul, during higher temperatures, as well. Bull trout will continue to use the Columbia River as migratory and overwintering habitat during this time period.	CHJ = 18.8% of days over 15°C; high = 18.7°C PRD = 21.9% of days over 15°C; high = 21.7°C MCN = 25.0% of days over 15°C; high = 23.8°C Under MO1, there is no difference from NAA.	CHJ = 18.8% of days over 15°C; high = 18.7°C PRD = 21.9% of days over 15°C; high = 21.7°C MCN = 25.0% of days over 15°C; high = 23.8°C Under MO1, there is no difference from NAA.	CHJ = 18.9% of days over 15°C; high = 19.3°C PRD = 21.5% of days over 15°C; high = 21.8°C MCN = 25.2% of days over 15°C; high = 23.8°C Under MO1, there is no difference from NAA.	CHJ = 19.1% of days over 15°C; high = 18.7°C PRD = 21.4% of days over 15°C; high = 21.8°C MCN = 24.5% of days over 15°C; high = 24.0°C Under MO1, there is no difference from NAA.	Bull trout are seen in this river reach in all months of the year, even when temperatures exceed 18°C. However, the majority are seen in late spring and early summer ~ leaving the mainstem for cooler habitats. PUDs have bull trout management plans. PIT data mouth of Okanagan, etc.
Dams create migration barriers for adfluvial populations. May be more useful to couch in terms of delays, not barriers.	Fish passage at dams – mean bull trout per year.	Ladder counts at PUDs show fish in the system from Apr through Nov. Mean BT/YR: MCN = 0.0, PRD = 4.0, WAN = 4.4, RIS = 46.8, RRC = 98.7, WEL = 42.6. Under the NAA, bull trout will continue to pass all dams in this reach except CHJ. An unknown number may be delayed or blocked.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Projects typically don't study bull trout, some opportunistic sampling/tagging. Wells has array and weir at Okanagan that may provide additional information on movement. Possibly Wenatchee at Tumwater Dam. PUD annual reports.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Hanford Reach							
Temperatures to support FMO Oct to Jul.	Temperatures in FMO habitat.	Water temperature in Hanford Reach. Temperatures currently support FMO habitat form Oct through Jun (when bull trout are present). This is the same as Line 10, above. We would use the same metrics as PRD. PRD = 21.1% of days over 15°C; high = 21.6°C. Under the NAA, water temperatures in the Hanford reach are conducive for bull trout FMO habitat. However, bull trout are rarely found here.	PRD = 21.9% of days over 15°C; high = 21.7°C No difference from NAA	PRD = 21.5% of days over 15°C; high = 21.8°C Under MO2, there is no difference from NAA	PRD = 21.4% of days over 15°C; high = 21.8°C Under MO3, there is no difference from NAA	PRD = 21.8% of days over 15°C; high = 22.3°C Under MO4, temperature is slightly higher because of changes in upstream operations. We do not expect few 10ths of a degree to have difference impacts than the NAA.	Rarely seen below PRD. Too far from source tributaries.
TDG Effects – bull trout leaving in spring before TDG increases. The USFWS recommends maintaining TDG at 110% or less for bull trout habitat.	Percent of days mean daily TDG levels over 110 at CHJ tailwater and MCN forebay from Oct to Jul.	TDG over 110%; CHJ tailwater = 11.3% MCN forebay = 26.0% Under the NAA, there continues to be a risk for negative impacts from TDG on bull trout May through Jul in this reach of the river.	TDG over 110%; CHJ tailwater = 11.8% MCN forebay = 28.0% No change from NAA	TDG over 110%; CHJ tailwater = 16.7% MCN forebay = 15.8% Under MO2, TDG is expected to have greater potential for negative effects to bull trout just below CHJ and a reduced potential for negative impacts near McNary Dam.	TDG over 110%; CHJ tailwater = 10.1% MCN forebay = 25.5% Under MO3, there would be a slight reduction in the potential for negative effects from TDG to bull trout populations.	TDG over 110%; CHJ tailwater = 8.2% MCN forebay = 29.8% (70.2% tailwater) No change from NAA	Several studies found that bull trout were not severely impacted by TDG because of their ability to sound and avoid high TDG surface waters. Weitkamp et al., 1980; Weitkamp et al., 2003.
White Sturgeon							
Dams create barriers to movement.	Sturgeon passage at dams	Sturgeon have been documented passing upstream at only TDA. Downstream passage is more common. Recruitment from upstream sources suggests downstream passage at most dams. Under the current conditions white sturgeon will continue to pass upstream at TDA in limited numbers, while larger numbers of white sturgeon will continue to pass downstream of PUD and project dams in this reach of the Columbia River.	No measures address upstream migration of white sturgeon, so no difference from NAA.	No measures address upstream migration of white sturgeon, so no difference from NAA.	Under MO3, the four lower Snake River dams will be removed and white sturgeon from MCN pool and the Hanford Reach will have access to the Hells Canyon Complex. Connectivity of these populations would likely increase spawning and recruitment success and would increase fitness of the entire population.	No measures address upstream migration of white sturgeon, so no difference from NAA.	Upstream sources often cited as seeding downstream habitats. Downstream movement from upper Columbia River pools supports this (2011). Sturgeon can't use ladders. Emigration out is 5% or less. PUDs stock since 2011, 27,000 hatchery fish, common juveniles in CHJ to PRD. Check if supplementation fish or CRITFC fish (experimental sturgeon culture, released 20,000 juveniles at Rock Island about 2003). Some remain, some flushed out, see all the way down below MCN. Hildebrand et al., 2016; and 2013 Management Plan.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Spawning sites limited in slow water habitats. Need high spring flows over cobble/gravel habitats at 10°C to 12°C to initiate spawning (May to Jun).	Water flows over cobble/gravel substrates (May to Jun) 25th percentile at PRD.	Currently, adequate spawning substrates are located in the tailwaters of CHJ and the PUD dams. Mean 25th percentile (May to Jun) for NAA = 207,431 kcfs. Peak is 247,375 kcfs. Under the current conditions flows and temperatures are adequate for white sturgeon spawning. However, suitable habitat or substrate are limiting. They lack cobble/gravel substrate. Limited to tailraces at PUDs and Hanford Reach. Check PUDs. Substrate may not be limiting for spawning.	Mean 25th percentile (May to Jun) for MO1 = 202,565 kcfs (2.3%). Peak is 242,822 kcfs. MO1 high flows are ~ 2.3% lower and white sturgeon spawning success may be somewhat reduced when compared to the NAA. Lower number of adults may limit success even under high water years. Supplemental fish should help augment these populations.	Mean 25th percentile (May to Jun) for MO2 = 204,499 kcfs (1.4%). Peak is 245,911 kcfs. MO2 high flows are ~ 1.4% lower and white sturgeon spawning success may be somewhat reduced when compared to the NAA.	Mean 25th percentile (May to Jun) for MO3 = 202,474 kcfs (2.4%). Peak is 242,968 kcfs. MO3 high flows are ~ 2.4% lower and white sturgeon spawning success may be somewhat reduced when compared to the NAA.	Mean 25th percentile (May to Jun) for MO3 = 202,412 kcfs (2.4%). Peak is 242,896 kcfs. MO3 high flows are ~ 2.4% lower and white sturgeon spawning success may be somewhat reduced when compared to the NAA.	White sturgeon generally initiate spawning at 10°C to 12°C during the peak or descending limb of the hydrograph. Higher flow years have better success. Tailraces of dams (less than a mile) and open river in Hanford Reach areas are only spawning habitats. Substrate is stable, probably not affected by flows. Hildebrand et al., 2016.
Higher flows can influence rate of outmigration of hatchery supplementation fish, resulting in loss of juveniles from project area. Some of these fish are seen downstream of MCN.	Outflows in May/Jun. Percent increase or decrease in high flows in May/Jun at PRD.	Flows rise rapidly starting in May and peak ~ 4 Jun, then drop rapidly till Jul. Mean median flow (May to Jun) for NAA at PRD = 168,562 kcfs. Under current conditions, an unknown number of hatchery supplemental white sturgeon will be entrained from the project area.	Mean median flow (May to Jun) for MO1 at PRD = 163,644 kcfs (2.9). Slightly lower flows under MO1 would decrease risk for outmigration of supplemental fish from the project area.	Mean median flow (May to Jun) for MO2 at PRD = 165,727 kcfs (1.7). Slightly lower flows under MO2 would decrease risk for outmigration of supplemental fish from the project area.	Mean median flow (May to Jun) for MO3 at PRD = 163,355 kcfs (3.1). Slightly lower flows under MO3 would decrease risk for outmigration of supplemental fish from the project area.	Mean median flow (May to Jun) for MO4 at PRD = 167,638 kcfs (0.5). Slightly lower flows under MO4 would decrease risk for outmigration of supplemental fish from the project area.	Populations are not self-sustaining. Hatchery supplementation is needed to build populations. Hatchery fish are released in May/Jun timeframe. Target release of 200g fish. PUDs have natural recruitment studies information. Higher flows could increase outmigration of hatchery-raised supplemental fish from the project areas. PUDs time spill releases and put fish in locations to reduce losses of hatchery fish. High flows promote spawning of wild fish. Timing of releases is important for retaining these fish. June is peak critical month for entrainment. More easily lost from project area. Question for group – does the team want high flows in May and June to promote spawning or low flows to promote retention of hatchery fish?

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Natural recruitment is inconsistent. Very high flow years can lead to recruitment. When discharge rates at MCN reach or exceed 250 kcfs, there is generally a detectible level of recruitment in the reservoirs.	Outflows in May/Jun. Average daily discharge from May through Jul peak flows for NAA 25% is over 250 kcfs at MCN.	The NAA shows median flows for May through Jul at 245,457 kcfs. Days over 250 kcfs = 10.1% (9.3 days).	The MO1 alternative shows median flows for May through Jul at 242,054 kcfs (1.4%). Days over 250 kcfs = 9.6% (8.8 days). Slightly reduced flows at MCN for MO1 will likely result in minor reductions in spawning success for white sturgeon.	The MO2 alternative shows median flows for May through Jul at 242,470 kcfs (1.2%). Days over 250 kcfs = 9.6%. Slightly reduced flows at MCN for MO2 will likely result in minor reductions in spawning success for white sturgeon.	The MO3 alternative shows median flows for May through Jul at 242,929 kcfs (1.0%). Days over 250 kcfs = 9.6%. Slightly reduced flows at MCN for MO3 will likely result in minor reductions in spawning success for white sturgeon.	The MO4 alternative shows median flows for May through Jul at 241,812 kcfs (1.5%). Days over 250 kcfs = 9.9%. Slightly reduced flows at MCN for MO4 will likely result in minor reductions in spawning success for white sturgeon.	PUDS natural recruitment data. Very minimal to no recruitment in pools between PRD and CHJ. General theory is that high flow events can lead to low-level natural recruitment, but it is still very low due to low numbers of adults in area. When discharge rates at MCN reach or exceed 250 kcfs, there is generally a delectable level of recruitment in the reservoirs. NPPC, 2013.
Hanford Reach – very minimal recruitment now. Sturgeon need very high flows to spawn and recruit. High flows distribute larvae before exogenous feeding, provide drift, and trigger spawning.	High flows – Compare 25% exceedance for each alternative.	Currently, adequate spawning substrates are located in the tailwaters of CHJ and the PUD dams. Mean 25th percentile (May to Jun) for NAA = 207,431 kcfs. Peak is 247,375 kcfs. Under current conditions, white sturgeon spawning will result in limited recruitment in high flow years.	Mean 25th percentile (May to Jun) for MO1 = 202,565 kcfs (2.3%) Peak is 242,822 kcfs. MO1 high flows are ~2.3% lower and white sturgeon spawning success may be somewhat reduced when compared to the NAA.	Mean 25th percentile (May to Jun) for MO1 = 202,565 kcfs (2.3%) Peak is 242,822 kcfs. MO1 high flows are ~2.3% lower and white sturgeon spawning success may be somewhat reduced when compared to the NAA.	Mean 25th percentile (May to Jun) for MO1 = 202,565 kcfs (2.3%) Peak is 242,822 kcfs. MO1 high flows are ~2.3% lower and white sturgeon spawning success may be somewhat reduced when compared to the NAA.	Mean 25th percentile (May to Jun) for MO1 = 202,565 kcfs (2.3%) Peak is 242,822 kcfs. MO1 high flows are ~2.3% lower and white sturgeon spawning success may be somewhat reduced when compared to the NAA.	Young-of-year recruitment and timing same as below MCN, but far lower recruitment in MCN pool.
Flow and turbidity affect suitability and amount of spawning habitat. Need turbidity for egg and larval survival.	Outflows at projects, and turbidity levels in water quality data.	Limited qualitative evaluation of turbidity was completed by the water quality team. No issues with turbidity and suspended sediments.	No difference from NAA anticipated.	No difference from NAA anticipated.	Significant increase during breaching of lower Snake River dams and for several years after depending on erosion rate of deposited materials. Subsequent amounts dependent on watershed land-use practices and runoff events.	No difference from NAA anticipated.	Water qualitative matrix.
TDG – 50% mortality at elevated TDG ~ 130%. Larval sturgeon are most impacted as they drift in the water column.	Percent of days TDG over 118% = no mortality (Counihan et al., 1998).	Percent of days over 118%; MCN = 0.9% CHJ = 0.8% Under the NAA, TDG is not likely to have a negative impact on white sturgeon.	Percent of days over 118%; MCN = 0.6%; CHJ = 0.8% No change from NAA.	Percent of days over 118%; MCN = 0.6% CHJ = 0.8% No change from NAA.	Percent of days over 118%; MCN = 0.6% CHJ = 0.8% No change from NAA.	Percent of days over 118%; MCN = 1.1% CHJ = 0.8% No change from NAA.	Elevated TDG at tailraces are likely source of stress. Larval sturgeon are more impacted as they drift in the water column. Adult sturgeon use deep habitats. This metric was not effective in separating the alternatives.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Extreme low flows and higher reservoir temperatures can cause increased mortality of adults in and females going attritic above 18°C.	Temperatures in reservoirs (flows are related to temperature).	Temperature and flow in MCN reservoir. Mean temperature (Jul to Aug) = 21.1°C Mean flow (75%) in MCN during hot months (Jul to Aug) = 135,142 kcfs. Extreme low flow or high temperature years would continue to result in mortality events.	Mean temperature (Jul to Aug) = 21.1°C Mean flow (75%) in MCN during hot months (Jul to Aug) = 135,142 kcfs. Extreme low flow or high temperature years would continue to result in mortality events.	Mean temperature (Jul to Aug) = 21.1°C Mean flow (75%) in MCN during hot months (Jul to Aug) = 135,142 kcfs. Extreme low flow or high temperature years would continue to result in mortality events.	Mean temperature (Jul to Aug) = 21.1°C Mean flow (75%) in MCN during hot months (Jul to Aug) = 135,142 kcfs. Extreme low flow or high temperature years would continue to result in mortality events.	Mean temperature (Jul to Aug) = 21.1°C Mean flow (75%) in MCN during hot months (Jul to Aug) = 135,142 kcfs. Extreme low flow or high temperature years would continue to result in mortality events.	2015 elevated temperatures cased higher mortality of fish below MCN. Did not see those mortalities above MCN. Use 2015 data to test this assumption. Recent, increased number of adult die-offs due to stress during high temperatures (female attrition coupled with thermal stress).
Flows relationship to early recruitment. Hatched larva need to be distributed to suitable habitats. Without flow risk, of failure increases.	–	–	–	–	–	–	Colville Tribes a good source for this information.
Food sources – linked to reservoir productivity.	Reservoir productivity – taken from water quality matrix at MCN pool ~ surrogate for system productivity.	Carlson TSI: mesotrophic or eutrophic; limited data. Under the NAA, MCN pool is productive and has adequate food sources for white sturgeon.	No change from NAA.	No change from NAA.	Productivity and food resources would be reduced during breach and until new equilibrium established.	No change from NAA.	Foods – white surgeon have a seasonal diet; crayfish, clams, and shad are important prey. Sockeye salmon are seasonally important and may vary from pool to pool. They are opportunistic and likely prey switch with availability (see food source notes from lower river analysis). Water quality qualitative matrix 7-11.
Recreational fisheries can stress WS and compound stress from heat and other services. Catch and release fishery from PRD to CHJ. Harvest of two 43-inch to 54-inch fish annually below PRD.	Harvest/hooking mortality.	Catch and release angling hooking mortality is ~3%. Harvest in MCN pool = 2 fish per year between 43 and 54 inches. A limited number of white sturgeon would be harvested and/or killed from hooking mortality under the NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	The measure is not affected by any of the alternatives and should be removed from the analysis.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Okanogan sockeye runs (>500,000 fish in the run – most died before reaching MCN in 2015) could possibly interact with temperatures on stressed which sturgeon. Large consumption of sockeye and high temperatures led to mortality, as WS were stressed with high metabolic requirements. 2015 mortality event in the JDA pool. Appears to be more prevalent below MCN.	Temperatures in MCN and PRD pools, sockeye runs, exceedance of 21°C.	Percent of days temperature is over 21°C. MCN tailwater = 9.7% PRD tailwater = 1.3% Under current conditions, mean high temperatures (>21°C) will occur nearly 10% of the year at MCN and only about 1% of the year at PRD. High temperatures have been linked to juvenile mortality and adult stress (Hildebrand, 2016). Current high temperatures will have minor negative effects to white sturgeon.	Percent of days temperature is over 21°C. MCN tailwater = 9.7% PRD tailwater = 1.3% High temperatures under MO1 would not differ from the NAA.	Percent of days temperature is over 21°C. MCN tailwater = 9.2% PRD tailwater = 2.1% High temperatures under MO2 would not differ from the NAA.	Percent of days temperature is over 21°C. MCN tailwater = 9.0% PRD tailwater = 1.6% High temperatures under MO3 would not differ from the NAA.	Percent of days temperature is over 21°C. MCN tailwater = 9.6% PRD tailwater = 3.1% There would be a slight increase in the occurrence of high temperatures above MCN. There would be a minor increase in risk of mortality to white sturgeon under MO4.	High temps can interact with huge sockeye runs to increase mortality events. In warm temperatures, sturgeon are unable to metabolize efficiently. Similar issues in the Fraser River. Temperatures greater than 70°F and large sockeye run in 2015, large mortality events, and sockeye in sturgeon samples. Specific pools were more affected than others, could be related to temperatures or numbers of sockeye. Routinely high 20°C to 21°C in pools in late summer, but in 2015 was early to mid-Jul, much earlier than normal, and sockeye population may be a factor.
Northern Pikeminnow							
Prefers slow water in lakes and rivers. Riverine habitats favor native species.	Water velocity	Except for the Hanford Reach, water velocities are slowed behind a series of mainstem dams. Under the NAA, northern pikeminnow will continue to have slow-moving reservoir forebays to thrive in.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Water velocity shows relatively little change within the alternatives. Recommend deleting this metric, as it does little to help in the decision process. Northern pikeminnow morphology and physiology are adapted to allow for a sustained swimming performance in fast currents. Pikeminnow can swim against currents of 115 cm/sec, for an average time of 28 minutes before becoming fatigued (Mesa and Olson, 1993).

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Spawn in rivers and lakes with gravel and cobble substrates. Northern pikeminnow are spring spawners (Apr to Jun). These fish spawn over cobble gravel substrates primarily in tailraces.	Substrate composition.	Currently, the Hanford Reach and project tailraces provide a wide range of spawning substrates that provide adequate spawning habitat for northern pikeminnow. Spawning substrate is not a limiting factor for northern pikeminnow populations. Under the NAA, the Hanford Reach and project tailraces would provide adequate spawning substrates for northern pikeminnow in the mainstem Columbia River.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Alternatives do little to alter the spawning habitats of northern pikeminnow. Recommend deleting this metric as it does little to help in the decision process. In the lower Columbia reservoirs, northern pikeminnow migrated upriver to spawn in the fast water below a dam or into a tributary stream when the temperature reached 14°C in Jun or Jul (Gadomski et al., 2001). They broadcast adhesive eggs over gravel, cobble, or rubble substrate.
Spawn above 14°C, temperatures induces spawning. Alternative changes could change spawn timing.	Temperature in reservoir tailrace (mean date reaching temperatures reach 14°C in PRD tailwater).	Water temperatures at PRD reach 14°C on average by May 31. Under the NAA, northern pikeminnow would have adequate water temperature to induce spawning by May 31.	Water temperatures at PRD reach 14°C on average by May 31. No change from NAA.	Water temperatures at PRD reach 14°C on average by May 31. No change from NAA.	Water temperatures at PRD reach 14°C on average by May 31. No change from NAA.	Water temperatures at PRD reach 14°C on average by May 31. No change from NAA.	Alternatives do little to alter the spawning habitats of northern pikeminnow. Recommend deleting this metric as it does little to help in the decision process.
Juveniles rear along shorelines where shallow water provides forage and low velocities at temperatures > 15°C.	Shoreline habitat available and temperatures over 15°C. Number of days with surface temperatures >15°C at PRD from Jun through Oct.	81% of all days during rearing Jun to Oct >15°C. Northern pikeminnow would have adequate rearing temperatures and habitats for 81% of the rearing period.	84% of all days during rearing June to Oct >15°C. Under MO1, there would be a minor increase in the number of adequate rearing days vs NAA.	82% of all days during rearing June to Oct >15°C. No change from NAA.	82% of all days during rearing June to Oct >15°C. No change from NAA.	83% of all days during rearing June to Oct >15°C. Under MO4, there would be a minor increase in the number of adequate rearing days vs NAA.	–
Food source – larval and juveniles feed primarily on invertebrates.	Invertebrate populations/use productivity from water quality team as surrogate.	MCN is mesotrophic to eutrophic. Under the NAA, the Columbia River (MCN pool) is considered moderately productive, and would provide adequate invertebrate and zooplankton populations.	Warmer August could lead to species shift in zooplankton, but could also have more growth in summer. This would lead to slight increase in food resources for larval and juvenile northern pikeminnow.	No change from NAA.	TN and TP concentrations will increase during a breach and likely for some time after. All concentrations will reflect inflows after system equilibrates. Productivity will be depressed during breach and until new equilibrium is established in MCN and would have a minor negative impact on northern pikeminnow in this pool.	No change from NAA.	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Harvest and sport fish reward program is the major influence on populations, continuation of sport reward program. Reward program targets 10% to 20% of the pikeminnow population.	Northern pikeminnow exploitation rates	Currently, the northern pikeminnow sport fish reward program removes 10% to 20% average of 12.7% exploitation. Continuation of the sport fish reward program would remove ~ 12.7% of adult northern pikeminnow.	No change from NAA.	No change from NAA.	Under a breach scenario, there would likely be a slight reduction in productivity in the MCN pool during breaching, with slow return of productivity. Anglers may see a slight reduction in harvest of NPM.	No change from NAA.	Pikeminnow control program has reduced number in recent years. Use population data from Hanford reach or upper Snake reaches to estimate in more natural habitat.
Abundant juvenile shad provide forage for pikeminnow in MCN pool.	Shad populations	–	–	–	–	–	Cannot find references that support this. Recommend removing this relationship.
Siberian prawns are important food source. Sontag, 2013	Qual – effects to prawns	–	–	–	–	–	Cannot find reference that supports this. Not in Sontag 2013. Recommend removing this relationship.
Juvenile salmon as food source, 70% fall Chinook salmon annually lost to predation bottleneck in MCN to PRD reach (McMichaels et al., 2017). Northern pikeminnow switch to smolt diet when they begin migrating (Shively et al., 1996).	Relative abundance of juvenile salmon and steelhead available to northern pikeminnow. Survival estimates from each alternative RIS to BON. Assume a long-term increase in survival = a long-term increase in smolts.	Under the NAA, upper Columbia Chinook survival is estimated at 0.695 and upper Columbia steelhead survival is estimated at 0.658. Under the NAA, juvenile salmon and steelhead would continue to survive at current rates. Forage in the form of smolts for northern pikeminnow is not likely to change.	Under MO1, Chinook survival is estimated at 0.700 and steelhead survival is estimated at 0.656. No change from NAA.	Under MO2, Chinook and steelhead survival are estimated at 0.682 and 0.634, respectively. Under MO2, there would be a minor reduction in smolt survival in the upper Columbia River that may lead to a reduction in foraging success of northern pikeminnow.	Under MO3, Chinook and steelhead survival are estimated at 0.701 and 0.656, respectively. No change from NAA.	Under MO4, Chinook and steelhead survival are estimated at 0.710 and 0.661, respectively. Minor increase in smolt survival would likely lead to an increase in forage for northern pikeminnow during outmigration of juvenile salmon and steelhead.	Shively et al. (1996) determined the food habits of northern pikeminnow in the Clearwater/Snake Rivers before and after the release of 1.1 million Chinook salmon smolts from Dworshak National Fish Hatchery. Prior to the release, northern pikeminnow consumed 38 % crayfish, 26% insects, 19% non-salmonid fish, and 16% wheat kernels. Twenty-four hours after the release, northern pikeminnow consumed 54% juvenile salmonids, 7% crayfish, 9% insects, 4% other, and 22% wheat kernels. Seven days after release, juvenile salmonids comprised 86%, crayfish 5%, and wheat kernels 5% of the diet.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Water temperatures increase metabolic rates and predation of pikeminnow. Cooler, longer would decrease metabolic rates of pikeminnow, warmer, earlier increase rates.	Cumulative temperature at PRD for Apr to Jun and percent days over 12°C.	1072 cumulative temperature and 54.1% of all days Apr to Jun > than 12°C. Pikeminnow would continue to be actively feeding while juvenile salmonids are present, becoming most active in mid-May (May 13).	1071 cumulative temperature and 53.3% of all days Apr to Jun > than 12°C. No change from NAA.	1072 cumulative temperature and 53.8% of all days Apr to Jun > than 12°C. No change from NAA.	1073 cumulative temperature and 53.6% of all days Apr to Jun > than 12°C. No change from NAA.	1070 cumulative temperature and 53.3% of all days Apr to Jun > than 12°C. No change from NAA.	If cool for longer periods, fall Chinook salmon could outmigrate before increased feeding by pikeminnow. Trigger temperature for pikeminnow ~ 12°C metabolic rates increase and consumption goes up (Peterson and Ward, 1999). No difference in effects from alternatives on temperature Apr to Jun. Recommend deleting this metric.
CHJ to PRD pikeminnow targeted removal program is used to control populations. Exploitation rates relate to northern pikeminnow population levels.		Under the NAA, the PUDs would likely continue the removal of northern pikeminnow from the Columbia River.	No change from NAA.	No change from NAA.	No change from NAA.	No change from NAA.	PUDs have a targeted pikeminnow removal program. The PUDs currently use set lines, seines (a net that hangs vertically in the water), traps, and angling tackle to remove northern pikeminnow and increase the overall survival of migrating juvenile salmonids. No change in metric from alternatives. Recommend removing the metric.
Walleye							
Walleye populations favored by reservoir environments (temperatures and slower velocities). Outside the Hanford Reach, PUD reservoirs currently slow water to less than half a foot per second. Walleye populations are well established.	Number of walleye and qualitative discussion of habitat.	Outside the Hanford Reach, PUD reservoirs currently slow water to less than half a foot per second. Walleye populations are well established, estimated at ~ 15,000 in MCN transition (McMichael, 2018).	No change from NAA.	No change from NAA.	No change from NAA.	No change from NAA.	McMichael estimated ~ 15,000 walleye in the MCN pool in 2018. See paper for trend data. This metric does not detect differences in the alternatives, but is a statement of status.
Spawn in spring, 4°C to 10°C over benthic habitats less than 10 feet deep. Gravel or cobble substrates are best. Prefer slow-moving rivers or lakes with wave action to clean substrate.	Qual of shoreline habitat available. Miles of riprap. Date temperatures reach 4°C and 10°C at PRD and MCN.	PRD at 4°C Mar 8 and 10°C Apr 30. Substrate not likely a limiting factor. MCN at 4°CC on Mar 3 and 10°C on Apr 26. Under the NAA temperatures will be suitable to induce walleye spawning from Mar 8 to Apr 30.	PRD at 4°C on Mar 8 and 10°C May 1. No change in substrate is expected. MCN at 4°C on Mar 3 and 10°C on Apr 26. No change from NAA.	PRD at 4°C on Mar 7 and 10°C May 1. No change in substrate is expected. MCN at 4°C on Mar 3 and 10°C on Apr 25. No change from NAA.	PRD at 4°C on Mar 8 and 10°C Apr 30. MCN at 4°C on Mar 2 and 10°C on Apr 25. Substrate in MCN pool will be altered as sediment is released from the Snake River Dams. There will be short-term losses of suitable spawning substrate on the south shore of MCN pool for an unknown distance downstream from the Snake River confluence. This sediment should be redistributed over time.	PRD at 4°C on Mar 8 and 10°C May 2. No change in substrate is expected. MCN at 4°C on Mar 3 and 10°C on Apr 26. No change from NAA.	NWPPC, 2004, Volume III, Chapter 7, Walleye.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Flow and temperature can affect walleye recruitment. Walleye recruitment is best when water temperatures are above 6°C.	Flows and temperatures at PRD. Lack of flows and low temperature (below 6°C) would limit recruitment days below 6°C Mar to May at PRD.	35.0% of days below 6°C in Mar to May at PRD. Current regime of flow and temperatures will continue to support high recruitment and growth of walleye fry on ~ 65% of days in the rearing period.	35.3% of days below 6°C in Mar to May at PRD. No change from NAA.	34.8% of days below 6°C in Mar to May at PRD. No change from NAA.	34.8% of days below 6°C in Mar to May at PRD. No change from NAA.	35.0% of days below 6°C in Mar to May at PRD. No change from NAA.	Certain flow conditions and temperature conditions result in widely varying success of recruitments, but don't know what those are. Alternatives do not change this metric. Recommend deleting.
Fry are pelagic, feed on zooplankton, and switch to insects and a fish diet at about 8 weeks.	Production zooplankton abundance Apr through May.	Zooplankton levels for PRD are relatively low compared to the lower Columbia and Snake Rivers. PRD = 0-200/m3 versus IHR and JDA at 10X that amount. The lower Snake and Columbia Rivers have higher densities of zooplankton and would provide better rearing habitat than PRD	No change from NAA.	No change from NAA.	Zooplankton in MCN would be depressed during breaching of the lower Snake River dams until a new equilibrium was established.	No change from NAA.	Emerson et al., 2015
Juveniles can be limited by flows that transport juveniles to less advantageous areas. Mechanism: drop in forebay elevation moves increased flows could flush juvenile walleye out of rearing areas in the Yakima Delta and into the main channel where more susceptible to predation.	MCN forebay elevation drops Apr through Jun.	Water elevations are not currently manipulated at MCN pool during the Apr through Jun timeframe. No impacts to larval walleye are expected.	No change from NAA.	No change from NAA.	No change from NAA.	Under MO4, water elevations would be dropped by 1 foot on average years in mid-Apr on dry years hey could be dropped by as much as 3.5 feet in mid-May. These conditions may reduce survival of larval walleye that would be flushed from nursery areas.	Juveniles rearing in Yakima could manipulate flows at MCN. Potential drop 5 feet for 24 hours to flush the juveniles out of bays, then raise back to normal. Walleye rearing - 15°C and higher – Apr to Jul. Potential negative impact to navigation barge traffic MCN to ICH. Note: also potential effect to fall Chinook fry.
Adults avoid light and prefer deeper water.	Qualitative description of deep water habitat available.	Depth data will show there is adequate depth for walleye. Under the NAA, walleye will continue to have deep water habitat available.	No change from NAA.	No change from NAA.	No change from NAA.	No change from NAA.	As they grow older, walleye avoid light. They migrate offshore into deep water during the day and onshore at twilight (Scholz et al., 2014). None of the alternatives has an effect on water depth for the project area. Recommend removing this as a metric for selection.
Walleye juveniles and adults exhibit the best growth in water temperatures between 20°C and 24°C (Barton and Barry, 2011).	Percent of days water temperature is over 20°C at MCN pool mid forebay.	17.6% of all days over 20°C. Best growth for walleye occurs on about 17% of the days of an average year.	17.9% of all days over 20°C (~1 day warmer). No change from NAA.	17.7% of all days over 20°C (<1 day warmer). No change from NAA.	17.7% of all days over 20°C (<1 day warmer). No change from NAA.	17.3% of all days over 20°C (<1 day cooler). No change from NAA.	None of the alternatives has a significant effect on water temperatures in this reach. Recommend removing this metric from selection.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Smallmouth Bass							
Smallmouth bass are nest spawners, so flow fluctuations can impact nesting success. Stable flows when temperatures trigger spawning, followed by a drop in flows could desiccate nests.	Water elevation Apr to Jun at MCN pool.	MCN water elevations will remain fairly constant at 338.7 feet in most years, with a 1-foot operating range, which is not likely to impact smallmouth bass nesting success.	No change from NAA.	No change from NAA.	No change from NAA.	Measure O8 allows for a drawdown of 1 foot in average years. In the driest years, there may be a drawdown of 3.5 feet, which would reduce nesting success of smallmouth bass on the driest years.	Study would be needed to know if it would be effective. Spawning dates for smallmouth bass are temperature driven (Edwards et al., 1983).
Temperature at spawning: 12°C to 15°C triggers spawning (Scholz et al., 2014).	Temperatures in MCN. Date that they first exceed 12°C (surface temperatures.	Data surface water at MCN reaches 12°C ~ May 3. Under the NAA, smallmouth bass spawning may be initiated as early as May 3 on an average year.	Surface water at MCN reaches 12°C on May 2 – one day earlier than NAA on average. No change from NAA.	Surface water at MCN reaches 12°C on May 2 – same day as NAA on average. No change from NAA.	Surface water at MCN reaches 12°C on May 1 – two days earlier than NAA on average. May be slightly earlier spawn under MO3 with early warming.	Surface water at MCN reaches 12°C on May 2 – same day as NAA on average. No change from NAA.	Smallmouth bass spawn in Apr and May in the Columbia River (Wydoski and Whitney, 1975). Early spawning (Apr and May) could be unsuccessful if followed by high flows that reduce temperatures and induce nest failure. Smallmouth bass migrate into the Yakima and spawn in May of each year.
Flows and temperature relationships – increased flows after spawning could decrease water temperatures (influx of cooler water). If smallmouth bass have already spawned and then get cooler males may abandon the nests, resulting in recruitment failure.	Flows at MCN and PRD after temperatures reach 12°C – May 3 on average for the NAA.	Temperatures to induce spawning would occur May 3 on average, while flows reach their peak at MCN in early June. Under the NAA, smallmouth bass are expected to abandon nesting on an unknown number of years.	Temperatures to induce spawning would occur May 3 on average, while flows reach their peak at MCN in early June. No change from NAA.	Temperatures to induce spawning would occur May 3 on average, while flows reach their peak at MCN in early June. No change from NAA.	Temperatures to induce spawning would occur May 3 on average, while flows reach their peak at MCN in early June. There is a greater likelihood for early heating and cooling in MO3, which would slightly increase the risk of nest failure of smallmouth bass under this alternative.	Temperatures to induce spawning would occur May 3 on average, while flows reach their peak at MCN in early June. No change from NAA.	Look at MO data for decrease in water temperature after reaching 55°F.
Diet, food source dynamics? See McMichaels, 2018).	Forage base changes in the Hanford Reach and MCN poo.	Changes in prey items are dependent on salmon availability. Large numbers of up upper Columbia Chinook are consumed by smallmouth bass that rely heavily on juvenile salmon during spring outmigration. Under the NAA juvenile salmon and steelhead will continue to be an important part of smallmouth bass diets during the spring outmigration. Smallmouth bass will switch to sculpin and crayfish as salmon numbers decline.	No change from NAA.	No change from NAA.	Productivity will likely be depressed during breach and for some time offer earl	–	Sandrollers are a dominant food source when no salmon are available. Up to 35% of smallmouth bass diet was comprised of sandrollers in a 2014 study (Sontag, 2014), but later study estimated high salmon predation (Erhardt et al., 2018).

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Optimal temperature range for adult rearing is 21°C to 27°C (Edwards, 1983).	Percent of days temperatures are over 21°C at MCN pool – surface.	13.5% of all days over 21°C ~ 49 days per year. Current conditions provide ideal rearing conditions for smallmouth bass at MCN pool for ~ 49 days a year.	14.8% of all days over 21°C ~ 54 days a year. Under MO1, there would be a minor increase in days of higher temperatures and ideal rearing conditions for smallmouth bass than the NAA.	13.5% of all days over 21°C ~ 49 days a year. No change from NAA.	13.2% of all days over 21°C ~ 48 days a year. No change from NAA.	14.4% of all days over 21°C ~ 53 days a year. Under MO4, there would be a negligible increase in days of higher temperatures and ideal rearing conditions for smallmouth bass than the NAA.	Edwards et al. (1983) gave the upper temperature limit for adult smallmouth bass a 30°C, the optimum range for adult rearing as 21°C to 27°C, and the optimum range for spawning as 12.8°C to 21°C.
Turbidity can limit smallmouth bass growth and feeding success,	Turbidity levels during outmigration Apr through Jun.	Turbidity is dependent on water flow year and land use practices. Currently, sediment levels are approximately 2 mg/l. Under the NAA, turbidity will not change from current conditions. High water years will likely limit smallmouth bass growth.	No change from NAA.	No change from NAA.	Significant increase during breaching and for several years after depending on erosion rate of deposited materials. Subsequent amounts dependent on watershed land-use practices and runoff events. May decrease foraging efficiency of smallmouth bass during this timeframe.	No change from NAA.	Data was insufficient to do quantitative analysis of turbidity (Water Quality Appendix, 7-11). Sontag (2014) showed that highly turbid waters reduced foraging success of smallmouth bass and consumption of smolts, while Erhardt et al. found that, under clear water conditions, smallmouth bass have improved foraging success and smolt composition.
Adults go inactive at temperatures less than 10°C.	Water temperatures less than 10°C at MCN pool dates above and below and percent of days inactive.	Apr 24 is first day over 10°C. Nov 15 is last day over 10°C (55.8% or 204 days active). Under the NAA, smallmouth bass would have ~ 204 days of water temperatures over 10°C or 204 days when they would be active.	April 26 is first day over 10°C. Nov 15 is last day over 10°C (56.0% or 204 days active). No change from NAA.	Apr 25 is first day over 10°C. Nov 15 is last day over 10°C (56.2% or 205 days active). No change from NAA.	April 23 is first day over 10°C. Nov 15 is last day over 10°C (55.4% or 202 days active). Under MO3, there is likely a shift in smallmouth bass activity forward in the calendar year by a couple days and a decrease of 2 days in activity. Not likely a significant change for smallmouth bass.	Apr 25 is first day over 10°C. Nov 15 is last day over 10°C (56.0% or 204 days active). No change from NAA.	–
High turbidity displaces from (2,000) JTU.	Turbidity levels during outmigration May through Jun.	Turbidity is dependent on water year and land use practices, but will generally be highest during the spring runoff on high water years. Under the NAA turbidity will not change from current conditions and will limit fry survival in high water years.	No change from NAA.	No change from NAA.	Turbidity will experience a significant increase during breaching and for several years after depending on erosion rate of deposited materials. Subsequent amounts dependent on watershed land-use practices and runoff events. Highest sediment levels will occur after juvenile rearing season is over, but may decrease rearing success during high water events following breaching.	No change from NAA.	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Native Fish Community							
Mountain whitefish is strong fishery in the fall, and top bycatch for salmon and steelhead anglers. Feed heavily on fall Chinook salmon eggs in the fall.	See northern pikeminnow.	–	–	–	–	–	–
Game Fish							
Other game fish include crappie, perch, bluegill, and largemouth bass. Most do not occur in great numbers, particularly in the Hanford Reach. Alternative sources of game fish include inputs from irrigation water returns. Largest concentrations are in reservoir pools where MCN has the highest concentrations.	–	–	–	–	–	–	–

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3.8.4 Region C

3.8.4.1 Snake River Basin

Table 3-80. Snake River Resident Fish Qualitative Effects Analysis Matrix

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Bull Trout							
Cold water required, >15°C limits distribution.	Water Temperatures in FMO habitat (number of days above 15°C - 80 year POR) Taken at LGS - most bull trout counts.	Water Temperature regime in reservoirs similar to current. Temperatures currently supports FMO habitat when bull trout are present. Temperature exceeds 15°C degrees only 0.3% (54 of 16939 days) of the time from Nov through May. June through Oct temps exceed 84.6% (10,324 of 12209 days) of the time. Year round temps exceed 15°C 35.6% (10378 of 29149). Low numbers of bull trout would continue to use Snake River reservoirs and river as forage, migration, and overwinter habitat as temperatures allow (primarily November through June).	Temp exceeds 15°C only 0.3% (54 of 16939 days) of the time from Nov through May. June through Oct temps exceed 84.2% (10,283 of 12209 days) of the time. Year round temps exceed 15°C 35.5% (10337 of 29149). No difference from NAA. Warmer temperatures are seen in August under MO1 from altered cooling flows should not impact bull trout in the Snake as they are in tributaries at that time. Could be subadults holding in cold water refuge at the Clearwater that may be negatively impacted by August flow reduction. Check Temperatures Downstream for hot water.	Temp exceeds 15°C only 0.3% (54 of 16939 days) of the time from Nov through May. June through Oct temps exceed 85.3% (10,414 of 12209 days) of the time. Year round temps exceed 15°C 35.9% (10467 of 29149). Summer Temps would be slightly warmer, but bull trout are not expected to be in the system in large numbers at that time. No difference from NAA.	Temp exceeds 15°C only 0.4% (65 of 16950 days) of the time from Nov through May. June through Oct temps exceed 76.5% (9,341 of 12209 days) of the time. Year round temps exceed 15°C 32.7% (9405 of 29159). Because of smaller water body (less thermal inertia) overall temperatures would be cooler and more suitable for bull trout except in June and July. There would be minor impacts to Bull trout in the system in June and July (reduced stress and survival) but remainder of the time they occur in mainstem would be cooler and more suitable for bull.	Temp exceeds 15°C only 0.3% (54 of 16939 days) of the time from Nov through May. June through Oct temps exceed 84.8% (10,348 of 12209 days) of the time. Year round temps exceed 15°C 35.7% (10402 of 29149). No difference from NAA.	Few bull trout in Snake River during late summer and early fall months when there are temperature limitations. Bull trout most often seen at projects April through June, but have been recorded in the mainstem nearly every month of the year. Water temps influenced by warm Brownlee outflows. Hells Canyon relicensing could result in changes important for cumulative effects. May draft if predicting 16.5°C by October, so takes less time for cool water out. Won't exceed 16.5°C. Would result in cooler temp inflows to lower Snake River projects. Barrow et al., 2016
Mainstem passage seen as limiting to bull trout migration.	Number of bull trout passing through ladders and Separators	(2006-2014) IHR <1 BT/year; LGR ~ 3 BT/year; LMO ~ 17 BT/year; LGS = 50 BT/year Checked PTAGIS = Limited data matches relative abundance at dams. Bull trout found passing SR projects in low numbers. Would continue to pass in the future. Seen at projects primarily in Apr to Jun when they are leaving the mainstem for cooler waters.	No difference from NAA.	Bull trout would continue to pass projects in limited numbers. However, the team expects reduced survival under this alternative as a higher portion of fish would pass via turbine routes. This passage route generally has lower survival.	Long term impacts: Removal of four lower Snake River dams would reduce any delays in passage. High flows may cause seasonal velocity barriers for bull trout at dam sites where velocities may reach over 12 feet/second. Dams may provide foraging areas for adult bull trout during outmigration. During breach there may be short term passage issues at tributary mouths. Fish come to mainstem and cannot reascend.	No difference from NAA. Additional spill may cause delays in bull trout passage at dams in May and June when they are moving out of the system to avoid temps.	Snake River Dams passage, operates except for Jan 1 to Feb 28. Bull trout do get past the projects, but may get entrained downstream to some extent. Use ladders except when closed. Barrow et al., 2016

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Entrainment – bull trout can get entrained at Snake River run-of-river dams. Populations tend to be moved downstream and not move back up (i.e., Asotin fish are seen below LGR, but few see back up at Asotin).	Number of tagged bull trout passing dams in ladders or bypass systems.	6 of 9 bull trout tagged in the Tucannon River were seen at dams downstream from the Tucannon river. However, genetic studies show fish moving down the system from above Tucannon with Tucannon genetics. Bull trout would continue to be entrained in low numbers. Because of low numbers in the system effects are not likely significant.	No difference from NAA.	Bull trout would continue to pass projects in limited numbers. However, we expect reduced survival under this alternative as a higher portion of fish would pass via turbine routes. This passage route generally has lower survival.	Long-Term Benefit. Improved passage for bull trout moving up or downstream.Short term impacts to fish as they try to reascend rivers in the spring and find they are perched.	No known relationship between spill and attraction for bull trout. Potential for additional delay and fallback with higher spill.	Tucannon and Walla Walla River Bull Trout have been tracked downstream and most appear lost through entrainment. Some Imnaha fish are seen in Asotin Creek and some also dipped into LGR and back up multiple times through the ladder. Ladders not designed for bull trout, but they pass. Note: Idaho Power entrainment plan under development in relicensing process; (cumulative effects). Note: while higher spill alts could result in higher fallback in spring and summer, there would be no spill in winter. There is a lack of data to support this and low numbers of fish in the system.
Dworshak entrainment – in colder parts of the year, bull trout further down in the reservoir could be entrained.	Entrainment relationship	Literature and discussions with Corps staff indicate this is not an issue at Dworshak. No effect. No need to discuss.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Potentially an issue in winter. Ask Paul Pence. Relationship discussed in SOR. Recent discussions indicate no issue with this.
Migration access to mainstem habitat. LMO and IHR connect Walla Walla and Tucannon sub-basins.	Bull trout movement data	Corps data shows limited numbers of bull trout accessing FMO mainstem habitats. Bull trout migrate to FMO habitat in November and December, then back to tributaries in Mar to May. Count data in winter is limited. Low numbers of bull trout will continue to use mainstem FMO habitats. Some movement between populations will continue.	Low numbers of bull trout will continue to use mainstem FMO habitats. Some movement between populations will continue. No Change from NAA	Low numbers of bull trout will continue to use mainstem FMO habitats. Some movement between populations will continue. However, the team expects reduced survival under this alternative as a higher portion of fish would pass via turbine routes. This passage route generally has lower survival.	Long term benefit from removal of 4 lower Snake River dams would improve connectivity of Bull trout populations. Short term impacts to fish as they try to reascend rivers in the spring and find they are perched.	Low numbers of bull trout will continue to use mainstem FMO habitats. Some movement between populations will continue. Additional spill may cause delays in bull trout passage at dams in May and June when they are moving out of the system to avoid temps.	Larger bull trout that use the SR are drivers of the population. These fish are generally more productive and more mobile. The loss of these larger, fluvial fish from the community could drive a change in the community structure. Some Tucannon fish using SR, down, then up to Walla Walla. Movement primarily downstream. Jarbridge study - Even when bull trout wander, they tend to remain genetically very distinct. In St. Mary - some did move between spawning tributaries and spawn at the new site. (Mogen et al. 2005).

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Forage for bull trout in lower Snake River – need adequate forage for migrating juvenile and adult bull trout.	Forage Fish/Smolt Numbers	See other species tabs in this sheet and the anadromous fish. Currently, relatively high numbers of juvenile salmonids in the system when bull trout are migrating (Nov-June). Peak numbers in the SR occur in Apr-Jun. Siberian Prawns may provide additional forage (Tiffen et al. 2017). Healthy populations of forage fish for bull trout would continue to be available to support migratory bull trout.	Healthy populations of forage fish for bull trout would continue to be available to support migratory bull trout. No change from NAA	Healthy populations of forage fish for bull trout would continue to be available to support migratory bull trout. No change from NAA	Temporary reduction 2 to 7 years in forage for bull trout would be expected as a result of breaching (River Mechanics Modeling – 2 to 7 years to clean embedded cobble for invertebrate use). Forage fish and invertebrates would be expected to increase over time after initial sediment pulses. Change from zooplankton to macroinvertebrates. would benefit juvenile and subadult bull trout.	Healthy populations of forage fish for bull trout would continue to be available to support migratory bull trout. No change from NAA	Forage base has increased with introduced species under the NAA. Low numbers of salmon smolts available for bull trout forage in tributaries. Alternatives the increase smolt production are expected to increase forage for adult and sub-adult bull trout.
Forage in Dworshak.	Forage Fish	Are forage fish populations stable or increasing? Is there data to support this?	–	–	–	–	Look at potential to affect forage base through operations. This metric did not appear useful in detecting differences in the alternatives and was discarded.
Predation – potential predation by catfish, walleye, or smallmouth bass is probably a minor issue. Competition more of an issue because, with more predators, there is more competition. Warmer temperatures are generally associated with a higher risk of predation.	Populations of predators and Water Temperature (Alternatives with higher temperatures would be associated with higher risk of predation).	Numbers of Walleye have increased, Northern Pikeminnow are down, while Catfish and SMB are relatively abundant. Temp exceeds 15°C only 0.3% (54 of 16939 days) of the time from Nov through May. June through Oct temps exceed 84.6% (10,324 of 12209 days) of the time. Year round temps exceed 15°C 35.6% (10378 of 29149). Temperatures are generally cold when bull trout are in the system - Predation is not likely a significant impact to adult bull trout during winter months.	Temp exceeds 15°C only 0.3% (54 of 16939 days) of the time from Nov through May. June through Oct temps exceed 84.2% (10,283 of 12209 days) of the time. Year round temps exceed 15°C 35.5% (10337 of 29149). Warmer temperatures seen in August under MO1 from altered cooling flows should not impact bull trout risk to predation in the Snake as they are in tributaries at that time. No difference from NAA.	Temp exceeds 15°C only 0.3% (54 of 16939 days) of the time from Nov through May. June through Oct temps exceed 85.3% (10,414 of 12209 days) of the time. Year round temps exceed 15°C 35.9% (10467 of 29149). Summer Temps would be slightly warmer, but bull trout are not expected to be in the system in large numbers at that time. No difference from NAA.	Temp exceeds 15°C only 0.4% (65 of 16950 days) of the time from Nov through May. June through Oct temps exceed 76.5% (9,341 of 12209 days) of the time. Year round temps exceed 15°C 32.7% (9405 of 29159). While temperatures will not differ greatly from the NAA, predator numbers and composition are expected to be altered as a result of dam breaching. Reservoir species are likely to be less dominant while riverine species will be more prevalent. Large sediment flushes and increased BOD may reduce non-native predators during the breach and up from 2 years to7 years. Short term reduction in predation risk followed by increases in this risk to similar pre-breaching levels.	Temp exceeds 15°C only 0.3% (54 of 16939 days) of the time from Nov through May. June through Oct temps exceed 84.8% (10,348 of 12209 days) of the time. Year round temps exceed 15 C 35.7% (10402 of 29149). No difference from NAA.	Minor effect in projects because they are used primarily in winter by adult bull trout. Not many predators on adults. (Med impact in CEM). Potentially avian predation on large adults, more susceptible in tributaries.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Habitat degradation – bull trout require cold water environments with complex habitat. The Snake River is used for FMO habitat.	Habitat loss/Elevated TDG Days TDG over 110% from November thru June LWG	Mainstem is FMO habitat - not a limiting habitat to bull trout populations in the lower Snake River. Days over 110% Nov-Jun - 7212/19350 = 37.3% (Mean 106.1). Elevated TDG may negatively impact an unknown number of bull trout.	Days over 110% Nov-Jun - 7206/19350 = 37.2% (Mean 106.2). No difference from NAA.	Days over 110% Nov-Jun - 6530/19350 = 33.7% (Mean 105.5). Slight reduction in TDG may have minor reduction in risk of GBD in Bull trout.	Reduced TDG (104%-105%) levels would benefit bull trout. However, breaching would have an initial negative impact on water quality as sediment is released and oxygen demands increase.	Days over 110% Nov-Jun - 9354/19350 = 48.3% (Mean 111.1). Higher TDG may impact additional (vs NAA) bull trout in May and June when leaving the system. Minor increase in risk of GBD.	Habitat loss is an important factor in tributaries, but FMO habitat is not a limiting factor within the project area. Bull trout more sensitive to GBD than Chinook. McGrath et al 2006. Beeman et al. 2003.
Non-native hybridization – hybridization with brook trout can be a factor in bull trout losses.	Number of Brook trout in area of analysis.	Brook trout numbers limited in Snake river mainstem habitats. Hybridization is not a major factor in bull trout populations in the Snake River mainstem habitats.	No difference from NAA.	No difference from NAA.	No difference from NAA.	No difference from NAA.	Does not appear to be a factor in the project area.
Sediment Tolerance – during dam breach, high sediment releases are expected that could exceed bull trout tolerances.	Bull trout tolerance to high sediment loads	Input natural sediment levels in NAA. Expect current suspended sediment to remain low (2 mg/l) under the NAA (Not during runoff). Under the NAA there are no anticipated negative effects from sediment to bull trout.	No difference from NAA.	No difference from NAA.	Sediment loads may reach 25,000 mg/l for short periods of time. An estimated 26 days of sediment over 5,000 mg/l could result. However, during August thru October, limited numbers of bull trout occur in the mainstem and short term effects to bull trout are not likely to occur. Severity index for sediment shows that bull trout in the mainstem would experience an index of ~11 = 20% to 40% mortality from sediment (Newcombe and Jenson 1996). Long term impacts would include elevated sediment during the spring freshet the following year. These conditions are likely to negatively impact bull trout.	No difference from NAA.	Newcombe and Jenson 1996.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Oxygen Tolerance – during dam breach, high sediment releases may increase BOD to levels that deplete oxygen in the system. Bull trout equilibrium is lost at 2 ppm to 3 ppm.	Bull trout tolerance to low oxygen levels (loss of equilibrium at 2 to 4 mg/l - Doudoroff and Shumway 1970)	Oxygen levels are expected to remain high during the NAA. No effect to bull trout.	No difference from NAA.	No difference from NAA.	Short term impacts: sediment loads may reach 25,000 mg/l for short periods of time and oxygen may be reduced to near 2 ppm. An estimated 26 days of sediment over 5,000 mg/l could result. Reduced Oxygen may be associated with that level of sediment. However, during August thru October, limited numbers of bull trout occur in the system and short term effects to bull trout are not likely to occur. BOD would occur after initial flush of sediment. Any bull trout in the mainstem would likely be killed. Most bull trout leave mainstem river by July.	No difference from NAA.	Water quality team discussions with USGS indicate low oxygen likely in two flushes. Chemically as sediments are released and biologically as plant and animal matter degrade.
Dworshak spawning access to tributary streams during drawdown.	Dworshak Spawning Access to tributary streams.	Bull trout upstream migration occurs primarily in May and June when the DWA pool is rising and near its peak (Hanson et al. 2006) Information from project biologists indicates that upstream passage is not likely an issue. Bull trout have access to most spawning areas under the NAA.	Under MO1 drafting for cooling/augmentation is begun sooner and could have an impact to bull trout migrating in the latter half of June.	Under MO2 drafting for power generation can reduce the pool relative to the NAA and may have an impact on bull trout migrating in May and June.	No change from NAA	No change from NAA	Talk to the Corps and Idaho Fish and Game. No known issue with current operations.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
White Sturgeon							
Migration access to extended habitat is important for population connectivity.	Fish Ladder and Bypass Numbers	Bypass Numbers by dam: LMO: 5 to 10 per year LGO: 15 to 20 LGR: 25, 0, 40 in 2018 (from enlarged orifice). PTAGIS data for sturgeon - very few hits from sturgeon on Snake River dams. 13 total PIT tagged WS were seen at the LS Dams. 11 of these were seen at Ice Harbor, but only one in the ladder. The rest in the bypass. One fish at LGR in Bypass and 1 in LGO in adult fish return Sturgeon Working Group is seeing increases in Juvenile sturgeon upstream of LGR dam (Hughes and Lepla 2018 - Idaho Power. Current populations in the IHR, LMO, and LGR are recruitment limited. These populations would continue to decline (Hildebrand, 2016) with most of the recruitment coming from upstream sources that are entrained into the lower Snake projects.	In MO1, no change is expected that would improve passage for Sturgeon. No difference from NAA.	In MO2, no change is expected that would improve passage for Sturgeon. No difference from NAA. Survival may decrease for downstream migrants as more of them are put through the turbine vs spillway.	The breaching of the lower 4 Snake River dams would reconnect white sturgeon populations from McNary to Hells Canyon. Movement between populations would be unrestricted and spawning habitat would increase. Recruitment would likely increase. Spawning habitat would likely increase from 200 to 3000 acres. Short Term effects currently include lack of connectivity.	In MO4, no change is expected that would improve passage for Sturgeon. No difference from NAA.	Currently, habitats are fragmented with limited passage at the dams. Declining populations from lack of recruitment. Potentially some spawning still happening, smaller fish from Snake River. Sturgeon adults are trapped between project structures. The Dalles ladder does have limited sturgeon movement, but lower Snake River ladders don't pass sturgeon. Sturgeon captured at juvenile bypass facilities are released downstream. There is a general downstream movement of sturgeon because they don't use ladders in current design. Potentially some bigger ones move through turbines. In both the Ice Harbor and Lower Monumental reservoirs, the age structure is skewed towards older individuals, indicating those population segments are recruitment limited. There appears to be a gradient of reduced juvenile abundance in the lower Snake white sturgeon population segments with increased downstream distance from LGR. This suggests that many of the white sturgeon in the lower Snake reservoirs may have been entrained through the dams (Hildebrand, 2016).

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Harvest or predation removes large adults. Catch and release mortality may remove a limited number of white sturgeon.	Harvest of Sturgeon	Harvest is not allowed in the Snake River, but catch and release mortality could be a minor impact (2.7%). Predation of adults is not likely to occur in this section of the river. Catch and Release mortality is estimated at ~ 3% (Robichaud et al. 2006) which may have minor impacts to white sturgeon populations. No known predators.	No difference from NAA.	No difference from NAA.	Assume no difference from NAA. May be short term effects that would require closure of the season.	No difference from NAA.	Not harvesting anymore. Harvest not affected by projects, except limited harvest below Ice Harbor. Feed this information to the Econ Team.
Juveniles need adequate forage early in life; age at first feeding is important. Movement from hatch to environment with food is critical; reservoirs provide for these fish. Larval sturgeon eat benthos, periphyton, and zooplankton.	Qualitative discussion of food resources. Lack of data for this metric.	Currently, lower Snake River reservoirs are classified as either mesotrophic or mildly eutrophic and are dominated by zooplankton communities. These resources are adequate for larval fish, but as WS grow they switch increasingly to aquatic invertebrates. Beneficial for larval fish less so for juvenile fish.	No difference from NAA.	No difference from NAA.	Long term effects: Loss of zooplankton and conversion to invertebrates. Short term effects would include loss of forage base at time of breaching. 2 to 7 Year recovery of invertebrate resources would limit recruitment and survival. Beneficial to juvenile fish less so for Larval fish.	No difference from NAA.	Larvae need Benthos, periphyton, and zooplankton. Juveniles switch to invertebrate diet. Reservoirs provide good food for larval fish, but spawning habitat is limited. Introduced shrimp, (Mysis, Siberian prawns) Mysis could provide forage. Mesotrophic to eutrophic.
TDG relationship with young sturgeon – sensitive to TDG (McGrath et al., 2006; Counihan et al., 1998; and Weitkamp, 2008).	Days from Apr 1 through Jul 31 TDG > 120%	TDG Apr through Jul number of days over 120%. High = 136% TDG; 809/9760 days over 120 = 8.3%; WQ plots show that the majority of these dates are in Jun and July. Under the NAA elevated TDG would have an adverse effect on White sturgeon for pars of June and July.	High = 136% TDG; 889/9760 days over 120 = 9.1%; WQ plots show that the majority of these dates are in Jun and July. There would be a negligible increase in exposure to high TDG and adverse effect under MO1 vs NAA.	High = 136% TDG; 660/9760 days over 120 = 6.8%; WQ plots show that the majority of these dates are in Jun and July and that there would be a moderate decrease in exposure to high TDG in the fall and a slight decrease during April through July under MO2 vs the NAA. This would improve conditions for larval White Sturgeon.	High = 104% TDG; 0/9760 days over 120 = 0%; TDG conditions would be ideal for most of the Lower Snake River under this alternative. No negative effects from TDG to white sturgeon are expected under MO3.	High = 136% TDG; 5163/9760 days over 120 = 52.9%; WQ plots show major increases in exposure to high TDG from Apr through July and moderate increases in parts of April and May when compared with the NAA. There would be negative impacts to white sturgeon fry under MO4.	TDG of 118% altered buoyancy of larval sturgeon 130% TDG 50% mortality. Fish would be more prone to predation. Larval stage is drifting stage and often in shallow water.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Hydrology needed to cue spawning – high velocities during the descending limb of hydrograph in Apr to Jul (Hildebrand et al., 2016).	Water velocity > or = 2.6 f/s mean water column April thru June. Qualitative discussion.	Enter current flow data from HH, see summary hydrograph at LGR. Mean flows for Apr, May and Jun are 74, 100, and 102 kcfs, respectively. 12°C to 18°C. Hildebrand 2016. Water velocities are modified in reservoir areas. However, high flows are occurring in spring at tailrace locations. These locations are likely the only spawning habitat available.	No difference from NAA.	No difference from NAA.	The removal of the 4 lower Snake River dams would increase spawning habitat and produce higher velocities to induce spawning. Lower Snake River Juvenile Migration Feasibility Report (2002) estimates that spawning substrate for Chinook salmon would increase from 226 to 3,521 acres under a breach scenario. These substrates would also benefit Sturgeon. HEC RAS modeling shows that average velocities in a breached scenario would reach between 6 and 8 feet/second during the spring runoff. Average velocities for the year would be ~ 4 feet/ second compared to ~ 0.4 feet/second under the NAA. These conditions would lead to more successful spawning and recruitment for white sturgeon	High Spill may provide higher velocities in area if the tailrace and may induce spawning in more years. Check with Ryan Laughery.	Flow velocities are currently not adequate in reservoirs to induce spawning except in tailraces. Some spawning occurs, most likely in tailraces where velocities are higher. No spawning found in LGR, velocities not adequate, probably spawn upstream of LGR Reservoir. Parsley and Kappenman (2000) captured fertilized eggs. Spawning 1km below Little Goose. Juvenile gradient is indicative of entrained through dams. (Devore et al. 1999)
Temperature criteria for spawning/egg incubation. Cold water during high flow events is needed to cue spawning. Temperatures outside 8°C to 18°C show reduced egg survival; mortality >20°C (Lepla and Chandler, 2001).	Temperatures from 8°C to 18°C from Apr to Jun at IHR because of high white sturgeon population below dam.	8.2% (504/6160) of modeled days between April 15 and June 30 were above 18°C and 0.3% (21/6160) days were below 8°C. 2.7% of these days were over 20°C (168/6160). Water temperatures in the lower Snake River are suitable for egg incubation and spawning during most years. On warm years survival would be reduced.	7.9% (486/6160) of modeled days between April 15 and June 30 were above 18°C and 0.3% (21/6160) days were below 8°C. 2.6% of these days were over 20C (161/6160). No change from NAA.	8.7% (534/6160) of modeled days between April 15 and June 30 were above 18°C and 0.3% (21/6160) days were below 8°C. 3.1% of these days were over 20C (194/6160). No change from NAA.	Water Quality modeling shows that water temperatures will likely be warmer in June and July by 2 to 4 degrees and cooler September through December by the same amount. More days will likely exceed optimum temperatures for egg incubation under MO3 than the other alternatives. Earlier warming may induce adults to spawn earlier and reduce any negative impacts. Unknown impact to white sturgeon.	8.2% (505/6160) of modeled days between April 15 and June 30 were above 18°C and 0.3% (21/6160) days were below 8°C. 2.7% of these days were over 20°C (169/6160). No change from NAA.	Temperatures are suitable for sturgeon spawning in most years in the lower Snake River projects below LGR dam.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Sturgeon are highly sensitive to in-river contaminants (selenium, methyl mercury), potential sub-lethal effects (Little et al., 2014).	Selenium, methyl mercury levels	Sampling to date did not show elevated levels of these contaminants. Sandy check sampling of sediments in reservoirs (Water Quality Appendices 7-7 thru 7-10. Sediment contaminants are not likely to affect white sturgeon populations.	WQ is not likely to change from NAA under MO1.	WQ is not likely to change from NAA under MO1.	The breaching of the lower four Snake River dams will re-entrain dormant sediments that may contain elevated concentrations of heavy metals. These metals will have an unknown impact on Sturgeon	WQ is not likely to change from NAA under MO1.	Sediment sampling for dredging, wasn't a big issue in current sampling; have not hit threshold for selenium. (Dredging EIS).
Rearing habitat – Yolk sack larvae (YSL) need cover at early life stages. Gravel substrate. The YSL need cobble gravel substrates with interstitial spaces to survive and grow well.	Substrate description in Lower Snake Reservoirs	Previous work shows gravel and cobble habitats occur primarily in the tailrace of each dam. Rearing habitat for YSL is present in tailraces of each dam. This is likely a limiting habitat in the lower Snake River.	No difference from NAA.	No difference from NAA.	Long term: The breaching of the lower four Snake River dams would likely improve habitat for both spawning and rearing. River mechanics modeling shows that current sediment deposits would likely be scoured to the original bed and restore additional gravel cobble substrates within 2 to 7 years. Short term: Release of sediments during breaching would silt cobble and gravel substrates temporarily. These would be scoured clean in 2 to 7 years. Short-term reduction in sac fry hiding cover. Long term increase in the same.	No difference from NAA.	Yolk Sack Larvae (YSL) need cobble gravel substrates with interstitial spaces to survive and grow well. Other reservoir (John Day) has gravel substrate to provide hiding cover for early life stage. Snake River reservoirs have less habitat.
Sediment Tolerance – during dam breach, high sediment releases are expected that could exceed white sturgeon tolerances.	White Sturgeon tolerance to high sediment loads	Current sediment concentrations are near 2 mg/l. Under these conditions there are no negative impacts to white sturgeon.	No difference from NAA.	No difference from NAA.	Short term impacts include Sediment loads ~ 5,000 mg/l for short periods of time. Severity rating of 11 ~ 20% to 40% mortality of white sturgeon (Newcombe and Jensen 1996). Long Term impacts: spring flushing flows the following year(s) would reactivate perched sediments and increase sediment concentrations. These concentrations may have negative impacts to white sturgeon.	No difference from NAA.	Sediment loads may reach 25,000 mg/l for short periods of time. High sediment loads may limit egg and larval survival.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Oxygen tolerance – during dam breach, high sediment releases may increase BOD to levels that deplete oxygen in the system. Equilibrium is lost at 2 ppm to 3 ppm.	White Sturgeon tolerance to low oxygen levels (loss of equilibrium at 1 to 3 mg/l)	Oxygen levels are near saturation under current conditions. These levels are expected to remain high during the NAA. No effect to white sturgeon.	No difference from NAA.	No difference from NAA.	Sediment loads may reach 25,000 mg/l for short periods of time and oxygen may be reduced to near 2 ppm. An estimated 26 days of sediment over 5,000 mg/l could result. Reduced oxygen may be associated with that level of sediment. Short term effects to white sturgeon could result in the loss of sturgeon populations. The loss of mature adult fish would be a significant effect. Long term impacts would include elevated sediment during the spring freshet the following year(s). These conditions may also negatively impact white sturgeon (See WQ Appendices 7-7 thru 7-10).	No difference from NAA.	Sediment loads may reach 25,000 mg/l for short periods of time and oxygen may be reduced to near 0 ppm. An estimated 26 days of sediment over 5,000 mg/l could result. Reduced Oxygen may be associated with that level of sediment.
Adult forage – crayfish, shad, sockeye salmon	Loss of or enhancement of food resources	Currently there is suitable forage for white sturgeon in the lower Snake River. Forage is not limiting. No effect to white sturgeon.	No difference from NAA.	No difference from NAA.	Short Term: Potential loss of adult forage base during breaching. Forage populations could see major reductions during breaching under MO3. This loss would be a major negative impact for white sturgeon adults. Long Term: forage populations would shift and return in 2 to 7 years.	–	–
Redband Rainbow Trout							
See notes - use steelhead comparisons	–	Within the Snake River Basin, redband rainbow trout that interact with the projects are classified as steelhead. Those in tributaries are not likely to be affected by actions at the projects.	–	–	–	–	Redband Rainbow Trout are divided into two subgroups. Those that are anadromous - or steelhead, and interior redband - or resident rainbow trout (Muhlfeld et al., 2015).
Westslope Cutthroat							
See notes on distribution	–	–	–	–	–	–	Westslope Cutthroat occur in Dworshak Reservoir and the Clearwater River Basin, but will not likely be affected by alternatives for this EIS.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Kokanee							
Dworshak Entrainment – Average discharge January through March is negatively related to kokanee survival as fish are entrained at higher discharges (Bennett, 1997).	Mean Dworshak outflow (Jan - Mar)	Mean Discharge (Jan-Mar) = 4041 cfs. Highest risk in Late February and all of March. Max = 10,563 cfs. High water years have greater risk of entrainment. Median years have risk in late March.	Mean Discharge (Jan-Mar) = 4016 cfs. Highest risk in March. Max = 10,564 cfs. No change from NAA	Mean Discharge (Jan-Mar) = 7176 cfs. Highest risk in January. Max = 10,000 cfs. Moderate increase in risk in January and early February	Mean Discharge (Jan-Mar) = 4046 cfs. Highest risk in March. Max = 10,568 cfs. No change from NAA	Mean Discharge (Jan-Mar) = 4018 cfs. Highest risk in February and March. Max = 10,582 cfs. No change from NAA	Note: data is not clear on number of fish entrained. Presumed a significant number. Kokanee entrainment is positively related to discharge during January thru March. However, the use of lower gates to release water away from kokanee populations has likely reduced the effect. During winter kokanee congregate near the dam making them susceptible to high discharge. In 1996, high late winter releases caused entrainment losses of ~ 90% of all kokanee (Maiolie and Elam, 1996).
Dworshak Spawning Access – 25% of spawning tributaries are inaccessible if reservoir elevation drops below 1450 in September and October.	Reservoir Elevation	Mean elevation for months of September and October is 1521 ~ 90% access to spawning on a median year. Under current conditions, spawning kokanee will have access to approximately 90% of their spawning habitat.	Mean elevation is 1525 ~ slightly better access than under the NAA ~ 90%. Under MO1 kokanee, would have access to slightly more spawning habitat.	Mean elevation is 1521 ~ Same as NAA ~ 90%.	Mean elevation is 1522 ~ Same as NAA ~ 90%.	Mean elevation is 1521 ~ Same as NAA ~ 90%.	Discussions with project biologists indicate reproduction for kokanee is not an issue.
Northern Pikeminnow							
Prefers slow water in lakes and rivers.	Qualitative discussion of water velocity	Lower Snake River dams have reduced water velocities within this reach. Current velocities are ~ 0.4 feet/ second. Reservoir conditions would continue to favor pikeminnow populations.	No difference from NAA	No difference from NAA	Velocities are projected to increase dramatically. Mean velocities under NAA would be ~ 0.4 feet/second while velocities in a breached river would be ~ 4 feet/second. There would be reduced slow water habitat for northern pikeminnow. Higher velocities will likely reduce access or time of exposure to downstream migrating smolts. However, northern pikeminnow are a riverine species, expected to do well in a riverine environment and may increase in numbers per unit area (Corps, 2002).	No difference from NAA	Native fish species with artificially elevated populations due to reservoir environments that favor them. Reward program has probably stabilized these populations.

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Spawn in rivers and lakes when water temperatures reach between 14°C and 20°C, which is usually April to June. These fish spawn over cobble gravel substrates primarily in tailraces on the lower Snake River.	Portion of the habitat dominated by cobble and gravel substrates.	Tailraces and tributary habitats have gravel cobble substrates, while reservoirs have sand. Under the no action alternative the lower Snake River would continue to provide adequate gravel (river/tailrace) and sand (reservoirs) substrates for spawning.	No difference from NAA	No difference from NAA	Lower Snake River Juvenile Migration Feasibility Report (2002) estimates that spawning substrate for Chinook salmon (gravel and cobble similar to NPM needs) would increase from 226 to 3,521 acres under a breach scenario. This alternative would increase spawning habitat for northern pikeminnow in the Snake River.	No difference from NAA	Northern pikeminnow migrate to spawning areas in mid to late spring. These are primarily tailrace areas with clean substrates. Females can release up to 30,000 eggs (Gadomski et al., 2001).
Spawn above 14°C.	Temperatures in reservoir tailrace - Use IHR because of large numbers of northern pikeminnow.	Water temps reach 14°C ~ 5-June. Current temps support successful spawning in late spring.	Spawning Temps reach 14°C ~ 3 Jun - No difference from NAA	Spawning Temps reach 14°C ~ 3 Jun - No difference from NAA	Spawning Temps reach 14°C ~ 31 May – Northern pikeminnow spawning may be induced earlier under MO3.	Spawning Temps reach 14°C ~ 3 Jun - No difference from NAA	Gadomski etal. 2001.
Larvae and juveniles rear along shorelines where shallow water provides forage, low velocities at temperatures > 15°C.	Shoreline habitat available Number of days with surface temperatures > 15C at Ice Harbor June thru October	Rearing habitat in backwaters and slower shoreline habitats. Rearing temperatures (>15°C) from June through October ~ 88.7% of days (10,826). Current habitats and temperatures support successful rearing of northing pikeminnow.	Rearing temperatures over 15°C Jun-Oct 88.3% of days (10777). Slightly fewer days over 15°C. Hotter August and cooler July and September, but no real difference in rearing.	Rearing temperatures over 15°C Jun-Oct 86.9% of days (10616). This would be slightly fewer days over 15°C under MO2. Negligible difference from the NAA	Rearing temperatures over 15°C Jun-Oct 77.6% of days (9479). This would be fewer days over 15°C. Growth of northern pikeminnow juveniles would see minor reductions under MO3	Rearing temperatures over 15°C Jun-Oct 89.3% of days (10897). Slightly more days over 15°C. No real difference in rearing.	Gadomski etal. 2001.
TDG relationship for rearing habitat – shallow water habitats more impacted than deeper habitats.	Days Surface TDG over 120% at IHR April - July	TDG Apr through Jul number of days over 120%. High = 136% TDG; 809/9760 days over 120 = 8.3%; WQ plots show that the majority of these dates are in Jun and July. Under the NAA elevated TDG would have an adverse effect on larval and juvenile northern pikeminnow, primarily in June and July.	High = 136% TDG; 889/9760 days over 120 = 9.1%; WQ plots show that the majority of these dates are in Jun and July. There would be a negligible increase in exposure to high TDG and adverse effect under MO1 vs NAA.	High = 136% TDG; 660/9760 days over 120 = 6.8%; water quality plots show that the majority of these dates are in Jun and July and that there would be a minor decrease in exposure to high TDG in the fall and April through July under MO2 vs the NAA.	High = 104% TDG; 0/9760 days over 120 = 0%; TDG conditions would be ideal for most of the Lower Snake River under this alternative. No negative effects from TDG to northern pikeminnow are expected under MO3.	High = 136% TDG; 5163/9760 days over 120 = 52.9%; WQ plots show major increases in exposure to high TDG from Apr through July and moderate increase in risk in April and May when compared with the NAA. There would likely be negative impacts to northern pikeminnow under MO4.	ODFW sampled northern pikeminnow and did not show increased gas bubble disease. Dramatic gas bubble disease signs were observed with prolonged exposure to 115% in the shallow water. At 125% and 130% TDG in depths of 26 cm mortalities occurred without extensive gas bubble disease signs. With exposure to 125% TDG the times to 50% mortality were northern pikeminnow 15.2 hour.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Food source – larval and juvenile northern pikeminnow feed primarily on invertebrates.	Status and/or trends in current Invertebrate populations.	Water quality data shows that the lower snake river is mildly Eutrophic with relatively healthy zooplankton populations. Invertebrate populations are limited to reservoir species. Current invertebrate communities support larval and juvenile northern pikeminnow populations.	Warmer August could lead to species shift in zooplankton, but could also have more growth in summer. This could lead to minor increase in food resources for larval and juvenile northern pikeminnow.	No difference from NAA	Change from reservoir to riverine habitats will alter forage base and change productivity. Conversion from zooplankton dominated reservoir to insect dominated stream. Zooplankton expected to drop to less than 10% of current biomass. Would be replaced, in time with macro-invertebrates. Expect a major reduction in food resources during breach with slow return over time. Short term reductions in northern pikeminnow populations followed by slow recovery to some unknown population level.	No difference from NAA	Currently, highest concentrations of zooplankton occur in reservoir reaches with much lower concentrations of zooplankton in river reaches.
Pikeminnow reward program objective to remove 10% to 20% of large northern pikeminnow. Numbers are down from historic highs.	Pikeminnow Population estimates.	Exploitation rates vary from 7.5 to 17%. Under the no action alternative the NPM reward program would continue to remove ~ 12% of the population over 200mm in length.	No difference from NAA	No difference from NAA	No difference from NAA	No difference from NAA	Pikeminnow control program has reduced numbers in recent years. Metric dose not determine differences between the alternatives.
Sediment tolerance – during dam breach, high sediment releases are expected that could exceed northern pikeminnow tolerances.	Northern pikeminnow tolerance to high sediment loads	Mean Sediment concentrations prior to removal ~ 2 mg/l. There would be no negative impacts to NPM under current conditions.	No difference from NAA.	No difference from NAA.	Sediment loads may reach 25,000 mg/l for short periods of time. Over 5,000 mg/l for 26 days. These levels create a severity index of 11 ~ 20-40% mortality of NPM (Newcombe and Jensen 1996).	No difference from NAA.	Measured in time and concentration. Use severity index from Newcombe and Jensen (1996).

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Oxygen tolerance – during dam breach, high sediment releases may increase BOD to levels that deplete oxygen in the system. Equilibrium of northern pikeminnow estimated lost at 2 ppm to 3 ppm.	Northern pikeminnow tolerance to low oxygen levels (loss of equilibrium at 2 to 4 mg/l)	Oxygen levels are expected to remain near saturation during the NAA. No effect to northern pikeminnow.	No difference from NAA.	No difference from NAA.	Sediment loads may reach 25,000 mg/l for short periods of time and oxygen may be reduced to near 2 ppm. An estimated 26 days of sediment over 5,000 mg/l could result. Reduced Oxygen may be associated with that level of sediment. Short term effects to northern pikeminnow could result in the loss of these populations. Long term impacts would include elevated sediment during the spring freshet the following year(s). These conditions may also negatively impact northern pikeminnow.	No difference from NAA.	–
Walleye							
Walleye populations favored by reservoir environments.	Number of walleye in juvenile bypass system or sampling and qualitative discussion of habitat changes	Juvenile bypass system numbers in LMN (2012-2018; 8, 9, 92, 337, 608, 733, 352). Reservoirs in the lower Snake River dams are ideal walleye habitat. Fish are in LMN and IHR, now increasingly in Little Goose and adults are in Lower Granite. Under the No Action alternative walleye numbers are expected to continue to expand upriver and increases in numbers.	No difference from NAA	No difference from NAA	Under MO3, reservoir habitats would be converted to riverine habitats. Walleye numbers would likely decrease and then stabilize at reduced levels	No difference from NAA	Separator numbers increasing as the fish go up the river. Correlate to salmon predation losses. Arntzen et al. 2012
Spawn in spring, 4°C to 10°C over benthic habitats less than 10 feet deep. Gravel or cobble substrates are best. Prefer slow-moving rivers or lakes with wave action to clean substrate.	Quality and quantity of shoreline habitat available.	Suitable water temps for spawning occur from mid Feb to mid Apr. Areas of shoreline gravel and flow exist throughout the Lower Snake River. Under the No Action Alternative adequate spawning habitats exist for walleye.	No difference from NAA	No difference from NAA	Under MO3, reservoir habitats would be converted to riverine habitats. Cobble and gravel substrates are expected to increase significantly under this alternative. At the same time slow water habitats preferred by walleye are expected to decrease significantly. Overall, suitable walleye spawning habitat is likely to increase under MO3.	No difference from NAA	–

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Walleye fry require adequate zooplankton to grow.	Productivity and Zooplankton	Water quality analysis indicates that the lower Snake River is Mesotrophic to lower Eutrophic. Zooplankton and other sources of food for walleye fry are plentiful except in the Clearwater River. Under the no action alternative river and reservoir productivity is relatively high and food resources for walleye fry are plentiful.	Warmer August ~ Possible zooplankton species shift in zooplankton that may lead to increased food resources for pelagic walleye fry.	No difference from NAA	Change from reservoir to riverine habitats will alter forage base and change productivity. Conversion from zooplankton-dominated reservoir to insect-dominated stream. Zooplankton expected to drop to less than 10% of current biomass. Would be replaced in time with macro-invertebrates. Expect reduction in productivity during breach, with slow return over time leading to reductions in walleye populations with likely recovery to some lower population level.	No difference from NAA	Water Quality Appendices 7-7 through 7-10
Rearing – increases in prawns and opossum shrimp (neomysis) food source allows predatory fish to get to piscivory stage sooner (Tiffan et al., 2017a).	Trend in prawn numbers as documented in bypass reports.	Bypass reports: 464,000 individuals collected at LGO in 2015 Introduced shrimp are expected to continue to expand and provide a food source.	Warmer August could increase summer growth and production of zooplankton. May lead to increased food resources for Siberian prawn and Mysid Shrimp.	No change from NAA	Change from reservoir to riverine habitats will dramatically reduce Siberian prawns in the lower Snake River. Zooplankton, the main forage item for Siberian prawns, is expected to drop by over 90%. Mysid shrimp are a lentic species and would be flushed from the system in a riverine system. Losses of these species would likely be replaced by other species, but would lead to short term reductions in walleye populations.	No change from NAA	Mysis shrimp are large portion of the diet for Siberian prawns. Both are food resources for juvenile walleye and smallmouth bass, but the team does not know to what extent.
Juveniles can be limited by high or variable water velocities in rearing areas that transport juveniles to unsuitable habitats.	Water flows or velocities (April - May) at LGR	Median flows in the lower Snake River are relatively high at this time (81,287 cfs) Flows on the lower Snake River are relatively high during fry rearing. Successful rearing will occur at limited sites with adequate shelter from high flows.	Flows in MO1 are not expected to differ from the NAA. Median flow is 81,303. No difference for juvenile walleye.	Flows in MO2 are not expected to differ from the NAA. Median flow is 81,226. No difference for juvenile walleye.	While flows in the lower Snake River for MO3 are not expected to change significantly (81,266), under a breach scenario the team would expect velocities to change dramatically. Estimates of water travel time go from 0.4 feet to 4 feet per second. We expect juvenile walleye rearing habitat to be limited and recruitment of walleyes to be reduced.	Flows in MO4 are not expected to differ greatly from the NAA. Median flow is 81,266. Slightly lower than NAA - no difference for juvenile walleye.	The literature discusses the potential for fry losses due to high or variable flows in rearing areas, but no specific values are given.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Adults prefer offshore habitat in deeper water during daylight hours and move to shallower feeding sites at night.	Qualitative description of deep water habitat available.	Adult resting and feeding habitats are not limited. Under current conditions there is adequate resting and feeding habitat for adult walleye.	No change from NAA	No change from NAA	Under MO3 there will be reduced resting and feeding habitat. Velocities will be increased dramatically and deep water habitats will be limited. MO3 would reduce suitable habitat for walleye.	No change from NAA	Washington has no limits on bass, walleye, catfish in Columbia River tributaries.
Rearing fry require temperatures > 15°C for growth and feeding.	Temperature from April -July at LGO % of days over 15°C.	Median date that Lower Snake hits 15°C is June 4. Percent of all days over 15°C = 39.3%. Currently, temperatures are cold for optimum growth when fry first hatch. Best growth occurs after mid-June.	Median date that Lower Snake hits 15°C is June 3. Percent of all days over 15°C = 39.2%. No change from NAA	Median date that Lower Snake hits 15°C is June 2. Percent of all days over 15°C = 39.5%. No change from NAA	Median date that Lower Snake hits 15°C is June 10. Percent of all days over 15°C = 42.0%. Negligible increase in warm days for rearing, but there may be a shift later in the year of about a week for rearing to begin.	Median date that Lower Snake hits 15°C is June 3. Percent of all days over 15°C = 39.5%. No change from NAA	–
Sediment tolerance – during dam breach, high sediment releases are expected that could exceed walleye tolerances.	Walleye tolerance to high sediment loads	Mean sediment concentrations prior to removal ~ 2 mg/l. There would be no negative impacts to walleye under current conditions.	No difference from NAA.	No difference from NAA.	Sediment loads may reach 25,000 mg/l for short periods of time. Over 5,000 mg/l for 26 days. These levels create a severity index of 12 ~ 40% to 60% mortality of walleye. Walleye appear to be more resistant to high total suspended solids at first and then more sensitive to long-term total suspended solids. Greater numbers would be expected to die during breaching.	No difference from NAA.	Measured in time and concentration. Use severity index from Newcombe and Jensen (1996).
Oxygen tolerance – during dam breach, high sediment releases may increase BOD to levels that deplete oxygen in the system. Equilibrium lost at 2 to 3 ppm.	Walleye tolerance to low oxygen levels (loss of equilibrium at 2 to 4 mg/l)	Oxygen levels are expected to remain high during the NAA. There would be no negative impacts to walleye under current conditions	No difference from NAA.	No difference from NAA.	Sediment loads may reach 25,000 mg/l for short periods of time and oxygen may be reduced to near 2 ppm. An estimated 26 days of sediment over 5,000 mg/l could result. Reduced oxygen may be associated with that level of sediment. Short term effects to walleye could result in the loss of these populations. Long term impacts would include elevated sediment during the spring freshet the following year(s). These conditions may also negatively impact walleye.	No difference from NAA.	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Smallmouth Bass							
Spawning in slower water of lakes or rivers less than 18 to 20 feet deep. Prefer rocky or cobble habitats. Riprap is good.	Spawning habitat	Spawning habitat abundant in Snake River reservoirs Spawning habitat for smallmouth bass is not limiting on the Lower Snake River	No difference from NAA	No change in NAA	Under MO3, there would be a dramatic change in habitat from reservoir to riverine. Suitable spawning substrate would increase. However, velocities would increase and reduce spawning sites to the slower more protected sites. Spawning habitat is not expected to be a limited habitat under MO3.	No difference from NAA	Warmer temps are conducive to smallmouth bass, rivers and lakes both are good habitat (compared to walleye-lakes preferred)
Optimal range for adult rearing is 21°C to 27°C (Edwards et al., 1983).	Percent of days Temperatures over 21°C at LGO pool - Surface	14.3% of all days over 21°C ~ 52 days a year. Current conditions provide ideal rearing conditions for SMB in the Lower Snake River for only 52 days a year. Temperatures are moderately below optimal growth.	16.6% of all days over 21°C ~ 60 days a year. Under MO1, there would be a negligible increase in days of higher temperatures and ideal rearing conditions for SMB compared to the NAA.	15.1% of all days over 21°C ~ 55 days a year. No change from NAA	1.0% of all days over 21°C ~ 4 days a year. Under MO3, ideal rearing temperatures would be reduced significantly. Surface temperatures that are much warmer in reservoir habitats would be mixed in a riverine system. Smallmouth bass growth would be moderately reduced under this alternative.	14.4% of all days over 21°C ~ 53 days a year. No change from NAA	Edwards et al. (1983) gave the upper temperature limit for adult smallmouth bass as 32°C, the optimum range for adult rearing as 21°C to 27°C, and the optimum range for spawning as 12.8°C to 21°C.
Turbidity can limit smallmouth bass growth and feeding success.	Turbidity levels	Turbidity rarely exceeds 200 NTUs in the lower Snake River. Sontag Thesis (Sontag, 2013) found drop in smallmouth bass predation during high turbidity flows on the Snake River.	Turbidity limits feeding success of smallmouth bass in early runoff of some years (2017) on the Snake River.	No change from NAA	No change from NAA	Total suspended solids expected to reach 20,000 mg/L during breach and remain greater than 5,000 mg/L for 26 days. Elevated concentrations would occur during spring runoff and other high-flow or precipitation events. Will return to less than 50 mg/L after river bed stabilizes (Water Quality Appendix 7-11). Negative short-term impacts with no long term impacts.	No change from NAA

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Dworshak drawdown timing could interrupt spawning/ rearing cycle.	Timing of pool elevation changes/relative to smallmouth bass spawning in Dworshak	Pool at 1520 in winter then fills to 1600 starting in late April or Early May. Reaches full pool by July 4th, then drawdown drops water to 1520 by September. Temps reach 16°C on about May 7th. In most years smallmouth bass will nest and the fry will leave the area before drawdown would desiccate the nest. Under the NAA, smallmouth bass spawning and nesting would not be impaired by drawdowns.	No change from NAA	Overall water levels are lower under MO2 for all water year types, but water levels do not drop until early to mid-July - not likely to desiccate the nests. No change from NAA	No change from NAA	No change from NAA	Smallmouth bass spawn on rocky shorelines at in water depths from 1 to 5 meters. Spawning begins at 16C° ~ early May. Lake levels drop starting in mid-July and likey do not desiccate smallmouth bass nests till late July after smallmouth bass have already reared and moved out (Edwards et al., 1983). Cold water influx after the start of spawning could induce nest abandonment with a possibility for a second less successful attempt when water temperatures warm.
Reservoirs support sand roller (Percopsis transmontana) populations that provide an alternate food source for smallmouth bass when smolts are low or not in the area.	Sand roller population status and change	Sontag (2013) found that ~35%, by weight of SMB diet was sand roller in lower granite pool. Smolts were only 5%. However, Erhardt et al. (2018) found that smolts were a major portion of smallmouth bass diet. Water conditions were different for these years with clear water in 2018 and turbid water in 2013. Under NAA, smallmouth bass will switch to alternate prey if smolts are limited.	No change from NAA	No change from NAA	Under MO3, the four lower Snake River dams would be breached. During breaching, large amounts of sediment would be released and alternate prey populations are expected to be significantly reduced. Under MO3, there would be reduced forage for smallmouth bass for an unknown time period. Smallmouth bass populations would be temporarily reduced.	No change from NAA	Sontag (2013) found that ~35%, by weight of the smallmouth bass diet was sand roller. Smolts were only 5%. Peamouth and chiselmouth were second at ~19% each. Smallmouth bass are piscivorous after about 2 years. Erhardt et al. (2018) estimated that smallmouth bass ate over 300,000 smolts in a 22-km reach of the lower Snake River. Water conditions were different in these years where turbid conditions during the 2013 study limited smallmouth bass foraging success. In 2018, clear water allowed greater success.
Adults go inactive at temperatures less than 10°C.	Water Temps less than 10°C at LGO pool dates above and below and % of days inactive.	Days below 10°C = 46.0% ~ 168 days. Water temps reach 10C at ~ April 25 and back to 10°C on Nov 12. Under the NAA SMB are not likely to be active until May, at which point SMB growth would increase and maximize in July and August. These fish would go dormant in early November.	Days below 10°C = 46.0% ~ 168 days. Water temps reach 10°C at ~ April 25 and back to 10°C on Nov 12. No change from NAA.	Days below 10°C = 46.2% ~ 168 days. Water temps reach 10°C at ~ April 26 and back to 10°C on Nov 12. No change from NAA	Days below 10°C = 49.4% ~ 180 days. Water temps reach 10°C at ~ April 26 and back to 10°C on Oct 26. Under MO3 there would be a minor increase in the length of the winter starvation period for smallmouth bass. Survival would likely decrease slightly and growth would be reduced.	Days below 10°C = 46.0% ~ 168 days. Water temps reach 10°C at ~ April 25 and back to 10°C on Nov 12. No change from NAA	Edwards et al., 1983.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Embryo require temperatures between 13°C and 25°C for normal development. Nest building and spawning occur at 13°C and 20°C.	Water temps after spawning - May thru June.	Water temps reach 13°C at ~ May 8. Days over 13C May thru June = 70.6%. Under the NAA Temperatures are conducive to embryo development ~ 70% of May through June.	Water temps reach 13°C at ~ May 7. Days over 13°C = 75% Under MO1, there would be a minor increase in days of suitable rearing for embryos.	Water temps reach 13°C at ~ May 9. Days over 13°C = 71.8% No change from NAA.	Water temps reach 13°C at ~ May 29. Days over 13°C = 51.5% Under MO3, there would be a moderate reduction in the number of days in May and June that would provide suitable development for smallmouth bass embryos. Survival of smallmouth bass embryos will likely decrease.	Water temps reach 13°C at ~ May 9. Days over 13°C = 74.4% Under MO4, there would be a minor increase in days of suitable rearing for embryos.	There may be another spawning period if there is a sudden drop in temperature during the first attempt. Edwards et al., 1983.
Fry require low flows – velocities of <0.2 meters/ second (0.65 feet/second) for rearing.	Water flow from May 30 to mid-October	At the end of May flows are near their annual peak (113 kcfs). These drop to ~ 70 kcfs by the end of June. Conditions are best for fry in July and August with low flows and high water temps. Under the NAA, rearing habitats would be restricted to backwater and off channel habitats during May and June. These habitats would expand in July and August.	No difference from NAA	No change from NAA.	Under MO3, water flows would not change significantly, but water velocities would increase dramatically. Expect Mean velocity go from ~ 0.4 feet/second to 4 feet/second. Rearing habitat for SMB fry, during May and June, would see major reductions under this alternative relative to the NAA.	No difference from NAA.	–
Sediment tolerance – during dam breach, high sediment releases are expected that could exceed smallmouth tolerances.	SMB tolerance to high sediment loads	Turbidity rarely exceeds 200 NTUs. Total suspended solids are generally around 2 mg/l. Current sediment and turbidity levels are suitable for smallmouth bass growth and survival. High water years with greater turbidity may limit smallmouth bass foraging success.	No difference from NAA.	No difference from NAA.	Sediment loads may reach 25,000 mg/l for short periods of time. Over 5,000 mg/l for 26 days. These levels create a severity index of 11 ~ 20% to 40% mortality of SMB (Newcombe and Jensen, 1996). Under MO3 there would be a Major short term impact from sediment during breaching. Short-term impacts would include greater turbidity during Spring flows ~ 30 mg/l total suspended solids (water quality presentation).	No difference from NAA.	Measured in time and concentration. Use severity index from Newcombe and Jensen, 1996).

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Oxygen tolerance – during dam breach, high sediment releases may increase BOD to levels that deplete oxygen in the system. Equilibrium lost at 2 ppm to 3 ppm.	Smallmouth bass tolerance to low oxygen levels (loss of equilibrium at 2 to 4 mg/l)	Oxygen levels are expected to remain near saturation during the NAA. No effect to smallmouth bass under the NAA.	No difference from NAA.	No difference from NAA.	Sediment loads may reach 25,000 mg/l for short periods of time and oxygen may be reduced to near 2 ppm. An estimated 26 days of sediment over 5,000 mg/l could result. Reduced oxygen may be associated with that level of sediment. Short term effects to Smallmouth bass could result in the loss of these populations. Long-term impacts would include elevated sediment during the spring freshet the following year(s). These conditions may also negatively impact smallmouth bass.	No difference from NAA.	–
Native Fish Community							
Sucker species (bridgelip, largescale) native spp., requirements similar to northern pikeminnow.	See northern pikeminnow relationships. Also see page B4-27 from Appendix B of the 2002 Juvenile Salmon Migration Feasibility Study (Corps, 2002) for fish expected to be found under the alternatives.	Under the NAA, fish communities would be dominated by reservoir species (walleye, catfish, perch, smallmouth bass, northern pikeminnow, carp, crappie, and sucker)	No Change from NAA	No Change from NAA	Change to riverine species (sucker, northern pikeminnow, smallmouth bass, white sturgeon, mountain whitefish, and sculpin spp.)	No Change from NAA	How do these fish pass through adult ladders? Ladders favor the larger size classes. Assume similar response as northern pikeminnow from alternatives. Under MO3, will these be impacted differently than other species already analyzed?
Mountain whitefish in tributaries do occur in juvenile bypass system samples	Number of fish in bypass	LMN 2017 = 521; 2018 = 235. Varies by year. Effects similar to northern pikeminnow.	No Change from NAA	No Change from NAA	Increase in mountain whitefish relative to NAA.	No Change from NAA	Are mountain whitefish a major species of concern in the lower Snake River?
Game Fish							
Walleye, smallmouth bass, and catfish	See walleye/smallmouth bass	Assume outputs would be similar to those from the walleye and smallmouth bass analysis	NA	NA	NA	NA	Assume metrics that improve smallmouth bass and walleye will help most of the game fish in this basin.
Bluegill, perch, and crappie are reservoir species. Do they need additional analysis?	See walleye for similar results	Reservoir community supported by current conditions.	NA	NA	Would expect large reductions in these fish.	NA	River environment not conducive to these species.

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3.8.5 Region D

3.8.5.1 McNary Dam to Estuary

Table 3-81. Qualitative Effects to White sturgeon and other resident fish in the lower Columbia River - (McNary to Eastuary)

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
White Sturgeon Flow and Temperature Relationship							
Temperature affects suitability for embryo incubation. McCabe and Tracy (1994) captured sturgeon embryos (eggs) in the 11 kilometers of river been river kilometers 223 to 234. In the BON tailrace, white sturgeon spawned at water temperatures ranging from 10°C and 19°C (McCabe and Tracy, 1994). Wang et al. (1985) found successful embryo incubation occurs between 10°C and 18°C, and the optimal water temperatures is from 12°C to 14°C. Wang et al. (1985) also found temperatures above 18°C increase embryo mortality and 20°C and higher is lethal for embryos.	BON temperature, ext. year set. Dates and number of days temperature is >10°C but 18°C, Apr 15 to Jul 15. Optimal same data set >12, <14.	**Data Outputs:** Days > 10°C, <18°C: 2011 HF/LT: 5/5-7/15, 72 days 2012 AF/LT: 4/23-7/8, 74 days 2013 LF/AT: 4/24-6/28, 66 days 2014 AF/AT: 4/29-6/30, 63 days 2015 LF/HT: 4/18-6/4, 48 days Days >12°C, <14°C: 2011 HF/LT: 5/14-6/9, 27 days (includes 2 days slightly >14) 2012 AF/LT: 5/14-5/30, 17 days 2013 LF/AT: 4/24-6/28, 8 days 2014 AF/AT: 4/29-6/30, 10 days 2015 LF/HT: 4/18-6/4, 15 days (includes 2 days slightly >14)	**Data Outputs:** Days > 10°C, <18°C – Difference from NAA: 2011 HF/LT: 5/5-7/15, 72 days, 0 2012 AF/LT: 4/23-7/8, 74 days, 0 2013 LF/AT: 4/24-6/28, 67 days, +1 day 2014 AF/AT: 4/29-6/30, 63 days, 0 2015 LF/HT: 4/18-6/4, 48 days, includes 3 days slightly >18°C). Similar to NAA. Days >12°C, <14°C – Difference from NAA: 2011 HF/LT: 5/14-6/9, 27 days, 0 (includes 2 days slightly >14) 2012 AF/LT: 5/14-5/30, 17 days	**Data Outputs:** 2011: 5/5-7/15; 72 days 2012: 4/23-7/8; 74 days 2013: 4/24-6/27; 67 days, plus 1 day 2014: 4/29-6/30, 63 days 2015: 4/18-6/5; 49 days, similar to NAA. **Effects to Resource:** Same as NAA. **Notes:**	**Data Outputs:** Days >10, <18: 2011 HF/LT: 5/5-7/15, 72 days 2012 AF/LT: 4/22-7/7, 74 days 2013 LF/AT: 4/24-6/28, 66 days 2014 AF/AT: 4/29-6/30, 63 days 2015 LF/HT: 4/18-6/4, 48 days Days >12, <14: 2011 HF/LT: 5/14-6/9, 27 days (includes 2 days slightly >14) 2012 AF/LT: 5/18-6/11, 17 days, more fluctuations 2013 LF/AT: 5/4-5/9, 6 days, -2 days 2014 AF/AT: 5/10-5/21, 12 days, +2 days 2015 LF/HT: 5/1-5/15, 15 days (includes 2 days slightly	**Data Outputs:** Days >10, <18: Difference from NAA 2011 HF/LT: 5/5-7/15, 72 days, 0 2012 AF/LT: 4/23-7/8, 74 days, 0 2013 LF/AT: 4/23-6/28, 67 days, +1 day 2014 AF/AT: 4/29-6/29, 62 days, -1 day 2015 LF/HT: 4/186/4, 42 days, Includes 3 days slightly > 18°C), Similar to NAA. Days >12, <14: Difference from NAA 2011 HF/LT: 5/14-6/9, 27 days, 0	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		Effects to Resource: Differences in temperature regime could have an effect on sturgeon spawning. Under the NAA, BON tailrace would provide white sturgeon with the proper temperatures for spawning from mid-Apr to mid-Jul in high water years, and from mid-Apr through Jun in average water years. In years of low flow conditions, water could get too warm for sturgeon recruitment by Jun, resulting in poor or no recruitment. **Notes:** Could use input from others on whether looking at temperatures in BON tailrace would be useful or if another metric would be better? (Comment from Bjorn van der Leeuw.) For BON tailrace, McCabe and Tracy (1994) mentioned spawning months as mid-Apr to mid-Jul.	2013 LF/AT: 4/24-6/28, 8 days 2014 AF/AT: 4/29-6/30, 10 days 2015 LF/HT: 4/18-6/4, 15 days (includes 2 days slightly >14) **Effects to Resource:** Same as NAA. **Notes:** Incubation at 14°C to 16°C is about 5 to 7 days. At upper end, the temperature climbs up within a week, and the eggs are very sensitive to increasing temperatures. Temperature is a bigger driver than flows. Need flows to broadcast/disperse the eggs.		>14°C) **Effects to Resource:** Same as NAA. **Notes:** See BON_Mapped80yrTemp_NAA	(includes 1 day slightly >14) 2012 AF/LT: 5/7, 5/8, 5/14-5/30, 19 days, +2 days 2013 LF/AT: 5/4-5/9, 6 days, -2 days 2014 AF/AT: 5/11-5/20, 10 days, 0 2015 LF/HT: 5/1-5/13, 14 days (includes 1 day slightly >14°C), -1D **Effects to Resource:** Similar to NAA. **Notes:**	
Spawning – flows needed for successful spawning and recruitment. 250 kcfs in Apr 1-Jul 31 in MCN tailrace. Since lower Columbia dams are run-of-river, outflow at MCN will correlate with outflows at JDA, TDA, and BON.	MCNARY_OUT_FLOW summary hydrograph Days >250 kcfs from 4/1-7/31 and number of those days within temperature requirements (above). Alternate method: 5 Ext Yr from WQ, flows and temperatures.	**Data Outputs:** Median: 5/16-6/21, 35 days 25th percentile: 4/17-7/14 (88 days, all within temperature requirement) Alternate Method – (See MCN_Ext_Yr_NAA) 2011: 5/12-7/24 (74 days) 2012: 4/25-7/11 (78 days) 2013: 5/9-6/30 (53 days, minus 11 that fall below 250 kcfs in that period) 2014: 4/14-6/14, plus 5 more (49 days, not all consecutive) 2015: 0 days (extreme low water year) **Effects to Resource:** Flow and temperature conditions would continue to be adequate for sturgeon	**Data Outputs:** Summary hydrograph days >250 kcfs Median May 17-Jun 20, 34 days 25 percentile: 4/19-7/13, 85 days Alternate Method – See MCN_Ext_Yr_NAA 2011: 5/12-7/24, 74 days 2012: 4/25-7/11, 78 days 2013: 5/9-6/29 (52 days, minus 12 fall below 250 kcfs in that period) 2014: 4/14-6/14, plus 5 more (49 days, not all consecutive) 2015: 0 days (extreme low water year) Change in Average Monthly Outflow: May: -2%	**Data Outputs:** **Effects to Resource:** Spawning and recruitment would be similar to the NAA in high and average flow years. In low years (2013), about 8 fewer days in recruitment conditions, but in low water years there is no recruitment and the concern is with survival, which is dependent on temperature. Temperature would be similar to the NAA. **Notes:**	**Data Outputs:** Summary Hydrograph days > 250 kcfs Median: 5/17-6/20 (34 days) 25th Percentile: 4/18-7/13 Alternate method – See MCN_ExtYr_NAA_working 2011: 5/12-7/24, 74 days 2012: 4/25-7/11, 78 days (same number, 1 day later) 2013: 5/9-6/28, 51 days (-16 fall below 250 kcfs in that period) 2014: 5/3-6/22, 6/21-6/29 (51 days) 2015: 0 days (extreme low water year) May/June flows **Effects to Resource:** Wet and average years similar to NAA.	**Data Outputs:** Summary Hydrograph: Median: 5/17-6/21 (35 days) 25th Percentile: 4/19-7/13 (85 days) Alternative method: See MCN_ExtYr_NAA_working **Effects to Resource:** Wet and average years similar to NAA. Dry years NAA and MO4 were similar, still high risk for sturgeon survival in LF/HT years. MO4 provided an extra day in optimal range in AF years. **Notes:** Extreme low years (2015), no spawning under any alternatives, but into survival mode. 18°C to 20°C, duration, and how quickly to those temperatures are critical.	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		spawning and recruitment most of the mid-Apr to mid-Jul time in high flow years, but only about half that time in average flow conditions. Low flow years would likely not provide enough time with suitable conditions for any recruitment to occur. **Notes:** Optimal temperature and flows in X days would be a good spawning year. Opportunity to look at if temperature correlates to flows in effects analysis modeling with both datasets. This criteria is also important for successful recruitment and larval drift. This amount of flow and above 250 kcfs also maintains more consistent forebay/tailrace elevations, and reduces chance of stranding/dewatering below BON. In years of extreme low flows and warm water, higher than typical adult mortalities have been documented (Olaf Langness document, e.g., 2015).	Jun: -1% **Effects to Resource:** Median years, 2 fewer days; high flow years, 3 fewer days within temperature and flow window. There could be a slight reduction in years with recruitment success. **Notes:** Graphic that shows it more clearly over years… Above 17°C leads to mortality. JDA pool is an outlier. 7 of the last 21 years were successful. Successful spawning over time in each of the pools. Overlay temperatures, check with water quality to use this way.		Dry year, more days in June with flows below 250 kcfs would reduce spawning success. Less days with turbulent flow to disperse eggs. Timing in Jun could affect larval dispersal. About 14°C trigger spawning. In LF/HT years, the rate of increased temperatures was faster, would increase risk of mortality. LF/HT concern is with survival. No recruitment, focus on survival of adults. Faster rate of rise up from 18°C to 20°C is higher stress, especially on females. AF/AT year, reached 20°C quicker. In Jul, increased risk of atresia later in spawning period. LF/AT year not much difference, slightly fewer days, but very close in temp. HF/LT year MO3 offers more days in optimal. Also a little slower getting up and past 20°C. Late Jul-Aug, extend better survival days. **Notes:** See BON_Mapped80yrTemp_NAA for this data. See Flow_Fcst_Comparisons for incremental lower flows in May/Jun in dry years. Any sturgeon recruitment under any alts? See Mcnary_Outflo Additional days in April may increase cues, but days in Jun are more critical to recruitment from the egg and larval dispersal mechanism. Lower projects more mixed; 2015 die-offs more in JDA, 2015 more in JDA and TDA and MCN, BON less die-offs noticed; more thermal	Stress contributed to atresia, temperature conditions also caused Chinook salmon die-offs, sturgeon gorged = metabolic stress.	

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
					refugia? (Olaf has report of this.)		
Spawning generally occurs in areas with fast-flowing waters over coarse substrates (Parsley et al., 1993). McCabe and Tracy (1994) concluded that spawning in the BON tailrace occurred in days with mean discharges from BON ranging from 120 kcfs to 371 kcfs.	BON outflow: Bonneville_Out_Flow (Excel file). Mean monthly outflow, Apr-Jul. +Qualitatively look at hydrographs of lo, average, and hi years.	**Data Outputs:** Median outflows: Apr = 212989 May = 275261 Jun = 295709 Jul = 204315 99% outflows: Apr = 120584 May = 189943 Jun = 168665 Jul = 128003 **Effects to Resource:** From the data provided by H&H, it shows the BON tailrace always has flows 120 kcfs or greater from Apr to Jul for suitable spawning habitat. Note: This does not indicate flows adequate for sturgeon using the habitat or for recruitment. See above flow/temp relationship. **Notes:**	**Data Outputs:** Change from NAA Median outflows: Apr: 208,570 (-2%) May: 268,886 (-2%) Jun: 293,731 (-1%) Jul: 202,273 (-1%) 25% Outflows Apr: -2% May: -2% Jun: -1% Jul: -1% **Effects to Resource:** Outflows during spawning months would be well within the range of spawning needs for white sturgeon below BON, but would be slightly less (1%-2% is median water years and 1%-5% in very dry years) than the NAA. Minor changes in outflows would not relate to discernable changes to velocities. Sturgeon habitat would be similar to NAA. **Notes:** Use MCN flows >250 kcfs as the criteria for successful spawning at all lower Columbia areas. Counihan and Chapman, 2018. Discharge 6/16-7/31 focused more on recruitment.	**Data Outputs:** Change from NAA Median outflows: Apr: -2% May: -1% Jun: -1% Jul: same as NAA **Effects to Resource:** Same as NAA. **Notes:**	**Data Outputs:** Change from NAA Median: Apr: -2% May: -3% Jun: -2% Jul: -1% 25th (Higher flows): Apr: -2% May: -2% Jun: -1% Jul: -1% **Effects to Resource:** Same as MO1 Slightly lower flows in pre-spawning period could reduce sediment transport slightly. Not a big impact from flows. **Notes:**	**Data Outputs:** Median outflows: Apr: 208,220 (-2%) May: 270,820 (-3%) Jun: 292,998 (-1%) Jul: 204,946 (+3%) **Effects to Resource:** Minor changes in outflows would not relate to discernable changes to velocities. **Notes:**	–
Availability of interstitial habitat important for survival and growth of yolk sac and feeding larvae. Substrate alteration (if present) would have multiple effects on white sturgeon in the lower Columbia River downstream of BON.	Change in peak flows or sediment transport.	**Data Outputs:** **Effects to Resource:** **Notes:** Change in peak flows can affect scouring of habitat. Increased peak flows keep interstitial habitats. Annual distribution of sediment, where eggs and larvae settle need peak flows to clean substrate. Combine with interstitial space. If tied to	**Data Outputs:** River mechanics, Chapter 3. No change. **Effects to Resource:** Same as NAA. **Notes:**	**Data Outputs:** River mechanics, Chapter 3. No change. **Effects to Resource:** **Notes:**	**Data Outputs:** Dam breach – Sediment team "due to the increase in amount of sediment passing from the Snake River, potential increase in amount of sediment." **Effects to Resource:** Slightly lower flows in pre-spawning period could reduce sediment transport slightly. Not a big impact from flows.	**Data Outputs:** River mechanics, Chapter 3. No change. **Effects to Resource:** Same as NAA. **Notes:**	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		sediment changes in MO3? Likely changes mostly attenuated by BON dam. Hydrology regime is more important to manage any sedimentation effects from dam breach scenarios.			Dam breach could increase sediment and fill in interstitial spaces. **Notes:** Dam breach – sediment.		
Lack of upstream white sturgeon (both juvenile and adult) passage prevents population connectivity (Parsley et al., 2007).	Presence of physical barrier. Qualitative assessment of measures.	**Data Outputs:** None. **Effects to Resource:** Continued disconnection. Under the NAA, dams will stay6 in place without any major modifications to existing fish passage structures. BON will continue to provide a negligible amount of passage for sturgeon through the fishways. White sturgeon passage downstream through BON (likely through spillways and turbine unites) has not been measured. **Notes:** There is a net downstream movement of sturgeon through dams, so very few sturgeon move upstream through BON by the fishways, but PIT data shows sturgeon move downstream through BON, most likely through the spillway. Some connectivity downstream, very little upstream; populations continue to be isolated in NAA; may be some effect of PHSP structures or new turbines/ slow roll starts.	**Data Outputs:** S4: Modify BON ladder. **Effects to Resource:** Would depend on fishway spacing. Likely a benefit to sturgeon passage where sturgeon are able to enter ladders. Vertical slot fishway easier for sturgeon to pass upstream. **Notes:** Fish passage for sturgeon is not a ladder; ladders are not effective for sturgeon. Possible small incremental benefit if sturgeon are able to use the ladder. Need to specifically look at case by case basis. WA and Bradford fishways pass a few sturgeon but very rare. Not likely to use them.	**Data Outputs:** No mods that would improve sturgeon passage. **Effects to Resource:** Same as NAA. **Notes:**	**Data Outputs:** Modify BON ladder **Effects to Resource:** Same as MO1, possible slight incremental benefit. **Notes:** Bradford and WA shore ladders; sturgeon are able to get into these ladders, but sturgeon don't sue the ladders much. (Comparing to The Dalles – TDA is much bigger ladder and still passes relatively few sturgeon.)	**Data Outputs:** Same as NAA. **Effects to Resource:** Same as NAA. **Notes:**	–
Turbine units at BON are a known source of injury and mortality for juvenile and adult sturgeon. Also relative to JDA, TDA.	Qualitative assessment of measures.	**Data Outputs:** None. **Effects to Resource:** Injury to white sturgeon during turbine unit startups can lead to injury and direct mortality. Under the NAA, this would continue to possibly occur, although it has never been measured and the slow	**Data Outputs:** IFP turbines at JDA. **Effects to Resource:** Could have a positive effect for sturgeon in the JDA pool, lower impact mortality and injury. Unknown survival through sturgeon. Idaho Power may have data on passage survival through the	**Data Outputs:** IFP turbines at JDA. **Effects to Resource:** Same as MO1 **Notes:**	**Data Outputs:** IFP turbines at JDA. **Effects to Resource:** Same as MO1. **Notes:**	**Data Outputs:** IFP turbines at JDA. **Effects to Resource:** Same as MO1. **Notes:**	McCabe and Tracy, 1994.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		roll procedure has presumably greatly reduced blade strikes during turbine startups. **Notes:** The occurrence of blade strikes has been greater reduced by the slow roll procedure for turbine unit start-ups. Need to make sure the slow-roll is being used at all of BON.	turbines. Effective for smaller fish (steelhead). **Notes:** They swim into draft tubes from downstream.				
TDG effects on sturgeon larvae – 118% altered buoyancy, 131% had 50% mortality rate in lab (Counihan et al., 1998).	TDG	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** Spill test 115/120. **Effects to Resource:** Similar to NAA. **Notes:**	**Data Outputs:** Spill to 110%. **Effects to Resource:** Less effects than NAA. **Notes:**	**Data Outputs:** Spill to 120% - See water quality presentation. **Effects to Resource:** MCN and BON – Reduced TDG levels in Aug could reduce exposure. MO3 is below 110, NAA is above in Aug. JDA and TDA – Higher TDG at JDA mid-Apr through mid-June, could be critical time for emerging larvae seeking refuge in interstitial spaces. Lower than NAA in Aug, below 110. **Notes:** Scott B. – depth compensation reduces effects of TDG. This relationship developed with lab studies. Sturgeon typically in lower part of water column. Shallow areas important to larvae so could be affected by TDG.	**Data Outputs:** Spill to 125%. See water quality presentation for MO4 – TDG compared to NAA. **Effects to Resource:** Increased TDG, prolonged increase of TDG from 120 to about 125% TDG at MCN, JDA, TDA, and BON. Expect detrimental effects to juvenile sturgeon. Eggs and larvae most susceptible. Depth compensation – adults tend to be lower to be able to compensate. Larvae mostly also in deep eddy areas where likely less TDG, but if swept near shore they could be very susceptible. **Notes:** Depth compensation is 10% per meter in the water.	–
Changes in pool/tailrace elevation affect early juvenile life stage survival (egg, incubation, free-swimming larvae).	Look at summary hydrographs for drops in pool elevation at JDA, TDA, BON.	**Data Outputs:** Pool elevations are steady. **Effects to Resource:** N/A **Notes:** Can have spawning every year, doesn't mean will get recruitment, movement of juveniles down to right habitat is important.	**Data Outputs:** Approximately 1 foot higher JDA pool elevations late Mar-early June (avian predation measures) **Effects to Resource:** Drop in early June could strand larvae in JDA pool. **Notes:**	**Data Outputs:** No operational changes to elevations. **Effects to Resource:** Same as NAA. **Notes:**	**Data Outputs:** Operate JDA between elevations 262.5 and 265.5 (2.5 feet more range than NAA). See MO3 draft change description. **Effects to Resource:** Slight increase in SWH with 1-foot elevation increase habitat available for juveniles. If elevation is higher, then drops in June (as modeled in draft change document), then could	**Data Outputs:** JDA, TDA, BON all drawdown to MOP from late Mar to mid-Aug. **Effects to Resource:** Not likely to strand, drawdown is prior to spawning times. However, lower elevations would likely lead to less SWH available for larvae habitat. **Notes:**	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
					potentially strand larvae that have moved into the SWH. **Notes:** Had deleted this relationship in MO1 workshop as redundant with flow. Added back in here for JDA pool measure. Rate of change? – Elevation changes in spring/summer would be similar to what happens throughout the year. Up or down 1 foot to 1.5 feet in a day. How much shoreline inundated with 1-foot elevation change. Check with wildlife team or Chuck. May fluctuate – go down for a couple hours, then back up, or a day (example on weekends). Drop in modeled elevation in Jun may be a modeling artifact – measure is through end of Sep. Sue ask Kasi.		
Load following at BON has been shown to dewater early life stages downstream of BON (van der Leeuw et al., 2006).	BON tailrace elevation – daily changes.	**Data Outputs:** **Effects to Resource:** **Notes:** Fluctuations in tailrace (BON) are larger than pool elevation.	**Data Outputs:** Same as NAA. **Effects to Resource:** **Notes:**	**Data Outputs:** Ramping rates for safety. **Effects to Resource:** Same as NAA. **Notes:** See MO3 notes. Would not expect elevation changes at BON.	**Data Outputs:** Ramping rate restrictions? No installation of fish screens? **Effects to Resource:** Same as NAA. See notes. **Notes:** Birgit – no elevation changes, wouldn't expect changes at BON. BON doesn't have ramping rate restrictions.	**Data Outputs:** Same as NAA. **Effects to Resource:** Same as NAA. **Notes:**	Parsley et al., 2007
Pinnipeds, mainly Stellar sea lions, are known to prey on white sturgeon in the BON tailrace. Stellar sea lions have increased their abundance and seasonal presence (Tidwell et al., 2019).	Qualitative assessment of predation risk.	**Data Outputs:** None. **Effects to Resource:** Pinnipeds may have altered the spawning of white sturgeon in BON tailrace as they attempt to avoid predation. The ODFW points out that there is direct predation on sturgeon and harassment of spawning sturgeon by Stellar sea lions. The harassment can cause sturgeon to depart the spawning area or abort	**Data Outputs:** **Effects to Resource:** Lower flows at BON in dry years May and Aug could increase predation risk. **Notes:** Changes in temperature/flow likely not changing pinniped predation. Changes in spill? Likely not. Don't see predation right in the tailrace. Sturgeon have likely moved in response to the predation pressure from sea lions. Still seeing evidence of sea lion predation in the	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** 99% Exceedance (lowest flow years) May: -5% Jun: -2% Jul: -5% **Effects to Resource:** Lower flows in May-Jun in low flow years could exacerbate issues with crowding increasing predation risk. **Notes:** Spill/flows would not change pinniped behavior or numbers,	**Data Outputs:** Spill to 125% **Effects to Resource:** **Notes:**	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		spawning for the year (reabsorption of eggs). Continued predation, degree uncertain. Direct mortality of spawning fish and juvenile fish, also sea lions harassing the white sturgeon (making white sturgeon injured or having to spawn elsewhere). Colin Chapman of ODFW pointed out that harassment of spawning sturgeon may lead to stress and aborting spawning activity for that year. Female sturgeon are able to resorb eggs if they abort spawning. **Notes:** ODFW (Peter Stevens) is working on a memo that links the increase in Stellar sea lions to an overall reduction in year classes of sturgeon on the lower Columbia River population. The immediate BON tailrace is the only area of the lower Columbia River systematically observed to measure predation of white sturgeon by pinnipeds (primarily Stellar sea lions). Pinniped predation had been increasing, recently reports are less in the BON tailrace (unclear if predation less, sturgeon gone, or sturgeon moved). Future hazing/removal of pinnipeds uncertain below BON; downstream predation degree is uncertain. Pinniped predation on white sturgeon has also been observed in the lower Willamette River. The BON tailrace is in a state of flux in reference to pinnipeds. Sturgeon predation by pinnipeds peaked in 2010 and has been in strong decline since. It seems that white	lower river. CRSO operations not the affecting factor.		but could change fish concentration. (Bjorn) If fish are present, sea lions will predate on them. Anything concentrates sturgeon? Or salmon – predation is intense when salmon are in the area. 2015 – saw aggregations of fish at ladders, with high numbers of pinnipeds. WA shore – low water could concentrate fish. At low flows, operations (using only 2 powerhouses) tends to concentrate fish more. Not enough water to use PH1. Just PH2 producing power and no flow at PH2, and forced spill. Presence of salmonids decreases risk of sturgeon predation. (Based on observations at the dam only). CRITFC surveys further downstream. Differences in pinniped species. Stellar sea lions eat more sturgeon than California sea lions. Any relationship with how spill may affect?		

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		sturgeon do not use the BON tailrace for overwintering habitat now (conjecture from Bjorn), mainly due to the presence and predation pressure from Stellar sea lions. New Federal law passed in 2018 will allow for the removal of Stellar sea lions in the Columbia River. This may alter the number of Stellar sea lions that inhabit the BON tailrace.					
Sculpin, walleye, and smallmouth bass are predators of embryos and age-0 white sturgeon.	Qualitative.	**Data Outputs:** Coordinate with resident fish teams. **Effects to Resource:** Under the NAA, predatory fish will continue to consume white sturgeon early life stages and age-0. **Notes:** The rate of predation has never been measured.	**Data Outputs:** Not likely to change walleye, sculpin, and bass populations. **Effects to Resource:** Same as NAA. **Notes:**	**Data Outputs:** Not likely to change walleye, sculpin, and bass populations. **Effects to Resource:** Same as NAA. **Notes:**	**Data Outputs:** Not likely to change walleye, sculpin, and bass populations. **Effects to Resource:** Same as NAA. **Notes:**	**Data Outputs:** Not likely to change walleye, sculpin and bass populations. **Effects to Resource:** Same as NAA. **Notes:**	Tidwell et al., 2019
Reservoir maturation trend – changes in prey species availabilities over time (diet and diet competition changes with size).		**Data Outputs:** **Effects to Resource:** **Notes:** Reservoir environments may be in maturation, sedimentation, and invasive macrophytes could reduce conditions for sturgeon (predation, food availability, invasive spp., etc.) as reservoirs mature. Any changes that could change prey species availability/food webs. White sturgeon eat – larva - plankton, diatoms juveniles- crayfish, clams, then fish adults - larger fish Growth rates patterns, Snake River growth rates change over time. (Growth rates faster in recent years).	**Data Outputs:** No changes. Minor changes in water quality team matrix of slightly higher zooplankton production, but not likely an effect. **Effects to Resource:** **Notes:** No changes.	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** Not likely to change walleye, sculpin, and bass populations. **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	Carcass observations, WDFW reports (Olaf summary report).
The area downstream of BON provides good spawning habitat over the range of flows that typically occur (Parsley and	BON Outflow. Number of days mean outflow from BON is greater than 75 kcfs during spawning months. For BON	**Data Outputs:** Bonneville_Out_Flow (Excel file)	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Beckman, 1994). White sturgeon are known to spawn in the tailrace of BON. Parsley and Beckman (1994) determined that high-quality spawning habitat was present at discharges greater than 74,867 cfs (round up to 75 kcfs). The amount of spawning habitat for white sturgeon increased as discharge increased.	tailrace, McCabe and Tracy (1994) mentioned spawning months as mid-Apr to mid-Jul.	Average_Monthly_Discharge tab Median outflows: Apr = 212989 May = 275261 Jun = 295709 Jul = 204315 Modeled 99% outflows: Apr = 120584 May = 189943 Jun = 168665 Jul = 128003 99% chance exceeding 75kcfs every day mid-Apr to mid-Jul. **Effects to Resource:** From the data provided by H&H, the BON tailrace always has flows 75kcfs or greater from Apr to Jul. Under the NAA, the BON tailrace provides adequate flows to support white sturgeon spawning. **Notes:**	WDFW, ODFW interpretation, the flows at MCN, 250 kcfs are the correct optimal flows to continue on down below BON. Use MCN 250 kcfs. Recruitment data shows less recruitment at the lower levels. Flows at 120 kcfs may provide spawning habitat, but recruitment needs higher flows. See MCN 250 kcfs. Downstream of BON has more complex habitat and takes less water to be successful, but won't see a difference in this metric.				
Flow affects larval dispersal. McCabe and Tracy (1994) captured white sturgeon larvae from river kilometer 45 to river kilometer 232, suggesting wide dispersal after hatching. Larvae were collected as far downstream as the upper end of the Columbia River estuary, which is a freshwater environment.	BON Outflow	**Data Outputs:** Median outflows: Apr = 212989 May = 275261 Jun = 295709 Jul = 204315 99% outflows: Apr = 120584 May = 189943 Jun = 168665 Jul = 128003 **Effects to Resource:** In general, it seems that the lower Columbia River produces a year class every year. Under the NAA, this trend would continue. **Notes:**	**Data Outputs:** Median outflows: Apr: 208,570 (-2.0%) May: 268,886 (-2.3%) Jun: 293,731 (-0.9%) Jul: 202,273 (-0.7%) 99% outflows: Apr: 118,394 (-1.8%) May: 180,280 (5.0%) Jun: 166,684 (-1.2%) Jul: 125,666 (-1.8%) **Effects to Resource:** **Notes:** Include in flow/temperature relationship for recruitment.	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** Median outflows: Apr: 208,220 (-2.3%) May: 270,820 (-2.9%) Jun: 292,998 (-1.1%) Jul: 204,946 (+3.3%) 99% outflows: Apr: 117,910 (-2.2%) May: 211,380 (+10%) Jun: 167,146 (-0.1%) Jul: 121,251 (-5.2%) **Effects to Resource:** **Notes:**	–
White Sturgeon Measures (Suites)							–
Water velocity and substrate for spawning habitat (combined in flow and temperature relationship).	BON Outflow	**Data Outputs:** **Effects to Resource:** High water velocity is a benefit to white sturgeon spawning.	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		Adhesive eggs are widely distributed by high water velocity and clean course substrates provide a good surface for the adhesive eggs to attach (Parsley et al., 2002). Flows create more turbulent water that is beneficial for spawning habitat (keeps predators away, aerates, embryos, spreads out). **Notes:** It seems BON tailrace provides consistent spawning habitat each spring.					
Spawning – flows needed for successful spawning. 250 kcfs in Apr 1 to Jul 3 in MCN tailrace. Since lower Columbia River dams are run-of-river, outflow at MCN will correlate with the outflows at JDA, TDA, and BON.	Outflow at MCN tailrace.	**Data Outputs:** MCNARY_OUT_FLOW Excel file. Summary hydrograph > 250 kcfs Median May 16 to Jun 21 (35 days) 25th Percentile (highest water years): Apr 17 to Jul 14 (88 days) (Specific dates taken from Summary_Discharge_ Hydrographs). **Effects to Resource:** Provides optimal spawning flows throughout spawning season in average years or above, and high enough flows to provide spawning in 75% of the time (this statement needs to be verified). Team – is magnitude or duration more important? Number of days? Or higher flow? (can look at mean monthly) **Notes:** Optimal temperature and flows in X days would be a good spawning year. Opportunity to look at if temperature is a correlate of flow in effects analysis modeling with both datasets.	**Data Outputs:** Summary Hydrograph days >250 kcfs Median: 5/17-6/20 (34 days) 25 Percentile: 4/19-7/13 (85 days) **Effects to Resource:** **Notes:** Graphic that shows it more clearly over years… Above 17°C leads to mortality. JDA pool is outlier. 7 out of last 21 years were successful. Successful spawning over time in each of the pools. Overlay temperatures, check with water quality to use this way. Blaine – has a figure of sturgeon recruitment graphed on flow and temperature conditions. EP values? Proportion of nets with a positive catch = 1 sturgeon caught. Also have CPUE. Published annually in sturgeon management task force annual updates. Laura email link to these.	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** Summary Hydrograph: Median 5/17-6/21 (35 days) 25th Percentile 4/19-7/13 (85 days) **Effects to Resource:** **Notes:**	–

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		This criteria is also important for successful recruitment and larval drift. This amount of flow and above 250 kcfs also maintains more consistent forebay/ tailrace elevations and reduces chance of stranding/dewatering below BON. In years of extreme low flows and warm water, higher than typical adult mortalities have been documented (Olaf Langness document e.g., 2015).					
Changes in pool/tailrace elevation affect early juvenile life stage survival (egg, incubation, free swimming larvae).	Covered below under flow criteria, do not retain separate.	**Data Outputs:** **Effects to Resource:** N/A **Notes:** Can have spawning every year, doesn't mean will get recruitment; movement of juveniles down to right habitat is important. Possible stranding in shallows.	**Data Outputs:** Delete this relationship. **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	–
Appropriate temperature for embryo incubation time Bjorn – combine with first line? Or is that one spawning trigger and this one egg development? Combined with flow and temperature relationships.	Optimal is 14°C to 16°C	**Data Outputs:** May to Jul temperatures in tailraces below all 8 projects. **Effects to Resource:** Some years temperatures maintained, others may not be in NAA. Increase in egg morality >18°C. Complete mortality >20°C. No regulations in place currently. **Notes:** Colin Chapman has a metric for temperature weighted usable area for spawning habitat (Parsley et al.), turbulence and flow not captured. Metric covers spawning and incubation; not covering once moving, stable temperatures also important.	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	–
Optimal temperatures for yolk sac larvae are 13.5°C to 16°C. Mortality at >20°C.	Temperature in the BON tailrace and other locations in the lower Columbia River.	**Data Outputs:** BON temperature, Warrendale temperature.	**Data Outputs:** Incorporate into flow/temperature model for spawning and recruitment.	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	McCabe and Tracy, 1994 Wang et al., 1985

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		Effects to Resource: The yolk-sac larvae life stage is short, but lab studies (Wang et al., 1985) found mortality at >20°C. **Notes:** Temperature affects rate of growth at this life stage, flows make habitats available.	**Effects to Resource:** **Notes:**				
Juvenile growth is optimal at 20°C to 24°C, no growth >26°C (Lebreton and Beamish, 2004). Juveniles can grow rapidly at 16°C during the first 4 months of life (in laboratory). In the wild, it would be dependent on temperature and food limitation (Brannon et al., 1984).	Temperature in the BON tailrace and other locations in the lower Columbia River.	**Data Outputs:** BON temperature, Warrendale temperature. **Effects to Resource:** Water temperatures exceed 20°C and juveniles grow rapidly. **Notes:**	**Data Outputs:** No change in temperature. But looked at BON river elevation changes in MO1, at most the change would be about 0.53 foot lower in MO1 compared to NAA. **Effects to Resource:** Would translate to a minimal effect on sturgeon feeding habitat. (See notes for relationship with river elevation with warm water temperatures.) **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** No change. **Effects to Resource:** If flows decrease in summer, couples with temperatures to affect their metabolic needs relationship. (Higher temperatures = higher metabolic needs, but food could be limited if less flows? (Below BON is more important.) **Notes:**	McCabe and Tracy, 1994 Parsley and Beckman, 1994
Spawning – flows needed for successful spawning. 250 kcfs in Apr 1 to Jul 31 in MCN tailrace.	Flows MCN tailrace, BON >120 kcfs.	**Data Outputs:** Summary hydrograph shows 250 kcfs or above in median water years approximately [insert dates], and 25th percentile [insert dates]. **Effects to Resource:** Provides optimal spawning flows throughout spawning season in average years or above, and high enough flows to provide spawning in 75% of the time. **Notes:** Optimal temperature and flows in X days would be a good spawning year. Opportunity to look at if temperature is a correlate of flow in effects analysis modeling with both datasets. This criteria is also important for successful recruitment and larval drift.	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	Wang et al., 1985/1986 – Blaine Parket/Laura H. Also Parsley et al, 1993; McCabe and Tracy, 1994; Miller and Beckman, 1996; and BPA annual report 1986-050-00.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		This amount of flow and above 250 kcfs also maintains more consistent forebay/tailrace elevations and reduces chance of stranding/dewatering below BON. In years of extreme low flows and warm water, higher than typical adult mortalities have been documented (Olaf Langness document e.g., 2015).					
Appropriate temperature for embryo incubation time.	Optimal is 14°C to 16°C.	**Data Outputs:** May to Jul temperatures in tailraces below all 8 projects. **Effects to Resource:** Some years temperatures maintained, others may not be in NAA. Increase in egg mortality >18°C. Complete mortality >20°C. No regulations in place currently. **Notes:** Colin Chapman has a metric for temperature weighted usable area for spawning habitat (Parsley et al.); turbulence and flow not captured. Metric covers spawning and incubation; not covering once moving; stable temperatures also important.	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	Hildebrand et al., 2016; Counihan and Chapman, 2017 – Colin Chapman, ODFW.
Extreme low flows and higher reservoir temperatures can cause increased mortality of adults and females going atretic above 18°C. Incorporated into flow/ temperature relationship.	Temperatures in reservoirs.	**Data Outputs:** Temperature flows in reservoirs. **Effects to Resource:** Extreme low flow or high temperature years would continue to result in periodic large mortality events. **Notes:** Recent – increased number of adult die-offs.	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	Wang et al., 1985/1986) – Blaine Parket/Laura H. Also Parsley et al., 1993; McCabe and Tracy, 1994; Miller and Beckman, 1986; and BPA annual report 1986-050-00.
S4: Modification to BON fish ladder.		**Data Outputs:** **Effects to Resource:** Could be more (slightly) effective passage for white sturgeon at BON.	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	McCabe and Tracy, 1994; Wang et al., 1985.

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		Notes:					
Improved fish passage turbines at JDA.		**Data Outputs:** **Effects to Resource:** Could have a positive effect for sturgeon in the JDA pool, lower impact mortality and injury. Idaho Power may have data on passage survival through the turbines. Effective for smaller fish (steelhead). **Notes:** The swim into draft tubes from downstream (slow roll).	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	McCabe and Tracy, 1994; Parsley et al., 1993
Temperature improvements in the Snake River – remind Snake River group to evaluate.		**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	Van der Leeuw et al., 2006
Looked at all lamprey measures.		**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	**Data Outputs:** **Effects to Resource:** **Notes:**	Miller and Beckman, 1996; Gadomski and Parsley, 2005b; and Golder and LGL, 2013.
Bull Trout							
Temperature would be the most important factor in the mainstem	Temperature measured at dams and tailraces; look at WQ presentations and briefs, if any change see temp files.	Currently there is limited migration and habitat use in mainstem	Same as NAA	Same as NAA	Same as NAA	Same as NAA	There is limited bull trout data since fishways are not measured at all times. There are also several unmonitored routes. Chances for mitigation include more tagging to monitor movement. Barrows et al 2016; BT and climate change from AFS 2008;
Importance of thermal refugia - recent paper from EPA.	Presence or absence of thermal refugia	Bull trout would continue to use thermal refugia at the tributaries listed in the notes.	NO change in surface temps from modeling results. Bull trout would continue to use thermal refugia as in the NAA.	NO change in surface temps from modeling results. Bull trout would continue to use thermal refugia as in the NAA.	NO change in surface temps from modeling results. Bull trout would continue to use thermal refugia as in the NAA.	NO change in surface temps from modeling results. Bull trout would continue to use thermal refugia as in the NAA.	Thermal Refugia includes Tribs at BON Pool: Wind River mouth, Herman Creek (OR side), Drano Lake, White Salmon, Klickitat, Deschutes (less so now due to Pelton RoundButte dam - warmer water than previously); at TDA Tailrace-Fifteenmile Creek; JDA pool - Willow Creek; further upstream not as well known - tribs typically warmer. Changes in surface temps could make thermal refugia even more important. Increases temp over time from 60's till now. Commonly >20°, thermal refugia is very important. Bull trout can be found in the summer in mainstem. Modeled temps will

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
							not give level of detail to look at thermal refugia. Temps > leads to concentrations of fish in refugia pools, subject to angling impacts. Bigger tribs are probably ok. Groundwater recharge is limited.
Adults move downstream during fall and overwinter in reservoirs (Oct-Feb).	Presence of structures; may effect ability to pass dams safely,vailability of passage routes; lack of passage due to closure and winter maintenanc	Currently, populations are segmented by dams. Bull trout do move between areas, but could be delayed.	Structural measure to construct additional powerhouse surface passage routes at McNary - operate March 1 through August 31 could have minor benefits to downstream passage, but most bull trout have moved out of the mainstem when surface passage routes in use. McNary structure sweeps around dam and pulls surface passing fish over the spillway. Uses about 8kcfs attraction flow.	Additional powerhouse surface passage at MCN and JDA. Similar benefits as MO1 for McNary.	Additional powerhouse surface passage at MCN and JDA. Similar benefits as MO1 for McNary.	Additional powerhouse surface passage at MCN and JDA. Similar benefits as MO1 for McNary.	Move downstream more readily than upstream; can affect genetics with downward migrations. Access to winter passage can be important. Downstream migration in winter - passage is through turbines. Configuration of dams can affect passage. Timing of ice and trash sluiceway March 1-Dec. 15. Lack of habitat connectivity due to dams can lead to more isolated populations and less access to some habitats. There is generally a low knowledge of populations and limited data. BON and TDA bull trout use ice and trash sluiceway. Additional surface passage routes - may reduce turbine passage and increase survival. Extending the duration of juvenile bypass facilities could improve bull trout passage. Barrows et al 2016 - page 21
Movement through the turbines can cause injury/mortality.	Movement of fish during turbine operation.	Bull trout are more benthically oriented (compared to smolts), but do pass through turbines and survive. Also depends on size - blade strike incidence increases with increased size. An unknown number of bull trout would continue to pass through turbines with some mortality associated.	Turbine replacement measure would reduce blade strike rate and lead to better survival (physical and CFD models show an improvement for fish. At John Day - would provide safer passage for bull trout. Smaller fish less likely to strike. May be some improvement for bigger fish, if it increases the size of fish that can pass. Would be minor improvements in fish passage, but limited number of bull trout in the system leads to undetectable differencs.	Same as MO1	Same as MO1	Same as MO1	Tracking in PUDs - show bull trout in the ladders or JBS, peak is in end of May/June - starting to move out due to warm temps. May be there in the winter (FMO) but move out is when they start to show up in ladder counts. Larger fish more likely to strike. Larger fish survival for turbine passage was 90% compared to spillway (97%) but with increased fallback with spillway determined about equal (24" steelhead in study, about the same as bull trout in the system). Normandeau 2014.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Project configurations can affect bull trout susceptibility to predation.	Predation of bull trout - recovery of pit tags at avian colonies	Limited numbers of bull trout and lack of data make any detection unlikely. An Unknown number of bull trout may be exposed to increased predation.	No change from NAA.	No change from NAA.	No change from NAA.	No change from NAA.	Notches in spillway inserts could make any bull trout passing through weir notches could increase risk to predation by birds of smaller fish. Potentially greater risk to juveniles than adults. Keep in context - very few bull trout.
Fluctuations due to changes in BON pool can suppress vegetation on the delta at the mouth of the Klickitat and Hood River. This can make bull trout subject to predation when trying to access tributary or use thermal refugia.	River Stage Columbia R2 172.17 (Klickitat) and Columbia R2 170.31 (Hood River)	Change in river stage from current operation. The more the river drops, the more potential for decreased access.	No change from NAA.	No change from NAA.	No change from NAA.	No change from NAA.	Flat shallow areas where fish pass through - low water leads to suppressed vegetation. Bull trout use Klickitat for spawning and thermal refugia.
Temperature would be the most important factor in the mainstem	Temperature measured at dams and tailraces; look at WQ presentations and briefs, if any change see temp files.	Currently there is limited migration and habitat use in mainstem	Same as NAA	Same as NAA	Same as NAA	Same as NAA	There is limited bull trout data since fishways are not measured at all times. There are also several unmonitored routes. Chances fir mitigation include more tagging to monitor movement. Barrows et al 2016; BT and climate change from AFS 2008;
Importance of thermal refugia - recent paper from EPA.	Presence or absence of thermal refugia	Bull trout would continue to use thermal refugia at the tributaries listed in the notes.	NO change in surface temps from modeling results. Bull trout would continue to use thermal refugia as in the NAA.	NO change in surface temps from modeling results. Bull trout would continue to use thermal refugia as in the NAA.	NO change in surface temps from modeling results. Bull trout would continue to use thermal refugia as in the NAA.	NO change in surface temps from modeling results. Bull trout would continue to use thermal refugia as in the NAA.	Thermal Refugia includes Tribs at BON Pool: Wind River mouth, Herman Creek (OR side), Drano Lake, White Salmon, Klickitat, Deschutes (less so now due to Pelton RoundButte dam - warmer water than previously); at TDA Tailrace-Fifteenmile Creek; JDA pool - Willow Creek; further upstream not as well known - tribs typically warmer. Changes in surface temps could make thermal refugia even more important. Increases temp over time from 60's till now. Commonly >20°, thermal refugia is very important. Bull trout can be found in the summer in mainstem. Modeled temps will not give level of detail to look at thermal refugia. Temps > leads to concentrations of fish in refugia pools, subject to angling impacts. Bigger tribs are

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							probably ok. Groundwater recharge is limited.
Adults move downstream during fall and overwinter in reservoirs (Oct-Feb).	Presence of structures; may effect ability to pass dams safely, availability of passage routes; lack of passage due to closure and winter maintenanc	Currently, populations are segmented by dams. Bull trout do move between areas, but could be delayed.	Structural measure to construct additional powerhouse surface passage routes at McNary - operate March 1 through August 31 could have minor benefits to downstream passage, but most bull trout have moved out of the mainstem when surface passage routes in use. McNary structure sweeps around dam and pulls surface passing fish over the spillway. Uses about 8kcfs attraction flow.	Additional powerhouse surface passage at MCN and JDA. Similar benefits as MO1 for McNary.	Additional powerhouse surface passage at MCN and JDA. Similar benefits as MO1 for McNary.	Additional powerhouse surface passage at MCN and JDA. Similar benefits as MO1 for McNary.	Move downstream more readily than upstream; can affect genetics with downward migrations. Access to winter passage can be important. Downstream migration in winter - passage is through turbines. Configuration of dams can affect passage. Timing of ice and trash sluiceway March 1-Dec. 15. Lack of habitat connectivity due to dams can lead to more isolated populations and less access to some habitats. There is generally a low knowledge of populations and limited data. BON and TDA bull trout use ice and trash sluiceway. Additional surface passage routes - may reduce turbine passage and increase survival. Extending the duration of juvenile bypass facilities could improve bull trout passage. Barrows et al 2016 - page 21
Movement through the turbines can cause injury/mortality.	Movement of fish during turbine operation.	Bull trout are more benthically oriented (compared to smolts), but do pass through turbines and survive. Also depends on size - blade strike incidence increases with increased size. An unknown number of bull trout would continue to pass through turbines with some mortality associated.	Turbine replacement measure would reduce blade strike rate and lead to better survival (physical and CFD models show an improvement for fish. At John Day - would provide safer passage for bull trout. Smaller fish less likely to strike. May be some improvement for bigger fish, if it increases the size of fish that can pass. Would be minor improvements in fish passage, but limited number of bull trout in the system leads to undetectable differencs.	Same as MO1	Same as MO1	Same as MO1	Tracking in PUDs - show bull trout in the ladders or JBS, peak is in end of May/June - starting to move out due to warm temps. May be there in the winter (FMO) but move out is when they start to show up in ladder counts. Larger fish more likely to strike. Larger fish survival for turbine passage was 90% compared to spillway (97%) but with increased fallback with spillway determined about equal (24" steelhead in study, about the same as bull trout in the system). Normandeau 2014.
Northern Pikeminnow							
Facts about NPM not relationships.	–	–	–	–	–	–	NPM Plasticity allows them to adapt to different environs; different life histories between free-flowing and impounded

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							river sections. Abundance from estuary to TDA is the highest; may be higher food avail. and habitat suitibility in LCR. Further upstream project have lower lesser abundances. LCR Province Plan 2004-05 NWPCC
Water temperatures affect growth and recruitment. Spawning occurs in June-July when temps are ~65 oF, over clean rocky substrate in a range of depths in rivers and tribs.	Temperature	Temperatures not expected to change under the NAA. Current temperature profile is suitable for NPM spawning and life history.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Tolerates a wide range of water temperatures. LCR Province Plan 2004-05 NWPCC
Increased turbidity impacts ability to forage. May decrease feeding effectiveness if turbidity increases. Sight predators.	Turbidity/flow	Turbidity not expected to change. Would continue at approximately 2 mg/l. NPM predation not expected to change because of turbidity.	No change from NAA	No change from NAA	May see an increase in Turbidity during breaching, but this would be a negligible impact.	No change from NAA	LCR Province Plan 2004-05 NWPCC; gadomski?
Inundation of clean rocky substrate in a range of depths in rivers and tribs affects habitat availability.		Robust pikeminnow popn's still supported. Some year to year changes in population or size structure, but no long-term trend in abundance or distribution.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	In reservoir areas, typically in tailraces of JDA, BON, TDA. Changes in flows - high flows followed by low flows could affect recruitment; Spawn June/July, freshet peak or dropping, stabilizing. Spawn at multiple depths so not limited to just shallow veg. Less sensitive to potential dewatering. Some tribs have viable pop'ns seeding pools downstream with juvies. Likely would not affect popn' level with pool fluctuations.
General info: When <300mm in length thier diet primarily invertebrates. As size increases, crayfish and fish become more important. Generally only older individuals eat a lot of salmon; salmon intake increases with pikeminnow size and salmonid abundance. Pikeminnow reward program objective to remove 10-20% of large NPM. Numbers are down from historic highs.	Pikeminnow suppression efforts	Exploitation rates vary from 7.5 to 17%. Under the no action alternative the NPM reward program would continue to remove ~ 12% of the population over 200mm in length.	Assuming pikeminnow program continues, there would be no change.	No change from NAA	No change from NAA	No change from NAA	Pikeminnow suppression targets >250 mm, use as a criteria? Targeted to reduce predation but balancing native pikeminnow populations healthy. Altering size structure. LCR Province Plan 2004-05 NWPCC Pikeminnow suppression plan?
General info: In 65 oF, eggs hatch in 7 days. Larvae are free swimming in 14 days.	Temperature at MCN Tailwater	Water temps reach 14C ~ early June. Current temps support successful spawning in late spring.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	LCR Province Plan 2004-05 NWPCC

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Flows in July to distribute larval NPM downstream. Larvae drift downriver at night for 1-3 days in July. High flows can push them past rearing habitats. Rearing survival appears highest in low flow years, high shoreline water temps (>20 oC), and abundant veg.	Flows in tailraces	Abundance of pikeminnow recruitment would continue. Range of flows would continue and larval rearing would be variable depending on july flows.	No change from NAA	No change from NAA	No change from NAA	Increased spill may be a slight impact, depending on water levels (if high to begin with, could move pikeminnow out further), slight negative to pm. Minor increases in May flows in low water years and May/June in low (75% ile years) potentially benefit, but small. Small amount of water. Depends on daily/weekly fluctuations.	Larvae drift downriver at night for 1-3 days in July. Abundances highest in tailraces and below BON. Drift is brief prior to recruiting to shoreline sand, silt areas to rear. High, turbulent flows could blast them past the slackwater habitat where they begin to feed. Godomski et al. 2001 in Garcia 2014, LCR Province Plan 2004-05 NWPCC
Presence of walleye can reduce pikeminnow numbers (negatively correlated).	Walleye Populations	Walleye populations are stable in lower Columbia River. NPM would continue to thrive in Lower Columbia River.	Walleye numbers are not expected to change as a result of this alternative = no change in NPM competition.	Walleye numbers are not expected to change as a result of this alternative = no change in NPM competition.	Walleye numbers are not expected to change as a result of this alternative = no change in NPM competition.	Walleye numbers are not expected to change as a result of this alternative = no change in NPM competition.	Competition does not appear to limit production. Beamesderfer et al. 1996 in LCR Province Plan 2004-05 NWPCC; Steve Williams PSMFC - NP management program annual report
Removal program appears to reduce the population size structure, no compensation in productivity or competition has been observed. Ave exploitation = 12% of est. popln >250 mm.	NPM Removal	Some year to year change or size structure, but not a long-term trend in abundance or distribution.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Exploitation rates vary from 7.5 to 17%. Under the no action alternative the NPM reward program would continue to remove ~ 12% of the population over 200mm in length. Refs in LCR Province Plan 2004-05 NWPCC; Steve Williams citation
Water velocities from 3.28 to 4.27 ft/s could limit predation in high-salmon areas. Infer velocity ranges from flows where high flows could limit NPM.	Flows in tailraces	In high water years NPM may be limited in their ability to consume salmon in mainstream habitats.	No change from NAA	No change from NAA	No change from NAA	Increase in flows during May and June could limit NPM, but only occurs on low flow years that are already below average flow. No impact to NPM.	Increased flows could reduce salmonid predation. Velocities in bypasses, ladders. By excluding pikeminnow from areas where salmon are moving through structures. Thins out concentration of prey and predators. Mesa and Olson 1993 in LCR Province Plan 2004-05 NWPCC
Presence of juvenile shad increases growth of fish predators, including pikeminnow - overwinter survival	Shad expansion	Shad numbers have been increasing under the NAA. These populations will likely plateau in the future. Juvenile shad will provide additional forage for NPM.	Slight upstream potential for shad migration, but power operations could likely negate that effect. Likely no change to shad-pikeminnow abundance relationship from system operations.	No change from NAA	No change from NAA	Slight upstream potential for shad migration, but power operations could likely negate that effect. Likely no change to shad-pikeminnow abundance relationship.	Look at shad migration and reproduction based on flow; general idea is that shad do not migrate as far during high flow years. Fall forage availability - stronger and more fecund predators going into winter - more/stronger pikeminnow (and other predators). Mesa and Rose 2014

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Operational measure in MO1 designed to raise water levels during April and May in JDA to disuade avian nesting. Could impact spawning fish as waters are pulled back down in June.	Water level fluctuations during spawning.	Water levels are not expected to fluctuate more than the one foot operating range under the NAA in the spring and summer. This minor change in water levels is not expected to impact NPM recruitment.	Designed for avian predation disruption. Would not be much difference for northern pikeminnow. (Note for walleye - they tend to spawn earlier than t (0.1ft change) hat time, so not affected). Habitat - tailrace spawners, below McNary not much habitat.) Note for smallmouth bass - small effect, would not be enough fluctuation to interrupt nesting success.	No change from NAA	No change from NAA	No change from NAA	
Operational measure to provide additional flexibility up to one foot more in MO1.	Water level fluctuations during spawning.	Water levels are not expected to fluctuate more than the one foot operating range under the NAA in the spring and summer. This minor change in water levels is not expected to impact NPM recruitment.	Elevation April 1-June 1 would be 1 foot higher, but includes assumptions. Would likely actually fluctuate around. Otherwise same as NAA. Elevations no change to NAA in modeling, but additional flexibility in that range not likely to have any effects on pikeminnow, bass, walleye, etc.	No change from NAA	No change from NAA	No change from NAA	
Walleye							
General info: Demersal fry, juveniles, adults prefer dim light; often found near substrate with cover during the day; if water too clear will feed at night.	Turbidity velocity	Reservoirs typically provide these conditions. Turbidity is low in the Columbia River.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Ali et al 1977 in McMahon et al. 1984
Spawning Nearshore over coble and gravel in early spring in temperatures starting at 4C in 1-20 feet of water.	Suitable spawning temperatures and habitat	Reservoir habitats provide areas of coble and gravel along the shoreline and in tributary inlets - Spring temperatures reach spawning temps in Late February	No change from NAA	No change from NAA	No change from NAA	No change from NAA	
General info: Critical velocity for adults (~30 cm) is 74 cm/s; for juveniles at 20 cm is 60 cm/s	Velocity, hydrodynamics where potential changes could influence walleye juveniles.	High flows in spring would have negative impacts to larval Walleye by moving them from nursery areas.	Not in MO1 or MO4. Potential mitigation measure.	No change from NAA	No change from NAA	Not in MO1 or MO4. Potential mitigation measure.	Proposed research - fluctuations of McNary pool to interrupt spawning success near lower end of Bateman Island in Yakima delta. Poor swimmers when newly hatched, flush out to cooler, faster water when they can't survive it. Hard river level needed to McNary lock in most flow years would impede ability to fluctuate. Causeway is perfect rearing area for walleye.

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
							Measure to increase flows would impact this. Refs in McMahon et al. 1984 McMichael (proposal to increase flows during walleye spawn/hatch - sweeping out)
Adult optimum temp is 20 -24C; they avoid temps higher; growth ceases <12C. LCR below BON has fastest growth.	Temperature Profile	Warmer temps reach optimum growth in late summer. Growth ceases in late fall early winter. Reservoir conditions have favored walleyes, would continue. Numbers are increasing, would expect to continue.	No change from NAA	No change from NAA	No change from NAA	Water Temperatures would be slightly higher in late summer and early fall on dry years as MCN flows are depleted and less water is moved down river in these years.	Larvals do better in warm calm water. Really big spawning years (calm, low water, warm) Refs in McMahon et al. 1984
Adult abundance greatest at DO levels >3-5 mg/L; can tolerate 2 mg/L for short time; embryos need >3.4 mg/L	DO	DO levels would be suitable for all life stages. Ranging from 9-11 ppm.	No change from NAA	No change from NAA	Possible deficit during drawdown and possibly longer depending on TSS concentrations. Not expected to have more than a minor impact to walleye.	No change from NAA	–
Spawning preference for clean rocky uneven surfaces (gravel/rubble) to protect from predators, or vegetation mats, with moderate waves/good circulation to keep eggs oxygenated and free of sediment; poor embryo survival on sand, muck, or detritus.	Shoreline velocity, turbidity	Abundant areas of gravel and cobble for Walleye Spawning	See similar relationship in pikeminnow.	Same as MO1	Same as MO1	Same as MO1	Similar to pikeminnow discussion - dropping water levels after spawning. But not much ability to affect at a pop'n level. Homogenized flow regime, reduced variability in seasonal/daily flows.
High embryo production associated with stable or rising water levels in spring to maximize littoral area and minimize embryo stranding	water levels/flow	Water levels are not expected to fluctuate by more than two feet. No measurable impact to fish populations.	Not enough change to make a difference.	No change from NAA	No change from NAA	Same as MO1. Not much water compared to the area.	–
Spawning occurs March - early May or when water temp is 4.4 - 10 oC	Temperature in tailrace areas	Water tempertures would reach 4C about March 10 and would reach 10C about the first of May. Tempteratures are ideal for Walleye spawning.	No change from NAA	Not enough change to make a difference.	Not enough change to make a difference.	Not enough change to make a difference.	LCR Province Plan 2004-05 NWPCC
Walleye tend to spawn in areas of moderate current below McNary, JDA, TDA to keep the water free of silt, which can suffocate eggs. Too much current will wash eggs ashore.	Velocity/flow	High flow water years may negatively impact eggs and larvae by washing to unsuitable habitats.	Minor flow changes, very small areas it might make a difference (i.e. mitigation areas).	No change from NAA	No change from NAA	No change from NAA	LCR Province Plan 2004-05 NWPCC
Gonad maturation in females requires winter temps <10C (50F)	Temperature	Water tempertures below 10C from Mid November to early	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Refs in McMahon et al. 1984

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		May. Water tempertures are suitable for maturation.					
Optimum temps are 6-9C for fertiliztion and 9-15 oC for incubation	Temperature	Water temperatures reach 6C mid March and 9C late April; and 15C on early June. Temperatures are suitable for fertiliztion and incubation	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Refs in McMahon et al. 1984
Poor embryo survival when spring temps increase too slowly (<0.18 oC/day), or are cold weather fronts, cold reservoir releases, etc.	Temperature	Cold Springs will have an unknown impact on embryo survival. No known operations in Basin D that would impact spring water temperatures.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	All Run of river reservoirs. Moot point.
Conditions that slow fry growth (low temp, low zooplankton abund, delayed hatching) increase overwinter mortality (small fish fare worse)	Tempertures Productvity	Adequate temperatures for growth and survival. Zooplankton abundant in most years.	Slightly more growth in summer could support to slightly higher shad populations or other fish that eat the same. All yoy fish could potentially increase, but could not quantify and likely very minimal effect.	No change from NAA	Zooplankton possibly depressed during breach and until new equilibrium established	No change from NAA	Changes in pop'n structure (pikeminnow crew incidental catch). JDA - more smaller fish, likely harvest-driven. No limit on walleye. Series of low water scenarios could reduce growth/condition factor due to reduced forage base.
Newly-hatched fry require food (plankton) at 3 days after hatching, no fins for several weeks so limited mobility (surface oriented); need low velocities. This life stage population-limiting below BON.	Velocity	Hi flow years would have negative impacts to larval Walleye. However, there are no known operations that are expected to change flows.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Opportunity to limit production LCR Province Plan 2004-05 NWPCC
Most abundant in tailraces, less mid-res., least abund. in forebays. Below BON, found down to RkM 137, but most numerous from RkM 178-234.		There is an increasing trend in recent years	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Increasing trend in pikeminnow sampling. Fishing crews - last five years walleye and bass numbers have increased. 2015 extremely productive water year, not sure if seeing an increasing trend, or just a boom from one water year and moving through time Proportional stock density not as strong in JDA, increased in BON and TDA (to some degree). Williams et al 2017 - Julie sent link., P. 142-Creel data.
General info: Demersal fry, juveniles, adults prefer dim light; often found near substrate with cover during the day; if water too clear will feed at night.	Turbidity velocity	Reservoirs typically provide these conditions. Turbidity is low in the Columbia River.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Ali et al 1977 in McMahon et al. 1984

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
Smallmouth Bass							
Spawning occurs mid-May -late June, when water temps hit 15.6-18.3C (60-65F).	Temperature		No change from NAA	No change from NAA	No change from NAA	Slight increase in temperature in summer and fall of dry years as augmentation water is depleted.	LCR Province Plan 2004-05 NWPCC
Spawning habitat = shoreline areas, gravel/rubble as well as sand/rock substrate. Usually in 2-5 ft water near submerged cover (log, boulder, etc.). Flooding (low temp/siltation) or water level drop results in reproductive failure.	Flow/velocity	Protected bays, low velocity, off-channel sloughs.	Could potentially be affected by increased elevation April 1 - June 1 from flexibility measure. May affect individual nests but they vary in depth of spawning, likely not an affect at population scale. Spawn mid-May to mid-June; depends on temps so changes annually. The later half of spawners may be affected.	No change from NAA	No change from NAA	No change from NAA	Protected bays, low velocity, off-channel sloughs, increased elevations and cooler flows tend to interrupt incubation… males excavate depression and guard it. May desert if rapid decline in water temp or water level. Fidelity to nest sites. LCR Province Plan 2004-05 NWPCC Wydoski and Whitney 2003
"Winter starvation period" occurs below 7-10 C; small fish die first; must grow big enough in first year to survive overwinter --> warm summer temps required for growth.	Temperature	SMB would face a winter dormant period from Mid to late November to mid to late April. Some smaller and less fit fish would not survive.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Juvenile shad are important fall forage for smb. Shuter et al. 1980, Henderson and Foster 1956 in Brown et al. 1990 Mesa and Rose…
Discharge has greater imapct than temp during nursery season. Fry displaced from nests at 8 mm/s in lab. High velolicty during first year in general inhibits growth; energy expended for movement and not feeding; pushed out of prime forage areas. Less overwinter survival.	Velocity	High Flow years would have negative impacts to SMB fry. There are no measures in the NAA alternative that would change flow.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Larimore 2000, Simonson and Swenson 1990 in Brown et al 2009
pH 6.0 - 9.0; prefers 7.9-8.1	pH	pH is generally between 6.5 and 8.4 in this reach of the river (WQ Appendices). These values are suitable for SMB. There are no measures that should change pH.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Brown et al. 2009
DO requirement >6.0 mg/L; spawning >7 mg/L; embryos >6.5 mg/L	DO	DO is between 7.5 and 10 (WQ Appendices). These values are suitable for all life stages of SMB.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Brown et al. 2009
Optimal adult temp 21.1-26.7C (70-80F). Sudden drops in temp may cause mortality. Some adults will occupy high temp waters if food/cover available.	Temperature / flow / shallow water areas inudated by high pool elevations	Optimum water temperatures for SMB are not reached until mid summer and occur July and August only. Temperatures are cooler than optimum and SMB growth will be reduced. No Measures are	No change from NAA	No change from NAA	No change from NAA	MO4 temperatures may be warmer in late summer and fall on dry years as augmentation waters are depleted. Higher temperatures would benefit SMB.	Refs in Brown et al. 2009; LCR Province Plan 2004-05 NWPCC

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
		included that should change temperature.					
Prefer gravel or rocky substrate, rooted vegetation, or artificial structures (pilings etc.) for cover. Can tolerate mild salinities. Below BON, few numbers but occur down to RkM 71.	Suitable Substrate	Under the NAA there are suitable substrates for SMB in all reservoirs. Rip Rap and some rocky areas and inlets provide these habitats.	Predation reduction measure may inundate other habitats and then dewater them in June.	No change from NAA	No change from NAA	No change from NAA	Zimmerman and Parker 1995 in LCR Province Plan 2004-05 NWPCC
Optimal water velocity for yearlings 10 mm/s	Flows	High Flow years would have negative impacts to SMB yearlings. There are no measures in the NAA alternative that would change flow.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	–
Clear water required to spy prey; increasing turbidity decreases prey availability.	Turbidity	Turbidity levels are generally low for the lower Columbia River. Total Suspended Solids range from 1 to 5 ppm with higher levels in spring. Visibiltiy should not be impacted in most years.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Brown et al. 2009
Not all bass spawn each year; poorly understood. If temperatures drop during incubations males may abandon the nest. Males that leave nest are not replaced and brood dies.	Temperature Drops	On some unknown number of years sudden drops in water temperature may induce nest abandonment.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	–
Spawning time dependent on temp and rate of temp increase. Spawning often initiates at 15-16C.	Temperature	Water temperatures reach 15C in mid May. Water temperatures are suitable for SMB spawning.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Refs in Brown et al. 2009
Nests excavated in mud, sand, or gravel. Parental care required to prevent predation of eggs, larvae (15 days) --> removal by fishing impacts survival. Current exploitation rates in the LCR are low.	Harvest	An unknown number of adult males will be harvested and nests will fail. No measures are included that would change harvest.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Brown et al. 2009, Refs in LCR Province Plan 2004-05 NWPCC
Shift to fish prey during first year very important for caloric intake and growth needs.	Prey availability	Adequate prey are available for juvenile SMB. No measures are included that would change prey.	No change from NAA	No change from NAA	No change from NAA	No change from NAA	Refs in Brown et al. 2009.
By 3 in in length, eating almost any life form in sight. Crayfish most common item. Diet consists of sculpin, cyprinids, suckers, and sand rollers. Juvenile salmon are eaten during migration (<100 mm). Negative correlation	See above.	–	–	–	–	–	SMB in JDA system and below Tumwater Falls. Also invasive crayfish in JDA system. Shifts in predation dynamics is key, Pikeminnow program - no clear signals yet, but do have year to year changes. Design of

Affected Environment Important Relationships/Criteria	Affected Environment Metric	Environmental Consequences NAA	Environmental Consequences MO1	Environmental Consequences MO2	Environmental Consequences MO3	Environmental Consequences MO4	Notes
between size of bass and salmon consumption (small eat the most). Competition for food not a limiting factor.							sport reward program isn't designed to detect SMB, but just pikeminnow removed. Brown et al. 2009, Refs in LCR Province Plan 2004-05 NWPCC
Smallmouth make and tend nests until hatching. If nest is disturbed or increases by more than 4' of depth, they will abandon the nest.	Pool/river elevations	Water depth will not fluctuate by more than 2 feet in the NAA. Effects to nesting bass are expected to be negligible.	Water levels may fluctuate by as much as 4 feet under MO1. There may be minor impacts to nesting SMB.	No change from NAA	No change from NAA	No change from NAA	–
Gamefish							
Catfish	Definitely a predator, not well-studied, can be a key predator below some dams. Caught below McNary and JDA more than BON. Ccats predation on smolts (Vigg) - stomach contents and observations. Catfish not as prevalent, but 2nd highest level of predator on salmonids. Channel catfish not as susceptible to capture with methods used. Walleye and bass dominant gamefish.						
Predator Evaluation	1. Level of salmonid predator, 2. Relative abundance. Pikeminnow - high predator and high abundance, Channel Catfish - high predator, low abundance, SMB - less predator, high abundance, Walleye - high predator, low abundance (at the time).						

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CHAPTER 4 - RAW DATA

Table 4-1. Raw COMPASS data for Upper Columbia spring Chinook for each of the 80 modeled years by Alternative

Year	Species	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	Mean Travel Time	Mean MigRate	Mean Temp	Mean Flow	Mean FSpill	Mean Gas	UC Travel Time	UCMig Rate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
NAA																										
1929	Chinook_1	0.6904	0.6624	0.4566	133.5	148.1	152.62	29.143	28.649	13.910	163.67	0.7157	9.6040	20.302	9.745	12.004	99.14	0.5559	1.9926	7.0678	24.801	15.250	204.15	0.7861	13.7010	213.74
1930	Chinook_1	0.7285	0.5909	0.4298	132.34	144.39	147.48	22.825	30.253	15.068	149.57	0.7077	9.3519	14.588	12.585	13.121	108.96	0.5199	2.1624	6.4951	25.677	16.489	176.05	0.7981	13.1655	180.98
1931	Chinook_1	0.7264	0.5723	0.4151	132.43	144.38	146.91	23.325	30.034	15.115	142.80	0.7151	9.5657	15.047	12.226	13.187	103.62	0.5355	2.8520	6.5361	25.445	16.564	167.44	0.8025	13.0225	173.76
1932	Chinook_1	0.7210	0.7227	0.5203	131.81	143.3	147.27	22.285	31.819	13.289	259.03	0.6860	11.9397	14.454	13.807	11.629	174.84	0.4943	3.9177	6.0187	30.206	14.393	313.97	0.7743	16.0093	322.77
1933	Chinook_1	0.7289	0.7188	0.5232	131.85	143.23	149.2	21.514	31.685	13.864	253.76	0.6891	11.6296	13.708	13.568	12.226	165.55	0.4954	2.7673	6.0194	29.505	14.983	309.70	0.7783	16.2142	322.42
1934	Chinook_1	0.7445	0.6218	0.4623	131.39	139.92	141.72	17.006	34.229	15.014	250.81	0.6878	12.2342	9.800	18.230	13.260	213.61	0.4979	6.4751	5.4432	31.434	16.312	274.55	0.7811	14.9576	280.19
1935	Chinook_1	0.7235	0.6981	0.5043	132.26	143.63	148.65	22.800	30.748	13.933	207.60	0.6872	9.8206	14.700	12.842	12.236	146.37	0.4866	1.6098	6.3189	27.641	15.111	246.20	0.7802	14.1886	255.72
1936	Chinook_1	0.7174	0.6377	0.4568	132.09	144.17	145.99	22.467	32.518	14.148	255.29	0.6938	12.1901	15.107	13.251	12.217	173.80	0.5063	4.6040	5.5769	31.760	15.587	307.30	0.7814	16.0255	317.22
1937	Chinook_1	0.7035	0.6820	0.4791	132.9	146.04	151.01	26.984	28.902	13.663	169.50	0.7038	9.3162	18.144	10.865	11.928	111.14	0.5268	1.5314	7.0507	24.868	14.852	206.59	0.7822	13.4876	216.61
1938	Chinook_1	0.7251	0.7082	0.5127	131.78	143.55	147.84	21.641	31.975	13.711	247.61	0.6859	11.5123	13.928	13.941	11.989	165.24	0.4933	3.2926	5.9190	30.092	14.879	300.12	0.7743	15.6813	309.47
1939	Chinook_1	0.7052	0.5825	0.4102	132.43	146.69	148.21	25.776	30.276	14.347	180.22	0.6923	9.5024	17.648	12.042	12.207	132.23	0.4922	1.8641	6.3567	26.909	15.988	210.53	0.7861	13.6219	216.31
1940	Chinook_1	0.7335	0.6170	0.4519	131.89	143.27	145.86	21.119	31.684	14.770	200.10	0.6805	9.5427	13.351	13.918	12.907	142.57	0.4750	1.4289	6.0099	28.536	16.132	236.69	0.7737	13.9788	243.59
1941	Chinook_1	0.7349	0.6496	0.4766	132.13	142.84	147.3	22.083	30.178	14.708	152.60	0.7104	9.3389	13.744	13.099	13.141	103.68	0.5322	2.0459	6.5791	25.514	15.825	183.72	0.7940	13.1957	189.43
1942	Chinook_1	0.7029	0.7281	0.5110	132.54	146.51	151.52	26.437	29.387	13.063	205.79	0.6960	9.9932	17.794	11.234	11.416	132.19	0.5101	1.6231	6.8282	26.347	14.175	253.22	0.7805	14.5340	261.78
1943	Chinook_1	0.7221	0.7170	0.5170	131.68	144.06	148.8	22.134	31.826	13.647	248.16	0.6867	11.3797	14.345	13.810	11.902	168.08	0.4950	2.9154	5.9953	29.812	14.825	299.12	0.7759	15.6863	309.39
1944	Chinook_1	0.7098	0.6601	0.4678	132.94	145.69	151.22	26.332	28.711	14.140	143.15	0.7197	9.2441	17.516	10.651	12.430	95.57	0.5526	1.9860	7.0445	24.142	15.369	173.86	0.7992	13.1149	180.06
1945	Chinook_1	0.7089	0.6821	0.4828	132.7	145.31	149.58	25.160	30.742	14.035	211.93	0.6961	10.3448	17.154	11.517	12.214	130.19	0.5173	2.0191	6.2333	28.528	15.280	263.92	0.7735	14.7410	275.31
1946	Chinook_1	0.7223	0.7168	0.5170	131.54	142.2	146.01	20.945	33.041	13.610	283.56	0.6926	13.4108	13.501	14.700	11.858	208.79	0.5138	6.5734	5.6486	32.142	14.787	332.36	0.7765	16.5312	341.77
1947	Chinook_1	0.7359	0.6442	0.4733	131.52	141.72	144.24	19.440	33.659	14.727	255.83	0.6905	11.8624	12.258	15.202	12.923	174.77	0.5025	3.8777	5.4200	32.509	16.031	308.46	0.7781	15.9258	316.45
1948	Chinook_1	0.7183	0.7454	0.5346	132.06	143.7	147.23	21.258	34.516	13.505	392.91	0.7242	17.4105	14.526	13.948	11.709	240.26	0.5431	6.3788	4.9385	36.435	14.715	488.92	0.8256	23.9489	509.49
1949	Chinook_1	0.7303	0.7011	0.5112	131.62	142.1	145.59	20.338	33.141	13.895	283.00	0.6996	13.0093	13.056	14.458	12.290	184.97	0.5196	4.2822	5.4916	32.499	15.019	344.67	0.7861	17.3310	358.80
1950	Chinook_1	0.7105	0.7292	0.5174	132.27	145.11	149.88	23.921	31.503	13.393	272.60	0.6908	12.0603	16.023	12.773	11.626	174.99	0.5003	2.8540	6.0984	30.011	14.581	333.18	0.7815	16.7059	349.74
1951	Chinook_1	0.7350	0.7171	0.5263	131.45	141.17	145.47	19.138	33.248	13.818	273.42	0.6887	12.4871	11.686	15.936	12.241	198.17	0.5033	4.8536	5.6561	31.659	14.884	322.02	0.7752	16.1468	332.41
1952	Chinook_1	0.7174	0.7247	0.5191	131.74	143.51	147.27	22.205	32.439	13.234	282.08	0.7010	13.6785	14.696	13.599	11.588	185.37	0.5287	6.0247	5.6929	32.026	14.352	344.63	0.7833	17.4203	354.31
1953	Chinook_1	0.7234	0.7433	0.5368	132.12	142.76	148.99	22.299	31.117	13.266	248.76	0.6908	11.5021	14.346	12.860	11.900	160.42	0.5029	2.8960	6.1351	29.383	14.181	305.47	0.7762	15.9067	318.29
1954	Chinook_1	0.7094	0.7467	0.5289	132.2	144.2	148.98	23.803	31.347	12.898	274.51	0.6939	12.6350	15.831	12.869	11.288	190.35	0.5128	4.7256	6.1475	30.093	13.981	328.49	0.7791	16.5187	340.97
1955	Chinook_1	0.7019	0.7386	0.5176	132.79	145.4	151.44	26.095	30.027	13.083	235.48	0.6956	11.0627	17.731	11.306	11.479	150.77	0.5176	2.5334	6.5517	27.813	14.163	288.84	0.7738	15.4557	302.98
1956	Chinook_1	0.7232	0.7465	0.5391	131.57	142.91	146.34	19.867	34.016	13.065	356.31	0.7141	16.1392	12.804	15.447	11.449	241.03	0.5410	7.1216	5.2354	34.681	14.138	429.87	0.8058	20.7796	445.86
1957	Chinook_1	0.7219	0.7378	0.5318	131.56	142.89	146.22	21.072	33.392	12.984	339.84	0.7100	15.4931	13.805	14.430	11.472	214.05	0.5339	6.1285	5.4359	34.065	13.997	419.86	0.7991	20.3894	434.88
1958	Chinook_1	0.7127	0.7130	0.5074	132.33	144.65	147.84	23.157	32.597	13.509	299.14	0.7016	13.6486	15.712	12.843	11.833	182.38	0.5245	4.4273	5.6442	32.702	14.667	373.49	0.7859	18.3748	388.97

Year	Species	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	Mean Travel Time	Mean MigRate	Mean Temp	Mean Flow	Mean FSpill	Mean Gas	UC Travel Time	UCMig Rate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1959	Chinook_1	0.7312	0.7225	0.5275	131.52	141.96	147.22	20.115	32.545	13.785	266.40	0.6808	11.3687	12.470	14.859	12.150	192.81	0.4873	2.8046	5.8525	30.701	14.891	313.84	0.7698	15.6862	324.16
1960	Chinook_1	0.7125	0.7227	0.5142	132.02	143.85	149.14	23.994	30.662	13.216	234.04	0.6791	10.5805	15.691	13.046	11.460	167.74	0.4763	2.2626	6.4971	27.830	14.397	275.34	0.7735	14.8716	285.87
1961	Chinook_1	0.7340	0.7270	0.5328	131.44	141.82	147.04	19.820	32.598	13.493	289.53	0.6866	12.4836	12.046	15.519	12.007	212.44	0.5006	4.0417	5.9644	30.684	14.488	338.61	0.7709	16.6262	347.43
1962	Chinook_1	0.7201	0.7066	0.5081	131.92	143.97	148.55	22.798	31.580	13.773	236.74	0.6756	10.7376	14.862	13.384	11.982	165.48	0.4711	2.5387	6.1523	29.336	14.982	284.19	0.7668	15.0055	288.98
1963	Chinook_1	0.7264	0.7015	0.5088	132.1	144.12	148.83	22.406	31.056	14.008	211.46	0.6976	10.4709	14.396	12.868	12.389	131.91	0.5172	2.1897	6.2285	28.402	15.102	263.20	0.7783	14.8462	270.23
1964	Chinook_1	0.7065	0.7213	0.5089	132.62	145.23	150.04	24.722	31.613	13.689	273.65	0.7001	12.2612	16.926	12.194	11.820	171.71	0.5224	2.8973	6.0153	30.327	14.960	338.75	0.7823	17.2142	350.38
1965	Chinook_1	0.7275	0.7323	0.5319	131.71	142.52	147.61	21.062	32.388	13.420	267.76	0.6860	11.7497	13.511	13.794	11.858	172.94	0.4974	2.6073	5.7417	31.583	14.491	330.45	0.7729	16.4807	335.80
1966	Chinook_1	0.7160	0.6117	0.4373	132.31	145.49	148.35	24.031	30.718	14.590	194.70	0.6832	9.3796	15.881	12.650	12.499	145.24	0.4775	1.3841	6.3944	27.144	16.110	227.27	0.7783	13.7574	233.24
1967	Chinook_1	0.6998	0.7237	0.5057	132.39	146.45	150.75	25.512	31.450	13.288	291.25	0.6984	13.0268	17.487	12.547	11.448	191.18	0.5217	4.0575	6.2228	30.116	14.515	356.05	0.7799	17.5907	365.78
1968	Chinook_1	0.7264	0.6856	0.4973	132.41	143.36	148.13	22.264	31.000	14.521	203.27	0.7009	10.2337	14.296	13.091	12.910	137.69	0.5240	2.3544	6.2064	27.607	15.649	243.31	0.7827	14.3324	254.99
1969	Chinook_1	0.7319	0.7111	0.5197	131.43	141.47	145.4	19.495	33.781	13.856	300.61	0.6932	13.4401	12.258	15.435	12.252	207.11	0.5151	5.0342	5.4440	33.328	14.959	361.80	0.7771	17.5322	366.88
1970	Chinook_1	0.6980	0.7226	0.5036	132.93	146.41	151.15	26.742	30.129	13.044	243.47	0.7071	11.7626	18.423	10.824	11.538	139.01	0.5497	3.0572	6.4981	28.682	14.053	311.05	0.7748	16.2276	319.27
1971	Chinook_1	0.7202	0.7443	0.5352	131.46	142.24	146.67	20.504	33.900	13.119	337.93	0.7057	15.6813	13.357	14.690	11.459	225.22	0.5365	7.4560	5.3268	34.859	14.226	412.92	0.7912	19.7641	418.93
1972	Chinook_1	0.7360	0.7425	0.5457	131.38	140.96	144.88	18.238	35.004	13.646	358.39	0.7149	15.7334	11.369	16.887	12.101	248.77	0.5426	6.1960	5.0651	35.426	14.672	432.68	0.8049	20.9224	433.02
1973	Chinook_1	0.7167	0.6757	0.4836	132.58	144.39	149.49	25.128	28.733	13.776	155.28	0.7134	9.0790	16.263	11.250	12.239	104.63	0.5403	1.4432	7.0696	24.257	14.868	188.21	0.7938	13.2238	193.48
1974	Chinook_1	0.7341	0.7408	0.5430	131.35	140.35	145.23	18.057	35.056	13.625	347.52	0.7109	16.5088	11.160	16.723	11.974	241.87	0.5467	9.0075	5.0962	35.644	14.727	418.73	0.7940	20.2472	422.85
1975	Chinook_1	0.7072	0.7444	0.5256	132.42	144.13	149.72	24.456	31.214	13.043	268.49	0.6938	12.2104	16.518	12.225	11.412	168.54	0.5107	3.2644	6.1241	30.060	14.135	333.11	0.7790	16.8372	342.66
1976	Chinook_1	0.7122	0.7504	0.5336	131.8	143.53	147.98	23.080	31.977	12.783	286.92	0.6964	13.2352	15.419	13.232	11.181	190.54	0.5189	4.9718	5.8287	31.545	13.860	353.11	0.7800	17.4931	354.95
1977	Chinook_1	0.7248	0.6484	0.4692	132.46	143.23	148.39	24.120	28.708	14.308	130.89	0.7198	9.4953	15.204	11.934	12.739	101.73	0.5380	3.3015	7.1408	23.151	15.450	149.47	0.8119	12.5938	155.37
1978	Chinook_1	0.7216	0.7120	0.5130	131.72	144.09	148.57	22.724	30.779	13.447	224.41	0.6819	10.2318	14.540	13.510	11.770	159.30	0.4792	1.8973	6.3779	27.729	14.556	265.35	0.7761	14.6841	273.99
1979	Chinook_1	0.7127	0.7007	0.4987	132.23	144.91	148.87	24.640	29.892	13.204	209.79	0.6926	10.1511	16.210	12.117	11.619	139.86	0.5006	1.8899	6.6110	26.960	14.294	255.25	0.7804	14.5429	262.72
1980	Chinook_1	0.7235	0.7305	0.5277	131.68	141.4	146.16	21.073	32.381	13.395	272.42	0.6993	12.9220	13.572	13.707	11.785	194.20	0.5263	5.6812	5.6928	31.616	14.503	326.86	0.7790	16.4960	331.45
1981	Chinook_1	0.7311	0.6988	0.5101	132.18	142.5	147.07	21.038	32.094	14.438	231.17	0.6917	10.8875	13.433	13.731	12.852	153.55	0.5074	2.6453	5.8369	29.942	15.553	281.41	0.7743	15.1366	289.56
1982	Chinook_1	0.7271	0.7279	0.5285	131.81	142.6	147.08	20.865	33.203	13.751	293.17	0.6931	13.1501	13.553	14.050	12.121	185.65	0.5143	4.2629	5.5205	33.007	14.870	365.26	0.7738	17.6661	370.19
1983	Chinook_1	0.7301	0.7335	0.5348	131.75	143.01	148.69	21.375	31.562	13.452	247.35	0.6870	11.2824	13.506	13.554	11.989	149.99	0.4981	2.2879	6.0583	29.759	14.430	309.95	0.7710	16.0116	317.95
1984	Chinook_1	0.7081	0.7170	0.5070	132.44	145.96	150.37	24.886	31.558	13.656	245.22	0.6974	11.4787	17.156	11.755	11.788	131.29	0.5316	2.1919	5.9449	30.654	14.931	319.66	0.7672	16.4422	325.76
1985	Chinook_1	0.7106	0.6876	0.4878	132.37	145.57	149.31	24.812	30.385	13.642	213.17	0.6915	10.1001	16.562	12.233	11.919	143.92	0.4976	1.6333	6.4558	27.540	14.839	256.90	0.7817	14.5719	265.72
1986	Chinook_1	0.7311	0.6940	0.5067	131.8	143.6	148.55	21.427	31.551	14.075	226.53	0.6885	10.8013	13.537	13.653	12.505	141.52	0.4998	2.1559	6.1064	29.028	15.144	281.59	0.7732	15.3911	285.54
1987	Chinook_1	0.7402	0.6014	0.4445	131.56	140.74	142.51	19.082	32.834	15.218	212.49	0.6873	10.4011	11.660	15.481	13.412	172.09	0.4871	3.2431	5.6759	29.845	16.573	240.18	0.7822	14.0647	243.54
1988	Chinook_1	0.7093	0.6835	0.4841	132.53	145.84	150.49	25.815	29.319	13.660	182.60	0.6861	9.2676	16.971	11.888	11.961	132.85	0.4837	1.4018	7.0508	25.135	14.812	215.32	0.7784	13.5043	221.31
1989	Chinook_1	0.7210	0.6855	0.4935	131.76	143.27	147.37	22.746	31.033	13.783	214.58	0.6807	9.9521	14.662	13.465	11.986	160.71	0.4752	1.8494	6.2970	27.970	15.019	250.77	0.7761	14.2715	253.17
1990	Chinook_1	0.7396	0.6186	0.4568	131.64	142.08	145.36	19.619	32.694	15.235	215.87	0.6781	10.0123	12.117	15.151	13.300	162.59	0.4710	1.9841	5.7639	29.562	16.658	251.19	0.7745	14.2865	254.33
1991	Chinook_1	0.7328	0.7175	0.5250	131.52	142.23	147.14	20.458	31.976	13.799	245.68	0.6806	11.0332	12.514	14.812	12.241	180.62	0.4854	3.0201	6.1516	29.343	14.839	289.78	0.7696	15.1412	289.39
1992	Chinook_1	0.7403	0.5936	0.4388	131.71	142.18	144.67	20.231	31.796	15.258	178.94	0.6862	9.7126	12.428	14.689	13.427	139.23	0.4782	2.6641	6.0607	27.798	16.618	205.66	0.7842	13.3781	208.41

Year	Species	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	Mean Travel Time	Mean MigRate	Mean Temp	Mean Flow	Mean FSpill	Mean Gas	UC Travel Time	UCMig Rate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1993	Chinook_1	0.6946	0.6884	0.4775	133.11	146.31	149.65	26.965	30.513	13.473	230.94	0.7097	11.2815	18.899	11.041	11.711	140.90	0.5499	2.7488	6.2658	28.982	14.705	291.40	0.7792	15.8017	296.43
1994	Chinook_1	0.7307	0.5933	0.4329	131.9	143.17	145.43	21.824	31.102	14.878	178.54	0.6893	9.1357	13.877	13.428	12.914	136.08	0.4831	1.2341	6.1957	27.326	16.358	205.59	0.7872	13.4125	210.92
1995	Chinook_1	0.7251	0.7226	0.5232	132.2	143.26	148.58	22.415	31.064	13.581	226.05	0.6917	10.5613	14.433	12.889	12.088	141.92	0.5067	2.0107	6.1785	28.899	14.599	280.16	0.7735	15.0986	289.54
1996	Chinook_1	0.7322	0.7272	0.5316	131.56	141.89	146.13	19.625	33.126	13.761	277.11	0.6908	12.5923	12.268	15.106	12.162	190.06	0.5098	4.3652	5.5608	32.066	14.893	333.86	0.7768	16.7347	341.74
1997	Chinook_1	0.7375	0.7443	0.5481	131.38	140.25	143.63	17.189	36.334	13.669	392.61	0.7298	18.3020	10.734	17.315	12.091	273.89	0.5708	9.7560	4.6518	38.380	14.729	473.17	0.8157	22.9379	476.53
1998	Chinook_1	0.7315	0.7142	0.5217	131.59	142.03	146.67	20.404	32.971	13.942	268.79	0.6967	12.4257	12.999	14.129	12.338	168.72	0.5244	3.9609	5.6170	32.282	15.027	335.37	0.7727	16.7205	342.80
1999	Chinook_1	0.7365	0.7234	0.5320	131.58	142.36	147.76	19.700	32.519	13.773	261.82	0.6857	11.8784	12.012	15.089	12.213	172.96	0.4986	3.2930	5.8905	30.569	14.799	320.20	0.7702	16.2374	328.01
2000	Chinook_1	0.7308	0.6289	0.4589	131.77	143.5	146.38	21.143	31.817	14.624	207.77	0.6809	9.9437	13.424	14.141	12.653	151.80	0.4763	2.0209	5.9609	28.712	16.052	243.22	0.7754	14.1850	250.93
2001	Chinook_1	0.7205	0.6538	0.4703	132.6	144.76	149.43	24.612	28.993	14.247	144.34	0.7170	9.6946	15.865	11.515	12.655	99.85	0.5457	3.1480	6.9731	24.199	15.375	172.87	0.7977	13.0619	179.87
2002	Chinook_1	0.7184	0.7104	0.5096	131.8	144.05	148.5	22.591	31.717	13.742	254.40	0.6840	11.3298	14.693	13.766	11.931	182.72	0.4875	2.9665	6.1138	29.360	14.962	299.92	0.7766	15.5760	309.36
2003	Chinook_1	0.7293	0.7058	0.5140	131.74	143.31	148.71	21.611	30.932	13.604	228.88	0.6905	10.6711	13.519	13.504	12.091	150.82	0.4997	2.0030	6.2874	28.098	14.639	275.88	0.7786	15.1100	292.98
2004	Chinook_1	0.7302	0.6864	0.5005	131.76	143.46	148.42	22.183	30.531	14.010	196.88	0.6851	9.6845	13.918	13.312	12.412	131.72	0.4853	1.5647	6.4811	26.782	15.103	234.02	0.7758	13.9616	254.35
2005	Chinook_1	0.7352	0.6667	0.4894	132.12	142.23	145.7	21.205	31.316	14.635	191.57	0.6938	9.6880	13.339	13.678	13.042	128.92	0.4997	1.6019	6.1041	27.910	15.766	232.58	0.7831	14.0444	237.85
2006	Chinook_1	0.7159	0.7174	0.5128	131.87	144.46	147.59	22.356	32.679	13.435	294.75	0.7004	13.2360	14.972	13.705	11.786	192.77	0.5254	4.1637	5.5766	32.351	14.561	362.19	0.7848	17.9553	369.38
2007	Chinook_1	0.7398	0.6867	0.5072	131.56	141.1	144.95	19.659	32.083	14.455	215.54	0.6844	9.7367	11.912	15.421	12.891	166.13	0.4787	1.6194	5.9759	28.602	15.547	248.01	0.7829	14.0878	253.38
2008	Chinook_1	0.7052	0.7145	0.5031	132.76	145.39	149.41	24.712	32.007	13.827	278.83	0.7104	13.0909	17.109	11.980	12.026	159.48	0.5545	3.9519	5.8236	31.458	15.037	354.22	0.7815	17.6496	370.93
MO1																										
1929	Chinook_1	0.6905	0.6693	0.4615	133.48	148.39	152.25	28.562	29.012	13.963	157.27	0.7726	10.0478	20.379	9.672	12.134	94.07	0.6256	2.0603	6.4081	25.811	15.278	196.83	0.8698	14.4974	206.14
1930	Chinook_1	0.7255	0.5826	0.4220	132.43	145.32	147.7	23.143	30.220	15.152	137.14	0.7578	9.3674	15.218	12.047	13.213	96.51	0.5988	2.1011	6.1842	26.028	16.595	163.48	0.8561	13.3431	168.52
1931	Chinook_1	0.7250	0.5729	0.4148	132.49	145.13	146.73	23.150	30.311	15.158	134.16	0.7765	10.0234	15.331	11.997	13.259	95.18	0.6092	3.0524	6.0757	26.352	16.612	158.49	0.8935	13.7489	164.98
1932	Chinook_1	0.7200	0.7296	0.5246	131.84	143.35	147.26	22.237	31.903	13.277	255.83	0.7025	11.5486	14.610	13.693	11.616	172.20	0.5182	3.1629	5.8128	30.559	14.387	310.47	0.7957	15.8969	319.07
1933	Chinook_1	0.7283	0.7258	0.5278	131.84	143.61	149.01	21.260	31.930	13.886	248.90	0.7210	11.5637	13.767	13.497	12.275	160.79	0.5392	2.4649	5.7047	30.202	14.993	304.78	0.8224	16.3421	317.25
1934	Chinook_1	0.7450	0.6227	0.4632	131.39	139.93	141.65	16.877	34.355	15.059	251.22	0.7011	11.6696	9.760	18.322	13.372	213.40	0.5221	5.3506	5.3522	31.719	16.332	275.30	0.7940	14.7693	281.31
1935	Chinook_1	0.7229	0.7041	0.5082	132.32	144.01	148.56	22.566	30.996	13.943	204.25	0.7252	9.8988	14.839	12.746	12.267	143.11	0.5390	1.3974	5.9448	28.365	15.113	242.77	0.8310	14.5336	252.24
1936	Chinook_1	0.7169	0.6310	0.4517	132.27	144.62	146.16	22.772	32.414	14.312	241.38	0.7074	11.2169	15.521	12.961	12.384	160.28	0.5288	3.0330	5.4732	31.639	15.786	293.14	0.7964	15.5267	302.99
1937	Chinook_1	0.7010	0.6871	0.4809	133	146.52	150.88	26.919	29.040	13.652	157.84	0.7682	9.8316	18.636	10.529	11.927	100.92	0.6095	1.8633	6.4919	25.531	14.841	193.81	0.8730	14.1897	203.69
1938	Chinook_1	0.7245	0.7138	0.5164	131.82	143.73	147.8	21.653	32.032	13.720	243.60	0.7036	11.1380	14.080	13.794	11.980	160.96	0.5209	2.6106	5.7795	30.349	14.902	296.31	0.7952	15.5459	305.62
1939	Chinook_1	0.7022	0.5834	0.4090	132.56	147.22	148	25.972	30.512	14.415	172.75	0.7470	9.8658	18.265	11.801	12.360	123.97	0.5587	1.8773	5.9330	27.739	16.037	203.41	0.8664	14.2592	209.64
1940	Chinook_1	0.7313	0.6144	0.4486	132.06	143.81	145.9	21.278	31.777	14.819	192.96	0.7202	9.4845	13.799	13.547	12.978	135.09	0.5336	1.1975	5.7202	29.100	16.189	229.69	0.8228	14.0948	236.82
1941	Chinook_1	0.7342	0.6646	0.4872	132.26	142.84	146.85	21.538	30.829	14.694	160.25	0.7597	9.8419	13.758	13.197	13.166	108.90	0.5877	2.0031	6.0173	27.102	15.783	192.93	0.8718	14.1045	199.23
1942	Chinook_1	0.6991	0.7348	0.5129	132.74	147.05	151.95	26.772	29.428	13.085	199.05	0.7291	10.0511	18.483	10.840	11.435	124.08	0.5644	1.8371	6.4734	26.785	14.205	247.08	0.8165	14.5115	255.98
1943	Chinook_1	0.7222	0.7259	0.5234	131.69	144.05	148.4	21.832	32.066	13.626	246.52	0.7098	11.1798	14.296	13.809	11.871	167.66	0.5247	2.2862	5.7417	30.434	14.813	297.10	0.8088	15.8393	306.77
1944	Chinook_1	0.7071	0.6626	0.4678	133.03	146.37	151.53	26.490	28.718	14.118	135.54	0.7604	9.2087	17.983	10.334	12.368	88.69	0.6158	1.9047	6.7358	24.419	15.368	165.61	0.8474	13.1771	171.80
1945	Chinook_1	0.7082	0.6837	0.4835	132.76	145.97	149.76	25.162	30.683	14.092	194.44	0.7434	10.3312	17.470	11.305	12.332	115.16	0.5841	1.8530	5.9183	28.585	15.320	244.52	0.8342	14.9981	255.61

Year	Species	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	Mean Travel Time	Mean MigRate	Mean Temp	Mean Flow	Mean FSpill	Mean Gas	UC Travel Time	UCMig Rate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1946	Chinook_1	0.7215	0.7229	0.5208	131.56	142.27	146.01	21.019	33.039	13.619	280.16	0.7010	12.7683	13.666	14.522	11.836	205.32	0.5265	5.3699	5.5585	32.265	14.821	329.05	0.7871	16.2949	338.52
1947	Chinook_1	0.7353	0.6457	0.4740	131.53	141.97	144.09	19.378	33.740	14.761	253.74	0.7010	11.2258	12.341	15.103	12.959	172.66	0.5199	2.5089	5.2746	32.801	16.080	306.31	0.7903	15.7884	314.47
1948	Chinook_1	0.7187	0.7502	0.5384	132.03	143.82	147.44	21.167	34.533	13.544	388.04	0.7260	16.7201	14.504	14.027	11.786	236.17	0.5519	5.5980	4.8679	36.451	14.743	483.27	0.8240	23.2028	503.91
1949	Chinook_1	0.7301	0.7085	0.5165	131.61	142.28	145.7	20.261	33.189	13.857	281.00	0.7071	12.6933	13.042	14.432	12.202	184.38	0.5340	3.8373	5.4287	32.642	15.005	341.74	0.7936	17.1248	355.66
1950	Chinook_1	0.7109	0.7349	0.5216	132.32	145.24	149.93	23.679	31.710	13.466	267.11	0.7096	11.7222	16.072	12.710	11.743	170.32	0.5298	2.4301	5.8067	30.594	14.646	327.40	0.8036	16.4875	343.56
1951	Chinook_1	0.7345	0.7240	0.5310	131.43	141.3	145.5	19.175	33.256	13.797	271.44	0.7008	11.9638	11.804	15.808	12.177	195.93	0.5235	3.7115	5.5751	31.775	14.886	320.01	0.7885	16.0604	330.49
1952	Chinook_1	0.7173	0.7300	0.5229	131.77	143.57	147.25	22.249	32.475	13.292	277.63	0.7064	13.1326	14.831	13.482	11.597	180.83	0.5385	5.1308	5.6062	32.136	14.449	340.19	0.7880	17.1068	349.94
1953	Chinook_1	0.7212	0.7505	0.5405	132.21	143.16	149.04	22.383	31.244	13.239	244.97	0.7209	11.4474	14.711	12.603	11.823	156.17	0.5470	2.5993	5.8550	29.903	14.180	301.71	0.8143	16.0639	314.76
1954	Chinook_1	0.7080	0.7549	0.5337	132.32	144.28	149.01	23.773	31.473	12.914	270.42	0.7110	12.3238	16.065	12.682	11.293	186.72	0.5399	4.2434	5.8835	30.568	14.010	324.24	0.7992	16.3710	336.49
1955	Chinook_1	0.7000	0.7465	0.5218	132.91	145.67	151.29	26.012	30.242	13.084	230.07	0.7344	11.1159	18.097	11.102	11.466	145.87	0.5717	2.2974	6.1035	28.520	14.177	283.06	0.8251	15.7804	297.11
1956	Chinook_1	0.7215	0.7510	0.5410	131.59	142.93	146.6	20.172	33.985	13.148	349.93	0.7115	15.3031	13.097	15.172	11.469	234.84	0.5476	6.2107	5.2533	34.693	14.267	423.48	0.7953	19.7898	439.33
1957	Chinook_1	0.7175	0.7439	0.5329	131.69	142.96	146.42	21.508	33.321	13.056	332.67	0.7167	15.2212	14.352	13.737	11.511	206.56	0.5562	6.2499	5.3291	34.365	14.099	413.50	0.7973	19.7367	428.45
1958	Chinook_1	0.7122	0.7194	0.5116	132.36	144.78	148.1	23.136	32.719	13.546	293.81	0.7144	13.3057	15.885	12.707	11.839	178.07	0.5505	4.1584	5.4520	33.097	14.731	367.63	0.7958	17.9601	382.89
1959	Chinook_1	0.7317	0.7301	0.5334	131.52	142.16	147.06	19.855	32.720	13.795	264.55	0.7034	11.2277	12.428	14.883	12.187	191.23	0.5206	2.3916	5.6337	31.150	14.887	311.59	0.7984	15.7853	321.99
1960	Chinook_1	0.7120	0.7312	0.5198	132.07	143.92	149.03	23.766	30.837	13.187	230.96	0.7072	10.4339	15.814	12.948	11.442	165.36	0.5170	1.9945	6.1423	28.431	14.365	271.87	0.8096	14.8703	282.06
1961	Chinook_1	0.7321	0.7352	0.5374	131.49	142.27	147.42	20.052	32.547	13.465	283.93	0.7098	12.2804	12.475	15.022	11.949	205.29	0.5365	3.6311	5.7679	30.969	14.474	333.88	0.7982	16.5649	343.02
1962	Chinook_1	0.7184	0.7129	0.5114	132.06	144.31	148.7	22.866	31.659	13.773	230.68	0.7047	10.5255	15.211	13.119	11.975	158.93	0.5134	2.1251	5.8703	29.785	14.994	278.26	0.8034	15.0074	283.31
1963	Chinook_1	0.7248	0.7076	0.5121	132.21	144.58	149.07	22.363	31.242	14.033	208.11	0.7288	10.4983	14.689	12.637	12.434	128.34	0.5629	2.0201	5.8920	29.067	15.123	260.14	0.8175	15.0879	267.04
1964	Chinook_1	0.7046	0.7286	0.5126	132.79	145.51	150.31	24.764	31.777	13.739	270.70	0.7224	12.2299	17.286	11.941	11.930	168.08	0.5588	2.8992	5.6948	30.989	14.990	336.35	0.8065	17.1417	348.04
1965	Chinook_1	0.7258	0.7399	0.5363	131.79	142.89	147.87	21.272	32.325	13.391	263.85	0.6978	11.5367	13.809	13.519	11.785	168.71	0.5166	2.3153	5.6549	31.641	14.485	326.68	0.7860	16.3817	332.11
1966	Chinook_1	0.7164	0.6115	0.4374	132.34	145.53	147.72	23.618	31.015	14.651	192.04	0.7162	9.6335	15.882	12.640	12.630	142.59	0.5268	1.8178	5.9757	27.974	16.159	224.45	0.8192	13.8433	230.53
1967	Chinook_1	0.6978	0.7315	0.5097	132.46	146.79	151.01	25.571	31.497	13.324	282.85	0.7171	12.6806	17.878	12.304	11.544	184.69	0.5498	3.4925	5.8893	30.477	14.529	346.46	0.8026	17.3984	355.67
1968	Chinook_1	0.7259	0.6908	0.5008	132.5	143.52	148.21	22.221	31.084	14.564	198.87	0.7293	10.0617	14.472	12.936	13.043	133.60	0.5665	2.1194	5.9850	27.996	15.647	238.67	0.8176	14.2475	250.32
1969	Chinook_1	0.7312	0.7188	0.5248	131.45	141.71	145.65	19.620	33.749	13.836	296.88	0.7004	13.1391	12.436	15.242	12.185	203.03	0.5270	4.6108	5.3929	33.392	14.964	358.20	0.7849	17.3432	363.46
1970	Chinook_1	0.6967	0.7275	0.5061	133.07	146.76	151.32	26.705	30.200	13.088	234.66	0.7276	11.3178	18.697	10.686	11.550	131.20	0.5796	2.3882	6.1882	28.945	14.126	301.41	0.8004	15.9861	309.65
1971	Chinook_1	0.7201	0.7502	0.5394	131.48	142.24	146.55	20.538	33.944	13.219	335.90	0.7047	15.0225	13.409	14.627	11.570	222.86	0.5428	6.4602	5.3128	34.945	14.337	411.41	0.7837	19.2479	417.28
1972	Chinook_1	0.7358	0.7488	0.5501	131.39	141.09	145.15	18.227	35.005	13.647	355.78	0.7184	15.1637	11.383	16.863	12.109	247.35	0.5572	5.6904	5.0385	35.484	14.667	429.35	0.8019	20.1159	429.45
1973	Chinook_1	0.7164	0.6907	0.4941	132.6	144.49	149.02	24.355	29.406	13.698	165.56	0.7586	9.7602	16.154	11.423	12.145	112.56	0.5923	1.6607	6.4034	25.850	14.786	199.65	0.8645	14.2031	206.00
1974	Chinook_1	0.7335	0.7475	0.5475	131.36	140.64	145.59	18.262	34.912	13.656	343.62	0.7102	15.7418	11.355	16.399	12.012	236.82	0.5498	7.7678	5.1069	35.525	14.760	415.64	0.7902	19.7480	419.86
1975	Chinook_1	0.7072	0.7523	0.5312	132.43	144.21	149.58	24.278	31.312	13.029	263.76	0.7094	11.7510	16.562	12.189	11.379	165.83	0.5367	2.4748	5.9010	30.352	14.134	327.32	0.7961	16.5838	336.15
1976	Chinook_1	0.7121	0.7579	0.5389	131.83	143.53	148.01	23.037	31.995	12.810	281.56	0.7029	12.7315	15.464	13.167	11.185	186.42	0.5324	4.3102	5.7414	31.625	13.906	347.12	0.7849	17.0952	348.55
1977	Chinook_1	0.7228	0.6528	0.4711	132.53	143.61	148.38	24.168	28.808	14.312	121.48	0.7766	9.7907	15.650	11.572	12.788	92.34	0.6101	3.4017	6.7410	23.739	15.434	139.67	0.8926	13.2037	145.85
1978	Chinook_1	0.7220	0.7178	0.5175	131.68	144.01	148.33	22.321	31.105	13.514	225.02	0.7068	10.1534	14.463	13.513	11.876	159.29	0.5185	1.6711	6.0517	28.555	14.615	266.31	0.8054	14.7300	275.18
1979	Chinook_1	0.7096	0.7046	0.4992	132.39	145.25	148.95	24.870	29.975	13.261	200.84	0.7318	10.1969	16.844	11.585	11.657	130.87	0.5573	1.6366	6.2102	27.551	14.374	246.53	0.8293	14.8513	254.00

Year	Species	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	Mean Travel Time	Mean MigRate	Mean Temp	Mean Flow	Mean FSpill	Mean Gas	UC Travel Time	UCMig Rate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1980	Chinook_1	0.7219	0.7384	0.5322	131.7	141.68	146.37	21.228	32.314	13.354	267.77	0.7091	12.3760	13.815	13.451	11.710	189.37	0.5398	4.6642	5.6046	31.674	14.478	322.25	0.7928	16.3053	326.98
1981	Chinook_1	0.7307	0.7065	0.5155	132.26	142.68	147.05	20.949	32.253	14.479	226.46	0.7230	10.7673	13.593	13.615	12.987	148.97	0.5532	2.2830	5.5868	30.476	15.545	276.61	0.8137	15.2405	284.73
1982	Chinook_1	0.7263	0.7349	0.5330	131.9	142.9	147.42	20.892	33.249	13.758	288.01	0.7063	12.8027	13.694	13.891	12.148	181.29	0.5402	3.8259	5.4054	33.285	14.864	360.01	0.7852	17.3739	364.60
1983	Chinook_1	0.7288	0.7423	0.5401	131.78	143.34	148.69	21.403	31.629	13.406	242.98	0.7130	11.0531	13.721	13.338	11.912	146.63	0.5380	1.7967	5.8700	30.126	14.396	305.33	0.8025	16.0018	312.72
1984	Chinook_1	0.7056	0.7238	0.5100	132.64	146.27	150.7	25.089	31.738	13.718	242.79	0.7194	11.3403	17.626	11.507	11.909	126.89	0.5664	1.8700	5.6782	31.318	14.978	318.68	0.7921	16.4838	325.03
1985	Chinook_1	0.7101	0.6937	0.4918	132.39	145.74	149.29	24.572	30.589	13.666	207.06	0.7247	10.0505	16.713	12.105	11.926	138.76	0.5447	1.3572	6.0647	28.154	14.883	250.26	0.8247	14.7876	258.79
1986	Chinook_1	0.7293	0.7011	0.5106	131.78	144.06	148.71	21.445	31.731	14.032	226.03	0.7211	10.8751	13.833	13.565	12.434	139.05	0.5491	2.0316	5.8261	29.619	15.117	281.66	0.8131	15.6433	286.39
1987	Chinook_1	0.7408	0.6031	0.4461	131.6	140.98	142.45	18.993	32.948	15.280	202.08	0.7313	10.5321	11.801	15.314	13.546	162.36	0.5385	3.1508	5.4446	30.291	16.608	229.29	0.8485	14.3948	232.71
1988	Chinook_1	0.7094	0.6812	0.4825	132.47	146.26	150.53	25.620	29.170	13.683	161.23	0.7354	9.3432	17.127	11.621	11.978	116.59	0.5571	1.8084	6.6982	25.032	14.853	190.69	0.8389	13.3844	195.41
1989	Chinook_1	0.7205	0.6931	0.4987	131.79	143.37	146.91	22.508	31.327	13.775	212.89	0.7200	10.0642	14.788	13.334	11.968	158.45	0.5248	1.4779	5.9322	28.821	15.022	249.40	0.8328	14.7541	251.96
1990	Chinook_1	0.7395	0.6198	0.4576	131.66	142.24	145.24	19.477	32.888	15.294	211.11	0.7137	10.0638	12.245	15.040	13.447	157.24	0.5230	1.9373	5.4905	30.212	16.679	246.64	0.8195	14.4398	250.03
1991	Chinook_1	0.7326	0.7249	0.5303	131.53	142.43	147.23	20.246	32.143	13.807	242.61	0.7032	10.7125	12.555	14.805	12.264	179.06	0.5197	2.3779	5.8974	29.793	14.839	285.76	0.7977	15.0840	284.92
1992	Chinook_1	0.7391	0.5915	0.4366	131.82	142.52	144.69	20.317	31.857	15.332	170.71	0.7293	10.1148	12.792	14.329	13.578	130.61	0.5429	3.3805	5.7818	28.283	16.666	197.54	0.8366	13.5706	200.49
1993	Chinook_1	0.6918	0.6956	0.4805	133.27	146.62	149.8	27.195	30.555	13.463	225.78	0.7313	11.0293	19.390	10.767	11.693	136.51	0.5833	2.1108	6.0039	29.331	14.703	285.70	0.8056	15.8446	290.63
1994	Chinook_1	0.7284	0.5852	0.4256	132.21	144.13	145.8	22.175	30.961	14.956	161.56	0.7362	9.4165	14.467	12.920	13.006	120.56	0.5539	1.8891	5.9577	27.381	16.450	187.70	0.8436	13.5022	192.67
1995	Chinook_1	0.7233	0.7298	0.5271	132.27	143.64	148.69	22.456	31.147	13.543	222.32	0.7200	10.5859	14.741	12.629	12.012	138.14	0.5493	1.8680	5.9116	29.333	14.577	276.46	0.8081	15.3050	285.88
1996	Chinook_1	0.7317	0.7358	0.5376	131.58	141.89	146.15	19.627	33.166	13.749	274.76	0.7012	11.8714	12.364	15.015	12.179	187.77	0.5249	2.8395	5.4643	32.279	14.862	331.42	0.7906	16.5120	339.34
1997	Chinook_1	0.7361	0.7503	0.5515	131.4	140.47	144.01	17.607	36.111	13.671	389.70	0.7242	17.5456	11.066	16.826	12.030	269.36	0.5740	8.9284	4.7417	38.150	14.768	471.28	0.7989	22.0168	475.02
1998	Chinook_1	0.7315	0.7237	0.5287	131.6	142.22	146.7	20.124	33.240	13.933	272.28	0.7034	12.2170	12.865	14.293	12.355	171.82	0.5346	3.5214	5.4691	32.869	15.002	338.83	0.7832	16.6209	346.47
1999	Chinook_1	0.7350	0.7296	0.5354	131.61	142.87	147.87	20.000	32.538	13.824	255.24	0.7081	11.3866	12.518	14.595	12.276	165.10	0.5284	2.1465	5.6863	30.981	14.857	314.62	0.8004	16.2018	322.46
2000	Chinook_1	0.7310	0.6298	0.4597	131.73	143.57	145.94	20.790	32.165	14.635	209.85	0.7094	9.8874	13.349	14.215	12.680	153.74	0.5171	1.6795	5.6791	29.574	16.069	245.44	0.8127	14.3521	253.24
2001	Chinook_1	0.7177	0.6581	0.4716	132.67	145.41	149.34	24.606	29.173	14.218	136.50	0.7759	10.1384	16.342	11.149	12.597	92.46	0.6195	3.2950	6.4883	24.969	15.367	164.46	0.8823	13.8257	171.77
2002	Chinook_1	0.7170	0.7176	0.5138	131.89	144.34	148.77	22.611	31.829	13.728	249.52	0.7089	11.0330	15.009	13.497	11.914	176.96	0.5248	2.3712	5.8164	29.913	14.956	295.65	0.8070	15.5410	305.29
2003	Chinook_1	0.7281	0.7135	0.5188	131.78	143.54	148.37	21.543	31.116	13.569	225.82	0.7204	10.5408	13.750	13.308	12.029	148.31	0.5397	1.5339	5.9867	28.738	14.618	272.54	0.8193	15.2885	289.38
2004	Chinook_1	0.7279	0.6898	0.5014	131.85	144.01	148.62	22.326	30.495	13.983	187.49	0.7262	9.7060	14.341	12.908	12.358	122.97	0.5489	1.6175	6.1990	27.068	15.089	224.14	0.8245	14.0220	244.28
2005	Chinook_1	0.7329	0.6730	0.4925	132.31	142.52	145.95	21.340	31.470	14.654	185.77	0.7389	9.9374	13.810	13.280	13.093	122.17	0.5623	1.5493	5.7677	28.632	15.771	227.44	0.8425	14.5712	232.87
2006	Chinook_1	0.7159	0.7234	0.5171	131.89	144.43	147.62	22.277	32.831	13.480	293.25	0.7076	12.9465	15.008	13.625	11.788	190.67	0.5409	3.7835	5.4640	32.743	14.639	361.22	0.7896	17.6872	368.62
2007	Chinook_1	0.7397	0.6934	0.5121	131.6	141.16	144.88	19.472	32.265	14.457	212.64	0.7166	9.7996	11.981	15.313	12.910	163.41	0.5205	1.3470	5.7183	29.173	15.536	244.88	0.8281	14.4217	250.36
2008	Chinook_1	0.7033	0.7214	0.5066	132.94	145.66	149.7	24.817	32.130	13.872	274.56	0.7284	12.8813	17.481	11.714	12.126	155.49	0.5860	3.6908	5.5548	32.029	15.066	350.16	0.7993	17.4795	366.46
MO2																										
1929	Chinook_1	0.6911	0.6468	0.4467	133.4	148.04	153.17	29.424	29.578	13.966	162.14	0.6598	4.1697	20.249	9.879	12.025	97.48	0.5377	0.7893	7.5614	24.505	15.339	202.74	0.6614	5.2214	212.19
1930	Chinook_1	0.7264	0.5660	0.4108	132.32	145.06	148.56	23.637	30.846	15.165	139.63	0.6511	4.2416	15.070	12.378	13.153	99.07	0.5142	0.7345	6.9878	24.654	16.647	166.02	0.6603	5.4527	170.70
1931	Chinook_1	0.7262	0.5531	0.4014	132.38	144.68	147.71	23.703	30.817	15.167	137.79	0.6550	4.2600	15.140	12.367	13.191	99.35	0.5180	0.7266	6.9809	24.673	16.657	161.91	0.6663	5.5334	167.86
1932	Chinook_1	0.7225	0.7176	0.5181	131.71	143.01	146.57	22.195	33.489	13.291	260.95	0.6587	4.3625	14.302	14.218	11.596	176.63	0.4876	0.7406	6.2404	31.677	14.416	315.70	0.7101	5.6529	324.87

Year	Species	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	Mean Travel Time	Mean MigRate	Mean Temp	Mean Flow	Mean FSpill	Mean Gas	UC Travel Time	UCMig Rate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1933	Chinook_1	0.7283	0.7140	0.5196	131.76	143.52	150.55	21.742	33.080	13.849	253.13	0.6612	5.1240	13.773	13.743	12.172	162.38	0.4833	0.8751	6.3408	30.430	14.990	310.31	0.7192	6.7236	324.07
1934	Chinook_1	0.7457	0.6122	0.4562	131.29	139.79	141.97	16.982	35.837	15.031	251.43	0.6467	4.6401	9.659	18.873	13.323	214.11	0.4828	1.2726	5.7169	32.469	16.309	275.35	0.6910	5.8851	280.79
1935	Chinook_1	0.7241	0.6849	0.4956	132.16	143.72	149.44	23.093	31.944	13.898	207.77	0.6396	4.1916	14.618	13.119	12.149	147.01	0.4621	0.7153	6.8514	27.993	15.110	246.11	0.6819	5.3709	255.56
1936	Chinook_1	0.7177	0.6209	0.4453	132.19	144.41	146.53	22.920	33.902	14.314	243.41	0.6580	4.3039	15.426	13.299	12.339	162.67	0.4945	0.7201	5.8765	32.563	15.804	294.87	0.7005	5.6389	304.84
1937	Chinook_1	0.7031	0.6623	0.4653	132.86	146.07	151.92	27.703	29.520	13.697	162.72	0.6402	4.2232	18.306	10.889	11.906	105.31	0.5090	0.7685	7.7670	23.932	14.927	199.15	0.6374	5.2883	208.85
1938	Chinook_1	0.7264	0.7035	0.5106	131.69	143.41	148.19	21.579	33.530	13.706	247.82	0.6584	4.3459	13.831	14.254	11.957	163.76	0.4852	0.9105	6.1100	31.354	14.892	301.17	0.7113	5.4857	310.87
1939	Chinook_1	0.7035	0.5611	0.3944	132.44	146.98	149.05	26.591	31.258	14.499	172.62	0.6419	4.2488	18.077	12.111	12.313	125.75	0.4715	0.6897	6.9073	26.654	16.183	202.39	0.6766	5.4557	207.55
1940	Chinook_1	0.7321	0.5970	0.4367	131.95	143.65	146.69	21.785	32.737	14.842	194.03	0.6318	4.3715	13.693	13.871	12.922	136.05	0.4609	0.7321	6.4966	28.594	16.257	230.99	0.6625	5.6591	237.77
1941	Chinook_1	0.7351	0.6404	0.4704	132.16	142.62	147.62	22.273	31.224	14.698	161.09	0.6331	4.5034	13.654	13.498	13.127	110.09	0.4930	0.7354	7.0169	25.299	15.807	193.66	0.6344	5.8984	199.64
1942	Chinook_1	0.7021	0.7138	0.5008	132.5	146.63	152.16	27.100	30.298	13.117	202.17	0.6502	4.1093	17.993	11.282	11.401	128.63	0.5002	0.6649	7.4533	26.147	14.277	249.27	0.6737	5.1912	258.36
1943	Chinook_1	0.7232	0.7100	0.5131	131.65	144.02	149.19	22.315	33.236	13.650	247.37	0.6563	4.3741	14.335	14.073	11.862	166.49	0.4882	1.0928	6.3455	30.689	14.853	298.76	0.7022	5.4440	309.38
1944	Chinook_1	0.7084	0.6449	0.4565	132.88	145.97	152.18	26.956	29.373	14.104	141.03	0.6550	4.2117	17.741	10.667	12.316	93.70	0.5305	0.7627	7.6009	23.316	15.377	171.49	0.6556	5.3161	177.65
1945	Chinook_1	0.7094	0.6680	0.4735	132.64	145.33	150.51	25.585	31.802	14.070	204.22	0.6547	4.2291	17.190	11.656	12.231	125.02	0.5060	0.7222	6.7807	28.579	15.336	254.72	0.6787	5.3746	265.76
1946	Chinook_1	0.7230	0.7146	0.5162	131.46	142.03	145.94	20.914	34.782	13.601	282.23	0.6712	4.7847	13.537	14.954	11.817	206.70	0.5061	1.1664	5.7391	33.900	14.801	331.46	0.7283	6.0741	341.02
1947	Chinook_1	0.7370	0.6363	0.4686	131.41	141.68	144.37	19.312	35.469	14.724	258.84	0.6589	4.9690	12.148	15.624	12.894	176.18	0.4949	0.9398	5.5588	34.215	16.052	312.37	0.7041	6.5554	320.89
1948	Chinook_1	0.7208	0.7463	0.5376	131.98	143.64	147.18	21.019	36.342	13.514	388.75	0.7080	4.3292	14.373	14.408	11.710	236.72	0.5314	0.6646	5.0095	38.237	14.738	483.86	0.7932	5.6473	504.82
1949	Chinook_1	0.7312	0.7025	0.5133	131.52	142.04	145.12	20.024	34.958	13.819	285.93	0.6823	4.3262	12.973	14.802	12.157	186.96	0.5100	0.8001	5.4151	34.411	14.977	347.77	0.7488	5.5685	362.28
1950	Chinook_1	0.7110	0.7241	0.5144	132.24	145.06	150.39	24.063	33.134	13.464	272.53	0.6667	4.9524	16.053	12.977	11.650	171.58	0.4921	0.6836	6.3723	31.441	14.695	334.96	0.7277	6.5691	352.69
1951	Chinook_1	0.7357	0.7143	0.5251	131.34	141.14	145.17	19.137	34.929	13.760	273.90	0.6659	4.7806	11.732	16.243	12.136	196.81	0.4958	0.8681	5.7645	33.259	14.855	323.14	0.7229	6.1894	334.14
1952	Chinook_1	0.7193	0.7255	0.5215	131.66	143.4	146.84	21.969	34.264	13.259	278.86	0.6925	4.4670	14.742	13.831	11.569	181.41	0.5291	1.3479	5.5700	34.041	14.412	341.64	0.7564	5.4728	351.68
1953	Chinook_1	0.7228	0.7373	0.5326	132.03	142.83	149.98	22.523	32.587	13.213	251.03	0.6624	4.1876	14.429	13.042	11.787	160.85	0.4928	0.5348	6.4325	30.596	14.163	308.79	0.7138	5.4444	322.20
1954	Chinook_1	0.7096	0.7412	0.5256	132.2	144.04	148.54	23.875	33.025	12.941	274.78	0.6716	4.4349	15.881	13.052	11.270	187.94	0.5031	0.7095	6.3306	31.757	14.073	329.89	0.7312	5.6335	343.58
1955	Chinook_1	0.7008	0.7287	0.5103	132.83	145.42	152.27	26.621	31.204	13.119	234.82	0.6593	4.5861	17.999	11.327	11.465	146.32	0.5126	0.6513	6.9708	28.333	14.240	290.21	0.6868	5.8511	305.59
1956	Chinook_1	0.7226	0.7483	0.5403	131.5	142.85	146.25	19.871	35.931	13.123	352.03	0.7006	4.6817	13.058	15.563	11.447	234.82	0.5306	1.3394	5.1461	37.000	14.243	426.14	0.7810	5.7935	443.22
1957	Chinook_1	0.7191	0.7393	0.5312	131.55	142.5	145.43	20.919	35.411	13.027	338.64	0.7100	4.3399	14.131	14.200	11.488	211.76	0.5373	0.8511	5.1161	36.971	14.070	419.71	0.7957	5.5527	435.11
1958	Chinook_1	0.7137	0.7131	0.5085	132.26	144.51	147.45	22.984	34.471	13.534	298.65	0.6874	4.6097	15.689	13.096	11.803	181.80	0.5199	0.7158	5.6551	34.741	14.731	372.88	0.7517	6.0480	388.92
1959	Chinook_1	0.7321	0.7194	0.5263	131.42	141.98	148.05	20.095	34.170	13.752	267.88	0.6531	5.4398	12.359	15.257	12.084	193.18	0.4774	0.6962	6.1008	32.060	14.876	315.82	0.7088	7.3688	326.42
1960	Chinook_1	0.7146	0.7116	0.5081	131.85	143.66	149.59	24.170	32.004	13.223	232.33	0.6389	4.2260	15.489	13.413	11.419	166.69	0.4567	0.6480	7.0333	28.488	14.437	273.18	0.6893	5.4151	283.90
1961	Chinook_1	0.7333	0.7255	0.5316	131.39	142.15	147.61	20.119	34.023	13.435	287.06	0.6673	4.3018	12.349	15.457	11.908	206.69	0.4881	0.7167	6.1180	31.969	14.460	337.98	0.7319	5.5682	347.86
1962	Chinook_1	0.7192	0.6947	0.4993	131.97	144.08	149.15	23.347	32.887	13.809	233.14	0.6383	4.5926	15.098	13.478	11.956	160.51	0.4597	0.6547	6.6270	30.003	15.058	281.31	0.6825	6.0798	286.57
1963	Chinook_1	0.7263	0.6907	0.5013	132.06	144.22	149.37	22.764	32.326	13.973	211.57	0.6559	4.2709	14.468	13.059	12.316	131.09	0.5008	0.7387	6.6707	29.015	15.098	263.89	0.6877	5.4436	271.08
1964	Chinook_1	0.7071	0.7185	0.5077	132.57	145.1	150.64	24.785	33.288	13.722	276.90	0.6780	4.5246	16.911	12.433	11.834	171.66	0.5160	0.6153	6.2527	31.855	15.016	343.81	0.7318	5.9454	356.96
1965	Chinook_1	0.7269	0.7298	0.5301	131.67	142.66	148.33	21.198	33.948	13.359	267.22	0.6612	4.3691	13.673	13.901	11.742	171.54	0.4938	0.8140	5.8720	33.081	14.464	330.31	0.7125	5.5733	336.00
1966	Chinook_1	0.7181	0.5942	0.4263	132.2	145.17	148.43	24.025	32.026	14.695	195.84	0.6293	4.2506	15.597	13.101	12.575	145.85	0.4572	0.6745	6.8338	27.425	16.247	228.95	0.6607	5.5049	234.63

Year	Species	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	Mean Travel Time	Mean MigRate	Mean Temp	Mean Flow	Mean FSpill	Mean Gas	UC Travel Time	UCMig Rate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1967	Chinook_1	0.6988	0.7233	0.5051	132.37	146.58	151.36	25.914	32.969	13.301	287.90	0.6808	4.2412	17.786	12.562	11.446	185.19	0.5127	0.5702	6.4846	31.517	14.548	353.92	0.7423	5.4487	364.92
1968	Chinook_1	0.7267	0.6760	0.4909	132.37	143.3	148.54	22.552	32.091	14.518	203.00	0.6598	4.7419	14.359	13.252	12.943	135.25	0.5130	0.7656	6.5868	27.765	15.627	244.13	0.6888	6.1860	256.58
1969	Chinook_1	0.7323	0.7154	0.5235	131.36	141.57	145.12	19.261	35.663	13.797	297.88	0.6814	4.3622	12.330	15.681	12.138	204.22	0.5038	0.7787	5.2949	35.466	14.933	358.92	0.7559	5.6369	364.40
1970	Chinook_1	0.6998	0.7128	0.4984	132.82	146.36	151.09	26.779	31.547	13.106	239.71	0.6774	4.2048	18.302	11.044	11.525	133.74	0.5389	0.7078	6.8165	29.640	14.172	307.34	0.7087	5.3282	316.92
1971	Chinook_1	0.7207	0.7494	0.5397	131.38	142.06	146.72	20.047	36.036	13.135	337.60	0.6985	4.3953	13.353	14.992	11.483	223.40	0.5278	0.9529	5.0306	37.666	14.252	413.19	0.7805	5.5765	419.66
1972	Chinook_1	0.7364	0.7454	0.5485	131.29	140.88	144.75	17.981	36.906	13.601	358.93	0.7013	4.4830	11.280	17.368	12.014	249.97	0.5328	0.7587	5.0541	37.437	14.656	432.21	0.7796	5.8343	433.35
1973	Chinook_1	0.7179	0.6701	0.4807	132.46	144.21	150	25.041	29.890	13.693	169.09	0.6409	4.3596	15.931	11.771	12.102	115.98	0.5046	0.7317	7.4697	24.383	14.805	203.53	0.6439	5.5679	209.42
1974	Chinook_1	0.7340	0.7472	0.5480	131.27	140.48	146.18	17.890	36.891	13.571	343.84	0.7010	4.6539	11.326	16.781	11.911	237.17	0.5349	1.4306	4.9162	37.914	14.680	415.02	0.7792	5.7188	420.27
1975	Chinook_1	0.7097	0.7410	0.5255	132.3	143.85	150.26	24.231	32.896	13.038	270.25	0.6688	5.0658	16.243	12.630	11.366	169.15	0.4979	0.6864	6.3326	31.580	14.158	335.31	0.7264	6.6109	345.68
1976	Chinook_1	0.7136	0.7511	0.5356	131.71	143.28	147.2	22.711	33.839	12.799	286.31	0.6833	4.3001	15.306	13.558	11.162	188.47	0.5103	0.5914	5.7305	33.621	13.902	353.01	0.7536	5.6232	355.45
1977	Chinook_1	0.7246	0.6343	0.4593	132.39	143.24	148.93	24.642	29.272	14.309	125.52	0.6649	4.4666	15.351	11.972	12.744	96.81	0.5247	0.8531	7.6734	22.102	15.451	143.60	0.6850	5.6995	149.47
1978	Chinook_1	0.7224	0.7020	0.5067	131.58	143.75	148.69	22.788	32.249	13.497	227.30	0.6417	4.3349	14.363	13.859	11.783	161.68	0.4685	0.5545	6.7802	28.675	14.639	268.68	0.6846	5.5944	277.42
1979	Chinook_1	0.7125	0.6846	0.4874	132.24	144.93	149.08	25.288	30.809	13.286	202.85	0.6454	4.1898	16.449	12.072	11.619	134.12	0.4898	0.6924	7.1845	26.819	14.434	247.76	0.6692	5.3501	254.60
1980	Chinook_1	0.7233	0.7289	0.5268	131.59	141.42	146.37	21.059	34.004	13.334	273.06	0.6742	4.4591	13.633	13.915	11.665	193.33	0.5154	0.9325	5.7742	33.195	14.472	328.22	0.7256	5.6614	333.10
1981	Chinook_1	0.7320	0.6909	0.5054	132.12	142.49	147.55	21.233	33.354	14.430	228.58	0.6544	4.2040	13.415	13.994	12.882	150.55	0.4935	0.5507	6.2072	30.448	15.524	278.74	0.6923	5.4796	287.49
1982	Chinook_1	0.7273	0.7310	0.5312	131.78	142.69	147	20.713	34.986	13.685	289.95	0.6793	4.6226	13.594	14.246	12.039	183.05	0.5070	0.6380	5.4821	34.981	14.816	361.62	0.7449	6.0541	366.65
1983	Chinook_1	0.7305	0.7289	0.5321	131.66	143.06	148.93	21.490	32.978	13.389	247.00	0.6580	4.6291	13.512	13.762	11.871	149.71	0.4885	0.5725	6.3237	30.807	14.399	309.22	0.7060	6.2695	317.78
1984	Chinook_1	0.7071	0.7111	0.5025	132.5	145.95	151.05	25.301	33.030	13.707	242.59	0.6719	4.2262	17.429	11.792	11.816	127.39	0.5352	0.5742	6.2480	31.801	15.009	317.81	0.6991	5.3955	324.60
1985	Chinook_1	0.7107	0.6718	0.4771	132.31	145.64	149.76	25.278	31.434	13.709	206.96	0.6410	4.3752	16.643	12.372	11.900	139.17	0.4789	0.6653	7.0038	27.523	14.963	249.67	0.6703	5.6011	258.33
1986	Chinook_1	0.7305	0.6886	0.5026	131.67	143.82	149.37	21.723	32.931	14.027	228.09	0.6574	4.3102	13.681	13.944	12.387	140.66	0.4894	0.7406	6.4162	29.808	15.133	283.71	0.7038	5.5452	288.83
1987	Chinook_1	0.7414	0.5869	0.4348	131.49	140.7	142.89	19.292	34.017	15.258	206.85	0.6393	4.3083	11.665	15.790	13.492	166.78	0.4668	0.7809	6.0382	30.017	16.598	234.44	0.6786	5.6332	237.30
1988	Chinook_1	0.7098	0.6564	0.4656	132.39	146.13	151.7	26.653	29.657	13.754	161.03	0.6297	4.1793	17.101	11.816	11.956	116.31	0.4761	0.6308	7.9225	23.485	14.973	190.55	0.6423	5.3309	195.12
1989	Chinook_1	0.7206	0.6738	0.4852	131.77	143.2	147.76	23.198	32.274	13.807	214.58	0.6319	4.4250	14.865	13.509	11.965	158.85	0.4562	0.6629	6.7060	28.552	15.076	252.19	0.6695	5.8975	254.73
1990	Chinook_1	0.7404	0.6044	0.4472	131.56	142.05	145.88	19.862	33.804	15.304	212.03	0.6289	4.5893	12.126	15.462	13.397	158.59	0.4563	0.6464	6.1570	29.461	16.710	247.27	0.6633	6.2401	250.75
1991	Chinook_1	0.7333	0.7109	0.5209	131.43	142.26	147.09	20.564	33.451	13.751	246.81	0.6476	4.1593	12.473	15.173	12.160	180.74	0.4711	0.6099	6.4540	30.379	14.816	291.07	0.6988	5.4728	291.49
1992	Chinook_1	0.7409	0.5749	0.4256	131.68	142.23	145.24	20.655	32.637	15.326	173.35	0.6206	4.2681	12.527	14.862	13.515	133.41	0.4583	0.6875	6.5455	27.151	16.682	200.42	0.6359	5.6074	202.77
1993	Chinook_1	0.6944	0.6789	0.4710	133.14	146.44	149.99	27.353	31.692	13.462	227.66	0.6684	4.1410	19.115	11.118	11.660	138.13	0.5331	0.6677	6.5951	29.503	14.727	287.42	0.6882	5.2957	293.21
1994	Chinook_1	0.7302	0.5717	0.4171	131.89	143.48	146.32	22.377	31.949	14.944	171.04	0.6322	4.2427	14.092	13.488	12.921	129.47	0.4659	0.6324	6.6957	26.784	16.480	197.62	0.6578	5.5665	202.55
1995	Chinook_1	0.7247	0.7129	0.5163	132.14	143.35	149.35	22.769	32.377	13.528	226.07	0.6533	5.3063	14.509	13.057	11.967	141.31	0.4929	0.8771	6.6142	29.692	14.587	280.47	0.6891	6.9494	290.22
1996	Chinook_1	0.7338	0.7279	0.5337	131.46	141.62	146.02	19.371	34.928	13.717	279.72	0.6686	4.5511	12.108	15.587	12.134	192.61	0.5080	1.0368	5.6201	33.878	14.834	336.47	0.7203	5.8211	344.27
1997	Chinook_1	0.7371	0.7530	0.5546	131.31	140.36	143.64	16.947	38.532	13.599	392.24	0.7274	5.2612	10.951	17.359	11.982	271.41	0.5651	1.5776	4.3467	41.560	14.683	473.98	0.8138	6.4135	477.94
1998	Chinook_1	0.7331	0.7156	0.5242	131.5	141.84	146.9	20.016	34.934	13.866	275.34	0.6704	4.4091	12.757	14.667	12.247	174.87	0.5069	0.9011	5.6252	34.424	14.958	341.68	0.7208	5.5932	349.81
1999	Chinook_1	0.7357	0.7212	0.5302	131.52	142.63	148.33	20.157	33.937	13.755	259.59	0.6610	4.7471	12.448	14.938	12.170	166.61	0.4841	0.6291	6.0714	31.828	14.804	319.91	0.7189	6.4858	329.46
2000	Chinook_1	0.7314	0.6152	0.4496	131.62	143.4	146.75	21.148	33.289	14.630	211.84	0.6317	4.2976	13.248	14.602	12.620	155.96	0.4572	0.6881	6.2987	29.506	16.092	247.45	0.6688	5.6060	254.81

Year	Species	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	Mean Travel Time	Mean MigRate	Mean Temp	Mean Flow	Mean FSpill	Mean Gas	UC Travel Time	UCMig Rate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
2001	Chinook_1	0.7191	0.6362	0.4571	132.54	145.19	150.74	25.393	29.481	14.228	135.95	0.6610	4.1868	16.162	11.430	12.549	93.28	0.5344	0.7521	7.6153	23.004	15.406	163.22	0.6661	5.3129	169.75
2002	Chinook_1	0.7187	0.7039	0.5055	131.76	143.96	149.05	22.804	33.171	13.756	253.41	0.6535	4.1427	14.743	13.968	11.888	180.50	0.4747	0.5959	6.4381	30.334	15.011	299.48	0.7106	5.4153	309.77
2003	Chinook_1	0.7289	0.6972	0.5078	131.65	143.45	149.36	21.963	32.127	13.565	228.47	0.6506	4.3075	13.654	13.627	11.987	148.67	0.4783	0.7235	6.6618	28.617	14.642	276.17	0.6966	5.5359	294.05
2004	Chinook_1	0.7290	0.6685	0.4870	131.73	143.75	149.48	22.945	31.233	13.998	189.43	0.6263	4.5004	14.177	13.293	12.310	125.77	0.4681	0.6703	7.1429	26.077	15.146	225.79	0.6424	5.9857	245.61
2005	Chinook_1	0.7345	0.6519	0.4785	132.17	142.25	146.19	21.772	32.110	14.647	186.51	0.6352	4.2240	13.559	13.721	13.047	123.85	0.4853	0.7270	6.6104	27.346	15.781	227.43	0.6477	5.3955	232.79
2006	Chinook_1	0.7178	0.7190	0.5158	131.72	144.16	146.98	21.986	34.620	13.453	295.75	0.6852	4.3393	14.805	14.043	11.755	192.62	0.5169	0.6588	5.5336	34.513	14.614	363.28	0.7524	5.6170	371.52
2007	Chinook_1	0.7389	0.6765	0.4995	131.44	140.89	145.03	19.985	33.324	14.447	218.06	0.6395	4.2266	12.003	15.685	12.875	167.62	0.4685	0.7013	6.3683	29.015	15.538	251.10	0.6789	5.4708	256.72
2008	Chinook_1	0.7040	0.7149	0.5029	132.83	145.51	149.19	24.888	33.740	13.860	280.36	0.7032	4.1332	17.453	11.922	12.050	155.60	0.5591	0.6050	5.8145	33.381	15.092	358.70	0.7570	5.3366	377.42
MO3																										
1929	Chinook_1	0.6892	0.6701	0.4615	133.42	148.37	152.04	28.417	30.631	13.886	155.60	0.7801	3.0718	20.595	9.712	12.026	93.49	0.6250	0.8898	6.1999	27.497	15.224	194.60	0.8888	2.4274	203.64
1930	Chinook_1	0.7256	0.5893	0.4273	132.35	145.28	147.39	22.649	32.099	15.113	134.47	0.7851	3.1143	15.252	12.163	13.185	94.59	0.6127	0.8849	5.8100	28.200	16.563	160.33	0.9125	2.5870	165.20
1931	Chinook_1	0.7256	0.5734	0.4158	132.39	145.01	146.53	22.729	32.000	15.118	131.98	0.7840	2.9656	15.296	12.168	13.226	93.89	0.6130	0.6179	5.8420	28.021	16.578	155.65	0.9089	2.5668	162.15
1932	Chinook_1	0.7201	0.7344	0.5285	131.74	143.15	146.69	21.630	34.010	13.193	255.59	0.7176	3.0862	14.586	13.944	11.556	172.13	0.5189	0.7117	5.3804	33.467	14.294	310.00	0.8333	2.7201	318.64
1933	Chinook_1	0.7282	0.7328	0.5332	131.76	143.42	148.71	20.701	34.149	13.806	248.44	0.7389	3.8934	13.786	13.704	12.179	160.97	0.5449	1.0425	5.2786	33.330	14.927	304.01	0.8622	3.6914	316.32
1934	Chinook_1	0.7459	0.6312	0.4705	131.3	139.8	141.16	16.126	36.852	15.054	250.96	0.7327	3.2609	9.664	18.818	13.351	212.86	0.5389	1.2175	4.8500	35.192	16.354	275.16	0.8590	2.9086	281.40
1935	Chinook_1	0.7230	0.7097	0.5128	132.23	143.85	148.14	22.042	32.960	13.847	203.43	0.7454	2.8423	14.836	12.942	12.168	143.18	0.5462	0.6503	5.5746	30.872	15.022	241.43	0.8755	2.2280	250.70
1936	Chinook_1	0.7155	0.6381	0.4562	132.23	144.71	145.94	22.406	34.565	14.262	238.41	0.7276	2.9358	15.747	13.083	12.355	157.92	0.5282	0.5909	5.0326	34.621	15.732	289.68	0.8482	2.5494	299.59
1937	Chinook_1	0.7021	0.6926	0.4859	132.87	146.13	150.29	26.298	30.819	13.544	160.92	0.7751	2.9604	18.445	10.791	11.847	104.31	0.6030	0.6164	6.2112	27.568	14.721	196.71	0.8961	2.4424	206.58
1938	Chinook_1	0.7251	0.7230	0.5239	131.73	143.54	147.25	20.975	34.242	13.653	243.19	0.7251	2.9800	14.034	14.086	11.972	160.82	0.5284	0.7036	5.2980	33.428	14.801	295.63	0.8426	2.5330	305.00
1939	Chinook_1	0.7018	0.5838	0.4094	132.49	147.3	147.81	25.627	32.344	14.382	168.97	0.7640	2.9101	18.406	11.944	12.353	120.76	0.5682	0.5970	5.5976	29.946	16.009	199.11	0.9007	2.3946	205.42
1940	Chinook_1	0.7322	0.6224	0.4553	131.87	143.7	145.37	20.595	33.935	14.768	189.99	0.7547	3.1626	13.715	13.800	12.949	132.98	0.5526	0.8608	5.2733	31.951	16.139	226.16	0.8932	2.6610	233.27
1941	Chinook_1	0.7355	0.6702	0.4926	132.16	142.68	146.55	20.935	32.732	14.664	158.14	0.7741	3.2839	13.617	13.497	13.141	108.28	0.5905	0.8711	5.7087	29.253	15.756	189.91	0.9054	2.8617	195.85
1942	Chinook_1	0.6983	0.7394	0.5159	132.61	146.96	151.39	26.334	31.247	12.956	197.55	0.7516	2.8239	18.624	10.940	11.320	124.13	0.5736	0.6335	6.0445	29.113	14.068	244.72	0.8652	2.1629	253.28
1943	Chinook_1	0.7228	0.7329	0.5294	131.6	143.93	148.08	21.255	34.147	13.563	246.23	0.7241	3.0231	14.251	14.097	11.865	166.85	0.5250	0.7332	5.3591	33.197	14.713	296.80	0.8444	2.5957	306.91
1944	Chinook_1	0.7079	0.6697	0.4737	132.89	146.26	151.13	25.857	30.480	14.040	132.76	0.7888	3.0964	17.899	10.503	12.331	87.27	0.6299	0.8880	6.3382	26.381	15.261	161.84	0.9066	2.4505	167.78
1945	Chinook_1	0.7092	0.6902	0.4891	132.64	145.61	149.23	24.485	32.719	14.007	196.83	0.7569	3.0913	17.304	11.568	12.253	118.26	0.5831	0.8400	5.5578	31.178	15.236	246.40	0.8692	2.4936	257.45
1946	Chinook_1	0.7218	0.7309	0.5272	131.47	142.08	145.53	20.379	35.248	13.548	279.95	0.7125	3.2840	13.605	14.848	11.829	205.20	0.5241	0.8253	5.1298	35.318	14.709	328.72	0.8189	2.8562	338.23
1947	Chinook_1	0.7360	0.6530	0.4802	131.43	141.81	143.71	18.730	36.042	14.697	252.86	0.7214	3.3337	12.263	15.450	12.925	172.27	0.5262	0.7032	4.8539	35.988	16.007	305.00	0.8360	2.9457	313.11
1948	Chinook_1	0.7187	0.7563	0.5432	131.97	143.65	147.17	20.591	37.708	13.478	385.70	0.7321	3.1285	14.479	14.307	11.727	235.69	0.5504	0.7670	4.4674	41.922	14.678	480.29	0.8415	2.6877	500.05
1949	Chinook_1	0.7301	0.7161	0.5224	131.53	142.2	145.56	19.756	35.444	13.776	278.25	0.7161	3.0742	13.082	14.638	12.172	182.28	0.5316	0.8488	5.0335	35.904	14.889	338.83	0.8184	2.5520	352.38
1950	Chinook_1	0.7100	0.7422	0.5266	132.25	145.14	149.41	23.169	33.928	13.369	267.78	0.7291	3.6263	16.192	12.899	11.633	171.99	0.5391	0.8385	5.3291	33.758	14.556	327.61	0.8445	3.3238	343.35
1951	Chinook_1	0.7349	0.7319	0.5375	131.34	141.14	145.12	18.537	35.499	13.709	270.53	0.7180	3.1966	11.757	16.151	12.141	195.42	0.5280	0.7532	5.1326	34.936	14.767	318.85	0.8283	2.6704	329.19
1952	Chinook_1	0.7163	0.7368	0.5274	131.67	143.5	147.02	21.781	34.641	13.195	277.22	0.7100	2.9417	14.897	13.717	11.552	180.76	0.5235	0.6774	5.2211	35.216	14.314	339.61	0.8115	2.5300	349.23
1953	Chinook_1	0.7221	0.7557	0.5453	132.09	142.93	148.56	21.752	33.319	13.160	245.02	0.7368	3.0144	14.596	12.872	11.806	157.12	0.5530	0.6320	5.4884	32.739	14.064	301.29	0.8492	2.5416	314.08

Year	Species	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	Mean Travel Time	Mean MigRate	Mean Temp	Mean Flow	Mean FSpill	Mean Gas	UC Travel Time	UCMig Rate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1954	Chinook_1	0.7067	0.7602	0.5368	132.25	144.24	148.65	23.433	33.452	12.801	269.89	0.7220	3.3940	16.269	12.777	11.187	186.68	0.5413	0.8576	5.4901	33.301	13.890	323.49	0.8258	2.9253	335.46
1955	Chinook_1	0.7006	0.7523	0.5267	132.85	145.5	150.85	25.436	32.206	13.019	228.48	0.7512	3.4215	18.054	11.284	11.478	145.18	0.5762	0.7890	5.7207	31.127	14.067	281.08	0.8633	2.9072	294.74
1956	Chinook_1	0.7212	0.7580	0.5463	131.51	142.88	146.49	19.718	36.683	13.048	349.45	0.7166	3.3109	13.164	15.510	11.426	234.99	0.5468	1.2354	4.8832	39.042	14.127	422.82	0.8091	2.7347	438.38
1957	Chinook_1	0.7168	0.7456	0.5341	131.66	142.68	145.86	21.132	35.881	12.943	333.37	0.7148	3.1120	14.439	13.948	11.411	207.91	0.5525	0.8662	5.0147	38.502	13.984	413.68	0.7964	2.5671	428.45
1958	Chinook_1	0.7113	0.7265	0.5164	132.28	144.75	148	22.735	35.039	13.456	292.16	0.7158	3.2578	15.985	12.895	11.795	177.58	0.5380	0.6284	5.1024	36.532	14.606	365.41	0.8110	2.9925	380.32
1959	Chinook_1	0.7320	0.7366	0.5388	131.43	142	146.66	19.242	34.980	13.716	263.42	0.7259	4.2461	12.427	15.136	12.094	190.84	0.5308	0.8905	5.1724	34.370	14.820	310.06	0.8461	4.4346	320.25
1960	Chinook_1	0.7122	0.7365	0.5242	131.99	143.72	148.24	23.143	32.855	13.104	229.90	0.7304	3.0086	15.802	13.174	11.378	165.31	0.5274	0.6668	5.6823	31.116	14.275	270.23	0.8590	2.5522	280.20
1961	Chinook_1	0.7325	0.7428	0.5437	131.4	142.1	146.84	19.359	34.892	13.344	282.67	0.7286	3.0925	12.423	15.330	11.855	205.26	0.5424	0.7139	5.2746	34.466	14.341	331.96	0.8403	2.7689	340.74
1962	Chinook_1	0.7190	0.7222	0.5189	131.97	144.15	148.12	22.209	33.793	13.702	229.89	0.7297	3.2118	15.154	13.383	11.968	158.64	0.5274	0.6808	5.4208	32.660	14.881	277.22	0.8541	2.8826	282.12
1963	Chinook_1	0.7248	0.7130	0.5164	132.12	144.47	148.59	21.849	33.220	13.939	207.05	0.7485	2.9792	14.701	12.798	12.337	127.84	0.5702	0.7009	5.5165	31.632	15.034	258.50	0.8605	2.4625	265.50
1964	Chinook_1	0.7039	0.7344	0.5166	132.8	145.39	149.76	24.286	33.984	13.681	268.12	0.7398	3.2697	17.386	12.052	11.872	166.84	0.5687	0.7552	5.2700	34.106	14.935	333.22	0.8425	2.7522	344.31
1965	Chinook_1	0.7260	0.7460	0.5412	131.68	142.68	147.34	20.636	34.576	13.274	264.13	0.7147	3.1141	13.778	13.759	11.684	169.45	0.5204	0.7045	5.1979	34.948	14.362	326.81	0.8249	2.7452	332.12
1966	Chinook_1	0.7161	0.6214	0.4447	132.26	145.45	147.35	23.070	33.147	14.584	192.12	0.7493	2.9479	15.953	12.854	12.584	143.00	0.5436	0.6485	5.5088	30.787	16.091	224.27	0.8880	2.4596	230.49
1967	Chinook_1	0.6982	0.7376	0.5146	132.36	146.63	150.48	24.894	33.806	13.223	285.43	0.7304	3.0587	17.803	12.611	11.450	188.10	0.5524	0.6938	5.4376	33.831	14.428	348.75	0.8338	2.4857	357.73
1968	Chinook_1	0.7264	0.6961	0.5053	132.41	143.4	147.59	21.567	33.167	14.536	197.20	0.7544	3.3189	14.430	13.148	12.969	133.45	0.5790	0.6862	5.5278	30.625	15.662	236.31	0.8701	2.9517	247.39
1969	Chinook_1	0.7315	0.7270	0.5314	131.34	141.48	145.17	18.901	36.258	13.742	297.57	0.7090	3.0784	12.301	15.670	12.144	205.28	0.5271	0.7366	4.9567	37.140	14.833	358.21	0.8076	2.6977	362.88
1970	Chinook_1	0.6961	0.7313	0.5087	133.04	146.78	150.95	26.329	32.058	12.995	230.86	0.7411	2.9329	18.856	10.774	11.526	129.41	0.5802	0.5949	5.8025	31.388	13.992	296.51	0.8336	2.4166	304.08
1971	Chinook_1	0.7192	0.7531	0.5413	131.38	142.16	146.16	20.146	36.531	13.131	334.54	0.7029	3.2516	13.505	14.844	11.466	222.48	0.5365	1.0357	4.9756	39.072	14.262	409.52	0.7857	2.7713	414.97
1972	Chinook_1	0.7365	0.7543	0.5551	131.3	140.91	144.84	17.663	37.899	13.566	354.91	0.7233	3.3720	11.326	17.308	12.029	246.98	0.5569	0.9662	4.6823	40.162	14.589	428.37	0.8144	3.1004	428.19
1973	Chinook_1	0.7165	0.6943	0.4971	132.49	144.32	148.64	23.961	31.059	13.585	164.94	0.7694	3.2289	16.159	11.567	12.049	112.54	0.5926	0.8719	6.1548	27.678	14.669	198.68	0.8915	2.6795	204.93
1974	Chinook_1	0.7331	0.7526	0.5513	131.26	140.5	145.12	17.730	37.610	13.588	340.81	0.7142	3.4907	11.389	16.649	11.926	234.74	0.5427	1.5506	4.6918	39.839	14.709	412.55	0.8078	2.9150	416.40
1975	Chinook_1	0.7079	0.7582	0.5363	132.34	144.02	149.08	23.620	33.491	12.956	262.43	0.7263	3.8817	16.492	12.428	11.390	165.75	0.5428	0.8242	5.4619	33.483	14.012	325.36	0.8332	3.7178	333.71
1976	Chinook_1	0.7106	0.7625	0.5415	131.75	143.42	147.62	22.605	34.215	12.697	283.24	0.7085	3.2861	15.607	13.333	11.082	187.87	0.5253	0.7088	5.3170	34.941	13.786	348.79	0.8064	2.9846	350.30
1977	Chinook_1	0.7231	0.6531	0.4719	132.43	143.41	148	23.747	30.333	14.257	120.88	0.7797	3.3703	15.621	11.715	12.713	92.23	0.6114	1.1006	6.5016	25.132	15.409	138.73	0.8993	2.7962	144.86
1978	Chinook_1	0.7216	0.7232	0.5215	131.59	143.92	147.75	21.764	33.167	13.414	224.40	0.7348	3.1372	14.539	13.737	11.772	159.70	0.5322	0.6702	5.5693	31.344	14.520	265.17	0.8641	2.6881	273.72
1979	Chinook_1	0.7088	0.7085	0.5018	132.31	145.17	148.48	24.487	31.785	13.134	200.36	0.7504	2.9982	16.979	11.710	11.551	130.86	0.5633	0.8080	5.8403	29.871	14.239	245.45	0.8709	2.3353	253.21
1980	Chinook_1	0.7217	0.7425	0.5354	131.61	141.47	145.8	20.704	34.427	13.264	267.58	0.7220	3.1864	13.842	13.614	11.621	189.30	0.5422	0.8423	5.2042	34.648	14.394	321.77	0.8233	2.7691	326.66
1981	Chinook_1	0.7313	0.7115	0.5200	132.19	142.54	146.59	20.338	34.458	14.446	225.56	0.7401	3.1093	13.536	13.860	12.911	148.70	0.5559	0.6786	5.1863	33.421	15.549	275.19	0.8541	2.7278	283.37
1982	Chinook_1	0.7259	0.7421	0.5383	131.82	142.81	147.14	20.350	35.749	13.674	288.28	0.7196	3.3196	13.757	14.096	12.057	181.69	0.5414	0.7957	4.9522	37.122	14.788	360.09	0.8178	2.8696	364.67
1983	Chinook_1	0.7289	0.7479	0.5447	131.69	143.15	148.07	20.808	33.743	13.294	242.07	0.7296	3.4431	13.717	13.535	11.817	146.69	0.5433	0.7489	5.4280	33.131	14.277	303.63	0.8395	3.3049	310.99
1984	Chinook_1	0.7057	0.7302	0.5149	132.55	146.13	150.12	24.517	33.909	13.654	238.84	0.7385	3.0592	17.656	11.625	11.842	124.57	0.5699	0.6668	5.2279	34.368	14.918	313.77	0.8367	2.5554	319.82
1985	Chinook_1	0.7093	0.7014	0.4972	132.33	145.74	149.04	24.196	32.501	13.572	205.97	0.7450	3.2068	16.869	12.245	11.888	138.18	0.5527	0.7952	5.6823	30.625	14.749	248.95	0.8689	2.6700	257.36
1986	Chinook_1	0.7299	0.7100	0.5179	131.69	143.9	148.17	20.814	33.868	13.952	223.65	0.7410	3.1217	13.776	13.819	12.402	138.88	0.5555	0.7365	5.4027	32.513	15.006	278.24	0.8572	2.8322	282.18
1987	Chinook_1	0.7417	0.6059	0.4491	131.52	140.92	142.16	18.439	35.108	15.287	199.09	0.7505	2.9631	11.779	15.594	13.532	159.75	0.5468	0.7195	5.0668	33.028	16.648	225.79	0.8892	2.5600	229.35

Year	Species	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	Mean Travel Time	Mean MigRate	Mean Temp	Mean Flow	Mean FSpill	Mean Gas	UC Travel Time	UCMig Rate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1988	Chinook_1	0.7083	0.6890	0.4877	132.39	146.34	150.24	25.271	30.962	13.606	157.87	0.7688	3.0480	17.363	11.686	11.949	113.77	0.5758	0.7799	6.2654	27.210	14.743	186.92	0.9065	2.4709	191.61
1989	Chinook_1	0.7202	0.7005	0.5041	131.8	143.31	146.73	22.163	33.260	13.728	210.41	0.7388	3.1008	14.990	13.362	11.981	155.30	0.5319	0.7682	5.5372	31.378	14.938	247.41	0.8733	2.6311	250.08
1990	Chinook_1	0.7402	0.6279	0.4644	131.58	142.1	144.74	18.805	35.242	15.295	209.92	0.7395	3.3263	12.172	15.378	13.424	157.13	0.5329	0.8071	5.0463	33.351	16.714	244.93	0.8757	3.2047	248.05
1991	Chinook_1	0.7330	0.7311	0.5355	131.43	142.27	146.65	19.591	34.322	13.714	241.84	0.7244	3.0974	12.520	15.073	12.173	178.79	0.5266	0.7879	5.4262	32.826	14.747	284.71	0.8449	2.7882	283.88
1992	Chinook_1	0.7403	0.5999	0.4438	131.76	142.42	144.23	19.605	34.099	15.329	168.65	0.7624	3.0253	12.689	14.666	13.556	129.26	0.5566	0.8114	5.3269	31.156	16.695	194.92	0.9078	2.5440	197.78
1993	Chinook_1	0.6926	0.7007	0.4849	133.18	146.61	149.49	26.594	32.479	13.372	221.31	0.7470	2.8895	19.320	10.968	11.673	133.99	0.5847	0.5399	5.6233	31.813	14.567	279.85	0.8434	2.4163	284.47
1994	Chinook_1	0.7291	0.5939	0.4327	132.12	143.94	145.22	21.508	33.073	14.895	161.52	0.7668	3.1097	14.393	13.177	12.967	120.58	0.5675	0.7896	5.5170	30.090	16.389	187.52	0.9087	2.6966	192.62
1995	Chinook_1	0.7234	0.7351	0.5314	132.18	143.47	148.23	21.921	33.113	13.429	220.77	0.7405	4.0514	14.743	12.805	11.915	137.98	0.5561	1.0446	5.5228	31.949	14.455	274.08	0.8538	3.8700	283.14
1996	Chinook_1	0.7322	0.7411	0.5422	131.51	141.77	145.7	18.957	35.514	13.705	274.83	0.7149	3.2359	12.294	15.335	12.105	188.35	0.5240	0.8893	5.0160	35.636	14.850	331.23	0.8255	2.9191	338.96
1997	Chinook_1	0.7361	0.7573	0.5570	131.32	140.31	143.81	17.015	39.356	13.588	388.99	0.7206	3.9614	10.973	17.281	11.993	269.03	0.5640	1.5485	4.3930	43.702	14.656	470.62	0.8006	3.4230	474.17
1998	Chinook_1	0.7317	0.7287	0.5328	131.51	142.13	146.2	19.599	35.442	13.859	268.36	0.7143	3.0610	12.914	14.465	12.267	169.07	0.5279	0.6436	5.0471	35.971	14.941	333.90	0.8157	2.7231	341.42
1999	Chinook_1	0.7361	0.7371	0.5421	131.49	142.56	147.21	19.100	34.874	13.717	257.14	0.7234	3.7655	12.225	15.104	12.166	168.18	0.5295	1.3038	5.2282	34.246	14.751	315.40	0.8380	3.5337	323.27
2000	Chinook_1	0.7316	0.6394	0.4674	131.64	143.44	145.47	20.116	34.404	14.571	209.43	0.7427	3.1094	13.305	14.495	12.645	153.34	0.5358	0.7184	5.1991	32.650	16.001	244.94	0.8806	2.8574	252.84
2001	Chinook_1	0.7190	0.6628	0.4761	132.53	145.26	149.12	24.107	30.739	14.140	134.52	0.7841	3.0763	16.192	11.369	12.558	91.57	0.6218	0.9068	6.2908	26.419	15.258	161.72	0.9010	2.4546	168.82
2002	Chinook_1	0.7178	0.7264	0.5210	131.77	144.18	148.24	21.951	33.980	13.661	248.20	0.7292	2.9739	14.927	13.792	11.906	176.82	0.5333	0.7106	5.3892	32.799	14.849	293.65	0.8507	2.4952	302.99
2003	Chinook_1	0.7276	0.7176	0.5217	131.72	143.6	148.16	21.170	32.967	13.464	221.96	0.7409	3.1304	13.905	13.368	11.940	144.61	0.5497	0.8586	5.6082	31.172	14.509	268.13	0.8619	2.5997	285.28
2004	Chinook_1	0.7282	0.6989	0.5086	131.77	143.92	148.11	21.720	32.465	13.910	185.78	0.7578	3.1778	14.328	13.111	12.329	121.79	0.5660	0.8022	5.7568	29.568	14.987	222.10	0.8891	2.7089	242.19
2005	Chinook_1	0.7341	0.6798	0.4987	132.2	142.41	145.61	20.702	33.486	14.622	182.65	0.7598	2.9093	13.671	13.584	13.070	120.46	0.5712	0.6236	5.4216	31.057	15.737	223.40	0.8874	2.3932	228.56
2006	Chinook_1	0.7156	0.7314	0.5230	131.81	144.37	147.5	21.806	35.170	13.381	291.95	0.7153	2.9121	15.087	13.871	11.744	190.72	0.5351	0.6174	5.0642	36.216	14.498	359.35	0.8138	2.3377	366.15
2007	Chinook_1	0.7405	0.7012	0.5188	131.51	141.03	144.51	18.818	34.404	14.424	211.82	0.7401	3.0674	11.891	15.668	12.892	163.31	0.5314	0.7176	5.3065	31.917	15.500	243.62	0.8778	2.8095	248.96
2008	Chinook_1	0.7032	0.7262	0.5102	132.83	145.57	149.21	24.356	34.331	13.804	272.30	0.7349	2.9942	17.525	11.856	12.066	154.15	0.5827	0.6848	5.2031	35.114	14.996	347.37	0.8183	2.4777	363.35
MO4																										
1929	Chinook_1	0.7010	0.6843	0.4790	132.91	146.97	150.4	26.245	30.063	13.786	173.11	0.7900	10.9866	18.485	10.722	12.026	113.66	0.5879	1.1657	5.9727	27.832	15.051	211.01	0.9474	16.7271	219.40
1930	Chinook_1	0.7293	0.6079	0.4427	132.31	144	146.04	21.944	31.124	14.964	153.07	0.7834	9.6472	14.445	12.658	13.110	113.81	0.5825	0.6683	5.7473	28.023	16.334	178.85	0.9356	14.8946	183.64
1931	Chinook_1	0.7300	0.5958	0.4343	132.26	143.72	145.26	21.802	31.203	14.964	157.07	0.7796	9.7843	14.322	12.794	13.150	118.22	0.5767	0.7240	5.7257	28.182	16.335	181.42	0.9310	15.0223	188.12
1932	Chinook_1	0.7187	0.7342	0.5269	131.89	143.37	146.74	21.884	32.631	13.280	253.71	0.7657	13.2205	14.828	13.596	11.645	170.11	0.5351	2.0689	5.2403	32.508	14.387	308.20	0.9397	20.1030	316.97
1933	Chinook_1	0.7284	0.7323	0.5327	131.84	143.56	148.8	20.837	32.498	13.859	248.17	0.7656	12.6721	13.751	13.501	12.286	160.83	0.5488	1.9824	5.2942	31.715	14.945	303.52	0.9256	19.0123	315.84
1934	Chinook_1	0.7446	0.6374	0.4739	131.38	139.89	141.35	16.470	35.066	14.974	250.63	0.7721	14.1099	9.812	18.241	13.320	213.39	0.5495	5.5954	4.8854	33.721	16.213	274.41	0.9486	19.0844	280.20
1935	Chinook_1	0.7229	0.7079	0.5110	132.32	143.97	148.16	22.197	31.570	13.916	203.37	0.7772	11.3878	14.848	12.718	12.278	143.05	0.5528	0.8897	5.5633	29.917	15.068	241.50	0.9496	17.6056	250.74
1936	Chinook_1	0.7155	0.6464	0.4618	132.31	144.77	146.08	22.480	33.097	14.264	238.46	0.7701	12.7208	15.713	12.833	12.357	158.24	0.5397	1.3879	4.9860	33.519	15.707	289.75	0.9448	19.6961	299.40
1937	Chinook_1	0.7099	0.6956	0.4930	132.5	144.81	148.73	24.862	30.102	13.565	174.37	0.7863	10.6431	17.039	11.463	11.878	120.13	0.5774	0.8005	6.0248	27.577	14.735	209.20	0.9472	16.3844	218.27
1938	Chinook_1	0.7240	0.7193	0.5200	131.85	143.82	147.49	21.252	32.747	13.713	240.36	0.7681	12.5922	14.249	13.707	12.005	157.53	0.5426	1.3750	5.2055	32.303	14.890	292.84	0.9380	19.4331	302.57
1939	Chinook_1	0.7020	0.6046	0.4238	132.55	147.17	148.28	25.372	31.399	14.372	186.98	0.7769	11.0270	18.083	12.031	12.324	136.35	0.5492	0.9492	5.5137	29.810	15.953	219.60	0.9508	16.9803	225.58
1940	Chinook_1	0.7311	0.6329	0.4620	131.93	143.71	145.64	20.803	32.568	14.756	197.45	0.7776	11.4395	13.761	13.583	12.937	140.07	0.5470	0.8617	5.2804	31.118	16.094	234.41	0.9558	17.7587	241.14

Year	Species	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	Mean Travel Time	Mean MigRate	Mean Temp	Mean Flow	Mean FSpill	Mean Gas	UC Travel Time	UCMig Rate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1941	Chinook_1	0.7372	0.6770	0.4983	131.88	142.22	145.81	20.442	31.823	14.580	179.03	0.7823	10.7150	13.072	13.832	13.079	127.14	0.5658	0.7831	5.5996	29.252	15.650	212.42	0.9484	16.5568	218.79
1942	Chinook_1	0.7065	0.7432	0.5243	132.46	145.66	149.95	24.813	30.566	12.964	208.26	0.7782	11.7879	17.187	11.568	11.353	138.90	0.5520	0.9428	5.8024	29.209	14.060	252.96	0.9518	18.3472	260.84
1943	Chinook_1	0.7222	0.7318	0.5277	131.68	143.98	148.11	21.340	32.761	13.602	246.69	0.7655	12.6295	14.305	13.832	11.879	167.24	0.5373	1.3022	5.2346	32.271	14.781	297.23	0.9374	19.5737	307.48
1944	Chinook_1	0.7144	0.6784	0.4839	132.57	144.58	148.65	24.379	30.037	13.983	161.21	0.7854	10.2572	16.564	11.230	12.299	115.44	0.5858	1.0311	6.0337	27.206	15.196	191.53	0.9374	15.6056	197.17
1945	Chinook_1	0.7106	0.6909	0.4902	132.69	145.44	149.09	24.331	31.471	14.067	196.65	0.7906	11.9616	17.048	11.628	12.344	119.74	0.5845	1.2812	5.5060	30.375	15.280	245.52	0.9525	18.3165	256.00
1946	Chinook_1	0.7206	0.7300	0.5253	131.58	142.26	145.54	20.574	33.771	13.603	278.83	0.7632	14.4332	13.819	14.415	11.858	203.50	0.5446	4.7991	4.9567	34.278	14.796	327.99	0.9281	20.2920	337.77
1947	Chinook_1	0.7348	0.6608	0.4848	131.53	141.97	143.88	18.982	34.440	14.688	252.83	0.7681	12.9820	12.410	15.024	12.928	172.76	0.5416	1.6860	4.8044	34.748	15.965	304.88	0.9401	19.9509	312.63
1948	Chinook_1	0.7184	0.7552	0.5417	132.02	143.74	147.2	20.776	35.108	13.551	385.37	0.7564	17.2489	14.492	14.074	11.822	236.04	0.5551	5.0793	4.4857	37.905	14.745	479.29	0.8984	24.8836	498.54
1949	Chinook_1	0.7292	0.7181	0.5229	131.62	142.32	145.37	19.875	33.750	13.802	279.37	0.7571	13.5318	13.172	14.310	12.202	182.76	0.5444	2.6547	4.9057	34.295	14.924	340.14	0.9101	20.1937	354.10
1950	Chinook_1	0.7106	0.7414	0.5260	132.33	145.28	149.45	23.221	32.338	13.438	265.94	0.7631	13.1287	16.124	12.693	11.740	170.36	0.5460	1.9059	5.2936	32.249	14.609	325.50	0.9237	19.8569	341.18
1951	Chinook_1	0.7341	0.7315	0.5363	131.43	141.27	144.89	18.633	33.989	13.737	271.40	0.7649	13.6654	11.827	15.789	12.167	195.89	0.5440	3.0915	5.0033	33.794	14.805	319.85	0.9321	20.0805	330.50
1952	Chinook_1	0.7161	0.7380	0.5277	131.75	143.6	146.77	21.723	33.138	13.226	277.43	0.7589	14.0537	14.895	13.457	11.571	180.77	0.5440	3.4706	5.0079	33.969	14.367	339.84	0.9163	20.6854	349.73
1953	Chinook_1	0.7215	0.7556	0.5443	132.22	143.05	148.55	21.836	31.949	13.202	247.19	0.7730	13.0257	14.643	12.650	11.837	159.47	0.5585	2.1417	5.3713	31.728	14.118	303.50	0.9351	19.5759	316.11
1954	Chinook_1	0.7073	0.7603	0.5370	132.32	144.31	148.42	23.301	32.100	12.870	269.82	0.7675	13.9544	16.141	12.646	11.265	186.72	0.5549	3.8329	5.3320	32.241	13.961	323.22	0.9283	20.1248	335.33
1955	Chinook_1	0.7033	0.7512	0.5275	132.68	145.1	150.33	24.927	31.120	13.076	234.00	0.7781	12.4869	17.527	11.432	11.493	151.81	0.5684	1.6231	5.5854	30.511	14.154	286.00	0.9381	19.0051	299.48
1956	Chinook_1	0.7214	0.7592	0.5469	131.6	142.98	146.35	19.728	34.520	13.090	349.45	0.7498	16.0469	13.146	15.175	11.446	234.95	0.5532	5.6916	4.7545	36.171	14.198	422.56	0.8858	22.0273	438.31
1957	Chinook_1	0.7165	0.7525	0.5384	131.7	143	146.15	21.097	33.760	12.998	330.71	0.7515	15.5717	14.437	13.690	11.491	206.65	0.5573	5.2240	4.8272	35.627	14.027	410.38	0.8845	21.6824	424.51
1958	Chinook_1	0.7110	0.7293	0.5177	132.36	144.87	147.74	22.739	33.261	13.487	289.59	0.7579	13.8587	15.988	12.639	11.820	176.15	0.5481	2.3751	4.9471	34.622	14.657	362.15	0.9080	20.8531	376.72
1959	Chinook_1	0.7318	0.7367	0.5383	131.52	142.12	146.71	19.343	33.449	13.761	263.86	0.7644	13.1117	12.424	14.889	12.197	191.18	0.5375	2.1383	5.1203	33.086	14.829	310.39	0.9370	19.6958	320.74
1960	Chinook_1	0.7122	0.7352	0.5229	132.07	143.83	148.39	23.184	31.582	13.182	230.33	0.7684	12.1579	15.782	12.993	11.458	165.35	0.5369	1.2991	5.5894	30.309	14.357	270.77	0.9460	18.6440	281.07
1961	Chinook_1	0.7318	0.7436	0.5433	131.5	142.27	146.79	19.565	33.162	13.414	282.28	0.7611	13.6114	12.539	14.963	11.943	205.13	0.5483	3.4832	5.2111	32.680	14.403	331.35	0.9163	19.5521	339.98
1962	Chinook_1	0.7185	0.7187	0.5156	132.06	144.22	148.11	22.310	32.443	13.754	230.00	0.7700	12.2978	15.194	13.149	11.984	158.89	0.5357	1.2659	5.3275	31.798	14.970	277.14	0.9481	18.9948	282.12
1963	Chinook_1	0.7281	0.7161	0.5206	132.06	143.72	147.68	21.214	32.268	13.963	216.69	0.7789	12.0538	14.064	13.150	12.408	139.78	0.5576	0.9434	5.3607	31.363	15.032	266.95	0.9487	18.8419	273.53
1964	Chinook_1	0.7047	0.7345	0.5169	132.8	145.47	149.83	24.310	32.329	13.752	265.36	0.7702	13.2062	17.291	11.931	11.967	164.33	0.5726	2.1915	5.2363	32.398	14.998	330.01	0.9150	19.8612	341.09
1965	Chinook_1	0.7256	0.7464	0.5408	131.79	142.85	147.36	20.700	33.080	13.338	263.28	0.7616	13.2344	13.837	13.481	11.773	168.62	0.5338	1.5367	5.0482	33.698	14.414	325.70	0.9311	20.5626	331.24
1966	Chinook_1	0.7189	0.6351	0.4559	132.23	144.87	146.87	22.566	32.027	14.493	201.44	0.7738	11.3105	15.347	13.080	12.533	152.66	0.5377	0.8644	5.4517	30.323	15.937	233.41	0.9553	17.4911	239.63
1967	Chinook_1	0.6985	0.7387	0.5152	132.5	146.84	150.54	25.101	32.053	13.298	281.10	0.7640	13.5445	17.909	12.277	11.555	184.34	0.5620	2.8357	5.3839	31.975	14.491	343.96	0.9077	19.9935	352.71
1968	Chinook_1	0.7305	0.7022	0.5122	132.21	142.65	146.71	20.844	32.167	14.458	207.02	0.7783	11.6630	13.618	13.674	12.954	146.57	0.5606	1.3200	5.4545	30.254	15.525	244.52	0.9471	17.7665	254.83
1969	Chinook_1	0.7306	0.7295	0.5322	131.44	141.69	145.04	19.078	34.392	13.775	295.65	0.7539	14.0630	12.465	15.218	12.178	202.98	0.5397	3.4106	4.8133	35.188	14.877	356.36	0.9091	20.5851	361.19
1970	Chinook_1	0.7015	0.7375	0.5166	132.7	146.15	150.08	25.245	31.106	13.013	237.22	0.7779	12.7035	17.869	11.161	11.528	138.56	0.5748	1.4079	5.5497	30.942	14.019	301.28	0.9315	19.7013	308.30
1971	Chinook_1	0.7193	0.7590	0.5451	131.48	142.31	146.12	20.032	34.468	13.173	333.68	0.7474	15.9500	13.487	14.579	11.567	222.08	0.5475	6.1683	4.7227	36.434	14.273	408.30	0.8875	21.8585	413.57
1972	Chinook_1	0.7352	0.7564	0.5553	131.39	141.12	144.89	17.917	35.486	13.620	354.76	0.7512	15.9156	11.478	16.801	12.114	247.43	0.5601	5.4584	4.6293	36.845	14.629	427.80	0.8815	22.1124	427.27
1973	Chinook_1	0.7215	0.7006	0.5047	132.36	143.59	147.85	22.982	30.361	13.633	179.17	0.7817	10.9347	15.211	12.080	12.109	128.84	0.5665	1.1930	5.9685	27.809	14.702	211.94	0.9462	16.5993	217.78
1974	Chinook_1	0.7329	0.7560	0.5533	131.37	140.65	145.02	17.760	35.451	13.607	342.46	0.7518	16.8993	11.363	16.404	12.015	236.86	0.5557	7.9429	4.5901	37.025	14.685	413.84	0.8906	22.3242	417.61

Year	Species	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	Mean Travel Time	Mean MigRate	Mean Temp	Mean Flow	Mean FSpill	Mean Gas	UC Travel Time	UCMig Rate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1975	Chinook_1	0.7077	0.7582	0.5358	132.42	144.12	149.18	23.626	32.041	13.020	262.54	0.7647	13.1840	16.495	12.243	11.422	165.80	0.5498	2.0216	5.3136	32.211	14.104	325.30	0.9235	19.9959	333.75
1976	Chinook_1	0.7111	0.7645	0.5428	131.81	143.56	147.41	22.473	32.705	12.750	281.27	0.7588	14.0654	15.531	13.140	11.159	186.41	0.5398	3.2052	5.1037	33.547	13.830	346.42	0.9199	20.8984	347.89
1977	Chinook_1	0.7263	0.6651	0.4823	132.36	142.49	146.55	22.936	29.625	14.229	143.20	0.7769	9.1348	14.809	12.222	12.710	114.87	0.5791	0.7990	6.3445	25.368	15.340	161.87	0.9217	13.9110	167.32
1978	Chinook_1	0.7213	0.7219	0.5199	131.72	144.14	147.89	21.943	31.809	13.487	222.45	0.7736	12.0510	14.628	13.400	11.874	157.46	0.5419	0.8639	5.5051	30.486	14.584	263.32	0.9528	18.8633	272.05
1979	Chinook_1	0.7091	0.7164	0.5072	132.42	145.29	148.63	24.349	30.795	13.198	207.54	0.7812	11.7916	16.832	11.660	11.620	136.76	0.5627	0.8892	5.6971	29.622	14.289	254.05	0.9492	18.4080	261.72
1980	Chinook_1	0.7213	0.7435	0.5355	131.72	141.74	145.8	20.773	32.982	13.312	266.12	0.7710	13.9836	13.901	13.349	11.698	187.96	0.5585	3.7817	5.0594	33.533	14.423	320.33	0.9324	20.2788	325.16
1981	Chinook_1	0.7306	0.7147	0.5213	132.2	142.25	146.3	20.411	33.109	14.427	231.76	0.7759	12.6349	13.529	13.738	12.948	156.52	0.5573	2.0496	5.1092	32.620	15.489	280.77	0.9432	18.9613	288.46
1982	Chinook_1	0.7261	0.7446	0.5398	131.9	142.87	146.89	20.367	33.925	13.728	287.10	0.7594	14.1462	13.724	13.850	12.159	181.16	0.5482	3.3024	4.8458	35.106	14.817	358.43	0.9116	20.8245	362.78
1983	Chinook_1	0.7282	0.7487	0.5444	131.79	143.32	148.16	20.933	32.295	13.350	242.33	0.7700	12.5765	13.814	13.261	11.895	146.55	0.5516	1.0380	5.3009	31.986	14.324	303.99	0.9337	19.6711	311.47
1984	Chinook_1	0.7061	0.7315	0.5158	132.64	146.16	150.16	24.454	32.517	13.717	241.05	0.7786	13.0625	17.553	11.550	11.938	126.49	0.5768	1.2873	5.1128	33.282	14.969	316.09	0.9315	20.5321	322.24
1985	Chinook_1	0.7093	0.6983	0.4946	132.41	145.8	148.85	24.258	31.155	13.610	206.31	0.7777	11.5604	16.823	12.050	11.910	138.43	0.5601	0.8478	5.6345	29.747	14.812	249.27	0.9444	18.0113	257.84
1986	Chinook_1	0.7296	0.7122	0.5188	131.78	143.64	147.97	20.818	32.488	13.964	226.78	0.7728	12.2849	13.713	13.678	12.409	143.47	0.5560	1.4199	5.3128	31.545	15.028	280.52	0.9371	18.9587	284.19
1987	Chinook_1	0.7395	0.6218	0.4591	131.59	140.96	142.6	18.569	33.821	15.201	215.17	0.7741	11.6683	11.778	15.452	13.489	174.03	0.5452	1.5319	5.0394	32.465	16.492	243.44	0.9516	17.6601	247.02
1988	Chinook_1	0.7133	0.6961	0.4957	132.31	145.4	149.15	24.170	30.269	13.549	178.57	0.7764	10.5732	16.321	12.141	11.898	132.64	0.5518	0.7887	6.0447	27.540	14.688	208.94	0.9478	16.3222	214.03
1989	Chinook_1	0.7196	0.6968	0.5007	131.87	143.41	146.83	22.322	31.877	13.769	210.49	0.7714	11.5454	15.035	13.155	12.003	155.30	0.5388	0.8796	5.4961	30.431	15.005	247.40	0.9492	18.0019	250.34
1990	Chinook_1	0.7396	0.6416	0.4738	131.66	141.65	144.24	18.892	33.859	15.183	219.07	0.7689	11.7287	12.106	15.292	13.379	166.68	0.5306	1.1741	5.0391	32.572	16.522	254.32	0.9520	18.0359	257.24
1991	Chinook_1	0.7322	0.7316	0.5349	131.53	142.42	146.47	19.750	32.845	13.771	242.38	0.7657	12.5058	12.615	14.759	12.269	178.98	0.5394	2.1957	5.3349	31.707	14.788	285.35	0.9375	18.7535	284.71
1992	Chinook_1	0.7396	0.6162	0.4551	131.81	142.04	144.06	19.561	32.873	15.213	188.21	0.7741	10.7554	12.489	14.729	13.495	146.84	0.5447	0.8245	5.3231	30.628	16.502	215.77	0.9492	16.5797	219.03
1993	Chinook_1	0.6956	0.7076	0.4914	132.86	146.27	149.01	25.909	31.456	13.352	229.95	0.7824	12.4195	18.694	11.228	11.640	142.67	0.5829	1.2508	5.4057	31.397	14.561	288.67	0.9346	19.3524	293.36
1994	Chinook_1	0.7306	0.6133	0.4474	132.13	143.52	145.2	21.130	32.098	14.821	181.86	0.7746	10.6444	13.933	13.388	12.930	137.72	0.5471	0.7812	5.4406	29.984	16.244	210.37	0.9469	16.4179	215.86
1995	Chinook_1	0.7244	0.7344	0.5312	132.24	143.44	148.06	21.749	31.912	13.492	222.59	0.7802	12.3137	14.534	12.724	11.988	141.26	0.5604	0.9530	5.4059	31.280	14.515	275.25	0.9499	19.2911	283.89
1996	Chinook_1	0.7314	0.7436	0.5430	131.57	141.85	145.64	19.151	33.849	13.682	274.52	0.7604	13.4681	12.414	14.961	12.137	187.59	0.5378	2.0902	4.9324	34.169	14.780	330.86	0.9278	20.5021	339.13
1997	Chinook_1	0.7362	0.7603	0.5589	131.39	140.37	143.7	16.977	36.537	13.584	391.05	0.7479	18.1078	10.820	17.177	11.990	273.00	0.5709	9.1834	4.3482	39.127	14.654	471.44	0.8625	23.2975	474.60
1998	Chinook_1	0.7311	0.7322	0.5345	131.61	142.18	146.09	19.591	33.958	13.896	271.90	0.7635	13.2179	12.916	14.251	12.359	172.16	0.5457	1.3610	4.8802	34.800	14.947	337.75	0.9242	20.6100	345.32
1999	Chinook_1	0.7346	0.7375	0.5410	131.62	142.87	147.45	19.530	33.199	13.783	255.14	0.7628	12.8130	12.589	14.531	12.279	164.62	0.5393	1.4704	5.1396	32.817	14.795	314.23	0.9280	19.7695	322.71
2000	Chinook_1	0.7300	0.6434	0.4690	131.77	143.71	145.87	20.606	32.746	14.577	206.83	0.7748	11.6698	13.585	13.992	12.658	150.47	0.5425	1.0183	5.2560	31.311	15.976	242.62	0.9545	18.0308	250.45
2001	Chinook_1	0.7234	0.6686	0.4829	132.41	144.07	147.7	23.172	30.010	14.109	155.35	0.7821	10.0594	15.267	11.936	12.535	112.01	0.5876	1.0988	6.1215	26.601	15.229	183.36	0.9269	15.2122	190.08
2002	Chinook_1	0.7152	0.7233	0.5166	132.07	144.55	148.62	22.504	32.356	13.740	244.89	0.7676	12.6071	15.362	13.268	11.946	172.11	0.5472	2.1425	5.3549	31.437	14.969	291.05	0.9344	18.8518	300.66
2003	Chinook_1	0.7284	0.7229	0.5257	131.77	143.06	147.67	20.925	31.949	13.520	231.38	0.7697	12.0771	13.673	13.432	12.019	154.16	0.5454	1.0993	5.4414	30.831	14.549	277.52	0.9386	18.5800	294.77
2004	Chinook_1	0.7287	0.7015	0.5105	131.83	143.43	147.6	21.562	31.435	13.908	195.40	0.7804	11.3779	14.117	13.134	12.324	130.65	0.5563	0.7314	5.6536	29.355	14.992	232.77	0.9543	17.5300	252.74
2005	Chinook_1	0.7346	0.6861	0.5033	132.2	142.29	145.44	20.527	32.293	14.541	195.07	0.7814	11.3600	13.394	13.553	13.013	132.48	0.5603	0.7877	5.3637	30.645	15.634	236.50	0.9520	17.7652	241.74
2006	Chinook_1	0.7150	0.7327	0.5231	131.91	144.56	147.5	21.868	33.463	13.426	290.90	0.7580	14.0876	15.144	13.551	11.774	189.51	0.5458	2.9935	4.9141	34.507	14.569	358.15	0.9117	20.9630	365.22
2007	Chinook_1	0.7368	0.7000	0.5150	131.64	141.29	144.69	19.466	32.918	14.411	215.20	0.7742	11.6233	12.393	15.053	12.886	163.74	0.5433	0.9740	5.2955	31.117	15.484	248.95	0.9530	17.9834	254.99
2008	Chinook_1	0.7023	0.7296	0.5117	133.07	145.68	149.15	24.512	32.650	13.893	272.19	0.7734	13.9455	17.665	11.572	12.168	153.61	0.5938	3.4750	5.0660	33.448	15.089	347.39	0.9050	20.2384	363.51

5513 **Table 4-2. Raw COMPASS data for Upper Columbia spring Steelhead for each of the 80 modeled years by Alternative**

Year	Specis	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	SAR	TotalReturn	PassageBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	UCTravelTime	UCMigRate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
NAA																													
1929	Steelhead	0.666248916	0.632267421	0.420082906	136.36	145.72	151.65	0.014301014	600.7225183	42005.59	23.94157091	26.4358665	13.99201476	166.3359467	0.775805832	9.691797233	14.14921066	20.55641851	12.33746891	98.6544342	0.61981777	2.037271047	7.27105163	22.30390544	15.05918646	209.5929769	0.882057955	13.77533213	219.4393158
1930	Steelhead	0.712967308	0.55750341	0.396383347	135.72	143.33	149.03	0.017082138	677.0669348	39635.96	19.59006698	27.47724043	15.24947821	151.932637	0.766596629	9.518367227	9.472159714	25.14749303	13.34673805	111.9056488	0.58433418	2.427107334	7.591118202	21.14308585	16.46270005	177.4645487	0.892086804	13.20366963	182.6908112
1931	Steelhead	0.713620774	0.547691938	0.389764484	135.64	142.76	148.32	0.01786028	696.0871	38974.03	19.70953019	27.16267787	15.25165424	145.8671473	0.768603154	9.517858187	9.499760568	24.65741456	13.39531784	112.0659241	0.586483845	2.708696938	7.679187	20.80718716	16.45874596	168.3926341	0.895135969	13.04980977	172.1629944
1932	Steelhead	0.737096225	0.683348848	0.502303261	135.48	141.21	146.68	0.018841001	946.324147	50226.85	15.88708223	31.4381677	13.44254354	266.0456665	0.738018397	12.21186514	6.967186421	31.3414316	11.97117825	178.7650574	0.543972299	4.123466873	6.363921016	26.20271368	14.39178276	324.319636	0.861785968	16.26212764	332.2500916
1933	Steelhead	0.732720177	0.666620771	0.487097697	135.51	142.07	148.94	0.01715036	835.3355645	48706.59	16.94489647	30.06588562	13.96810856	244.2289459	0.740083959	11.0784988	7.620649993	29.2026497	12.56655807	157.8198151	0.540554598	2.221878362	6.782396019	24.40085235	14.83907286	292.3617249	0.868396242	15.52876925	310.1208496
1934	Steelhead	0.755555868	0.584945231	0.440739352	135.42	139.56	144.58	0.020779217	915.7596191	44070.94	14.0614596	33.13223363	15.40391134	252.1664825	0.740278889	12.67047021	4.812136382	38.33120302	13.69296455	219.6295837	0.54913058	7.633825493	6.69210349	24.62763003	16.52213891	274.1846008	0.86942485	14.97213769	277.9576416
1935	Steelhead	0.728604005	0.655734277	0.476451452	135.56	142.17	148.45	0.017666009	841.646467	47642.14	17.52596933	29.59107409	14.00331968	216.7183563	0.740591777	9.884119614	8.054477751	28.49260859	12.61131077	150.9014801	0.537154061	1.481090093	6.929287612	23.80931149	14.87994226	256.6369197	0.871747533	14.32162364	268.4041138
1936	Steelhead	0.739398965	0.638674347	0.470931265	135.46	141.02	145.84	0.020318717	956.8083746	47090	15.77655023	31.59009799	14.01704998	262.7528229	0.744238816	12.61262255	6.826883703	32.09139381	12.22638626	183.8270416	0.554455173	5.35094986	6.390983328	25.98713673	15.13846652	314.6864319	0.866269261	16.26391125	321.6843567
1937	Steelhead	0.693029337	0.646021397	0.446474353	135.88	143.99	150.64	0.015347243	685.1716954	44644.61	21.21532558	27.40825692	13.74750551	173.1838664	0.761867088	9.245097649	11.39091042	23.61501647	12.27702713	114.6389847	0.582987019	1.32786659	7.293670282	22.29085171	14.74080515	210.1389338	0.88072441	13.52629677	219.8995514
1938	Steelhead	0.737670054	0.664997513	0.489194644	135.52	141.5	147.6	0.01809395	885.0841979	48916.03	16.10257776	30.87271314	13.87003816	253.5449087	0.735855478	11.47796774	7.024780005	30.46979326	12.28681221	166.0067505	0.534974086	2.926603794	6.527020603	25.45924442	14.86224031	306.8609924	0.863761862	15.72695875	319.5104065
1939	Steelhead	0.718935221	0.594343951	0.426114828	135.54	142.44	147.22	0.018874016	804.1976599	42608.72	18.60987329	28.76502103	14.05104866	188.1709005	0.744894892	9.596116042	8.872346938	27.56703083	11.95338631	143.9221924	0.540690577	1.912691903	7.190128386	22.57274257	15.40090418	217.8930766	0.878573726	13.74942398	221.0480804
1940	Steelhead	0.734537248	0.597387808	0.437591931	135.56	142	147.26	0.018948335	829.1084828	43756.27	17.10760844	29.67758831	14.84078941	204.861263	0.738240819	9.622672804	7.597287029	29.13747302	13.1035984	146.0655823	0.531303808	1.471988845	6.965864226	23.51330272	15.94532235	242.8117956	0.870349338	14.0775671	248.9853668
1941	Steelhead	0.717118652	0.592683247	0.42385017	135.62	142.41	149.26	0.016676536	706.7911115	42382.37	19.22429973	27.56888856	15.01307589	155.7409495	0.767632654	9.375377027	9.188687176	25.07003251	13.63585663	108.6326218	0.590836823	2.128535962	7.506246313	21.46508754	15.97537645	186.2904968	0.888690094	13.20183659	190.9008636
1942	Steelhead	0.696624328	0.686204583	0.476706069	135.88	144.47	150.45	0.015438215	735.9006639	47667.47	20.26621021	28.56490888	13.15611089	211.8618551	0.75419099	9.996490475	10.8436189	25.11101311	11.72654724	130.6556488	0.572223935	1.269269025	6.885605633	24.0041532	14.0560503	263.014979	0.872870535	14.69105522	274.4447937
1943	Steelhead	0.732425905	0.664817012	0.485584891	135.54	142.24	148.47	0.01727234	838.658835	48555.02	16.62929115	30.42930412	13.82936745	243.6681875	0.739531292	11.14815431	7.402001113	29.79753317	12.22018204	161.7753601	0.541861528	2.555113387	6.6817628	24.85380757	14.82806476	291.9827474	0.867534836	15.44693486	306.6471252
1944	Steelhead	0.692560648	0.619214796	0.427658436	136.05	143.96	150.92	0.015302699	654.3896376	42763.02	21.53606313	26.45549948	14.23205802	146.716097	0.775697248	9.384027314	11.38516003	22.17325788	12.80776157	101.3245636	0.608572009	2.22135942	7.625176489	21.05465428	15.16074419	176.2774328	0.89261499	13.14333741	181.5608521
1945	Steelhead	0.712875377	0.64563921	0.458988829	135.61	142.74	148.99	0.017253907	791.8825365	45895.84	18.88072969	28.97907525	14.11456916	217.45837	0.745822423	10.21266678	9.542371064	26.02881466	12.4951416	138.692218	0.554514793	1.683677435	6.801200211	24.27712386	15.16214768	266.2098796	0.868082225	14.72726385	277.750061
1946	Steelhead	0.746836775	0.677463827	0.504558619	135.41	140.05	145.51	0.020143503	1016.287043	50452.35	14.45776622	33.12772414	13.73247776	295.5112508	0.741631071	14.03902035	5.672197431	35.63371207	12.15379429	219.9254242	0.559647739	7.561790276	6.22537531	26.89543219	14.70193768	343.7383118	0.860754877	16.79220613	354.2666626
1947	Steelhead	0.744964978	0.626361382	0.465329573	135.42	140.38	145.5	0.020531673	955.3330171	46529.72	15.1609171	31.98422942	14.71941694	262.5380605	0.740904198	12.26929294	6.213565677	33.17781155	13.05935326	188.3582458	0.548192218	4.778421259	6.394307375	26.00634906	15.75776672	311.8035431	0.866359284	16.02589734	317.5050354
1948	Steelhead	0.742611038	0.702182809	0.520009301	135.49	141.28	146.49	0.019661839	1022.368226	51997.59	14.66448477	33.58220669	13.63674882	390.7264242	0.743290178	17.25152864	6.464741975	33.85511837	12.03846207	227.8420563	0.568057147	6.091303349	5.643071175	29.47553569	14.63319317	483.8569082	0.85223496	23.53525019	512.6174316
1949	Steelhead	0.744351515	0.677248887	0.50271979	135.48	140.69	145.81	0.020320058	1021.460656	50268.59	14.89139766	32.59076187	13.91674417	306.1541555	0.746133791	13.74906799	6.302367806	33.24740849	12.61876469	198.3971039	0.56727699	4.677742434	6.028361276	27.54638459	14.74189663	376.507899	0.862389823	18.20789242	390.5700684
1950	Steelhead	0.722770759	0.687741684	0.495706499	135.58	142.44	148.43	0.017453636	865.1346792	49567.59	17.37160432	30.58757116	13.42645404	263.7301208	0.738720025	11.54313737	8.337103158	29.22668999	11.87698765	168.9808655	0.542085728	2.357712102	6.489256337	25.72170827	14.36151759	320.8257497	0.864751389	16.09433881	338.431366
1951	Steelhead	0.750103468	0.677358072	0.506686368	135.42	140.05	145.57	0.020025027	1014.569391	50665.07	14.37929173	32.91505797	13.86227907	287.8231659	0.739073846	12.83663383	5.528922766	35.38599739	12.54220886	207.2877472	0.550785685	4.94596324	6.289597899	26.57631825	14.67799966	339.2739614	0.861296207	16.49735816	351.9765015
1952	Steelhead	0.740543364	0.698236449	0.515647195	135.43	140.7	145.93	0.019857772	1023.888154	51561.08	15.09567937	32.41711738	13.18844344	299.6526123	0.744816091	14.26039219	6.453210533	32.88962056	11.72987804	198.2387756	0.565909162	6.562682915	6.078793496	27.44274037	14.06925424	365.7752533	0.860752583	17.92998521	375.8179016
1953	Steelhead	0.734576333	0.693194344	0.507798046	135.5	141.37	148.18	0.017830833	905.3899708	50776.65	16.63399231	30.38185972	13.30651786	248.0320943	0.735656202	11.07519728	7.411855996	29.60509601	12.21180916	166.7906982	0.533402422	2.424000263	6.67178224	24.94769405	14.01295296	296.9039866	0.864496261	15.43658185	310.9993591
1954	Steelhead	0.729490723	0.708437519	0.515371876	135.49	141.5	147.07	0.018706238	964.0036934	51533.81	16.38925648	31.71572393	12.95467701	285.2212545	0.743060284	12.88842958	7.554796487	31.66423541	11.56308937	196.9823151	0.559644973	4.66118269	6.279444978	26.61688678	13.81271966	343.4774984	0.861970445	16.87468672	355.2219238
1955	Steelhead	0.709205968	0.688318955	0.486811177	135.72	143.11	149.85	0.016021997	779.9166948	48677.87	19.06611964	29.08780487	13.2350249	228.7616842	0.746622709	10.57972223	9.73714307	26.24669308	11.88707733	145.3152985	0.557777947	1.944566059	6.791189596	24.37391244	14.11847146	279.4420344	0.867562602	15.05012321	294.6135559
1956	Steelhead	0.74844683	0.713732071	0.53271609	135.46	140.75	145.73	0.019755248	1052.31976	53267.86	13.89974128	34.03014084	13.09352055	362.8167023	0.744417984	15.82348483	5.573331356	36.03033372	11.65209522	233.572049	0.567038482	5.681108475	5.7574002	28.91502422	13.95146116	441.3125203	0.859438052	21.02361981	464.1685181
1957	Steelhead	0.744365904	0.715599753	0.531197684	135.44	140.72	145.49	0.0205625	1092.201238	53116.17	14.428065	33.69119802	12.99275983	359.8696381	0.7477514	16.30565929	6.187798023	34.62020133	11.6796711	226.4468109	0.575346902	6.565492439	5.670682713	29.24885769	13.81447887	446.3062592	0.856992374	21.45654885	460.427002
1958	Steelhead	0.733352701	0.69177116	0.505911614	135.48	141.56	146.62	0.019576429	990.3335727	50588.06	15.9092247	32.07442629	13.45667667	314.8161397	0.745835731	14.24291404	7.366668791	31.21507938	11.98668194	189.3307922	0.567290959	4.840084171	5.984901503	27.91649053	14.36022536	392.3819631	0.859577258	18.90443039	410.5793762
1959	Steelhead	0.744646119	0.673604762	0.500212215	135.49	140.95	147.22	0.018642573	932.4599332	50017.77	15.36921795	31.68690933	13.86961689	261.4118439	0.732405035	10.97367713	6.238519013	33.06669761	12.49571857	190.0324097	0.53066619	2.249644303	6.578459665	25.34639618	14.71855021	305.6978455	0.861995459	15.36486673	316.8063354
1960	Steelhead	0.730655004	0.676055122	0.492598982	135.44	141.34	147.84	0.017828333	878.1619908	49256.54	16.92900029	30.34303422	13.3918122	234.5595032	0.736026979	10.35754917	7.588912457	30.1944046	11.8746603	169.90448	0.531782421	1.8515697	6.791248366	24.3433883	14.36820316	275.7124888	0.867789576	14.79480195	284.7590942
1961	Steelhead	0.74654482	0.685040456	0.5100016	135.44	140.99	147.06	0.018997066	968.7855625	50996.59	15.02251542	32.27606772	13.56913064	291.5760244	0.735669068	12.30050139	6.048351496	34.00762584	12.38577251	205.8944733	0.54170962	3.439746809	6.415529191	26.10434819	14.33914709	341.3759816	0.859413574	16.46914307	355.7980347
1962	Steelhead	0.734421648	0.659951047	0.483344034	135.53	141.9	147.99	0.017968466	868.4337457	48330.99	16.6584665	30.55207672	13.90308266	238.0409363	0.731628131	10.70274658	7.393145502	30.21356915	12.28575306	164.8475983	0.523556596	2.393145943	6.719407707	24.81836828	14.91213926	283.2463582	0.862816095	14.9259998	291.6112061
1963	Steelhead	0.714088011	0.658082999	0.468631004	135.82	143.48	149.28	0.016745895	784.713653	46860.06	18.52612872	29.19498054	14.10080185	221.4302226	0.753467398	10.51615612	9.243633389	26.28655648	12.72538567	133.7639908	0.573910916	1.81755271	6.74550207	24.60004713	14.95943069	277.0294189	0.869964321	15.07423353	286.8693542
1964	Steelhead	0.715701109	0.674571348	0.481457802	135.6	142.78	148.88	0.017110936	823.7656326	48142.64	18.12771751	30.28090159	13.82090918	264.1196696	0.744364583	11.70799286	9.137843281	28.11753494	12.16997166	162.21633	0.557743865	2.309331584	6.452831566	25.78973595	14.86825275	325.7921499	0.863920073	16.53990587	339.7792664
1965	Steelhead	0.740742843	0.689425026	0.509276549	135.49	141.29	147.48	0.018342422	934.0727992	50924.18	15.72777589	31.51204198	13.51626504	270.7516581	0.735489469	11.70628781	6.833944857	31.33243897	12.28103123	173.0768646	0.537252504	2.419916654	6.338687375	26.38578421	14.31542985	332.4185944	0.861928453	16.37687	340.9032288
1966	Steelhead	0.722297357	0.596193749	0.429439861	135.53	142.56	148.15	0.018100662	777.2652309	42941.26	18.38596508	28.95373494	14.58438428	194.2996755	0.742262882	9.300566832	8.668662339	27.86695974	12.57125607	147.7276306	0.534958345	1.241725397	7.179853812	22.68588019	15.8440574	223.7308375	0.877761245	13.71176879	229.9367371
1967	Steelhead	0.716601542	0.696951339	0.498057264	135.55	142.76	148.21	0.017833908	888.168947	49802.26	17.75172155	30.86524554	13.04438121	285.3639201	0.739859201	12.47166975	8.85402143	29.38409998	11.34992867	184.9039673	0.550485298	3.310203886	6.349435627	26.31765867	14.06985029	347.1437225	0.860198547	16.98835031	359.9823303
1968	Steelhead	0.717476293	0.624905863	0.447116698	135.68	142.67	149.21	0.016766155	749.5909655	44708.58	18.64182104	28.95535338	14.84329338	212.1714788	0.752712393	10.11497456	9.178485602	26.603014	13.42808495	142.3723511	0.568615952	1.869601822	6.934652492	23.64610375	15.82747587	253.7744166	0.87369592	14.39422313	267.215271
1969	Steelhead	0.74946985	0.682027808	0.509748482	135.42	140.16	145.48	0.020424357	1041.056208	50971.31	14.18635455	33.49927283	13.89615892	317.5819977	0.741047438	14.01916742	5.640974939	35.60191184	12.588661	216.5906097	0.560364085	5.416078758	5.982673094	27.87772591	14.72244851	384.2317149	0.857490927	18.14254888	389.8065491
1970	Steelhead	0.698704029	0.697985689	0.486337844	135.78	143.71	149.46	0.016512421	803.0092494	48630.62	19.74756846	29.20174264	12.99672432	251.3176081	0.754606779	11.70356545	10.75035226	24.87695068	11.75407143	141.7185944	0.584741449	2.602104211	6.452884957	25.87150343	13.79245313	320.7624359	0.863439649	16.28995919	331.5187073

Year	Specis	lnRivSurvUC	lnRivSurvLCol	lnRivSurv	MedDayRIS	MedDayConfl	MedDayBON	SAR	TotalReturn	PassageBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	UCTravelTime	UCMigRate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1971	Steelhead	0.747726792	0.710216644	0.529582271	135.4	139.77	145.28	0.020357062	1077.998668	52954.53	13.84393035	34.09446881	13.13077087	340.2588694	0.744369744	15.9513381	5.427406564	36.71049958	11.67762737	236.0802246	0.573044446	8.313017178	5.847414091	28.51026337	14.00046984	409.0449219	0.856573512	19.61240594	413.5070496
1972	Steelhead	0.755069095	0.702467048	0.528947226	135.39	139.73	144.88	0.020803411	1100.312978	52890.99	13.31399186	35.19468264	13.70050265	370.9874644	0.748230791	16.08858128	5.064956054	39.11563255	12.42215767	254.769754	0.579711235	6.273313332	5.682971701	29.22424097	14.5097092	446.9917094	0.856005132	21.28941536	451.8663635
1973	Steelhead	0.703740018	0.645799712	0.453219025	135.82	142.94	149.54	0.016416294	743.9667382	45318.8	20.25903304	27.27444674	13.78501803	166.3693212	0.763113411	9.087489748	10.33070934	23.75139959	12.56663551	115.4567963	0.582859665	1.280885839	7.391823083	21.90573875	14.60673189	201.3665517	0.883812924	13.35904026	205.3805695
1974	Steelhead	0.754960759	0.694014903	0.522508276	135.4	139.46	145.48	0.01985354	1037.29051	52247.13	13.32982135	34.66225889	13.72484811	334.0091929	0.747666125	16.2336297	4.80408068	39.0782354	12.37538986	248.4130005	0.578480691	10.05655012	5.960028008	27.92063974	14.55406125	389.7421621	0.85863482	18.9741203	393.3178711
1975	Steelhead	0.724037028	0.696123073	0.502626784	135.52	141.59	148.06	0.017760563	892.63578	50259.43	17.25529625	30.70452404	13.22479432	264.45672	0.740508552	11.90583836	8.275148332	29.4441377	11.8523819	171.4280396	0.548068798	3.073636532	6.432547852	25.85863083	14.12095658	324.2441559	0.864576687	16.44610008	332.3302917
1976	Steelhead	0.735963028	0.715458813	0.525097957	135.41	140.54	145.96	0.019724302	1035.650693	52506.33	15.42325316	32.43096204	12.83476823	302.5502848	0.742518206	13.91327359	6.825590581	32.78399816	11.44304523	204.3439575	0.561678591	5.705833817	6.034915537	27.5552897	13.69591379	371.2175293	0.859122396	18.0855484	371.2779236
1977	Steelhead	0.710912428	0.597260368	0.42342644	135.66	142.57	150.2	0.015838834	670.6154303	42339.95	20.16204751	26.71868545	14.54302254	134.3990855	0.775392571	9.504193322	9.694614559	24.23308933	13.3081562	107.3831848	0.598270401	3.281215811	7.93844831	20.03269968	15.46480831	151.3925807	0.901488384	12.53849856	156.6748962
1978	Steelhead	0.732922383	0.673840391	0.492509176	135.49	141.86	147.73	0.018076836	890.2397001	49247.54	16.81588978	30.17957303	13.45775515	227.8380066	0.73650882	10.20794172	7.457956344	29.92905627	11.93985653	163.6359436	0.530047408	1.776420832	6.806488767	24.18409994	14.37095372	269.5780741	0.869096617	14.68859943	277.1608276
1979	Steelhead	0.72089254	0.678863169	0.488035562	135.58	142.36	148.01	0.017970724	876.9799362	48800.48	17.96768662	29.53585026	13.18731937	224.7703054	0.741126523	10.32960835	8.644420475	27.71768236	11.81786098	149.3082123	0.541710985	1.758878517	6.771137014	24.42483744	14.06360865	274.0510813	0.868273109	14.82953342	282.6932983
1980	Steelhead	0.744713142	0.68924943	0.511876731	135.41	139.84	145.75	0.019876501	1017.364382	51184.28	14.82847346	32.32722448	13.48024305	282.7295695	0.745208583	13.57353312	5.966717243	33.76528481	12.19416332	212.0459198	0.564959931	7.107971382	6.299535796	26.47294773	14.31686989	330.8216858	0.862710287	16.57098707	334.6767578
1981	Steelhead	0.733694456	0.638690736	0.467309712	135.54	141.95	148.11	0.017939367	838.2723496	46728.09	16.69970819	30.41980318	14.76949387	242.327183	0.742454346	10.9727573	7.51813978	29.48509475	13.38607063	159.6325623	0.550138479	2.400975251	6.644774809	24.99501457	15.71691799	292.1136627	0.866184215	15.2484266	305.5116882
1982	Steelhead	0.739645065	0.688237635	0.507646235	135.5	141.17	146.76	0.019276811	978.5165528	50761.33	15.43971208	32.291341	13.81149419	303.1015798	0.739511215	13.34367552	6.798196137	32.32462638	12.48287449	193.855069	0.553836486	4.317320538	6.088740692	27.48155227	14.63798491	373.1160736	0.856855869	17.73592575	382.2354126
1983	Steelhead	0.729696053	0.688905634	0.501303291	135.6	142.18	148.59	0.017297363	867.0635355	50126.92	16.77759874	30.40378252	13.5382726	258.6691966	0.738984304	11.51198795	7.754656315	28.66982705	12.32794056	152.7498627	0.545691404	2.181530356	6.474699318	25.75899362	14.31016159	322.7564952	0.860907425	16.22451663	335.8362427
1984	Steelhead	0.700096032	0.671206573	0.468610703	135.91	144.16	150.03	0.015887315	744.4481274	46858.02	19.40159194	29.32825941	13.85539773	241.1227615	0.75501778	11.33712269	10.45581654	24.92446069	12.198386	124.8184753	0.589323971	1.978726029	6.412124053	26.03159967	14.91681019	315.2753245	0.861064424	16.30584717	323.6141968
1985	Steelhead	0.713998028	0.661532928	0.471028672	135.63	143.12	148.6	0.017336258	816.5313585	47099.63	18.60381129	29.50124029	13.65960013	224.3678624	0.746017811	10.31732532	9.296080172	27.44344139	12.13073616	146.2446991	0.553204688	1.610909081	6.763174742	24.48447225	14.60965316	274.124855	0.870183945	14.84425481	285.157196
1986	Steelhead	0.723132266	0.655011167	0.472351465	135.63	142.88	149.15	0.016984868	802.2287923	47231.97	17.64920327	29.60920992	14.16568921	232.9644709	0.746655674	10.81040356	8.418704152	27.42010958	12.81711941	139.5157013	0.559644091	1.775468516	6.688439697	24.74680611	15.01760658	290.2160645	0.866742174	15.51822178	298.473938
1987	Steelhead	0.748833448	0.56489706	0.421846129	135.42	139.83	144.87	0.020697813	873.0695751	42181.73	15.4582967	31.13864022	15.53203526	214.5740835	0.742606234	10.63393593	5.891608685	33.93097645	13.77324429	187.3819122	0.541656119	4.007687378	7.017732695	23.22080626	16.6917909	235.8832677	0.877088298	14.0199585	234.6411133
1988	Steelhead	0.711636167	0.653366038	0.463674457	135.6	142.82	149.01	0.016872578	782.2849523	46364.28	19.46020782	28.5087453	13.61303603	188.8932302	0.744362799	9.231730433	9.707812816	26.61285111	12.08130875	138.2659302	0.541377127	1.208559239	7.212058321	22.64930325	14.55791442	222.6292852	0.875389208	13.58396165	228.153183
1989	Steelhead	0.737465391	0.646518925	0.475468883	135.47	140.89	146.91	0.018576965	883.2155982	47543.59	16.47464682	30.2756181	13.89769929	216.13361	0.737760556	9.898717554	6.983544171	30.82462861	12.30478687	166.9889038	0.531554779	1.825783563	6.939640939	23.67829954	14.90485541	251.0706202	0.871519725	14.23936749	250.9316864
1990	Steelhead	0.74271721	0.571718389	0.423452742	135.53	141.66	147.73	0.018263849	773.3339343	42342.33	16.3176685	30.20555994	15.65222518	214.9676849	0.740011982	9.933166941	6.792673707	30.65183899	13.77896481	158.2018433	0.53609561	1.713493419	6.990459085	23.46302235	16.88228385	248.6991755	0.873397748	14.24313863	255.6394196
1991	Steelhead	0.741465344	0.675874637	0.499754183	135.51	141.31	147.05	0.018837916	941.3653062	49971.84	15.67342669	31.53141744	13.84889488	261.9426666	0.734438916	11.29796646	6.591616184	32.21652364	12.53615265	185.1005768	0.538080281	2.793658686	6.53121081	25.64834345	14.65371593	313.5745494	0.859342734	15.53390813	316.2115479
1992	Steelhead	0.740296022	0.553460323	0.408592902	135.52	141.34	146.85	0.019299141	788.4986401	40856.67	17.02403109	29.36696915	15.58924688	180.3924489	0.744413035	9.336532839	7.166963309	29.75047913	13.76831512	146.7739136	0.535394609	1.920115876	7.318487942	22.16191474	16.7962354	203.795077	0.882519722	13.29239301	204.3605652
1993	Steelhead	0.711867954	0.683067449	0.484910944	135.49	141.71	146.8	0.019193115	930.6334752	48487.88	18.27118358	29.97206633	13.08033695	257.5848226	0.752253222	11.79028829	9.35330084	27.13217271	11.45578976	166.2277435	0.579184666	2.892774487	6.365229264	26.00848796	14.08430147	322.7818247	0.863853246	16.50569455	324.4167175
1994	Steelhead	0.73414348	0.573883272	0.42014921	135.51	141.56	146.81	0.019258625	809.0993273	42012.31	17.45854771	28.96427624	14.97540194	180.5240631	0.747157137	9.095048233	7.600394994	28.63895764	13.18076019	142.7506775	0.542861655	1.193370473	7.314294457	22.13915028	16.13982089	206.3678284	0.882608046	13.42053048	208.6901245
1995	Steelhead	0.726384147	0.67933852	0.492097747	135.59	141.92	148.35	0.017623551	867.1934255	49206.51	17.43239768	29.99157521	13.61644745	234.3488973	0.741769242	10.5237715	8.232925177	28.33702459	12.4109108	150.6513641	0.546948296	1.710015988	6.653371677	24.98243827	14.40143394	287.8851929	0.865792751	15.16698861	297.2565308
1996	Steelhead	0.744245083	0.669429629	0.496844079	135.55	141.33	147.16	0.018309423	909.6293629	49680.94	15.08532096	32.03790281	14.15435359	279.6063812	0.740021197	12.55151273	6.281830579	32.52441571	12.82732506	180.9137268	0.552849376	3.856386805	6.252364606	26.66382287	15.07842382	341.5516357	0.861230403	16.83287557	353.0840759
1997	Steelhead	0.760483612	0.707377996	0.536464853	135.4	139.35	144.12	0.021111276	1132.468403	53642.82	12.46113482	36.35499859	13.74813251	403.4879883	0.755024906	18.8533082	4.491389483	41.14611194	12.44778156	279.3284363	0.599222374	10.04135885	5.398307234	30.49034392	14.55184078	486.9496053	0.853931854	23.68729607	491.192627
1998	Steelhead	0.740447515	0.674416088	0.497991259	135.47	140.83	146.78	0.019276639	959.8966223	49795.85	15.50757509	31.69088349	13.97433834	274.4852488	0.743556531	12.69255851	6.676479638	31.64731716	12.63062363	180.6594238	0.560794088	4.609864998	6.276448354	26.56537204	14.82384936	335.8836263	0.860963891	16.73822498	341.9326782
1999	Steelhead	0.738233713	0.675910559	0.497602132	135.59	141.81	148.03	0.017533749	872.4227171	49756.77	15.97482575	30.95872325	13.88457203	261.1365662	0.737424429	11.68087662	6.909820855	30.57375096	12.54228783	165.58078	0.540794647	2.802422762	6.516095534	25.56713274	14.6976072	318.1344147	0.862936278	16.05271022	332.9150085
2000	Steelhead	0.734213906	0.605082231	0.443033012	135.59	142.28	147.57	0.018283506	809.9633498	44300.22	16.93964633	29.73903253	14.73917707	209.8125153	0.739902893	9.892542521	7.461895704	29.13911329	12.94886303	148.0243439	0.535933542	1.749626732	6.934362322	23.65387757	15.85745017	248.5967433	0.870942483	14.24679629	258.4888
2001	Steelhead	0.702725543	0.618149133	0.433188623	135.77	143.44	149.74	0.016286421	705.4619653	43315.96	20.52967623	26.9934339	14.29820518	153.391834	0.769532138	9.605354619	10.44398811	23.58207364	12.92070332	108.8316025	0.594678485	2.708949733	7.554488987	21.28611074	15.18336582	183.2958196	0.889284899	13.16601467	189.16362
2002	Steelhead	0.733191198	0.664001563	0.485496085	135.53	142.19	148.24	0.017827159	865.4417306	48546.25	16.47920929	30.86556806	13.89682897	255.1195821	0.736979501	11.19476825	7.312524498	30.85666287	12.27488289	176.7440399	0.536532992	2.532357645	6.620640531	25.06767622	14.90851323	301.2319997	0.866304368	15.50660038	315.4120178
2003	Steelhead	0.725317063	0.669062751	0.483942476	135.67	142.79	149.21	0.016958224	820.6247414	48390.96	17.39748399	29.70241642	13.66075687	237.7915426	0.747588833	10.85170264	8.068681091	28.24107839	12.45128212	149.0857605	0.559439045	1.837171936	6.780530274	24.36315571	14.45616611	287.2476196	0.870516678	15.31826695	310.5326233
2004	Steelhead	0.726213938	0.644129114	0.466483454	135.52	142.35	148.66	0.017364678	809.9786861	46645.19	17.89483909	28.9273192	14.07253888	201.1300385	0.744534126	9.601276807	8.256919742	27.41801361	12.7149292	133.8473816	0.54685162	1.292749488	7.094523802	23.05838667	14.93765577	238.8176219	0.871843378	13.985437	260.3546143
2005	Steelhead	0.732803627	0.615340529	0.449678277	135.54	141.38	147.25	0.018458558	829.9879596	44964.94	17.31192802	29.44249565	14.94094168	200.6633687	0.746787597	9.688236487	7.847697109	28.29373587	13.5517601	137.1949249	0.549029368	1.356610334	6.925359637	23.56728991	15.89717817	244.7387009	0.87508134	14.26232076	247.3686066
2006	Steelhead	0.731123171	0.691980619	0.504526417	135.58	142.16	146.94	0.018996848	958.3763436	50449.23	15.92244461	32.10744535	13.45480989	308.675764	0.746006746	13.67149355	7.398377359	31.45398806	11.98796997	191.1772308	0.568564257	3.870939493	5.966487676	27.79925169	14.35037804	386.5618744	0.860577593	18.76284234	396.2957764
2007	Steelhead	0.746332594	0.628360347	0.467671137	135.44	140.31	146.31	0.019193024	897.540073	46763.87	15.63898605	31.05649573	14.77553743	224.5373128	0.738409704	9.83577439	6.260590702	32.76359573	13.37373009	178.1436707	0.531794938	1.65247798	6.832475722	23.95456783	15.71054188	257.5560786	0.873882343	14.23920449	260.1829529
2008	Steelhead	0.705830925	0.678172825	0.477353015	135.72	143.34	148.55	0.017497794	835.2080044	47732.19	18.66747867	30.51365758	13.94597454	290.8063471	0.755968128	13.16134582	10.05093446	26.95382785	12.33570099	162.9210327	0.592887744	3.35564723	6.078479245	27.35242778	14.98115238	371.8114065	0.861926297	18.05101299	390.7287292
		0.729151602	0.657511926																										
MO1-RESSIM																													
1929	Steelhead	0.659139727	0.626518894	0.411821528	136.39	146.23	152.21	0.013868946	571.1123953	41179.22	24.73661673	26.14081832	14.1279761	160.2684687	0.809595617	10.21229115	14.90145603	19.85939254	12.48327999	92.66375427	0.665872037	2.155863857	7.31681636	22.11414872	15.21645387	203.231603	0.92736272	14.65212313	213.1295929
1930	Steelhead	0.697315121	0.542012601	0.376908884	135.87	144.37	149.93	0.016181183	609.8423972	37688.37	21.09600341	26.64969103	15.41967093	138.6163457	0.797796074	9.495779125	10.87390101	23.07500311	13.44041004	98.09326782	0.640895319	2.410476565	7.702157184	20.72532709	16.71613741	164.3624369	0.920924236	13.2776444	169.7453918
1931	Steelhead	0.702595353	0.535956999	0.375520386	135.73	143.67	149.04	0.017079171	641.3168991	37549.65	20.73427038	26.66286251	15.38902639	135.9938726	0.808264209	9.977377224	10.44575045	23.45146993	13.46089954	101.2812012	0.639092076	2.813406086	7.762963325	20.50696072	16.66597827	158.77742	0.94894584	13.86925832	162.9610901
1932	Steelhead	0.735879592	0.683574971	0.501640515	135.48	141.24	146.73	0.018787001	942.3640264	50160.43	15.99710557	31.35165457	13.45901915	264.0314911	0.745898749	11.64651801	7.066834003	31.14136637	11.96476784	176.7681702	0.556461126	2.991874123	6.37515749	26.14383583	14.42889849	322.3898112	0.871322304	16.09029174	330.2741394
1933	Steelhead	0.728978858	0.667003662	0.484888842	135.52	142.42	149.32	0.016821926	815.6215215	48485.62	17.25296843	29.86118534	13.97300154	240.8104279	0.762916322	11.12008001	7.907184422	28.68957384	12.55737114	153.1962158	0.574239728	1.923069382	6.805420727	24.30037056	14.85896556	289.6455231	0.897177011	15.86670144	307.561676

Year	Specis	lnRivSurvUC	lnRivSurvLCol	lnRivSurv	MedDayRIS	MedDayConfl	MedDayBON	SAR	TotalReturn	PassageBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	UCTravelTime	UCMigRate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1934	Steelhead	0.755961491	0.584063921	0.440311522	135.41	139.54	144.54	0.020846178	917.8182273	44028.13	14.02913758	33.20454009	15.46854877	252.2846741	0.749399929	12.07905579	4.783104181	38.53490013	13.8103632	219.510495	0.565447277	6.471635818	6.688456044	24.6425	16.5629975	274.4423625	0.878594498	14.75685867	278.3503418
1935	Steelhead	0.725776747	0.655997054	0.474792735	135.58	142.42	148.69	0.017429305	827.4770009	47476.19	17.77610436	29.43452466	13.98925184	214.0510366	0.763643233	9.98213555	8.289106876	28.09272096	12.57679672	147.5612274	0.572376838	1.222186661	6.945953429	23.73847667	14.88241847	254.4031067	0.899480502	14.75189535	266.2869263
1936	Steelhead	0.735383102	0.626681982	0.459579071	135.49	141.43	146.26	0.019905256	914.7456437	45954.98	16.40077031	30.94654396	14.23432617	247.5729533	0.752269701	11.48415869	7.358368576	30.66472581	12.38963375	169.003421	0.567176148	3.522229338	6.48832728	25.51744167	15.41957029	299.2981618	0.875791341	15.68370636	306.183075
1937	Steelhead	0.680777989	0.64071867	0.434981549	136.05	144.67	151.42	0.014603338	635.175967	43495.26	22.46517119	26.77470224	13.78661607	160.3292582	0.802569193	10.00158608	12.52996606	22.19301442	12.29934597	102.8879318	0.641802505	2.021155334	7.409043148	21.84123793	14.80095323	196.5726573	0.931932062	14.33760619	206.0719604
1938	Steelhead	0.735073024	0.664672376	0.487233906	135.54	141.71	147.84	0.017844087	869.3644621	48720.03	16.34452452	30.73418458	13.88410829	249.9189311	0.747993579	11.17104643	7.246473312	30.15270905	12.25903587	161.3380676	0.554839292	2.405498552	6.548958674	25.35891035	14.90878916	303.8532104	0.877267222	15.58980664	316.7480164
1939	Steelhead	0.71053912	0.584188781	0.413942676	135.59	143.04	147.77	0.018296256	757.3080221	41391.42	19.52441205	28.26697769	14.22788537	178.6041728	0.778840085	9.822449168	9.725209355	26.33704166	12.11343822	133.5536835	0.584020326	1.58852241	7.256462932	22.30190405	15.61421537	208.7181218	0.925922235	14.45001419	212.2031097
1940	Steelhead	0.729226085	0.591871132	0.430416029	135.58	142.36	147.54	0.018686657	804.2522085	43038.85	17.61455916	29.24175038	14.90479221	198.4115184	0.762096134	9.502646705	8.062871277	28.02375657	13.11498852	139.080722	0.568556702	1.241550601	7.010143325	23.32001986	16.05770079	236.6725464	0.897894263	14.0791285	243.0126648
1941	Steelhead	0.719140105	0.599118956	0.429660376	135.65	142.36	149.2	0.01671407	718.0902645	42963.22	18.98658477	27.92050823	15.02990246	164.4294317	0.793486157	10.00096847	9.054767698	25.66282667	13.68185692	113.9947937	0.617165321	2.121410608	7.402357772	21.85118721	15.9755791	196.863884	0.931839516	14.29544767	202.4499817
1942	Steelhead	0.681359664	0.68344909	0.464387707	136.17	145.24	151.27	0.014549292	675.6082983	46435.82	21.96917784	27.99338697	13.25075912	206.1176498	0.775358505	10.12412298	12.54414755	23.39914366	11.78355579	122.0077972	0.611649683	1.647056603	6.894549921	23.93026081	14.1910154	259.2985509	0.891154051	14.64186986	271.2261963
1943	Steelhead	0.731920995	0.665448606	0.485711	135.54	142.25	148.51	0.017203364	835.5295605	48567.8	16.65770008	30.39503737	13.81996937	242.9339518	0.754689189	11.02452982	7.428226024	29.70478777	12.17456322	161.2504395	0.564183924	2.006418085	6.684240609	24.84219898	14.84562778	291.1949565	0.886744499	15.68965292	305.7077332
1944	Steelhead	0.680636163	0.615106462	0.417506225	136.21	144.7	151.66	0.014618036	610.2715634	41747.85	22.71233638	25.98500735	14.23422559	138.8846822	0.800926485	9.330326398	12.49799266	21.00201146	12.72571545	93.29890137	0.65243752	2.156852055	7.692898721	20.80690448	15.21889035	168.3666738	0.917974333	13.14553603	173.8861237
1945	Steelhead	0.700937986	0.637571768	0.445663896	135.72	143.7	149.99	0.016251671	724.2300195	44563.42	20.12001558	28.23644948	14.22874419	198.9455729	0.780059477	10.24054069	10.64316753	24.48729778	12.6306303	120.8039581	0.610068831	1.484483314	6.944912776	23.64765347	15.28912385	247.2746989	0.904934873	15.11680508	258.5808716
1946	Steelhead	0.745669371	0.677611812	0.503879972	135.41	140.07	145.56	0.020102297	1012.845975	50384.59	14.56957929	32.98032273	13.74361382	292.8631927	0.746000705	13.30073748	5.770509988	35.26046411	12.1187233	217.3389374	0.567264396	6.158595943	6.239914611	26.82683068	14.74786599	341.1187592	0.86610653	16.52507599	351.6068726
1947	Steelhead	0.743696212	0.623547432	0.462449971	135.43	140.51	145.6	0.020443163	945.3292582	46241.83	15.2569845	31.86143771	14.73530057	260.1961639	0.74330807	11.40544136	6.29557845	32.88798448	13.02330704	185.902298	0.555157608	2.897181463	6.409061506	25.93328384	15.8139631	309.4586334	0.867767711	15.84611233	315.2470703
1948	Steelhead	0.741338484	0.703873924	0.520368326	135.49	141.44	146.71	0.019396263	1009.253536	52033.4	14.80351968	33.42873604	13.68170376	386.2576711	0.747066686	16.54497941	6.582189351	33.51555134	12.0972393	222.0373474	0.575957555	5.210715675	5.665855631	29.36195396	14.68409761	480.006724	0.856156091	22.8041927	509.1902466
1949	Steelhead	0.744018318	0.678588291	0.503488244	135.48	140.82	145.97	0.020152019	1014.562041	50345.43	14.92257887	32.51923955	13.86098995	302.9714681	0.748748881	13.42468328	6.310760021	33.13142786	12.47693367	196.1838379	0.574088693	4.276851368	6.051430613	27.46121814	14.73292081	372.5466258	0.863959372	17.94868724	386.5704651
1950	Steelhead	0.721115399	0.685231212	0.492765894	135.6	142.59	148.63	0.017274496	851.1740383	49273.45	17.59540373	30.4291751	13.53086192	259.5818817	0.750676612	11.23950686	8.541627049	28.84996111	11.98163528	164.633548	0.561874703	2.008624244	6.510371462	25.61962691	14.48646005	316.7729034	0.87767149	15.87712391	334.4163208
1951	Steelhead	0.749075434	0.678786568	0.507059194	135.42	140.06	145.59	0.020021259	1015.12648	50702.43	14.45859043	32.82705943	13.81072566	287.3078674	0.744957849	12.3910898	5.605614334	35.13842802	12.41092281	206.5448944	0.563828263	3.940781355	6.292807028	26.55619092	14.6726621	338.9727834	0.865512222	16.43459272	351.677948
1952	Steelhead	0.739601703	0.695957744	0.513311032	135.44	140.81	146.07	0.019703046	1011.310644	51327.63	15.26743808	32.26095457	13.27368018	294.907014	0.747887922	13.707619	6.603711337	32.51056634	11.74411755	193.4240784	0.573310953	5.692974186	6.102265194	27.34446024	14.20897325	361.0460256	0.861809442	17.59233665	371.1176453
1953	Steelhead	0.731046157	0.694438447	0.506264539	135.51	141.6	148.47	0.017603458	891.143015	50623.18	16.97683172	30.17060549	13.25989106	245.7713938	0.755719091	11.07188155	7.744686514	29.00605368	12.0940733	163.0154449	0.564423937	2.040528154	6.683691725	24.89810024	14.00853491	295.3660177	0.888235052	15.7625947	309.9591675
1954	Steelhead	0.726626625	0.707180706	0.512437371	135.5	141.55	147.16	0.01861025	953.5949587	51240.31	16.68677327	31.47625614	13.03121974	283.297641	0.750771422	12.62438984	7.852842391	30.94192975	11.59326839	194.5464233	0.573437887	4.292617416	6.28116253	26.59574912	13.93154033	342.0055288	0.869991849	16.68941315	353.788208
1955	Steelhead	0.703947312	0.687839971	0.482865201	135.76	143.34	150.16	0.015697026	757.9054537	48283.38	19.62620649	28.84262117	13.25773195	225.3658808	0.771314859	10.72172373	10.2834886	25.56353945	11.87989464	140.8413895	0.595586392	1.688720703	6.807484493	24.30216022	14.16974767	276.6317266	0.897071878	15.53551141	292.148407
1956	Steelhead	0.747019817	0.712525837	0.530801856	135.45	140.72	145.77	0.019709015	1046.084734	53076.46	14.03164904	33.83810543	13.18262208	356.0410197	0.746172652	15.02287742	5.678385377	35.57629226	11.66764774	227.9602325	0.573325825	5.033572626	5.786572263	28.78856139	14.09737047	433.9434102	0.859913141	19.86585951	456.481842
1957	Steelhead	0.740964678	0.714431517	0.527907254	135.4	140.36	145.32	0.02073014	1094.288736	52787.33	14.63010326	33.51464807	13.08073457	352.5451569	0.751279177	16.06809855	6.360183537	34.25545301	11.72039337	222.8880798	0.586683914	7.11355238	5.701813638	29.09570871	13.94774961	436.5216726	0.858294149	20.50478506	449.8237305
1958	Steelhead	0.731544248	0.690168424	0.503494545	135.49	141.64	146.78	0.019394206	976.4230088	50346.12	16.11090481	31.86719697	13.53305473	310.1675741	0.752532924	13.88613036	7.550737411	30.67155286	11.99621887	184.9497131	0.582372305	4.605852509	6.004656538	27.82822918	14.48998213	387.6550802	0.863956064	18.40146955	405.7329407
1959	Steelhead	0.744223924	0.675093055	0.501033172	135.49	141.05	147.34	0.018524394	928.0702681	50099.9	15.43478796	31.60555216	13.84851723	260.0742757	0.747702416	10.88944625	6.294395894	32.86720169	12.45721016	188.3616241	0.55540041	1.838074422	6.588491201	25.30558652	14.71043142	304.4941508	0.879435927	15.59630481	315.7140503
1960	Steelhead	0.729282772	0.676434071	0.491949536	135.45	141.39	147.94	0.017738641	872.5938983	49191.7	17.0824355	30.24464535	13.40546042	233.0194295	0.751762554	10.21911643	7.736031502	29.9284266	11.86431484	168.0932617	0.556049529	1.614935684	6.798701704	24.30661518	14.4034907	274.3752136	0.88666295	14.75697033	283.4373169
1961	Steelhead	0.743268421	0.686611584	0.508927825	135.48	141.24	147.34	0.018789593	956.1911101	50889.4	15.39983255	31.92922899	13.52529564	289.1388041	0.750693846	12.09713896	6.412391275	33.01964791	12.28653297	200.2838135	0.566932797	2.92461915	6.431082621	26.03594083	14.32833385	340.4584045	0.875094901	16.50154805	355.9012451
1962	Steelhead	0.729714066	0.658601459	0.479263648	135.53	142.26	148.4	0.01756017	841.5381307	47923.12	17.11808841	30.20149343	13.93118051	232.028656	0.750978166	10.44067843	7.815690219	29.33389429	12.2673254	157.6110779	0.553890142	1.925964093	6.759512201	24.64197578	14.97775523	277.9008484	0.884914617	14.88246091	286.6026611
1963	Steelhead	0.70933055	0.657794414	0.465304571	135.88	143.8	149.59	0.01647782	766.6696473	46527.37	18.98727114	28.96373869	14.10169417	218.8796641	0.769853548	10.52057514	9.6981287	25.628132	12.71083336	130.5312576	0.601908854	1.602049017	6.753941819	24.55087977	14.97704585	275.0732676	0.886831572	15.3233641	284.8558655
1964	Steelhead	0.71110406	0.674886545	0.478588801	135.65	142.99	149.14	0.016851657	806.4481722	47855.72	18.59543051	30.01959358	13.88448645	263.0920369	0.758171581	11.62106614	9.616386265	27.27573762	12.25769081	158.9229279	0.581860951	2.185267448	6.444135457	25.81446058	14.93564288	326.2991791	0.877358764	16.47409519	340.7065735
1965	Steelhead	0.738003715	0.690422053	0.508127169	135.51	141.52	147.76	0.018105994	919.9534422	50809.33	15.99494931	31.26097593	13.46818816	267.2988413	0.742396462	11.4845528	7.080958098	30.67846684	12.1683939	169.0131714	0.551187131	2.085583282	6.360464871	26.28559036	14.30414502	329.2629801	0.867260635	16.31213498	337.9237671
1966	Steelhead	0.72117879	0.59060315	0.424754133	135.54	142.6	148.15	0.018095774	768.5767603	42472.72	18.51455949	28.86516895	14.71610629	192.540095	0.761789366	9.501446684	8.795490026	27.61693567	12.68706665	145.7337341	0.564541894	1.603210664	7.182978123	22.65792174	16.01157951	222.1905289	0.901523461	13.76406153	228.3727264
1967	Steelhead	0.713322258	0.696475776	0.495439781	135.57	142.99	148.49	0.017569929	870.4256878	49540.65	18.12008713	30.60240645	13.08956801	278.8666504	0.751903382	12.17374713	9.187134564	28.75397771	11.42172909	178.6747894	0.571876901	2.73257761	6.386289045	26.1682435	14.11005211	340.5239817	0.87218976	16.93001151	353.1629333
1968	Steelhead	0.71465741	0.625603501	0.44585691	135.75	142.85	149.44	0.016506075	735.8865461	44582.77	18.95615335	28.7623317	14.90543613	208.8628316	0.770644265	9.943788091	9.472752899	26.12203411	13.57371845	138.0315765	0.597578371	1.647607732	6.955831781	23.55200047	15.8506964	251.0898666	0.893641055	14.27402965	264.7608643
1969	Steelhead	0.748087212	0.683637899	0.510009201	135.42	140.28	145.61	0.020319463	1036.23956	50997.39	14.34414002	33.31916126	13.85043596	314.3655019	0.744655377	13.76314292	5.782444954	35.13903209	12.46267242	213.1752106	0.568316048	5.118418074	6.000035584	27.80192962	14.72313356	381.2165476	0.859661808	17.93888664	386.8091736
1970	Steelhead	0.689415652	0.694747378	0.477646135	136.08	144.3	150.06	0.015845012	756.7847036	47761.7	20.70511483	28.82657082	13.08634313	244.7512792	0.767272969	11.26754196	11.68955478	23.84179561	11.78772106	133.4431549	0.607130978	1.893470407	6.475501671	25.74953621	13.93064181	315.5870921	0.875563512	16.08873693	326.3772583
1971	Steelhead	0.74723643	0.709558933	0.528744912	135.4	139.78	145.31	0.020340658	1075.429293	52870.92	13.89651656	34.02268064	13.23051389	338.6826202	0.745591878	15.29499954	5.478145346	36.50386174	11.77122993	234.2005188	0.579584771	7.297385502	5.850420669	28.49062739	14.12173573	407.7100728	0.85453862	19.12252649	412.2297974
1972	Steelhead	0.754475365	0.705223515	0.530605142	135.39	139.78	144.96	0.020732552	1100.003672	53056.84	13.37037076	35.09483121	13.67525024	368.7238454	0.751519153	15.41667436	5.10882023	38.88378216	12.36317902	253.3161377	0.589449647	5.749497128	5.695882291	29.16357022	14.50655699	444.3198853	0.856414795	20.25219647	449.0969238
1973	Steelhead	0.705645777	0.65383039	0.460097607	135.86	142.85	149.36	0.016532361	760.5997062	46006.72	19.9827954	27.74876542	13.69415156	179.2484594	0.786033464	10.00230029	10.19350949	24.54755381	12.42810726	124.7001511	0.608683559	1.763862395	7.251718804	22.43987201	14.53553836	216.6160685	0.920366287	14.49332166	221.6179352
1974	Steelhead	0.753415137	0.695544891	0.522587981	135.4	139.63	145.73	0.019706592	1029.770913	52255.15	13.50422466	34.37977588	13.71388117	329.5584249	0.749327427	15.4927715	4.950850368	38.37770129	12.33893719	242.8484253	0.582181025	8.857205677	5.988810539	27.78590334	14.56229321	385.7797038	0.860571921	18.5150911	389.7504272

Year	Specis	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	SAR	TotalReturn	PassageBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	UCTravelTime	UCMigRate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1975	Steelhead	0.723940655	0.69592761	0.502418769	135.53	141.68	148.25	0.017569394	882.6619389	50238.61	17.29453312	30.67354338	13.22305965	260.8339528	0.750587648	11.41659011	8.28496471	29.50456319	11.81695175	167.9441833	0.565068257	2.01003859	6.46275574	25.72223378	14.14494228	320.2902934	0.875229607	16.32923913	328.4494019
1976	Steelhead	0.735116126	0.714112657	0.523506645	135.42	140.61	146.07	0.019591632	1025.567261	52347.21	15.54195012	32.28476717	12.91067257	297.7660899	0.745738036	13.29586832	6.920988381	32.45598261	11.47464523	200.037323	0.569758934	4.857338476	6.060012117	27.44386779	13.81005367	366.169342	0.860425095	17.58575551	366.1081848
1977	Steelhead	0.701173877	0.595300195	0.416254938	135.77	143.17	150.98	0.01511831	629.267162	41622.85	21.13912655	26.11245104	14.57763309	124.3103658	0.81220937	9.796126032	10.56580177	22.77907869	13.39992752	96.21108551	0.648652804	3.25969491	8.048148036	19.68627029	15.47257217	141.5754801	0.949948857	13.25398016	147.4373016
1978	Steelhead	0.733263964	0.672637043	0.49185843	135.5	141.8	147.68	0.018175473	893.9164842	49182.57	16.76559794	30.23062833	13.54115206	228.7969106	0.751054306	10.12085869	7.422049612	30.01078253	12.02319489	164.7418213	0.554044777	1.609491348	6.792441517	24.23999352	14.47251622	270.3425954	0.885666341	14.67761238	277.9974365
1979	Steelhead	0.716203475	0.674206276	0.481534907	135.58	142.58	148.29	0.017724535	853.4413427	48150.28	18.48992988	29.06446994	13.2768933	215.3370926	0.763586886	10.3685926	9.104765654	26.61805679	11.86119785	141.2717438	0.577083516	1.562415624	6.836362451	24.1266138	14.19620069	264.0232875	0.893697202	15.13386273	272.0703735
1980	Steelhead	0.742607282	0.690404534	0.51128449	135.42	139.99	145.98	0.019676299	1005.952346	51125.08	15.02084301	32.10217082	13.43637174	277.4212321	0.749493296	12.79549173	6.123152882	33.27484802	12.08875427	206.5235748	0.570193323	5.634774494	6.336745128	26.30517038	14.30876176	325.5943298	0.870267212	16.30209096	329.4769897
1981	Steelhead	0.731314162	0.639184069	0.466153331	135.57	142.16	148.35	0.017705669	825.3053295	46612.49	16.95422973	30.21778151	14.82651227	238.5808431	0.760664932	10.82559754	7.749398559	28.98775437	13.52991676	154.538028	0.581978992	1.983442688	6.669192299	24.89170638	15.73038149	289.143987	0.884458164	15.35635654	302.8158264
1982	Steelhead	0.737908899	0.690154564	0.507865151	135.52	141.34	146.94	0.019104649	970.1950407	50783.19	15.58169113	32.11504694	13.78378874	299.4672882	0.747443687	12.96844392	6.921873599	31.89169574	12.42909718	190.375589	0.569066772	3.834523535	6.107728794	27.39414664	14.62689654	369.7085215	0.864280164	17.41625261	378.5730896
1983	Steelhead	0.726473264	0.690814703	0.500472533	135.63	142.41	148.83	0.017044184	852.956261	50043.83	17.05711751	30.20725998	13.48657602	255.1877258	0.756859813	11.28131866	8.017829031	28.155668	12.21772118	149.2297546	0.574825504	1.596666479	6.492444471	25.68089587	14.29078722	319.5974223	0.880802761	16.30057089	332.4447632
1984	Steelhead	0.69583197	0.671078649	0.465667497	135.99	144.34	150.25	0.015707047	731.3742865	46563.45	19.88609932	29.20207501	13.92570972	239.7854416	0.767456534	11.14911809	10.94894049	24.49705053	12.29502869	121.6519623	0.609475446	1.593897247	6.405852899	26.04641992	14.98973672	315.1598155	0.874638865	16.31892141	323.7921448
1985	Steelhead	0.709873976	0.657256047	0.46528007	135.68	143.37	148.89	0.017000423	790.9412858	46524.8	19.03785613	29.20508402	13.74034074	218.4542786	0.764781734	10.22580787	9.697623342	26.71900774	12.14514694	140.492981	0.584824336	1.271317136	6.798558682	24.31627897	14.7444191	268.2384364	0.889916897	15.05992508	279.1360779
1986	Steelhead	0.717637318	0.65632512	0.469702679	135.66	143.25	149.48	0.016664787	782.6982156	46967.19	18.08171935	29.45200386	14.12713299	233.9940379	0.765042679	10.86157145	8.862797588	26.90372012	12.70685253	137.7142487	0.591265616	1.696283555	6.678690761	24.76392236	15.02519162	292.6868846	0.885796547	15.67964546	301.7268066
1987	Steelhead	0.747820581	0.557271667	0.415588691	135.43	140.06	145.17	0.020438777	849.3542455	41556.02	15.79176158	30.64439564	15.64163462	202.1183757	0.769634501	10.29887017	6.107631505	32.9934706	13.92180824	175.3839661	0.57231639	2.722377729	7.136979133	22.74680569	16.79149342	222.9511719	0.917878519	14.39505569	221.6410828
1988	Steelhead	0.701494193	0.639325839	0.447244207	135.7	143.53	149.82	0.016043964	717.5078894	44721.36	20.43960604	27.59229247	13.73958276	165.1197225	0.779054051	9.397430364	10.45201007	24.90367587	12.13502598	118.9304535	0.600218099	1.888688493	7.452152014	21.72892757	14.74950695	195.8474782	0.91130057	13.39119705	200.2751465
1989	Steelhead	0.736432873	0.646132408	0.474519516	135.48	140.97	147.04	0.018465497	876.1638093	47448.7	16.61142357	30.14874241	13.90758743	214.0924876	0.760996112	10.05565242	7.106978416	30.50082847	12.27701874	164.5399689	0.561670601	1.418253696	6.954004452	23.61987964	14.94503419	249.1176402	0.904241651	14.81932314	249.1729889
1990	Steelhead	0.74072429	0.568282001	0.419777984	135.54	141.86	147.95	0.01812583	760.8302767	41974.92	16.54796779	29.97363983	15.75924447	210.8787282	0.760562567	9.961048675	6.99199152	30.10112236	13.93418026	152.992334	0.568900195	1.704111409	7.023113877	23.3237363	16.97267056	245.1293106	0.896733026	14.32539042	252.431015
1991	Steelhead	0.740522148	0.676872743	0.49985549	135.51	141.39	147.13	0.01876521	937.9257118	49982.16	15.74758144	31.50403069	13.82052212	260.3703857	0.745525141	10.99984498	6.655204028	32.18565748	12.48533764	183.8967285	0.558854726	2.193667459	6.541957244	25.60367115	14.64191564	311.8215892	0.86983041	15.49924978	314.3146057
1992	Steelhead	0.736544405	0.54662826	0.401504205	135.54	141.68	147.23	0.019003743	762.9575383	40147.75	17.48427443	28.90300688	15.71676184	171.7614136	0.769943072	9.844071325	7.554618031	28.6646377	13.93050938	137.448645	0.576286435	2.9368536	7.393821597	21.87675613	16.91829459	195.5027186	0.910941521	13.4131248	196.324295
1993	Steelhead	0.708676739	0.682855146	0.482586481	135.5	141.83	146.95	0.019005766	917.1321531	48255.47	18.59683076	29.69958237	13.08470828	252.8544617	0.760628814	11.4346348	9.651768029	26.45344438	11.429245	161.800766	0.595681712	2.141694283	6.393825933	25.87746185	14.10973565	318.0155436	0.871447752	16.45768118	319.4374695
1994	Steelhead	0.723063025	0.5581925	0.402493675	135.54	142.46	147.62	0.018408206	740.8717416	40246.82	18.60919869	28.03929608	15.12649097	162.1389191	0.777600157	9.261930116	8.589506716	26.53498443	13.25218601	124.3155151	0.594181588	1.711952829	7.482076317	21.51167665	16.36615276	187.7415746	0.913554182	13.40010826	190.3322144
1995	Steelhead	0.723253381	0.680483446	0.490802556	135.61	142.15	148.62	0.017391177	853.5057486	49076.94	17.72822282	29.76843517	13.5657608	231.1767766	0.75850865	10.54691474	8.509960949	27.75943559	12.29454556	147.1356812	0.574446118	1.492329192	6.673694119	24.88917543	14.38775889	284.9125315	0.884159466	15.45041227	294.349823
1996	Steelhead	0.744451269	0.671357124	0.498412889	135.55	141.3	147.15	0.018339909	914.0205362	49837.79	15.10324872	32.00024304	14.17181498	278.0722076	0.746570926	11.8805961	6.290042639	32.45574281	12.87051105	179.508252	0.562551942	2.451585579	6.262383997	26.62359818	15.07900127	339.9108124	0.869830618	16.63397209	351.4550781
1997	Steelhead	0.759406136	0.710728329	0.538242177	135.4	139.41	144.21	0.021123832	1136.896912	53820.58	12.59387761	36.14788214	13.70563189	401.4917257	0.755872125	18.08695113	4.617053866	40.5523534	12.31982517	276.6596191	0.60516018	9.349642372	5.406578556	30.45461244	14.56077115	485.2970327	0.850854923	22.59066248	489.7820129
1998	Steelhead	0.740836237	0.677845622	0.500786255	135.46	140.9	146.83	0.019214487	962.1710279	50075.29	15.38906737	31.92944976	13.93649508	277.7684652	0.744834144	12.31148656	6.582476825	32.16710253	12.57862549	181.7385437	0.561592835	3.771466732	6.251634091	26.73183386	14.79480251	339.9185537	0.865928411	16.590048	346.9322815
1999	Steelhead	0.735093697	0.676487099	0.495908214	135.6	142.03	148.27	0.017439675	864.788139	49587.4	16.33948207	30.67140852	13.88670432	257.4612701	0.753630874	11.352882	7.25646466	29.79079403	12.52907791	160.3992889	0.56540533	1.87913537	6.536237225	25.47814568	14.71827666	315.3353119	0.882385125	16.16549087	330.4488831
2000	Steelhead	0.735535896	0.60446057	0.443374636	135.55	142.21	147.43	0.018423072	816.776405	44334.43	16.81892711	29.85983244	14.73296127	211.0633657	0.755958539	9.810965625	7.348065734	29.48462222	12.90702133	150.4062592	0.559067982	1.539961648	6.926344007	23.68033663	15.88602861	249.0982615	0.89222	14.28555822	258.6538391
2001	Steelhead	0.691926697	0.61405737	0.42370806	135.91	144.12	150.4	0.015634708	662.410386	42367.94	21.57179771	26.47305553	14.29405759	144.5669769	0.80675674	10.14044511	11.41106933	22.31710768	12.830793	100.4423141	0.64506861	2.918530941	7.633594334	20.99426634	15.23573621	174.1691895	0.939139952	14.05438439	179.9941559
2002	Steelhead	0.728385148	0.663256295	0.481772424	135.57	142.56	148.66	0.017417076	839.0486429	48173.91	16.91203304	30.62556175	13.91706753	250.9996307	0.753385993	10.90100255	7.726997942	30.22179438	12.24972115	170.5753418	0.564837512	1.984663725	6.641771212	24.96643412	14.96546857	298.3860016	0.88292099	15.44216959	312.9885254
2003	Steelhead	0.725144319	0.670605359	0.484942646	135.6	142.76	149.19	0.017014988	825.075835	48491.12	17.46432751	29.68426447	13.61166973	236.6982605	0.763641847	10.73805265	8.126192719	28.22311871	12.35122948	148.1019592	0.580529633	1.324148357	6.790206417	24.32914424	14.43837945	286.0451609	0.892931541	15.57473397	309.2570801
2004	Steelhead	0.71779921	0.641321834	0.459068435	135.53	142.84	149.18	0.016834151	772.7506676	45903.75	18.6565191	28.38930889	14.06343816	191.1302317	0.771085958	9.576274824	8.939836055	26.16240555	12.62471485	124.1845535	0.591294035	1.388940954	7.176739395	22.721942	14.98012845	228.6651408	0.89996922	13.94358381	249.9843597
2005	Steelhead	0.728076222	0.613922077	0.445747102	135.57	141.66	147.65	0.018127059	807.9562088	44571.83	17.80074234	29.05610674	14.98580392	194.2392944	0.77275511	10.00900312	8.294251919	27.32737336	13.61872635	129.9978165	0.587964329	1.356930757	6.970183164	23.37846283	15.93389432	238.7089513	0.90649574	14.8735528	241.4833679
2006	Steelhead	0.730813167	0.69141219	0.503898173	135.58	142.15	146.95	0.019006302	957.6597231	50386.43	15.96404731	32.11192106	13.51814721	308.0143545	0.750454232	13.3795637	7.442422599	31.44561553	11.98275051	190.1699921	0.579053229	3.586425924	5.965329707	27.80362826	14.46603584	386.0380656	0.863058011	18.38729095	395.9468994
2007	Steelhead	0.745279063	0.62849952	0.467114498	135.43	140.37	146.41	0.019071836	890.8124445	46708.27	15.77587421	30.89702132	14.80014935	221.9814484	0.756333424	9.933449884	6.37959522	32.36695105	13.40953159	175.1934479	0.556937072	1.321246517	6.851321578	23.87599724	15.72940445	255.3024597	0.897301505	14.65815838	257.960144
2008	Steelhead	0.701042373	0.678530036	0.474364105	135.92	143.58	148.81	0.017215714	816.5991456	47433.36	19.1597359	30.23324884	14.00049032	288.9249883	0.764834165	12.942815	10.55146107	26.07444636	12.41264153	159.3759521	0.611252278	3.086007261	6.072131395	27.36305946	15.04022868	371.441452	0.867916574	17.84662104	390.2695618
	Steelhead	0.725529156	0.655939192																										
MO2-RESSIM																													
1929	Steelhead	0.66493007	0.608083123	0.403771864	136.28	145.8	151.62	0.014403936	581.5560545	40374.8	23.82176759	27.52906393	14.00878328	164.787707	0.731212376	4.124074493	14.38221052	21.13742754	12.36644897	96.91950226	0.593636113	0.546806997	7.073190585	23.42977049	15.08794832	208.0885722	0.792092721	5.494961053	218.0890961

Year	Specis	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	SAR	TotalReturn	PassageBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	UCTravelTime	UCMigRate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1930	Steelhead	0.701735457	0.530319939	0.371628514	135.74	144	149.51	0.016595997	616.7239962	37161.01	20.36093049	28.0099369	15.29977932	141.1355331	0.721551086	4.107474045	10.51846302	24.53792252	13.36850834	100.7247391	0.569558659	0.483364183	7.474458709	21.81903429	16.56464275	166.9607112	0.790191034	5.538528626	172.0896301
1931	Steelhead	0.709884908	0.526266288	0.373070815	135.57	143	148.44	0.017688267	659.8629099	37305.12	19.7641854	28.14335405	15.23445085	140.5105097	0.719074879	4.111737883	9.8699449	25.26043544	13.36428356	106.9254456	0.559559712	0.453558123	7.519661866	21.62941169	16.46940072	163.0210241	0.793037603	5.609098077	166.5128632
1932	Steelhead	0.741242166	0.668853974	0.495096557	135.38	140.9	146.21	0.019246385	952.8167149	49506.27	15.27293703	33.24389021	13.42969799	268.3773122	0.729359443	4.304923769	6.732780114	33.4341546	11.95474186	181.250705	0.543521011	0.534649611	6.137460768	27.90115827	14.3839585	326.6651357	0.837489396	5.875922511	334.4804077
1933	Steelhead	0.730011356	0.647488709	0.472019741	135.43	142.38	149.2	0.016925743	798.8769775	47198.93	16.83109494	31.35285258	13.88748474	241.21008	0.719087151	4.860864548	7.857707441	30.12232516	12.46108742	153.6252869	0.521990621	0.64907009	6.587180153	25.73941758	14.77881845	290.5066986	0.830929577	6.555268819	308.3908081
1934	Steelhead	0.758229826	0.575046808	0.435414979	135.32	139.37	144.3	0.021021953	915.2649129	43538.53	13.53179042	35.04694629	15.37748362	252.9329702	0.718475722	4.455481029	4.64803955	41.03015891	13.76438408	219.7687286	0.537731543	0.919653499	6.479371831	26.09948665	16.43970617	275.3416087	0.824510326	5.950516274	279.2550659
1935	Steelhead	0.73011934	0.635630847	0.463443941	135.48	142.11	148.37	0.017764825	823.2502325	46341.59	17.06883478	31.01798127	13.8896197	215.6891866	0.709250459	4.154382523	7.94291836	29.93278629	12.46920757	150.5516479	0.510338753	0.475364321	6.737389207	25.08770048	14.78732411	255.2128499	0.815889418	5.635351643	266.8375244
1936	Steelhead	0.738222733	0.61542213	0.453690058	135.39	141.22	146.02	0.020130147	913.2264815	45366.11	15.86659377	32.65820832	14.16205527	248.889858	0.728127098	4.250532925	7.187195867	32.63169576	12.35305614	171.1266052	0.548482883	0.53425175	6.27887585	27.08073576	15.32417027	300.0118052	0.829291334	5.839751263	306.9619751
1937	Steelhead	0.68883542	0.614708064	0.422845599	135.86	144.11	150.7	0.015285345	646.2970762	42282.14	21.37337502	28.29018829	13.7584547	165.1030828	0.711290312	4.167303824	11.83359289	23.89937801	12.27882862	107.8432144	0.556674328	0.510610908	7.165395685	23.12762329	14.76352056	201.3073705	0.775381227	5.577117488	210.7129822
1938	Steelhead	0.738975945	0.648301521	0.478416089	135.43	141.41	147.51	0.01808312	865.0671822	47838.38	15.71194328	32.47241376	13.83894463	251.8873088	0.720866787	4.27842687	6.989637583	32.1861315	12.24568157	163.511261	0.526871639	0.626876891	6.325947613	26.93839856	14.84284623	305.9692332	0.831979285	5.749797851	318.4305725
1939	Steelhead	0.713924203	0.569441697	0.405975318	135.5	142.79	147.46	0.018621734	755.9539514	40595.25	18.90561754	29.68372534	14.12984937	180.2742788	0.711191536	4.153165459	9.476852119	27.8374833	12.06771507	135.4312988	0.516636497	0.438815686	7.038685724	23.51718745	15.48387941	210.3818054	0.813159337	5.637084126	213.6755524
1940	Steelhead	0.731637513	0.575332219	0.420351725	135.49	142.17	147.32	0.018895588	794.2293542	42032.53	17.09279717	30.74250226	14.81484706	198.6332001	0.707310464	4.24092387	7.899006158	29.68947357	13.06100407	139.5176483	0.515349314	0.470339608	6.805519223	24.59928452	15.94726992	236.806071	0.805331737	5.754237145	242.9854279
1941	Steelhead	0.72252928	0.575926085	0.415547088	135.55	142.07	148.73	0.017160549	713.0614961	41552.37	18.38499727	29.30219466	14.96972078	165.4591705	0.702125602	4.313534184	8.815049797	27.13111358	13.63535175	115.7338135	0.536828229	0.473159647	7.193352126	22.99136364	15.89839268	197.5918477	0.770646602	5.873046031	202.9403992
1942	Steelhead	0.690772913	0.65942592	0.454882542	135.88	144.74	150.75	0.015156528	689.3992062	45485.3	20.63638418	29.60365855	13.20885181	207.3892349	0.722426543	4.128144664	11.54565161	25.4301646	11.74190102	126.6974701	0.559014925	0.472657394	6.711850204	25.18914129	14.14566867	258.1542791	0.803723921	5.536954984	269.9503479
1943	Steelhead	0.732685158	0.646510854	0.473033512	135.45	142.31	148.48	0.017198332	813.4819713	47300.05	16.33492913	31.87780962	13.80268396	242.5392354	0.720189657	4.258398736	7.465951562	31.10203049	12.18167439	158.9868378	0.528259456	0.620776236	6.478526458	26.28567364	14.81575282	291.9714203	0.828730414	5.741960029	307.166687
1944	Steelhead	0.688848721	0.596796371	0.410532137	136.01	144.14	150.98	0.015292226	627.7601004	41050.93	21.57803766	27.45567225	14.14154924	144.2214539	0.722192373	4.144937758	11.76523724	22.6805251	12.65795784	98.76179199	0.575439698	0.513810164	7.442554325	22.00721205	15.10642735	173.7319132	0.786115229	5.558792735	179.1306305
1945	Steelhead	0.711506371	0.621937103	0.441899333	135.54	142.82	149.15	0.017094246	755.3537249	44187.6	18.81088713	30.02422457	14.10860513	207.3230647	0.719090196	4.169091985	9.736904263	26.71968232	12.51672859	132.1488419	0.540188333	0.463386926	6.692730784	25.19454601	15.15376091	254.0021667	0.81234766	5.644954567	265.0134277
1946	Steelhead	0.748732634	0.664748421	0.497030692	135.32	139.85	145.23	0.02036762	1012.26319	49699.63	14.02876852	34.89925435	13.70456352	294.397934	0.733889753	4.540838973	5.602309644	37.62177354	12.11241894	218.4538879	0.554099116	0.913278031	6.020437755	28.58879868	14.68822241	342.9405721	0.845422645	6.029005865	353.3635864
1947	Steelhead	0.747859266	0.61498367	0.45928535	135.32	140.2	145.22	0.020760471	953.4329164	45925.4	14.61156607	33.78470788	14.62777678	264.4725657	0.725288096	4.857750642	6.041029304	35.27209134	12.95992546	189.6972748	0.544615009	0.811617303	6.170455955	27.69150078	15.6819733	314.0943502	0.828412344	6.460438718	319.7397156
1948	Steelhead	0.74509853	0.687187053	0.511314092	135.4	141.25	146.45	0.019652868	1004.812405	51128.03	14.29896434	35.25985456	13.61715692	384.5147552	0.743220105	4.332387845	6.42033726	35.54653693	12.04104023	221.8281799	0.559948024	0.510896754	5.476662211	31.17215194	14.61391592	477.5983887	0.856788556	5.922847609	506.401001
1949	Steelhead	0.747069089	0.668837091	0.498976028	135.39	140.51	145.48	0.020593972	1027.518519	49894.14	14.35909607	34.4292505	13.78811887	309.4203176	0.745670268	4.270611101	6.15396373	35.27130687	12.43219662	200.6044739	0.569505838	0.611705333	5.797665097	29.38900228	14.64255889	380.6519165	0.85503309	5.7964332	394.5062561
1950	Steelhead	0.722547918	0.668695458	0.482495475	135.51	142.39	148.32	0.017558665	847.1471144	48246.67	17.1191821	32.09704553	13.46055158	263.1293304	0.723670315	4.711746083	8.462645203	30.46738596	11.90654449	165.9089172	0.533781201	0.496345431	6.266946465	27.35206831	14.42037582	322.0152842	0.83367455	6.391334494	339.8640747
1951	Steelhead	0.751963729	0.666571843	0.500544438	135.32	139.86	145.32	0.020284432	1015.259545	50051.17	13.93811894	34.69518397	13.74872831	289.0708506	0.732095886	4.661529599	5.459731549	37.3829891	12.37084942	207.6103546	0.546477103	0.609503096	6.071514785	28.2874288	14.59895515	340.9951884	0.846396943	6.17059498	353.8208618
1952	Steelhead	0.74292289	0.684764247	0.508023262	135.34	140.65	145.81	0.019935059	1012.67866	50798.88	14.77644666	34.03251892	13.23551826	295.2236298	0.747273346	4.368876994	6.476564229	34.41913349	11.72512054	193.0536407	0.570204577	0.960765707	5.892020732	29.11191915	14.16051372	361.6586812	0.857685695	5.762241642	371.8828735
1953	Steelhead	0.735422731	0.674432409	0.495306471	135.4	141.27	147.98	0.018013875	892.1843733	49527.62	16.22185951	31.94899786	13.22112522	249.0426992	0.717300319	4.211662275	7.376523793	31.13762318	12.0574316	167.3440155	0.521007341	0.417103285	6.449578755	26.49610799	13.9666543	298.404068	0.828936944	5.747068167	312.523468
1954	Steelhead	0.730258249	0.691672314	0.504400408	135.39	141.31	146.78	0.018986875	957.6421521	50437.06	16.06033798	33.322537	13.00798702	284.7764404	0.736139731	4.408386219	7.59912549	33.13834597	11.57500515	195.4203278	0.551741028	0.469344145	6.061651252	28.30719462	13.90595261	343.7560577	0.851101021	5.96639429	355.5675049
1955	Steelhead	0.706830675	0.663558286	0.468373286	135.64	143.1	149.78	0.01605282	751.8270909	46834.58	19.03872238	30.34682517	13.25732002	227.2908432	0.71662886	4.500910481	10.08379683	26.93644708	11.88541946	141.2628799	0.545721763	0.474549806	6.573789813	25.81858409	14.16415564	279.7084656	0.802030404	6.034395844	295.3250427
1956	Steelhead	0.749313327	0.697479287	0.521907834	135.37	140.62	145.57	0.019856251	1036.239977	52187.09	13.58936895	35.68863428	13.15142059	355.767509	0.742214268	4.500895699	5.596609175	37.62084296	11.65321732	226.4433197	0.558194041	0.82163763	5.580027528	30.64050935	14.05820608	434.3983358	0.861694217	6.005953352	457.1015015
1957	Steelhead	0.745038942	0.702387264	0.522582081	135.29	139.86	144.64	0.021284264	1112.210078	52255.04	13.91098145	35.79878276	13.04624354	359.6767955	0.753744236	4.337873745	6.037411585	37.38211355	11.70006409	231.4596191	0.577096137	0.697499454	5.457613491	31.15205326	13.9041427	443.0892995	0.871884137	5.863244206	455.9617615
1958	Steelhead	0.735694367	0.676593736	0.497076995	135.39	141.36	146.44	0.019752473	981.7929381	49704.81	15.49351233	33.73784534	13.48606847	312.8268209	0.744816651	4.412062343	7.303704262	32.80075856	11.96824837	188.1965454	0.567930147	0.550230116	5.787662953	29.6571626	14.42956877	389.8918864	0.852596631	5.9797956	408.0805969
1959	Steelhead	0.746297819	0.658470665	0.490735251	135.39	140.85	147.08	0.01873556	919.3587919	49070.26	14.90703629	33.37118532	13.75792472	261.9015991	0.715514444	5.305771273	6.143789083	34.940346	12.36384449	189.9152679	0.520649353	0.494310528	6.364748657	26.91507622	14.62159204	306.5288188	0.828152428	7.347337226	317.8108521
1960	Steelhead	0.734095007	0.654745931	0.479980699	135.38	141.22	147.61	0.017987053	863.2846544	47994.78	16.40077128	31.85107066	13.3761013	231.5537038	0.711135503	4.238555888	7.402245164	31.82711241	11.85113297	167.377124	0.511268654	0.426606286	6.60378252	25.66514422	14.36210918	272.4821625	0.822500567	5.786013643	281.528595
1961	Steelhead	0.745759635	0.66717615	0.496864381	135.39	141.12	147.22	0.018899904	939.0077035	49683.2	14.91197363	33.62501663	13.48247178	287.8244436	0.721167031	4.205914342	6.275299609	34.97173893	12.24968739	200.0726532	0.524289304	0.424660593	6.234532326	27.56608901	14.27982028	338.6866201	0.836517026	5.792749171	353.8418274
1962	Steelhead	0.732235351	0.637273858	0.465988719	135.43	142.03	148.12	0.017823917	830.5185964	46595.74	16.56558433	31.84801534	13.89903081	233.5776835	0.708459184	4.417983303	7.635496676	31.16850539	12.26084614	159.1108429	0.508739722	0.439563674	6.540808365	26.14209381	14.92993228	279.556043	0.816399346	6.043332944	288.1964111
1963	Steelhead	0.715081157	0.6405712	0.45742612	135.58	143.35	149.12	0.016939495	774.8118386	45739.96	18.15118448	30.63232599	13.98768482	220.4585973	0.725599702	4.188788211	9.227740139	27.57700983	12.59288464	133.0104187	0.551566014	0.492183411	6.540322095	26.0224	14.86522802	275.9535522	0.818931093	5.647085667	285.4354248
1964	Steelhead	0.716405011	0.658107003	0.470818357	135.52	142.66	148.69	0.017286482	813.8287455	47078.91	17.77409082	31.8079352	13.80348612	264.9239319	0.729863046	4.396677481	9.165926307	29.39498553	12.17907276	161.7139709	0.549818105	0.447655919	6.225642532	27.43932964	14.84987529	327.8520355	0.833417584	5.992090449	341.8993225
1965	Steelhead	0.741035844	0.673972436	0.498746612	135.4	141.25	147.38	0.018451894	920.2212116	49871.37	15.40334368	33.00702855	13.42322025	269.8062042	0.72303457	4.32289776	6.868582428	32.55978497	12.12880611	171.949881	0.534593549	0.552701497	6.134335913	28.01094392	14.255301	331.7599436	0.831822107	5.853213747	340.2171021
1966	Steelhead	0.725499439	0.575110961	0.416664967	135.43	142.22	147.74	0.018457213	769.0042896	41664.16	17.79652458	30.47221862	14.61780993	195.4354238	0.702170547	4.16206212	8.462693304	29.55848812	12.63591175	148.9784271	0.506718689	0.443064141	6.949911453	23.98127661	15.88557768	225.1734263	0.801255226	5.675451358	230.9348907

Year	Specis	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	SAR	TotalReturn	PassageBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	UCTravelTime	UCMigRate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1967	Steelhead	0.716316868	0.679382565	0.485979519	135.46	142.71	148.18	0.017851199	867.4809598	48595.11	17.58272161	32.22587331	13.00570793	278.9746399	0.72705792	4.248102711	9.012293935	30.39138558	11.33676472	179.2835083	0.539212751	0.405901748	6.177339472	27.77880121	14.02931118	340.5932515	0.836588383	5.759919375	353.0355225
1968	Steelhead	0.718247206	0.609742049	0.437339014	135.6	142.58	149.05	0.01692805	740.2880123	43731.44	18.30524102	30.30526505	14.80861117	210.950086	0.723436239	4.561456045	9.193224251	27.79671056	13.4675705	139.3312714	0.550788483	0.497969824	6.737368315	24.92078833	15.74935754	253.7348175	0.814945926	6.152745023	267.5537415
1969	Steelhead	0.751161539	0.672717795	0.504620423	135.33	140.1	145.37	0.020517061	1035.262398	50458.61	13.84433649	35.18619252	13.79057674	313.6116648	0.740071119	4.311998828	5.636898309	37.33847645	12.42011414	212.9472321	0.555023888	0.584247279	5.799431145	29.56524033	14.65188551	380.0574697	0.857482105	5.877703865	385.5653381
1970	Steelhead	0.697790362	0.675265771	0.470540638	135.7	143.8	149.5	0.016503464	776.5089307	47051.27	19.59269039	30.46989166	13.05637582	246.1043401	0.738551396	4.170832989	10.92619148	25.66077378	11.76214085	136.0611282	0.576696298	0.456311885	6.278735593	27.26777107	13.89557441	315.8570964	0.829143465	5.656515976	326.5307922
1971	Steelhead	0.749580841	0.697321427	0.521975838	135.3	139.59	144.97	0.020579234	1074.112528	52194	13.39359394	36.00843594	13.16196842	339.5226817	0.743634666	4.374583991	5.345023185	38.90244741	11.70459366	234.1515747	0.567759117	0.773643541	5.633992083	30.39345862	14.05352052	409.3042857	0.859379838	5.840993543	413.7596741
1972	Steelhead	0.757010003	0.691373944	0.522653686	135.29	139.54	144.59	0.021054697	1100.355334	52261.75	12.83343517	37.23614819	13.59279124	370.6481038	0.748372458	4.405650636	4.926488742	41.80361501	12.27941818	254.9835754	0.573398921	0.501276445	5.494590648	31.01970813	14.42817879	445.9941559	0.86214597	6.045664618	451.3241882
1973	Steelhead	0.710886822	0.629256083	0.44670977	135.73	142.53	148.9	0.017032984	760.8405615	44668.66	19.16794667	29.2429765	13.64495932	181.97503	0.706826813	4.228491642	9.750888228	26.22397452	12.38467999	127.6611984	0.542711759	0.475968468	7.032053098	23.6988076	14.4796141	218.9488627	0.777940283	5.711483891	224.0010071
1974	Steelhead	0.755705338	0.682243593	0.51486224	135.31	139.42	145.48	0.019885425	1023.754995	51482.68	13.04310874	36.30428489	13.62991168	328.2754079	0.74181779	4.535448162	4.822542265	40.9048524	12.25010738	243.3083221	0.569735545	1.090426266	5.809584364	29.42304478	14.48233414	383.0898438	0.851946046	5.935162574	387.4555969
1975	Steelhead	0.729146744	0.678216398	0.493834568	135.43	141.35	147.73	0.018033799	890.5192648	49380.57	16.53001638	32.45833113	13.21164163	264.0144643	0.726881192	4.789744588	7.911414593	31.52273995	11.81512604	171.1189789	0.540782076	0.521900308	6.224713035	27.42664588	14.1244057	323.9810994	0.834306349	6.442512949	331.7488403
1976	Steelhead	0.738655798	0.701848023	0.51770734	135.32	140.36	145.65	0.019996465	1035.164616	51767.38	14.93537561	34.20328819	12.88383191	301.3109222	0.741769209	4.349234804	6.70131059	34.69693465	11.45745449	202.1529022	0.557777214	0.507131016	5.826039709	29.30911837	13.77839899	370.5751953	0.859417647	5.941700538	370.5142822
1977	Steelhead	0.708464107	0.578941759	0.409590771	135.62	142.68	150.23	0.015822882	648.0557375	40956.87	20.13784872	27.56585078	14.5366443	128.6800145	0.729894622	4.239227064	9.961342096	24.58351808	13.34515038	101.3874268	0.575903293	0.539688504	7.803064898	20.73548007	15.42726882	145.6579336	0.805591901	5.668177138	151.1134033
1978	Steelhead	0.735966707	0.655665173	0.481880232	135.4	141.52	147.27	0.01856168	894.3928687	48184.91	16.16794188	31.91260605	13.45873362	231.7031993	0.714606009	4.349547647	7.21333167	31.9280988	11.94487133	167.1603607	0.519574443	0.39961181	6.556360848	25.77592969	14.38803832	273.7194977	0.82353884	5.890541211	281.3710938
1979	Steelhead	0.720582904	0.652595164	0.469597672	135.47	142.32	147.91	0.018096857	849.7752042	46957.06	17.80240362	30.68258776	13.24092236	217.0051432	0.71435539	4.160635696	8.786822289	28.47994081	11.83552513	143.5424652	0.533192867	0.453604943	6.619547397	25.54817253	14.15100304	265.4264704	0.80669709	5.655842483	273.1965332
1980	Steelhead	0.745997759	0.6757726	0.50342744	135.32	139.7	145.5	0.020060918	1009.857782	50339.56	14.39880897	34.01357846	13.39022535	282.7061839	0.731932635	4.385419879	5.903732672	35.53687742	12.04668217	210.903186	0.557496569	0.754763812	6.086685099	28.13944216	14.25919978	331.6788584	0.83617265	5.891716172	335.3459473
1981	Steelhead	0.734239451	0.622531972	0.456454652	135.46	142	148.19	0.017904475	817.2083939	45642.69	16.40122579	31.83718736	14.7312212	237.5076426	0.719667744	4.17990968	7.531511188	30.93043807	13.42638874	155.2888947	0.533967602	0.403858751	6.487445898	26.23023522	15.63158528	286.8230794	0.822146893	5.684367895	300.4051819
1982	Steelhead	0.740951621	0.676847222	0.500817057	135.42	141.1	146.67	0.019363231	969.6811823	50078.48	15.0366548	33.92299397	13.68856831	299.5032572	0.734867351	4.49458641	6.733218044	33.9510694	12.33396511	191.8316681	0.547297114	0.440103906	5.904563993	29.12319735	14.53213167	368.8361918	0.850430071	6.09023724	377.4519958
1983	Steelhead	0.731013848	0.670438061	0.489421259	135.52	142.07	148.45	0.017385991	850.8503979	48938.85	16.39222899	31.89833368	13.44313196	256.6496409	0.723013372	4.509415068	7.71544528	30.05448856	12.1761549	151.9720703	0.535399359	0.388565356	6.283063136	27.24813073	14.24484094	320.3638357	0.828616112	6.251318286	332.9926147
1984	Steelhead	0.699002598	0.652719571	0.455620493	135.86	144.01	149.88	0.016003437	729.1037973	45559.2	19.2422981	30.6585254	13.84742705	237.9419149	0.741179671	4.250168125	10.64659476	25.73604278	12.21579018	121.8152893	0.592313957	0.445548439	6.217608169	27.56215258	14.90876945	312.3347982	0.82296889	5.688201447	320.5012512
1985	Steelhead	0.710535643	0.63490329	0.450496435	135.59	143.35	148.79	0.01711328	770.9031157	45047.07	18.67768965	30.58878764	13.71152032	216.6986542	0.71549763	4.336790551	9.681175619	27.98951506	12.13251019	139.9483597	0.537500951	0.440705636	6.609181538	25.61971971	14.70731195	265.8312912	0.806007932	5.876859277	276.5330505
1986	Steelhead	0.721147425	0.637626141	0.459185643	135.54	142.97	149.17	0.016924388	777.0925621	45915.55	17.46967444	31.01185305	14.06503874	233.7017756	0.724670767	4.216070324	8.619395852	28.48314483	12.6595417	138.20242	0.543475336	0.463341796	6.463709526	26.2571657	14.95187759	292.4536184	0.82449763	5.743405884	300.9675598
1987	Steelhead	0.750679513	0.550263985	0.412500375	135.33	139.72	144.64	0.02091174	862.5521725	41247.27	15.12700646	32.47807718	15.5243639	208.9223562	0.712040205	4.228663848	5.868513331	35.40454175	13.86151657	181.3058197	0.51918247	0.630259055	6.863222905	24.25856391	16.63192272	230.676295	0.818739653	5.741620779	229.2389526
1988	Steelhead	0.702449375	0.612413892	0.429593772	135.63	143.4	149.6	0.016236624	697.4745388	42956.87	20.06561331	28.81735268	13.70780614	164.443222	0.702790309	4.143801331	10.43019301	25.9545001	12.12209339	118.243396	0.531230626	0.427644834	7.254292436	22.81352955	14.70694017	195.1779785	0.778047134	5.613316943	199.5900116
1989	Steelhead	0.738485079	0.627481333	0.462744092	135.38	140.76	146.64	0.018899674	874.5117172	46271.26	16.13368814	31.76857824	13.87858556	217.1845072	0.708216802	4.270717639	7.029603988	32.24941628	12.27888947	166.2161285	0.51252445	0.456833833	6.707317695	25.13088245	14.89594746	253.2895457	0.813011199	5.901429365	253.5335846
1990	Steelhead	0.743274223	0.553214538	0.410621143	135.44	141.63	147.68	0.01833977	753.0181274	41059.3	16.02811728	31.51089155	15.67593422	210.7418854	0.702816959	4.40928599	6.825356156	31.89211728	13.88217163	154.3601257	0.511717689	0.473591584	6.82343775	24.57884373	16.86535422	244.3662898	0.800174743	6.075740362	251.493103
1991	Steelhead	0.742997172	0.660003345	0.489702179	135.42	141.2	146.88	0.018991614	929.958937	48966.82	15.22308006	33.23256455	13.72925987	262.0229879	0.716479347	4.112098086	6.501721397	34.14704582	12.39393101	185.0493286	0.521981454	0.411086953	6.324467294	27.2106867	14.55128908	313.7264506	0.827601691	5.680706898	316.3543091
1992	Steelhead	0.740365465	0.532061553	0.393374736	135.43	141.37	146.81	0.01932067	759.979912	39335.07	16.82146145	30.52797981	15.6054395	174.2881358	0.69280993	4.134928586	7.271474868	30.78115092	13.86760559	139.9022736	0.505150369	0.431264538	7.166395091	23.09805375	16.77126408	198.2128245	0.777822723	5.685374588	198.6960144
1993	Steelhead	0.712727003	0.665414857	0.473602052	135.41	141.75	146.74	0.019293349	913.6838199	47357.45	18.06655061	31.27921958	13.03701706	251.6035411	0.734412141	4.167101574	9.458786458	28.12617954	11.40804882	161.7082336	0.569956714	0.486775398	6.209821828	27.35641647	14.04846684	315.3974457	0.823978235	5.684050242	317.2549438
1994	Steelhead	0.731938605	0.550217958	0.402168152	135.42	141.68	146.78	0.019233914	773.4812567	40214.45	17.41940121	29.94267395	14.94475937	173.0696218	0.703725806	4.136249298	7.851808608	29.22065465	13.13979378	135.6766022	0.517692292	0.417535186	7.179259665	22.99138006	16.13583899	198.7293345	0.794043799	5.678854689	200.8431244
1995	Steelhead	0.727005275	0.661628241	0.480341124	135.5	141.84	148.17	0.017802108	855.0610561	48031.45	17.06176353	31.46136364	13.5192077	233.6183421	0.720533997	4.836664649	8.222471029	29.66548057	12.2522768	150.1069916	0.534508365	0.617170191	6.447656132	26.45530392	14.33736531	287.3112183	0.82305633	6.481747717	296.4547424
1996	Steelhead	0.748889336	0.657738581	0.491892132	135.45	141.02	146.67	0.018663871	917.9979617	49185.83	14.42570338	33.9641072	14.11675549	281.2228739	0.730616105	4.414455829	6.000115886	34.90456117	12.82111435	184.0561249	0.553110221	0.729600459	6.026978545	28.42859318	15.00991154	342.6792806	0.834566851	5.935657402	353.6205139
1997	Steelhead	0.761747567	0.698812935	0.531582911	135.3	139.28	143.93	0.021345018	1134.586312	53154.62	12.07812261	38.36970189	13.645309	403.8903168	0.761744069	5.248225832	4.474039614	43.43043045	12.27695541	277.0291565	0.595939037	1.207009733	5.18707215	32.55152139	14.4901576	488.7108612	0.873301933	6.799521873	493.583374
1998	Steelhead	0.745657641	0.664344937	0.494688728	135.35	140.44	146.29	0.019659181	972.4515992	49465.52	14.74271116	33.86562861	13.83464483	280.5080282	0.729778157	4.306466544	6.306996539	34.60372927	12.47592373	186.7052673	0.549267241	0.684272718	6.033139072	28.47952241	14.69452111	341.4414927	0.834430973	5.757266233	348.0680237
1999	Steelhead	0.738242261	0.65938123	0.486109628	135.49	141.75	147.96	0.017708245	860.7551114	48607.59	15.76352458	32.36239229	13.79006208	259.257075	0.720484496	4.525067049	7.053777516	31.66393882	12.42804871	162.1522461	0.524098662	0.43646571	6.316193238	27.06520072	14.62390979	317.2811381	0.83358108	6.298971703	332.3251343
2000	Steelhead	0.738338401	0.589224666	0.434445311	135.45	141.98	147.17	0.018653939	810.3582803	43441.67	16.22329465	31.57303772	14.62904682	213.5799113	0.706315742	4.196091845	7.130350947	31.64171572	12.84513893	152.571936	0.51006715	0.439349359	6.700883269	25.09345956	15.75871086	251.8411942	0.809166312	5.758948396	261.3935852
2001	Steelhead	0.694593523	0.591536251	0.410307322	135.78	143.87	150.07	0.015940129	654.0024645	41028.68	21.03676705	27.70163111	14.23224201	144.576326	0.721536986	4.073909096	11.22447401	23.48903944	12.78559647	100.9832703	0.573111993	0.492726785	7.438559234	21.99022521	15.16234064	173.7336782	0.786213676	5.4646349	179.4012146
2002	Steelhead	0.733620458	0.645587211	0.472960407	135.45	142.11	148.18	0.017868438	845.049542	47292.86	16.15623164	32.33826723	13.87166144	252.9232208	0.717276324	4.156710355	7.343515038	32.2353148	12.22983723	174.4642548	0.520640692	0.423625353	6.421993501	26.49579639	14.90177917	299.3912404	0.829963833	5.72766611	313.5173035
2003	Steelhead	0.725800176	0.648819963	0.470261618	135.53	142.71	149.12	0.017068582	802.6169352	47023.06	17.09542968	31.08926835	13.57886588	235.8268901	0.717589723	4.234720868	8.117693812	29.48281407	12.31705379	147.0517395	0.531277996	0.452690208	6.584582061	25.69528555	14.40424856	285.6358032	0.818842242	5.756982401	308.6430664

Year	Specis	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	SAR	TotalReturn	PassageBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	UCTravelTime	UCMigRate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
2004	Steelhead	0.721890417	0.616243954	0.444244697	135.45	142.51	148.8	0.017174416	762.9145192	44421.57	17.99081134	29.86324281	13.99496288	192.8227305	0.700998195	4.303131466	8.641666651	27.77984372	12.57358704	126.8832748	0.525809333	0.422015038	6.962275565	23.97533707	14.89889558	229.8485184	0.779692233	5.920351485	251.0012665
2005	Steelhead	0.731549492	0.594921926	0.434612323	135.47	141.38	147.15	0.018570283	807.0373953	43458.54	17.17768193	30.58865616	14.9243618	195.5958761	0.706638314	4.106226292	8.028716207	29.09152757	13.57476673	132.1993149	0.532859114	0.447549477	6.765329674	24.65766508	15.85368649	239.6102575	0.787410607	5.558594371	242.3700562
2006	Steelhead	0.735326798	0.678956307	0.498563999	135.45	141.89	146.61	0.0193908	966.6914684	49853.1	15.33726855	33.98101667	13.47080746	308.7493225	0.744450994	4.247679814	7.173473164	33.64359242	11.95785046	191.7543213	0.565873614	0.413738251	5.760585897	29.57525851	14.40510877	385.7539622	0.85645015	5.837027738	395.7884827
2007	Steelhead	0.747779723	0.615823855	0.45986349	135.34	140.01	145.74	0.019810952	910.9729522	45983.3	15.10828108	32.81819547	14.72544028	229.3442912	0.712883611	4.153544927	6.13310428	34.90017443	13.35215702	182.3117188	0.523184109	0.447070861	6.582016438	25.50365528	15.63278659	262.9874064	0.817609082	5.685025116	265.585022
2008	Steelhead	0.702054822	0.666283755	0.467119398	135.94	143.48	148.64	0.017431493	814.2057017	46708.89	18.74647374	31.79568027	13.94456889	290.6570236	0.757233891	4.146317365	10.51155639	27.33740901	12.3575613	159.4416901	0.601117721	0.474562633	5.852884233	29.11711823	14.98484453	374.070343	0.854770859	5.599941408	393.2251587
	Steelhead	0.729338361	0.639482685																										
MO3-RESSIM																													
1929	Steelhead	0.659057583	0.633081932	0.416658866	136.3	146.07	151.87	0.014170583	590.3949617	41663.42	24.46719176	27.20893961	14.02843107	158.7624425	0.816176353	2.897089416	14.96999985	20.46920942	12.3753828	92.03311615	0.666428262	0.651703322	7.132199883	23.16968894	15.1222078	201.2351227	0.943323116	2.379861698	210.9797668
1930	Steelhead	0.695972715	0.547183856	0.380297021	135.81	144.35	149.73	0.016359018	622.0948626	38027.64	20.94596399	27.64134333	15.36672071	135.9479009	0.814733925	2.876894242	11.05320007	23.65268181	13.41258564	95.98946075	0.649769622	0.605591309	7.526816003	21.61045547	16.65978877	161.4322891	0.955562462	2.413587535	166.6564636
1931	Steelhead	0.70313196	0.541480644	0.380204614	135.63	143.5	148.69	0.017411386	661.9528778	38018.39	20.40437647	27.71268925	15.30642535	133.9785843	0.811405513	2.813508876	10.44216359	24.25098038	13.42297745	100.0456711	0.641398814	0.501331741	7.589482546	21.37178938	16.56714233	156.2945201	0.954710325	2.3938943	160.3340302
1932	Steelhead	0.737673203	0.688918976	0.507493725	135.38	141.03	146.39	0.01906943	967.6948287	50745.87	15.52565945	33.0065934	13.37273451	264.1188527	0.750471737	2.982259546	6.954154149	32.78264615	11.91963158	176.6412079	0.553013781	0.563421166	6.169353597	27.84446879	14.31756544	322.4273224	0.886255711	2.660070603	330.4920044
1933	Steelhead	0.730490433	0.674434485	0.491986039	135.42	142.18	148.95	0.01715435	843.9145886	49195.37	16.81589132	31.36888047	13.86704191	239.2740997	0.769889948	3.619940042	7.81844151	30.16279261	12.46196804	153.4296661	0.573503417	0.838274872	6.609809101	25.76274636	14.75038131	287.6140849	0.91528373	3.365056445	304.7875061
1934	Steelhead	0.758064737	0.590065337	0.446689368	135.32	139.36	144.27	0.02107	941.1088053	44665.82	13.55421252	34.95770354	15.46337821	251.6328247	0.767722354	3.121254933	4.666589677	40.79979306	13.77879276	218.8793915	0.575516218	0.98494699	6.484053127	26.05905498	16.58824412	273.7574717	0.915978869	2.724767456	277.6462097
1935	Steelhead	0.727351405	0.664824667	0.482892102	135.49	142.21	148.35	0.017765419	857.8269064	48286.33	17.34038726	30.82756961	13.87022985	213.4753347	0.774825623	2.684872894	8.199028105	29.44406553	12.48313217	147.6493134	0.574865296	0.508339036	6.752936304	25.01764072	14.7513531	253.4676005	0.925393343	2.024189375	265.1940918
1936	Steelhead	0.734989575	0.631931997	0.463820567	135.4	141.39	146.17	0.020016608	928.3524619	46379.11	16.13724359	32.36699354	14.18268172	244.4787516	0.757842443	2.871329317	7.432552278	31.89643526	12.35145283	166.1085266	0.555994603	0.491428858	6.305112317	26.95438904	15.36388954	296.0045522	0.901339342	2.540795396	302.9780273
1937	Steelhead	0.686771814	0.65180827	0.447022892	135.88	144.18	150.8	0.015184619	678.7472885	44699.66	21.56600379	28.17215619	13.66584517	163.9129985	0.806808588	2.873248523	12.01053557	23.62083495	12.21938057	106.6464722	0.634270829	0.541923201	7.180654697	23.06974911	14.65122302	200.0593643	0.949352751	2.392344331	209.5236816
1938	Steelhead	0.737261958	0.67131619	0.494250998	135.44	141.49	147.53	0.018140834	896.5496091	49421.63	15.85965739	32.33695845	13.83013109	249.1477905	0.759005296	2.88822482	7.11491552	31.78231796	12.25704346	161.1415131	0.559956163	0.565238798	6.348879531	26.93041338	14.82115173	302.7968089	0.900503933	2.487783323	315.530365
1939	Steelhead	0.708963229	0.587634065	0.416034022	135.52	143.09	147.64	0.018417944	766.2068986	41601.11	19.40073425	29.35800463	14.19713771	174.4323802	0.790140883	2.822391093	9.920354337	27.10643664	12.0992281	129.7131409	0.590796953	0.495543128	7.091981262	23.29227417	15.58700625	204.1676102	0.94806385	2.348642771	207.6969757
1940	Steelhead	0.729807224	0.597453432	0.43542198	135.5	142.3	147.35	0.018861294	821.2122521	43539.55	17.30261347	30.43961704	14.84521605	193.5569702	0.783542318	2.940563498	8.058974952	29.05627584	13.0926609	135.7818268	0.581458437	0.590792519	6.85530109	24.37053605	15.98882612	230.8290914	0.940526346	2.468380193	236.8222504
1941	Steelhead	0.720797537	0.605768934	0.436031622	135.55	142.18	148.9	0.016991732	740.8499001	43600.61	18.55014558	29.14302471	14.99672979	162.5850382	0.802603964	3.049285829	8.956424147	26.77300191	13.65259132	113.118187	0.619048291	0.601009315	7.217936262	22.88216822	15.94816049	194.5280762	0.952975055	2.658891713	199.8307648
1942	Steelhead	0.683702966	0.691839128	0.472356965	136	145.03	150.93	0.014902845	703.8981583	47232.47	21.43103266	29.30049259	13.09789289	204.7558375	0.787401964	2.696812117	12.33511838	24.54261281	11.66455116	122.1117737	0.616231757	0.512411678	6.717764549	25.16200101	14.00988118	256.9004745	0.917628149	2.006261885	268.5701294
1943	Steelhead	0.733203551	0.671823622	0.491901633	135.45	142.17	148.32	0.017398774	855.7902096	49186.81	16.2672435	31.83461095	13.77022177	241.4361735	0.762937276	2.935147893	7.381447762	31.03679984	12.17704449	160.03909	0.566370201	0.571315038	6.49415262	26.24603214	14.76048231	289.6313324	0.905360798	2.592974583	303.9824219
1944	Steelhead	0.680046964	0.622774116	0.422928105	136.14	144.61	151.45	0.014814849	626.5279737	42290.54	22.49333105	27.00363159	14.13630683	135.8790604	0.818879991	2.905157791	12.59350035	21.70853488	12.68963852	91.3093338	0.662245449	0.63361994	7.531802624	21.66038331	15.08038155	164.8022054	0.95451044	2.393425301	170.0206909
1945	Steelhead	0.705650091	0.646548872	0.455605292	135.59	143.26	149.43	0.016819816	766.2783385	45558.07	19.37293565	29.70935263	14.14432201	201.5546316	0.78716967	2.907460839	10.26728275	25.94973666	12.55742779	124.1134918	0.60645881	0.578281283	6.725640245	25.03417048	15.19645023	249.526268	0.926205426	2.43471912	260.6796875
1946	Steelhead	0.747288812	0.681610762	0.508655806	135.32	139.87	145.25	0.020364984	1035.802173	50861.92	14.08496842	34.80950424	13.68864422	292.5425578	0.748229903	3.121868885	5.644673154	37.32221617	12.11884041	217.1884613	0.564392859	0.763097453	6.034350254	28.61326442	14.65730349	340.6845144	0.875570605	2.763661395	351.107666
1947	Steelhead	0.745637411	0.630975322	0.469828088	135.33	140.32	145.32	0.020702225	972.5814275	46979.56	14.79854944	33.50701974	14.64226259	259.7858988	0.753503253	3.225375869	6.190407127	34.64621175	12.98402271	185.4816589	0.557914695	0.594519693	6.208620973	27.51224634	15.69445435	309.0236155	0.890919824	2.699940383	314.7936707
1948	Steelhead	0.743130294	0.708724176	0.525946016	135.39	141.23	146.37	0.019753136	1038.841529	52591.22	14.28966913	35.91981967	13.61945457	383.4922963	0.744976916	3.061219517	6.466255575	35.54198443	12.05391941	221.5406616	0.569253239	0.651789045	5.420960419	32.83166499	14.61327346	476.1961975	0.857722332	2.714531442	504.5915222
1949	Steelhead	0.745064726	0.682953223	0.50814027	135.38	140.68	145.71	0.020391319	1036.094944	50810.59	14.52822355	34.36570173	13.74819578	301.1651265	0.745540724	2.907328004	6.277857155	34.73842239	12.44086647	194.1381348	0.564902627	0.593041795	5.843091726	29.67198994	14.57231172	370.7533824	0.864201516	2.511920085	384.8374329
1950	Steelhead	0.722372691	0.692177557	0.499317852	135.5	142.36	148.26	0.017650066	881.2480357	49928.88	17.17281902	32.05334613	13.4145853	260.673465	0.760144114	3.360622998	8.486913115	30.39839342	11.87935123	166.2834534	0.569022027	0.628663594	6.295173496	27.31380849	14.35940933	317.8404134	0.895548274	3.049643422	335.2581787
1951	Steelhead	0.750765988	0.68498371	0.513551249	135.32	139.88	145.3	0.020275443	1041.176618	51351.61	13.99714617	34.62616759	13.69711412	286.7756266	0.750320596	3.055032814	5.500454023	37.06038719	12.37338142	205.9834686	0.563791651	0.585644656	6.089211054	28.39080261	14.51317994	338.2329661	0.879618078	2.416307911	351.0267944
1952	Steelhead	0.740317307	0.699338254	0.517016191	135.34	140.64	145.8	0.019936725	1030.690002	51698.06	14.81072596	34.09203516	13.17331149	294.5230723	0.74231546	2.863292156	6.511957109	34.22494109	11.69205666	193.0866119	0.55648165	0.546107036	5.890364088	29.42888839	14.07595905	360.5397542	0.864919821	2.533523053	370.6331482
1953	Steelhead	0.733542084	0.702952183	0.514930945	135.4	141.35	148.04	0.018000498	926.845812	51490.01	16.44978118	31.73071109	13.13778419	245.5908305	0.763917504	2.914521879	7.569720536	30.59398584	12.06026917	164.2360901	0.566041827	0.530418503	6.483361028	26.41443643	13.83419863	294.7146403	0.907577525	2.464985445	308.8162842
1954	Steelhead	0.726947017	0.712282736	0.517075395	135.4	141.39	146.87	0.018897719	977.0971067	51704.5	16.36507062	33.14930549	12.89062716	283.5183126	0.753273187	3.189995597	7.894018978	32.43616459	11.49792824	194.3654785	0.572915706	0.605521125	6.071198411	28.46267912	13.75965754	342.330897	0.877163957	2.853086392	354.2781067
1955	Steelhead	0.70576391	0.69559478	0.490245417	135.66	143.15	149.8	0.016041692	786.3913394	49021.72	19.18548379	30.21986693	13.18370361	223.9653397	0.780682767	3.230357613	10.18682826	26.73620012	11.88590469	140.2141479	0.597502616	0.598369414	6.616165891	25.68412756	14.04786666	274.9423854	0.918878138	2.804788619	290.218811
1956	Steelhead	0.748863149	0.716825839	0.536062324	135.36	140.56	145.48	0.019975384	1070.734125	53602.68	13.54198429	36.14646563	13.07573058	355.3076528	0.744949765	3.160466047	5.569176525	37.68212089	11.61504669	227.8785126	0.572521463	0.869994354	5.558889493	31.74784584	13.95410713	432.7582041	0.857652833	2.785399089	455.2355347
1957	Steelhead	0.742803843	0.717902768	0.532523277	135.29	139.93	144.7	0.021217024	1129.787227	53249.09	14.05084641	36.11011191	12.94868298	357.4075826	0.744125615	2.998297391	6.194981515	36.79146421	11.62105331	227.9171753	0.582171205	0.656326813	5.439651221	32.42570698	13.79583899	441.520991	0.845599761	2.621321191	454.6088867
1958	Steelhead	0.732607731	0.694483559	0.508079666	135.39	141.48	146.5	0.019670807	999.371433	50804.8	15.70059239	33.77199627	13.42835573	308.8077545	0.746058781	3.093752462	7.505507365	32.22080296	11.94733944	184.2262695	0.565637213	0.533685571	5.792651296	30.22919593	14.34580151	385.9097239	0.863192528	2.835557083	403.8259277

Year	Specis	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	SAR	TotalReturn	PassageBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	UCTravelTime	UCMigRate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1959	Steelhead	0.745917666	0.682801684	0.508609103	135.4	140.87	147.04	0.018804478	956.3487246	50857.5	15.0004091	33.22244284	13.74349569	258.7571035	0.758416117	4.148807255	6.208109513	34.57827439	12.37353897	187.731076	0.559097412	0.681368661	6.393219039	26.85175533	14.59670305	303.000824	0.903062811	4.388695459	313.9589844
1960	Steelhead	0.731028943	0.683918609	0.499272349	135.35	141.18	147.58	0.018063251	901.7900819	49924.02	16.63633941	31.73316627	13.31759097	232.5371002	0.765685529	2.944762033	7.64342922	31.43517093	11.81726398	168.0256378	0.562695181	0.527009118	6.598080866	25.69789633	14.29138549	273.842219	0.915932159	2.57668451	282.723175
1961	Steelhead	0.745154706	0.693787317	0.516263438	135.38	141.06	147.01	0.019113799	986.7099033	51622.91	14.9388992	33.71297155	13.37213904	287.6548096	0.756341323	2.964309126	6.302388787	34.83901814	12.195257	200.0629883	0.567828822	0.536372101	6.232371442	27.91986799	14.13816643	338.4040426	0.888533374	2.680940196	353.4532166
1962	Steelhead	0.731323005	0.666463634	0.486725871	135.48	142.11	148.15	0.017811652	866.882616	48669.41	16.67216825	31.71395884	13.87280032	231.3593577	0.765129048	3.10155528	7.720288754	30.8733796	12.26765957	157.0432861	0.563204789	0.561236024	6.562292054	26.0564883	14.88068295	277.24646	0.912398666	2.79176718	285.9081726
1963	Steelhead	0.709566216	0.665009676	0.471214485	135.85	143.7	149.33	0.016725003	788.059918	47118.67	18.67045692	30.26993329	13.9896944	217.9426707	0.780064414	2.821009346	9.727276087	26.59939589	12.61389599	129.8708801	0.605400178	0.564526498	6.561164416	25.91783458	14.85873286	273.9738057	0.909317752	2.273872435	283.7628479
1964	Steelhead	0.711298882	0.679935821	0.482967608	135.58	142.86	148.86	0.017129875	827.2684637	48293.9	18.28843768	31.49659766	13.830826	261.2105062	0.767253453	3.086011503	9.664615422	28.32714398	12.21846924	157.6603455	0.589999706	0.588522834	6.242631055	27.53492553	14.8761495	324.502538	0.89322107	2.661513587	338.5744934
1965	Steelhead	0.739987294	0.698001723	0.515797606	135.4	141.3	147.4	0.018426639	950.378422	51576.33	15.50947692	32.96986924	13.31967824	267.2823995	0.750060563	3.020659335	6.953499049	32.39934877	12.07212601	169.6613586	0.553026667	0.559680116	6.154594511	28.06291161	14.12446435	329.0570068	0.884962221	2.697662224	337.5050049
1966	Steelhead	0.722849401	0.59934181	0.432633884	135.44	142.4	147.87	0.018394037	795.745905	43261.08	18.07585591	30.22933929	14.63986066	192.2164602	0.780920082	2.850959229	8.708226889	28.99374253	12.6318697	146.0906281	0.572943154	0.529735816	6.984734245	23.83250738	15.92576504	221.5747808	0.942431599	2.41366004	227.5129242
1967	Steelhead	0.715231547	0.702297255	0.501609913	135.47	142.78	148.08	0.017995675	902.6297813	50158.15	17.61326947	32.38431539	12.97162685	281.8035695	0.756189414	2.945052109	9.061466545	30.41748805	11.31825657	181.6372192	0.572210526	0.538550454	6.157534592	28.16701734	13.98171759	343.6058502	0.882633845	2.459925234	356.3138733
1968	Steelhead	0.716103931	0.630800686	0.451093177	135.65	142.7	149.14	0.01684878	759.9930318	45106.71	18.5335596	30.09923869	14.87036432	207.6621358	0.785761584	3.201180077	9.400010943	27.30885842	13.4987484	137.6746155	0.604933256	0.572891307	6.759681098	24.80291557	15.85360257	249.5930023	0.925309141	2.816584845	262.993042
1969	Steelhead	0.749946372	0.688244502	0.51543238	135.32	140.03	145.24	0.020631174	1063.32782	51539.86	13.77868428	35.49007541	13.73290634	315.9557404	0.74102203	2.989326378	5.598641738	37.3942286	12.41976891	215.0582886	0.563284197	0.574338686	5.7705101	30.2962256	14.55876525	382.5615997	0.856779834	2.678171098	388.1356812
1970	Steelhead	0.689583271	0.699963737	0.482014141	136	144.22	149.83	0.016084978	775.2687388	48198.31	20.44148853	30.14585671	12.96106186	241.4078618	0.773276716	2.855479217	11.75495192	24.66451558	11.74934998	131.4017075	0.608194745	0.510021925	6.299471095	27.27948996	13.74966637	311.4424947	0.889518311	2.398235261	321.9587402
1971	Steelhead	0.748413747	0.711795717	0.531981539	135.29	139.6	145.03	0.020565919	1093.996472	53194.63	13.42750364	36.23190038	13.13463739	337.8972921	0.740839362	3.161488187	5.386730164	38.621653	11.67841625	233.6761719	0.572943023	0.865999603	5.625920482	31.18949298	14.02495432	406.9010264	0.849710286	2.828205297	411.2102356
1972	Steelhead	0.756664425	0.709089306	0.535801206	135.29	139.58	144.6	0.02108786	1129.812683	53576.45	12.853543	37.75354767	13.55789541	368.4647878	0.748305646	3.155808461	4.979773313	41.70001207	12.29609585	253.4012787	0.587019214	0.671309185	5.460387975	32.41156129	14.36237653	443.7544912	0.850358576	2.919839114	448.4985657
1973	Steelhead	0.706980952	0.664404567	0.469070435	135.76	142.65	149.04	0.016864558	791.0187593	46904.21	19.55961518	28.9596189	13.53365568	178.9124125	0.794495864	3.004520661	10.11342391	25.52090848	12.32918262	124.525882	0.609251019	0.605429012	7.061008967	23.57827991	14.3359917	215.9963608	0.941115061	2.573406051	221.0992889
1974	Steelhead	0.754462205	0.699077806	0.526698669	135.31	139.46	145.47	0.019914695	1048.831902	52666.23	13.07130072	36.43816814	13.61732979	327.0963053	0.748601485	3.279171928	4.87775372	40.55618292	12.26302929	240.841449	0.577715138	1.216146636	5.782225601	30.05240604	14.45706908	383.3356323	0.864136696	2.826637665	387.0356445
1975	Steelhead	0.725843066	0.702209641	0.508988329	135.43	141.48	147.88	0.017924783	912.2986684	50895.94	16.83885778	32.30038569	13.15508194	260.172347	0.75811885	3.47553978	8.187282115	31.05672319	11.82584839	167.8819458	0.566308856	0.631957138	6.25746429	27.42270884	14.03130802	319.5962931	0.893031567	3.24073419	327.4905701
1976	Steelhead	0.735531813	0.717778798	0.527219305	135.31	140.4	145.73	0.019911038	1049.685656	52718.78	15.1076228	34.24784918	12.78945268	300.2443695	0.742677924	3.157660532	6.874405816	34.28354543	11.38303051	201.8880066	0.561871502	0.583889008	5.825006686	29.7672054	13.67112176	368.9265798	0.861879279	2.927598258	368.9979248
1977	Steelhead	0.702583843	0.599944752	0.420927065	135.66	142.92	150.59	0.01548123	651.6097682	42090.31	20.70728397	27.19749643	14.50606842	123.6763494	0.812363869	3.036649652	10.47989818	23.68559825	13.31655045	96.40558014	0.648402238	0.730915326	7.855340719	20.54608595	15.42045625	140.5800578	0.950605204	2.526982461	146.1307526
1978	Steelhead	0.734809646	0.680245743	0.499159541	135.4	141.61	147.37	0.018461189	921.449615	49912.8	16.31957798	31.7098133	13.43744691	228.5470174	0.767427512	3.056254133	7.328326404	31.52658383	11.92678967	164.8946228	0.562428537	0.54019388	6.592974871	25.60387143	14.36460797	269.9070384	0.919650227	2.683716158	277.4730835
1979	Steelhead	0.717125502	0.683171753	0.489241447	135.49	142.4	148.02	0.017988425	880.0187305	48921.39	18.11007987	30.413129	13.13465424	214.9639231	0.774489926	2.826512791	9.071240395	27.78181314	11.7568203	141.0972717	0.580202609	0.563405961	6.642864905	25.45553541	14.02791897	263.3015594	0.918371409	2.279870418	271.4862061
1980	Steelhead	0.744066955	0.69561024	0.516864781	135.32	139.77	145.69	0.019895348	1028.254671	51683.17	14.56777331	33.76690565	13.31595402	277.5517802	0.754314473	3.106868074	6.029031053	34.94176048	12.01130199	206.8199951	0.571395043	0.833238685	6.130630426	28.01544897	14.16571951	325.6025085	0.881902675	2.709441846	329.463501
1981	Steelhead	0.732998226	0.643387373	0.470948966	135.48	142	148.05	0.018038578	849.4736244	47092.05	16.51525065	31.67886372	14.79262778	237.3135091	0.768900449	2.924011002	7.659165144	30.34706026	13.45781631	154.183075	0.582354081	0.529899043	6.474041328	26.31795083	15.73269876	287.2944539	0.904750387	2.48744609	300.8244019
1982	Steelhead	0.738519695	0.694808723	0.512420269	135.42	141.2	146.66	0.019421357	995.1254904	51238.72	15.2143878	33.97694601	13.66399231	299.1387685	0.749416562	3.167450313	6.921356037	33.48330744	12.35022984	189.8943024	0.569031584	0.593511641	5.893837482	29.65165096	14.48591614	369.1971436	0.8695485	2.818046967	378.2512817
1983	Steelhead	0.727932614	0.698249573	0.50757513	135.53	142.21	148.51	0.017360534	881.1177652	50754.07	16.62392998	31.77838965	13.34181951	254.1135864	0.76277649	3.245322017	7.933797956	29.52295875	12.12091522	149.3430664	0.575550187	0.548333812	6.295555413	27.40117919	14.11563762	317.9132385	0.895070344	3.049736232	330.3638916
1984	Steelhead	0.696048316	0.675257555	0.469360355	135.9	144.23	149.99	0.015946631	748.4240122	46933.05	19.60991647	30.52415408	13.8750658	235.9401484	0.776756395	2.978547714	11.00623021	25.29944046	12.24574108	119.2087448	0.613165623	0.561519617	6.226125553	27.58359905	14.94083738	310.6559906	0.894554585	2.540404618	318.9031982
1985	Steelhead	0.710290288	0.666428436	0.472702189	135.59	143.27	148.69	0.017209893	813.4672587	47267.42	18.72633135	30.56781359	13.63509668	217.2749359	0.776440152	3.080680941	9.729520917	27.9082911	12.10085831	139.5709991	0.589092836	0.570681691	6.608628713	25.64496706	14.59462452	266.8219274	0.915390025	2.694044764	277.7381897
1986	Steelhead	0.719053266	0.664289716	0.47699799	135.56	143.07	149.19	0.016972311	809.5230522	47696.69	17.66960473	30.90221337	14.02023328	231.9516363	0.775022075	2.977505596	8.793541431	28.13668873	12.66567059	137.2326019	0.594629496	0.565846443	6.48868183	26.28120605	14.87509044	289.985377	0.907915572	2.66723302	298.4658813
1987	Steelhead	0.749449375	0.561465764	0.420208215	135.34	139.93	144.94	0.020649532	867.6549403	42018.14	15.4097138	32.03001815	15.64648616	199.4435527	0.780259841	2.874709429	6.065346822	34.49036376	13.89787693	172.5206879	0.576052189	0.65511964	6.951685362	23.8698122	16.82962894	220.3316422	0.940994392	2.423539172	219.0927429
1988	Steelhead	0.699776755	0.646719044	0.451931935	135.59	143.51	149.73	0.016147004	729.6929553	45190.61	20.35471862	28.66097454	13.65986824	161.1595632	0.800141576	2.899984568	10.6810472	25.66291559	12.10636215	115.6537979	0.612400553	0.554210114	7.292662121	22.6641051	14.6357406	191.4136251	0.95348539	2.45901754	195.7338104
1989	Steelhead	0.736974577	0.654183808	0.481449201	135.38	140.84	146.82	0.018729651	901.6766627	48141.67	16.33233513	31.49629594	13.87265155	212.5974701	0.771979628	2.934224572	7.180064052	31.68717572	12.29159336	162.5490021	0.564766058	0.543280709	6.756396249	24.90824289	14.87805001	248.0301259	0.928818832	2.580643758	248.1387482
1990	Steelhead	0.742748714	0.572958306	0.424975448	135.45	141.67	147.62	0.01842979	783.1676561	42494.66	16.07859556	31.42445127	15.75690676	209.5668691	0.774395325	3.128777695	6.874175847	31.64304993	13.90318089	152.9059326	0.573579094	0.615012705	6.825306356	24.56780765	17.00248019	243.390063	0.927415848	2.878799011	250.2144318
1991	Steelhead	0.742263305	0.683064878	0.506312542	135.41	141.21	146.79	0.019089632	966.4666438	50627.83	15.3002037	33.15542446	13.69899972	259.7732259	0.753819627	2.870908934	6.557774782	33.87302319	12.40020428	183.4559875	0.56071544	0.566746587	6.344521657	27.25810372	14.5006218	310.9156799	0.889006009	2.532278597	313.5410156
1992	Steelhead	0.737871007	0.55102425	0.406021822	135.45	141.57	147.02	0.019196267	779.363085	40599.72	17.10706741	30.15925033	15.72269287	169.6177856	0.789839634	2.797209857	7.520441085	29.84469568	13.90801163	135.35047	0.583585811	0.538237041	7.205271877	22.92999736	16.9589688	193.2657928	0.954350382	2.309399426	194.1073456
1993	Steelhead	0.709300448	0.687072011	0.486665667	135.41	141.76	146.79	0.019173132	933.0355538	48663.7	18.27860483	31.12334672	12.98918006	249.34487	0.76616746	2.879655472	9.665681839	27.49971519	11.38959122	158.6973511	0.594068962	0.493920726	6.215282768	27.48525614	13.97537899	313.8009847	0.886410087	2.51829129	315.3572998
1994	Steelhead	0.725006239	0.566745286	0.410324823	135.44	142.2	147.21	0.018787248	770.8389087	41029.9	18.1314742	29.30952338	15.03109709	162.0446869	0.796011922	2.911229167	8.461697847	27.78744151	13.20375252	124.5812103	0.601225036	0.563564175	7.284469865	22.56693518	16.25115649	187.4503784	0.953709354	2.545328051	189.8856049
1995	Steelhead	0.724634323	0.689956762	0.499273449	135.51	141.96	148.28	0.017709259	884.126949	49924.56	17.30826951	31.19236899	13.41095734	230.3596105	0.769261863	3.41068596	8.434113622	29.0445756	12.19781437	146.9554993	0.57684789	0.730622125	6.481915608	26.30728535	14.19647948	283.8472951	0.909049541	2.890581707	293.1285706

Year	Specis	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	SAR	TotalReturn	PassageBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	UCTravelTime	UCMigRate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1996	Steelhead	0.746221109	0.674396926	0.502553079	135.45	141.15	146.84	0.018556618	932.5053277	50251.9	14.64955405	33.73164799	14.12198989	278.0857005	0.748625379	3.06863537	6.205830038	34.14461717	12.80324707	179.3740692	0.556501883	0.683304375	6.046420425	28.46545005	15.05318912	340.295934	0.879963607	2.761405418	351.6931152
1997	Steelhead	0.760840636	0.714588564	0.542936806	135.29	139.22	143.86	0.02138497	1160.988519	54289.93	12.0546625	39.10280723	13.59902509	400.9502736	0.747440373	3.939654843	4.477451727	43.5137352	12.28275089	276.1547791	0.596537149	1.277442729	5.159480684	34.32339318	14.41243951	484.7032013	0.83936429	3.606915842	489.2528687
1998	Steelhead	0.741811571	0.681523523	0.50486244	135.37	140.8	146.64	0.019380487	978.3862859	50483.06	15.06289735	33.48989669	13.83867137	274.1713684	0.748012559	2.902549587	6.593193993	33.48671288	12.49887447	178.5067444	0.556464303	0.494840223	6.06830591	28.45719974	14.6900986	336.0892487	0.87794892	2.571889679	343.0171204
1999	Steelhead	0.737410152	0.683027396	0.502974508	135.51	141.82	147.92	0.017696038	890.0039927	50293.97	15.79589887	32.33994542	13.76452026	257.2145528	0.759159103	3.352688046	7.065990061	31.51274243	12.42900944	161.7651428	0.564562258	0.758113849	6.334986903	27.1511286	14.58310795	314.2059733	0.89709873	3.16990761	328.815033
2000	Steelhead	0.737157606	0.613370177	0.451524807	135.46	142.04	147.17	0.018668183	842.8587452	45149.48	16.38442862	31.30333485	14.64851589	210.3121562	0.775153441	3.004134985	7.26050064	30.99903403	12.86654453	149.8506012	0.569612333	0.570785975	6.732377581	24.94871498	15.78295088	248.1405869	0.931348632	2.792479326	257.69104
2001	Steelhead	0.69240139	0.622565873	0.430467633	135.81	144	150.13	0.015887652	683.8757067	43044.48	21.25280198	27.55072165	14.18505274	142.6381673	0.812718193	2.820248376	11.41533744	23.14972624	12.79079838	99.08732452	0.64768616	0.607839268	7.4633075	21.90067834	15.08083169	171.7384135	0.95174551	2.260558856	177.4883575
2002	Steelhead	0.730011683	0.669999497	0.48843039	135.5	142.42	148.39	0.017707227	864.8165556	48839.75	16.48150603	32.09948266	13.86091938	249.7948741	0.764574804	2.878424819	7.643990278	31.55146346	12.25130615	170.070517	0.571683028	0.551808333	6.447459713	26.46079849	14.87043699	296.8959503	0.905102591	2.492437104	311.3011475
2003	Steelhead	0.722531516	0.67707872	0.488533697	135.54	142.89	149.18	0.017018204	831.3420011	48850.16	17.40969069	30.83665359	13.47983239	232.4613363	0.773923815	2.916867822	8.394708306	28.82565337	12.260429	143.769632	0.588307011	0.575215435	6.621263586	25.61794482	14.2831955	281.9601746	0.911500682	2.415293659	305.0435181
2004	Steelhead	0.718014311	0.651260388	0.466966588	135.45	142.75	149	0.016985243	793.1033387	46693.67	18.34268968	29.59490258	13.9661272	189.3726008	0.790812052	2.947703681	8.963675112	27.12354324	12.59206333	122.5420593	0.602017492	0.54588632	6.992667429	23.8451613	14.84112453	226.8299281	0.940108558	2.503063947	248.1354523
2005	Steelhead	0.728899203	0.620607613	0.451733921	135.49	141.57	147.46	0.01830004	826.6225011	45170.53	17.43974721	30.32517452	14.95534356	191.3225972	0.785958501	2.719410289	8.264941216	28.43575147	13.59353828	127.5070923	0.594742486	0.472146815	6.792682327	24.52746724	15.90807199	235.3639501	0.933601369	2.11877771	238.1486511
2006	Steelhead	0.732488919	0.696433027	0.50942356	135.49	142	146.64	0.019306926	983.4758771	50939.02	15.52313697	34.05161664	13.40375862	307.5854045	0.74752159	2.73980299	7.37207149	33.08516909	11.93321323	189.8729309	0.569411331	0.448886853	5.747603372	30.22005462	14.30530516	385.3170522	0.863928924	2.166742404	395.3374023
2007	Steelhead	0.747142648	0.63589627	0.474448011	135.34	140.19	146.1	0.019348117	917.9085381	47441.75	15.30475132	32.44427439	14.77182426	222.0673065	0.769249163	2.980013263	6.270077929	34.09462956	13.37966099	175.2225006	0.561900407	0.571236372	6.643467642	25.2171676	15.70962381	255.3961182	0.925449024	2.714322001	258.1043396
2008	Steelhead	0.700559575	0.681122601	0.476505655	136.1	143.53	148.6	0.017457791	831.8208139	47647.54	18.90798225	31.85511479	13.94146322	287.5315018	0.764026251	2.898747563	10.66433182	27.00304134	12.37459469	157.6786209	0.60863333	0.596547562	5.861279331	29.54836297	14.97111352	370.2283122	0.868043373	2.390946721	389.0479431
		0.72676091	0.662138378																										
MO4-RESSIM																													
1929	Steelhead	0.698128981	0.640066474	0.445614493	135.76	143.85	149.79	0.016234432	723.3811112	44558.45	20.59108986	27.55485277	13.8632295	177.9991343	0.808428391	11.03249541	10.81263384	23.8692547	12.28033314	116.9261551	0.613397521	0.964555335	7.244391263	22.48203148	14.89401356	216.1449025	0.972745915	16.95736313	225.5170288
1930	Steelhead	0.722403669	0.56480066	0.406887382	135.61	142.42	148.01	0.018024148	733.3333658	40686.16	18.80367666	27.78335829	15.09825548	155.8020533	0.80263332	9.596471081	8.691886276	26.10903482	13.24160805	121.0412628	0.603998512	0.630567437	7.578902632	21.17479755	16.27722247	179.1240514	0.967007538	14.87052194	182.4289093
1931	Steelhead	0.727567535	0.56197131	0.407742942	135.54	141.99	147.34	0.018934249	771.9796463	40771.6	18.37247173	28.01683309	15.08083382	161.2053416	0.798769056	9.749495359	8.291787356	26.75122812	13.28773975	129.1963409	0.594354793	0.720927298	7.541466981	21.29281479	16.239772	183.0805283	0.966232985	15.06757029	186.3124542
1932	Steelhead	0.734759658	0.685244999	0.502100247	135.48	141.25	146.74	0.018783284	943.0431436	50206.51	16.11907099	31.26740883	13.49691804	262.2636851	0.78248582	13.28729224	7.180642277	30.94639376	12.02007236	175.0967346	0.563234851	1.913717365	6.383938164	26.08894335	14.46831115	320.7249146	0.957451671	20.33493042	328.4512329
1933	Steelhead	0.729402904	0.667959693	0.485866211	135.52	142.39	149.29	0.016854772	818.8611351	48583.34	17.22598401	29.86319527	13.97780285	240.2129283	0.787466696	12.29998869	7.873094499	28.73568516	12.581147	153.1642273	0.576560354	1.536318326	6.81216529	24.27090683	14.85524559	288.7315165	0.956544946	18.55459849	306.4143372
1934	Steelhead	0.755975853	0.588177293	0.443421139	135.41	139.53	144.48	0.020853848	924.6379487	44338.96	14.03588405	33.1852903	15.42510599	251.8629883	0.79141342	14.76525049	4.782122448	38.52213454	13.78303375	219.4872314	0.580034187	6.974186707	6.695635349	24.61095137	16.49720478	273.8397776	0.971463501	19.27908619	277.59375
1935	Steelhead	0.726110893	0.656893563	0.475660496	135.58	142.39	148.65	0.017469631	830.9075193	47562.97	17.76115361	29.43009495	13.99451873	213.4972026	0.794373595	11.68548105	8.267540216	28.12154504	12.60550041	147.478894	0.577017757	0.839374363	6.952094197	23.70853475	14.87820991	253.625445	0.972429583	18.09308624	265.3795471
1936	Steelhead	0.733723545	0.630205196	0.461119578	135.49	141.51	146.4	0.019727817	909.6289062	46108.95	16.55557686	30.82892461	14.22954884	244.5277893	0.785535013	12.83885947	7.487413108	30.44883042	12.38275738	167.1150146	0.561530289	1.333107686	6.515314415	25.39009011	15.4058919	295.6726227	0.96614338	19.98148433	302.1954651
1937	Steelhead	0.712787543	0.647749691	0.46043263	135.57	142.54	149.12	0.016872056	776.7955539	46040.36	19.30147783	28.12851693	13.69920209	180.1574005	0.801275819	10.750621	9.483997971	25.8235233	12.22087173	128.4919128	0.594110242	0.804399145	7.277983755	22.34764123	14.69426918	213.3889618	0.972572118	16.59789912	221.0375214
1938	Steelhead	0.733155069	0.665291805	0.486415449	135.55	141.89	148.04	0.017659398	858.9202954	48638.14	16.5426006	30.58484678	13.91380374	246.772231	0.785855081	12.6482487	7.425992489	29.79678268	12.30198326	157.4780121	0.568404758	1.236016357	6.568601176	25.27037038	14.9424332	301.0829976	0.96004497	19.56823293	314.1419373
1939	Steelhead	0.712834834	0.594818099	0.422835999	135.61	143.14	148	0.018120926	766.1674251	42280.81	19.18579112	28.74656109	14.21289558	190.8420247	0.793954928	11.08023481	9.520804137	27.1197557	12.09209251	142.1337463	0.573267323	0.885274506	7.123081416	22.83948361	15.57659944	222.995074	0.973683427	17.15853874	227.4716644
1940	Steelhead	0.731189806	0.595883038	0.434500715	135.59	142.29	147.52	0.018686738	811.8864489	43447.2	17.45006044	29.373359	14.87920335	200.664798	0.794417603	11.53917017	7.911969095	28.34595369	13.11733074	142.2127106	0.573371723	0.818047261	6.996011838	23.38646071	16.00234636	238.4995906	0.975254784	17.98972456	244.602829
1941	Steelhead	0.733827426	0.609330545	0.445908414	135.57	141.69	148.14	0.017896065	797.9483331	44587.92	17.52730405	29.02411774	14.91575228	184.8910543	0.798153803	10.84039822	7.771107405	28.23574724	13.57049446	134.9048096	0.585044509	0.793681741	7.218437895	22.55762398	15.84618394	217.1693039	0.973151942	16.77382819	222.7259369
1942	Steelhead	0.714882261	0.689948629	0.491869831	135.6	142.79	149.13	0.016651804	818.9988217	49183.79	18.63296899	29.20287569	13.10208111	215.9269745	0.794383059	11.91417314	9.199252039	27.09610626	11.65020504	141.9461731	0.576704791	0.810393012	6.890577868	24.01255177	14.02144782	262.0452067	0.971707245	18.59550897	272.3589783
1943	Steelhead	0.732038154	0.668242859	0.487828648	135.55	142.24	148.55	0.0171541	836.7672135	48779.43	16.66057301	30.38812718	13.83123213	242.4080302	0.786919312	12.40779543	7.428787261	29.69408941	12.20048523	160.7226746	0.570129439	1.138925254	6.686767474	24.83148526	14.85700671	290.6378937	0.962295512	19.20495804	305.2093506
1944	Steelhead	0.71733157	0.632732177	0.452624884	135.61	142.44	148.91	0.017420405	788.439528	45259.54	19.09224074	27.63718207	14.02613633	169.8812475	0.801194208	10.32839042	9.131745875	25.00913708	12.60322189	127.6436874	0.597158876	0.88546561	7.42127651	21.79466618	14.95342811	198.3073018	0.96953996	15.88459865	202.5666046
1945	Steelhead	0.707341745	0.639401637	0.451025972	135.7	143.26	149.52	0.016628246	749.9275788	45099.62	19.52924229	28.59414384	14.23146273	202.2235036	0.804909864	11.93191865	10.07874152	25.44469984	12.65178108	125.9055038	0.603051341	1.023803234	6.916254178	23.76960108	15.28398132	249.8623784	0.973542283	18.47261683	260.571167
1946	Steelhead	0.744462228	0.680752103	0.505395378	135.41	140.08	145.57	0.020138746	1017.734679	50536.15	14.66074929	32.9089717	13.77177531	291.9196086	0.782494595	15.11169653	5.859738469	35.05840321	12.15949535	216.2178162	0.576562163	5.98346405	6.242298052	26.81206349	14.78045066	340.3347066	0.950911075	20.57113846	350.8437805
1947	Steelhead	0.743743723	0.629901355	0.467192303	135.43	140.5	145.6	0.020451765	955.4240207	46715.97	15.26609665	31.84613408	14.70673014	259.893453	0.785016194	13.28015912	6.300113082	32.87081861	13.0234581	185.9192993	0.566035286	2.175323987	6.413314998	25.91285289	15.75798718	309.0360718	0.962972909	20.13820465	314.6608276
1948	Steelhead	0.74130366	0.703534092	0.520092606	135.49	141.4	146.65	0.019449847	1011.504279	52005.77	14.78603226	33.44470243	13.72002036	385.928299	0.769488835	17.04749463	6.563691199	33.57319574	12.14231415	222.1536621	0.572425401	4.542918873	5.666745961	29.35513192	14.72898165	479.4311829	0.916324725	24.61188221	508.2977295
1949	Steelhead	0.743275997	0.6817551	0.505333573	135.48	140.84	146	0.020143916	1017.868865	50529.84	15.00073473	32.44609991	13.84695098	301.4435527	0.77507429	13.99375828	6.380226642	32.95933944	12.50943909	194.7011627	0.574319848	2.778608751	6.059864625	27.42450045	14.69795465	371.0773163	0.930237333	20.87874667	385.0036926
1950	Steelhead	0.720865291	0.688073489	0.494638225	135.6	142.6	148.63	0.017272445	854.3049564	49460.57	17.62305918	30.41688004	13.52121811	259.2107819	0.785784835	12.90199144	8.567007869	28.83132247	11.97180042	164.6411377	0.572519282	1.456788087	6.512551814	25.60543975	14.48088741	316.2524567	0.956569433	19.77836982	333.7026978

Year	Specis	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	SAR	TotalReturn	PassageBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	UCTravelTime	UCMigRate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1951	Steelhead	0.748886925	0.683358201	0.510345624	135.42	140.05	145.55	0.020076473	1024.522899	51031.02	14.45889318	32.81343872	13.78656413	287.0929494	0.781281629	13.94137479	5.6017268	35.12950864	12.42499218	206.4741852	0.573783481	3.405381536	6.296077371	26.53944005	14.63278341	338.6734111	0.948716203	20.29414805	351.306488
1952	Steelhead	0.738475987	0.70051105	0.515882712	135.43	140.81	146.07	0.019714259	1016.954902	51584.74	15.28353754	32.26135661	13.23690529	294.6308014	0.776419241	14.45767833	6.616009086	32.53869293	11.71920757	193.36539	0.570062247	3.742035055	6.105414227	27.32902453	14.17156235	360.6554464	0.938853343	21.14492337	370.6419067
1953	Steelhead	0.732756152	0.698040802	0.510081206	135.5	141.48	148.29	0.017758248	905.7553442	51004.77	16.79417746	30.30541485	13.24550559	248.1901499	0.786527354	12.75921468	7.577232152	29.34095569	12.12015724	166.1227844	0.568238133	1.616207385	6.667140633	24.97070452	13.9731981	297.5423228	0.962375522	19.42183828	311.8495789
1954	Steelhead	0.726145227	0.711475151	0.515207965	135.5	141.55	147.17	0.018601899	958.3231415	51517.49	16.71792288	31.46076194	13.00191994	282.9551849	0.7839008	14.10338321	7.880743444	30.92005884	11.57340889	194.493811	0.580585781	3.67187171	6.284130633	26.5782694	13.90045706	341.5654399	0.94745785	20.46432718	353.2147522
1955	Steelhead	0.714759915	0.68896007	0.491080676	135.65	142.64	149.44	0.016405139	805.5710507	49104.8	18.59922573	29.26725325	13.2606741	228.8439412	0.794423643	12.29604283	9.257254004	26.84464317	11.89072571	148.6799805	0.583843443	1.245749831	6.802777424	24.33981134	14.16774877	277.273969	0.966196428	18.88580561	291.9988403
1956	Steelhead	0.746986723	0.71447451	0.532229956	135.45	140.73	145.76	0.019724166	1049.706332	53219.3	14.03712666	33.83429955	13.14574706	356.1292124	0.768887925	15.61234115	5.682426006	35.57992376	11.64327679	228.218399	0.575862503	4.37845583	5.787379265	28.78274959	14.05963039	433.9367421	0.914476782	21.99207671	456.319397
1957	Steelhead	0.740181187	0.715714177	0.528295881	135.4	140.37	145.32	0.020730116	1095.092829	52826.18	14.64424619	33.50198252	13.05513763	352.4061483	0.767542854	16.16629985	6.371837914	34.23946018	11.71244011	223.0259186	0.580785158	5.909860039	5.703836724	29.08233772	13.91692305	436.233551	0.905765692	22.12305832	449.425354
1958	Steelhead	0.730655632	0.692444279	0.504541218	135.49	141.64	146.79	0.019304385	973.9224543	50450.84	16.20313603	31.7649195	13.50528692	305.4981842	0.774447725	14.08498159	7.614749014	30.50606676	11.98721523	182.5317444	0.571236494	2.314404082	6.03273648	27.71193602	14.45745532	381.8606669	0.92965891	21.22196547	399.1619568
1959	Steelhead	0.744441313	0.677628716	0.503061914	135.49	141.04	147.31	0.018562111	933.7263507	50302.81	15.42586549	31.60533316	13.84768162	259.6167837	0.783313915	12.78118722	6.28066653	32.89863762	12.48299904	188.3138489	0.562435892	1.486561871	6.592865765	25.2835129	14.69758431	303.877594	0.962608596	19.55711508	314.8978882
1960	Steelhead	0.729476895	0.676843069	0.492377966	135.45	141.36	147.92	0.017742452	873.5421592	49234.58	17.07453001	30.25213292	13.4283247	232.6569356	0.788151368	12.13487596	7.726840466	29.96366989	11.90106087	168.1025452	0.566889128	1.021143806	6.800039575	24.2953984	14.42775838	273.848175	0.968600621	18.82277282	282.7469788
1961	Steelhead	0.743414936	0.689367225	0.511071075	135.48	141.23	147.3	0.018830298	962.2960023	51103.6	15.40536594	31.91695454	13.5168986	288.3742015	0.779621951	13.44442854	6.411956042	33.01762496	12.31744308	200.0280823	0.571799883	2.765297985	6.436430976	26.01361885	14.30211957	339.459142	0.943334202	19.62439712	354.6586609
1962	Steelhead	0.729885598	0.659835344	0.480274319	135.55	142.24	148.41	0.017551592	842.90171	48024.23	17.10571057	30.2094761	13.9434562	231.8793427	0.787994993	12.27281923	7.803542197	29.36049439	12.29453888	157.5801819	0.565488967	1.239443767	6.759219915	24.64043907	14.99066178	277.6894124	0.967758755	18.89107466	286.3416748
1963	Steelhead	0.726780443	0.663807827	0.481110478	135.56	142.51	148.41	0.017676856	850.3960865	48107.88	17.47312918	29.76316908	14.02188638	226.3801493	0.793771711	12.19521246	8.192218691	28.00318887	12.66640987	144.3253876	0.579451579	0.841884124	6.738024384	24.65481502	14.88069932	277.8931122	0.968068868	19.10705956	286.9694519
1964	Steelhead	0.710530222	0.674797394	0.47813957	135.66	143.06	149.21	0.016782667	802.3934257	47810.84	18.67215291	29.93943298	13.92654285	259.7376526	0.791420774	12.96943625	9.675155699	27.12773326	12.30512638	156.3730621	0.592786691	1.491379356	6.462698847	25.73065717	14.98408667	322.5801341	0.951155851	19.90352821	336.6481934
1965	Steelhead	0.738249031	0.694736422	0.511472203	135.5	141.5	147.72	0.018152408	928.3829621	51143.79	15.98827094	31.2531439	13.45547237	266.8571594	0.779887992	13.11123867	7.069221616	30.68639467	12.18695354	168.9552612	0.559005958	1.232291269	6.364842087	26.26675397	14.27839088	328.6368917	0.954472462	20.49069627	337.1407776
1966	Steelhead	0.729818972	0.603444438	0.439189243	135.54	142.01	147.51	0.018689216	820.7565444	43916.05	17.61049505	29.57072443	14.54364319	204.1556091	0.789732299	11.28684314	7.994600385	29.24677475	12.5515152	158.1491394	0.561762834	0.784765971	7.075049236	23.11564661	15.78077809	233.8253632	0.975129217	17.49415795	239.7819824
1967	Steelhead	0.713349019	0.699028199	0.497273909	135.57	143.01	148.49	0.017567894	873.546856	49724.05	18.15441801	30.5772394	13.09582361	278.1501587	0.783095135	13.27233609	9.218763024	28.69499455	11.4279501	178.3454956	0.578353232	2.089419222	6.389111564	26.1531558	14.12180249	339.6852468	0.944009066	19.97621854	352.0823059
1968	Steelhead	0.73216933	0.629716726	0.459785785	135.54	141.68	148.24	0.017791015	817.952036	45975.57	17.35256691	29.67187998	14.79481144	215.2120372	0.793017379	11.72959103	7.866644204	28.89170693	13.42649994	153.4249329	0.57523545	1.036120605	6.950484574	23.60482575	15.73658069	252.0759633	0.971197695	18.01099586	263.6241455
1969	Steelhead	0.74749486	0.686952938	0.512076345	135.42	140.27	145.59	0.020347979	1041.899943	51204.1	14.34815241	33.30271405	13.83092569	313.8797841	0.772595555	14.38955816	5.780931622	35.12570706	12.48785896	212.9632416	0.572367033	3.567280006	6.004763618	27.78046524	14.6833477	380.5513611	0.928008586	21.01359431	386.0590515
1970	Steelhead	0.705022706	0.699827659	0.492031342	135.63	143.51	149.34	0.016722319	822.7348945	49199.81	19.18238544	29.34457068	13.02019806	246.6707738	0.793473375	12.71706239	10.12529659	25.61980216	11.74191608	142.0054443	0.592763019	1.073986459	6.511421755	25.62435434	13.84836976	312.5933533	0.955183307	19.88505332	322.4967957
1971	Steelhead	0.746387026	0.712127468	0.530055704	135.4	139.81	145.33	0.02033809	1077.958822	53001.97	13.93269527	33.97682268	13.21560955	337.5665476	0.771116253	16.27790909	5.507953674	36.40299234	11.76167164	233.3214233	0.579748398	6.989266014	5.856709674	28.46090205	14.10817337	406.5208079	0.919767698	21.80170043	410.8690186
1972	Steelhead	0.754473961	0.706353308	0.531454202	135.39	139.78	144.93	0.020776092	1104.077271	53141.72	13.37661225	35.08397754	13.66424224	368.4883392	0.771632466	16.06480926	5.112996593	38.86898293	12.38502293	253.3319153	0.589296928	5.490853786	5.697322592	29.15544154	14.48129193	443.9643606	0.906765362	22.20111465	448.5415955
1973	Steelhead	0.724772929	0.658010436	0.475590791	135.55	141.94	148.47	0.017585306	836.284328	47555.86	18.19877423	28.65145496	13.64637375	190.2452784	0.796336195	11.15912096	8.447443783	27.09221427	12.4151886	139.9924377	0.57999531	1.017006171	7.205948994	22.66180751	14.46947336	223.8010712	0.973126719	17.15961734	228.6638641
1974	Steelhead	0.753207976	0.698536102	0.524691128	135.4	139.63	145.7	0.019744082	1035.881935	52465.44	13.49772184	34.37730831	13.70725562	329.1098999	0.77888417	17.08069054	4.940509126	38.3979876	12.36092911	242.8283875	0.586818567	9.220161152	5.992088601	27.76881311	14.54274718	385.1587219	0.931554089	21.69923671	388.9115601
1975	Steelhead	0.724247151	0.697968959	0.504105887	135.53	141.65	148.22	0.017592742	886.80247	50407.29	17.28035738	30.67903152	13.24749921	260.4622416	0.784217222	12.9656999	8.269531816	29.53235123	11.86573009	167.9088379	0.571236429	1.443996954	6.463973999	25.71322597	14.16237434	319.7939097	0.954161396	20.01147262	327.7306519
1976	Steelhead	0.734126177	0.718115163	0.525732001	135.41	140.61	146.07	0.019590489	1029.866502	52569.72	15.56653668	32.26467171	12.87991714	297.4827718	0.775587198	14.44634813	6.942404211	32.41972012	11.45532265	200.0063751	0.570012668	3.686416531	6.062822089	27.42771158	13.77725538	365.77565	0.937151452	21.19230286	365.5746155
1977	Steelhead	0.723862496	0.603935261	0.435958417	135.55	141.51	148.68	0.01721187	750.3182461	43593.07	18.94291067	27.41211019	14.52875741	147.3503998	0.798998491	9.062950087	8.594085723	25.95529867	13.30327702	125.0999649	0.599447882	0.779061651	7.812492728	20.41210092	15.43458525	162.9597778	0.961794257	13.83667437	165.9924774
1978	Steelhead	0.732363147	0.672646986	0.491261688	135.5	141.86	147.75	0.018102747	889.261429	49123.01	16.89310235	30.11560875	13.53683097	226.4625936	0.789722111	12.09732816	7.530042887	29.77158732	12.01670094	162.8134338	0.566298535	0.829593658	6.81243521	24.14653331	14.4746898	267.8085378	0.97188281	18.96409488	275.2998352
1979	Steelhead	0.717450648	0.679849246	0.486411049	135.59	142.6	148.33	0.017653897	858.6479306	48637.87	18.33943252	29.24940947	13.24379063	219.3427236	0.793921201	12.04163963	8.991430789	26.96257617	11.83921375	144.5539398	0.57794964	0.848683202	6.799240932	24.30142304	14.15425587	268.491717	0.969294071	18.87365023	276.7297363
1980	Steelhead	0.742056141	0.693886217	0.513481144	135.42	140.06	146.07	0.019616436	1007.198281	51344.61	15.09209508	31.98252939	13.42137845	274.8871429	0.786621555	14.59093626	6.172824323	33.04586643	12.10453854	204.5228638	0.578376472	5.010877562	6.358055711	26.19972306	14.28047371	322.7682292	0.956944515	20.42171621	326.4420166
1981	Steelhead	0.737790131	0.643490775	0.473450142	135.51	141.34	147.65	0.018406922	871.4227319	47342.12	16.43955219	30.63831399	14.78475793	243.2318878	0.787616878	12.60748116	7.252262086	30.17456433	13.45978565	165.097821	0.56993928	1.78976841	6.648370638	24.99001141	15.69752789	289.990214	0.96351258	19.01325178	302.5993958
1982	Steelhead	0.737948358	0.692869819	0.509890392	135.52	141.32	146.91	0.019149482	976.3507267	50985.75	15.58094048	32.10550172	13.78259303	299.1756694	0.777745721	14.17725449	6.918158293	31.88332592	12.45867825	190.3048737	0.574658903	3.173508358	6.110264257	27.38188091	14.61222601	369.2972972	0.935663293	20.83954414	378.0173035
1983	Steelhead	0.726625503	0.693362125	0.50242297	135.62	142.39	148.81	0.017075616	857.8589941	50238.83	17.05214098	30.19641627	13.47267024	255.0143911	0.786913678	12.71267312	8.008804411	28.15095737	12.23485737	149.2864838	0.579276401	0.942561734	6.496009469	25.66294628	14.26353375	319.2503916	0.952289999	19.86086758	331.9732666
1984	Steelhead	0.696681878	0.67275858	0.467403418	135.98	144.3	150.23	0.015716666	734.5530961	46737.21	19.83166762	29.21364845	13.95786438	239.1999674	0.802682369	13.00117029	10.89294297	24.54142094	12.33450432	121.5174133	0.614716351	1.03026402	6.407610834	26.03624297	15.02594868	314.3586782	0.958325326	20.59399605	322.7971191
1985	Steelhead	0.709252386	0.660186626	0.466945386	135.68	143.4	148.91	0.01697867	792.7573795	46691.37	19.107411	29.17204505	13.71171932	217.8766266	0.798286612	11.92036842	9.761531502	26.65820369	12.1361618	140.2262909	0.59163284	0.835003042	6.803873301	24.28791981	14.70943785	267.5443344	0.967947463	18.58904394	278.3669739
1986	Steelhead	0.724208759	0.660626251	0.477109798	135.59	142.55	148.95	0.017132022	817.3303739	47707.76	17.56721134	29.72195791	14.07187436	234.7522736	0.791734067	12.27011719	8.343170404	27.72674545	12.69662132	143.1330048	0.585389137	1.041129589	6.681021512	24.78356213	14.9426713	290.8312073	0.958305875	19.10376112	298.6134949
1987	Steelhead	0.749257197	0.569717409	0.425686298	135.43	140.08	145.23	0.020574641	875.7783072	42565.91	15.46753103	31.13469557	15.58740724	216.9727214	0.790477225	11.74846079	5.945687473	33.64320366	13.88697796	185.3003265	0.570384452	1.88868854	6.973971039	23.43894052	16.70524247	240.2047679	0.972829302	17.61785905	240.6504364

Year	Specis	InRivSurvUC	InRivSurvLCol	InRivSurv	MedDayRIS	MedDayConfl	MedDayBON	SAR	TotalReturn	PassageBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	UCTravelTime	UCMigRate	UCTemp	UCFlow	UCFSpill	UCGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1988	Steelhead	0.718664082	0.65086724	0.466463252	135.55	142.65	148.86	0.017163553	800.565075	46643.32	18.70737523	28.63008765	13.5848313	184.6131571	0.795154237	10.74613908	8.879686207	27.33773761	12.02295895	138.2302948	0.577565554	0.773078501	7.284069434	22.38478919	14.56227207	215.2744573	0.973152975	16.62907592	220.0105286
1989	Steelhead	0.734850936	0.6452712	0.472868801	135.48	141.01	147.12	0.018450156	872.3905521	47283.64	16.81635672	30.02346863	13.94604041	212.0334819	0.790231101	11.5335128	7.302149922	30.17562877	12.33516235	162.4047607	0.56782299	0.857830441	6.964903042	23.56531693	14.98297071	247.2591756	0.971873293	18.05099916	247.2663116
1990	Steelhead	0.747511556	0.580412949	0.432667487	135.49	140.89	146.77	0.019085672	825.7190847	43263.82	15.88015331	30.79414961	15.62078355	220.9737152	0.786171526	11.62492617	6.430721343	32.06460217	13.83264217	169.0753296	0.558700922	1.049251068	6.912042394	23.78842219	16.78368807	253.3344447	0.970991015	17.8822879	258.121521
1991	Steelhead	0.740626469	0.680609134	0.502685588	135.51	141.37	147.1	0.018804493	945.2082348	50265.02	15.74862896	31.49099503	13.82071902	259.9704631	0.782868567	12.78823978	6.652626872	32.17308519	12.51145458	183.757135	0.567754087	1.970021105	6.545175985	25.58594495	14.63171164	311.2974243	0.955767006	19.29352164	313.6676636
1992	Steelhead	0.743029391	0.563768194	0.417739642	135.5	141.05	146.55	0.019612391	819.2324989	41771.17	16.67340133	29.91368959	15.60085011	193.928124	0.79102607	10.81712873	6.96365118	30.71253267	13.85407124	156.7585358	0.56703999	0.808972359	7.169944957	22.74035781	16.75077597	219.4615453	0.973536372	16.73410018	220.9672546
1993	Steelhead	0.714143784	0.688221559	0.490131609	135.48	141.69	146.81	0.019165687	939.3081882	49009.89	18.05211012	30.13461892	13.03308144	255.513503	0.790203427	12.84226423	9.106288165	27.74079514	11.39965763	166.1320953	0.590105015	1.328088307	6.392098695	25.91931566	14.04700136	318.9117839	0.951208889	20.05723381	320.4338074
1994	Steelhead	0.734796763	0.579563561	0.424685628	135.56	141.92	147.24	0.018996376	806.6947686	42465.72	17.41075118	29.13940122	14.97495295	185.7713959	0.792841149	10.69683076	7.631686836	28.7642345	13.15657177	143.5510529	0.57187289	0.743267059	7.236458153	22.45879601	16.13268948	214.0204112	0.972360661	16.58059434	217.8973389
1995	Steelhead	0.726831642	0.683349168	0.495307972	135.61	142	148.45	0.017531853	868.3100805	49527.57	17.39811425	29.8784628	13.54730848	231.1090139	0.793329702	12.40669243	8.168497741	28.15306078	12.30153999	148.9616119	0.57674472	0.800182104	6.683188394	24.85653525	14.35759846	283.8363495	0.969600548	19.55689724	292.8260498
1996	Steelhead	0.744726248	0.67570002	0.501822328	135.54	141.28	147.08	0.018384249	922.4964065	50178.63	15.10811055	31.98009647	14.1362772	277.6471202	0.779379629	13.43555855	6.288532376	32.43448557	12.84182663	179.3948944	0.56472536	1.758414292	6.268061712	26.59844881	15.03795147	339.3130798	0.950033238	20.61951303	350.7852783
1997	Steelhead	0.759434015	0.712003333	0.539227546	135.4	139.4	144.17	0.021068479	1135.990279	53918.95	12.50019671	36.28554782	13.66737734	402.264859	0.77004555	18.45291065	4.522839576	40.98663387	12.31893101	278.3939758	0.599739084	9.472418499	5.405610532	30.45289397	14.5036122	485.5736287	0.892607699	23.53283707	489.7180481
1998	Steelhead	0.741345155	0.681550957	0.503869771	135.45	140.82	146.72	0.019318579	973.3395526	50383.6	15.34761898	32.00866999	13.93180993	278.206958	0.780110818	13.29050341	6.541228354	32.41294143	12.59972115	182.7302704	0.566950029	1.400267959	6.250604719	26.7339954	14.78032986	340.0581309	0.949951867	20.70722834	346.8958435
1999	Steelhead	0.735202485	0.678598436	0.497529727	135.6	142.02	148.25	0.017462989	868.7751627	49749.51	16.34202373	30.6490089	13.88972187	256.7466543	0.783273435	12.6803776	7.252887338	29.75720051	12.55112495	160.0165802	0.569751945	1.204191852	6.542131051	25.452573	14.71388133	314.4234009	0.952821881	19.6086301	329.3964539
2000	Steelhead	0.733673095	0.606433307	0.443695059	135.57	142.35	147.61	0.018258965	810.0845434	44366.4	16.99181397	29.83048687	14.7253322	208.8579346	0.793649739	11.71796535	7.506283164	29.4555869	12.91635971	147.3700684	0.573427394	0.91015079	6.942225128	23.61794728	15.85537958	247.4620183	0.973956168	18.15734537	257.2190857
2001	Steelhead	0.71710725	0.626545658	0.448059064	135.6	142.5	148.76	0.017425671	780.722854	44803.03	19.1070514	27.70871838	14.14318123	166.1378138	0.802364115	10.25062747	9.107779533	25.42240899	12.75110168	123.8293716	0.602994269	0.936691439	7.459964827	21.63013141	15.03777107	194.8528468	0.966688633	15.71689812	200.1593781
2002	Steelhead	0.723388257	0.663901166	0.478932125	135.62	142.85	149.01	0.017053726	816.7012467	47889.9	17.37674655	30.34926267	13.96239942	247.9024567	0.789766066	12.57497528	8.182331026	29.43426811	12.30848198	165.5746246	0.581743518	1.771069932	6.653793886	24.90293071	15.01640304	296.4957275	0.958887686	18.96787882	311.4447021
2003	Steelhead	0.732488101	0.67556408	0.493476343	135.54	142.04	148.54	0.017662575	871.5472374	49344.29	16.86812851	30.09126228	13.58914769	242.468104	0.78635565	12.22622056	7.570248693	29.22944171	12.36608601	157.1286438	0.57066862	1.04959203	6.746949852	24.54075589	14.39727052	289.6742605	0.959270308	18.7934444	312.3175659
2004	Steelhead	0.726060523	0.647534844	0.46885122	135.55	141.94	148.41	0.017408848	816.1607445	46881.95	17.91925527	28.90860857	13.98726947	199.1722122	0.797959028	11.45155608	8.265043974	27.4400297	12.59479713	133.9851105	0.58391681	0.717633802	7.110605761	22.9956605	14.87111139	236.0294495	0.974578917	17.65118885	256.798645
2005	Steelhead	0.734120228	0.619908961	0.453830668	135.57	141.54	147.5	0.018219938	826.8245945	45380.21	17.18535925	29.45607205	14.89809316	200.2091497	0.797452036	11.53111842	7.712878436	28.352012	13.54653244	136.3704254	0.583379075	0.704584932	6.932889417	23.56056564	15.8304828	244.0730158	0.973113924	18.20176498	246.9970093
2006	Steelhead	0.729636035	0.693616759	0.504690628	135.59	142.25	147.08	0.018889305	953.2617891	50465.69	16.0997559	31.98784879	13.49643078	305.7730459	0.774704952	14.25509721	7.565072745	31.13890094	11.97887688	188.3767883	0.574300763	2.771722221	5.978578418	27.7469316	14.43987783	383.4224904	0.927683165	21.31107648	393.2098389
2007	Steelhead	0.742696224	0.631368505	0.467620333	135.43	140.4	146.38	0.01915631	895.7274113	46758.87	15.95325197	30.87303947	14.77835929	224.5832499	0.790285942	11.8406527	6.590066731	32.11987308	13.3954958	176.5461212	0.567748344	0.983233666	6.818776578	24.015858	15.70522499	258.7680232	0.97314171	18.40714137	261.8122253
2008	Steelhead	0.699838332	0.678834413	0.473761763	136.02	143.61	148.84	0.017183756	814.0502116	47373.24	19.2836508	30.12458637	14.0471817	288.2418869	0.789833438	13.93297168	10.68005586	25.72656759	12.46611671	158.2285477	0.613908279	2.740326691	6.068176225	27.37324489	15.09450038	371.1837616	0.928215156	20.71345536	389.9797363
	Steelhead	0.730768448	0.661022027																										

Table 4-3. Snake River MO1, MO2, MO4, Spring Chinook Raw Data

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
SCN NAA-RESSIM																																																		
1929	Chinook_1	0.796139478	0.647700812	0.515660187	0.365756474	126.12	135.01	142.16	133.81	20.93807184	24.44471029	12.65388312	141.2859135	0.828380632	12.93342246	10.62074901	11.34739039	11.49413624	60.04292526	0.774140596	10.96010571	7.804250337	22.13058118	13.1754783	183.8769811	0.787771215	13.4123582	206.1539459	0.491591623	0.508408377	0.717531834	0.848857116	0.898181256	5.323838092	23.9382859	13.32432537	0.831944799	14.84209175	1.980517991	20.27959295	13.43603865	0.81938227	14.91088676	1.543576814	16.46453617	13.49126863	0.81415683	15.77166748	0.590260902	0.406612982
1930	Chinook_1	0.804278467	0.624332921	0.502137524	0.125283865	103.47	118.18	126	135.11	26.06370439	19.99399697	12.13480384	134.5677302	0.822631883	12.54296027	13.99850442	9.138956748	10.01214256	63.4701561	0.751696122	10.22992878	8.940769009	18.54539091	12.86858352	170.9401983	0.793061068	13.10247779	178.6813965	0.790961695	0.209038305	0.697566432	0.831411616	0.881564784	6.135192923	19.9395292	13.07254982	0.840009105	14.55628071	2.399430059	16.89657341	13.41941961	0.832899451	14.70516141	1.881078802	13.58169774	13.71840239	0.835130781	15.71235418	0.572508562	0.404119514

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas
1931	Chinook_1	0.786080222	0.610756376	0.480103508	0.087393273	105.48	120.61	128.17	136.99	27.32403856	19.6838528	12.20684617	122.768589	0.838037444	12.6625809
1932	Chinook_1	0.831996219	0.71498872	0.594867911	0.324077283	118.08	126.09	133.3	130.18	21.52807996	23.51276158	11.78875385	229.565555	0.800687973	14.67671285
1933	Chinook_1	0.788051543	0.605349333	0.477046476	0.298621047	132.63	141.19	147.74	139.9	19.5174532	26.54113486	13.45913015	189.5281418	0.827056408	13.84255307
1934	Chinook_1	0.789894745	0.579005219	0.45735318	0.128486511	115.14	123.15	128.84	131.28	21.32771739	22.86475694	13.11439126	224.5402478	0.836053606	14.96528506
1935	Chinook_1	0.78934422	0.594601296	0.469345096	0.367296875	126.71	135.16	142.22	133.87	19.55102623	25.56453869	13.4506761	178.7149405	0.818495291	13.32235442
1936	Chinook_1	0.845418778	0.723340175	0.611525367	0.333061943	115.75	122.45	129.96	129.82	20.00474083	24.02567329	11.31317452	249.2831971	0.768971977	15.70124262
1937	Chinook_1	0.798983636	0.630165377	0.503491825	0.3483651	123.61	131.89	138.24	132	22.54630831	22.65031894	12.54366854	145.0930745	0.814100576	12.75649894
1938	Chinook_1	0.818685924	0.613322588	0.50211857	0.517955816	128.97	134.7	138.72	140.05	18.04005989	26.63888012	13.13850777	233.8864964	0.788285792	15.21415278
1939	Chinook_1	0.825478669	0.701954009	0.579448061	0.32222313	115.06	123.31	130.93	128.15	21.24222907	23.17470363	11.50060783	196.3006619	0.791314508	13.69446182
1940	Chinook_1	0.817389425	0.716113019	0.585343209	0.071434755	94.97	111.43	120.24	136.71	28.92552323	18.41468306	10.96335118	173.7409107	0.769612048	12.75526302
1941	Chinook_1	0.741156673	0.472966883	0.350542562	0.3604899	130.12	134.4	136.72	145.42	20.14474739	24.76326463	14.46998644	141.8917585	0.827543919	12.80198206
1942	Chinook_1	0.809055045	0.665602945	0.53850942	0.5287513	134.35	137.78	143.46	145.62	20.01762362	25.63654554	12.57128879	192.6626598	0.787499551	13.64193191
1943	Chinook_1	0.833701188	0.679464851	0.566470654	0.391063666	121.48	124.8	130	130.49	21.63657862	23.13671207	11.87734604	226.6440141	0.772937277	15.21069016
1944	Chinook_1	0.789375843	0.573690232	0.45285721	0.466906847	130.77	138.77	145.58	137.99	20.12309933	24.98512709	13.43693147	138.0514703	0.818616612	12.72033473
1945	Chinook_1	0.814179493	0.676466447	0.550765108	0.439869986	117.55	125.76	133.15	130.61	22.07028554	23.27300713	12.2078822	185.5525725	0.802603074	13.73854641
1946	Chinook_1	0.853950236	0.740009218	0.631931046	0.20152923	111.36	120.3	127.96	126.83	21.88304116	22.89806497	11.14467001	260.3187932	0.776295355	15.88498432
1947	Chinook_1	0.834974195	0.637781963	0.532531481	0.260701444	110.45	121	128.42	128.72	22.40099119	22.71730452	12.42078372	240.9466956	0.793250241	15.00870647
1948	Chinook_1	0.823649233	0.617298845	0.50843772	0.549903685	132.27	136.5	140.46	141.6	15.72880101	29.70199007	13.48974739	332.5056774	0.810696708	19.65732472

Year	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv
1931	15.36502703	7.805160938	9.924270058	43.79971161	0.789573109	10.9639595	8.880564667	18.62645397	13.10543346	159.2845179	0.797443122	12.85064872	172.5918274	0.845496867	0.154503133	0.685645452	0.825903931	0.877128863
1932	10.9735034	11.78654733	10.32664986	87.75227966	0.727964413	11.56060505	7.686701767	22.71880198	12.2923967	300.3189036	0.761635353	15.13457378	320.2585754	0.573472641	0.426527359	0.769032688	0.869311716	0.914627685
1933	10.11451642	11.84750574	11.96130962	60.38768997	0.794204235	11.27432823	7.026903592	25.1473771	14.10043669	254.4695994	0.767961651	14.17998457	278.4812012	0.547441845	0.452558155	0.683139565	0.833583085	0.88549665
1934	10.75567426	11.86823403	11.57977066	75.77511444	0.809118629	12.21225262	7.559784725	22.21043988	13.72465229	306.1560822	0.776526779	15.38456305	312.4604797	0.772977818	0.227022182	0.663295511	0.826779696	0.880429322
1935	9.788755387	12.23303024	12.03415737	65.2191185	0.767193937	10.73378983	7.253927737	23.95389282	14.07290093	237.716746	0.770494541	13.82725199	252.4838715	0.464919572	0.535080428	0.674058814	0.832347412	0.884956878
1936	9.354550317	13.78788867	10.08544731	124.7712357	0.62350896	13.40180359	7.761945821	22.40518161	11.68543577	311.3924052	0.774677734	15.74380056	324.694519	0.56796749	0.43203251	0.781125225	0.879835701	0.924247355
1937	11.74607373	9.855063562	10.97256966	58.86926651	0.742554522	10.47763287	8.08660432	21.05946419	13.2162075	188.1332703	0.780773054	13.21912209	201.5529938	0.502857233	0.497142767	0.700043577	0.835772683	0.886297696
1938	8.452583104	14.9251212	11.72978268	108.1472839	0.68293556	12.74192677	7.048870623	24.52982307	13.65339088	301.6244151	0.770220687	15.47824693	311.0754089	0.334261433	0.665738567	0.688950015	0.837655441	0.888937805
1939	10.30926319	12.2796745	10.58095608	89.40588837	0.699776602	11.15286713	8.058020651	21.57338729	11.82027928	252.740893	0.763253699	14.27966626	261.1381531	0.56776738	0.43223262	0.765658323	0.874430765	0.920409874
1940	15.96474791	8.904497715	9.242454147	81.64222565	0.63999629	9.57604866	9.31154228	17.98847624	11.45035998	219.7348531	0.762431423	13.66034738	229.9129181	0.891243434	0.108756566	0.772942225	0.86933838	0.914249531
1941	9.954864517	11.97697892	13.24363594	58.03632813	0.768330646	10.70613136	7.750114501	21.59798921	14.91866366	185.2690608	0.79066065	13.17095788	193.0798492	0.40467288	0.59532712	0.577984155	0.779922911	0.840114112
1942	10.10838376	12.02739659	11.32103405	85.48240356	0.677845597	10.60726318	7.511568457	23.1307433	12.9947834	245.8830236	0.772627811	14.28809667	254.6298065	0.339046935	0.660953065	0.731987078	0.8572483	0.905508699
1943	10.79946	12.84051731	10.45827236	117.3235153	0.637563264	13.36006889	7.888260953	21.57689416	12.35779603	286.7590942	0.772218386	15.27208694	300.0597839	0.484043951	0.515956049	0.739880601	0.85727722	0.904793721
1944	10.00564884	11.7684758	11.98400402	66.19074783	0.737448704	10.62554111	7.697632156	22.06445573	14.0709192	174.5335058	0.795565168	13.16020679	177.7637329	0.357078635	0.642921365	0.652852177	0.814025536	0.867856889
1945	11.35838079	11.1535203	10.67813892	75.99728546	0.726305115	11.3842577	7.957300231	21.77606355	12.75116412	237.396609	0.767486562	14.17873772	254.8943939	0.430113797	0.569886203	0.740224727	0.855888771	0.903465482
1946	10.91668554	12.945872	9.595863152	119.2784546	0.646028042	12.89437027	7.87241333	21.93667334	11.63576396	332.2824249	0.772999257	16.18660458	346.321167	0.729833151	0.270166849	0.788819209	0.878308176	0.922198395
1947	11.51395529	11.68489602	10.04371662	95.14977722	0.705314934	11.34666824	7.901351981	21.82367133	13.34972493	308.9882609	0.763155152	15.56093462	333.0570984	0.621608732	0.378391268	0.705476549	0.837281885	0.887326597
1948	7.195350647	17.1712239	12.18316555	141.9211639	0.700249541	15.67576027	6.110920787	28.60647382	13.99084727	430.3586833	0.808084567	21.03001261	452.8507385	0.309257351	0.690742649	0.697600895	0.844558028	0.894168661

Year	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1931	6.123497464	19.99607494	13.30498524	0.845288658	14.44270496	2.381845422	16.99848887	13.61086909	0.836037199	14.49025567	1.865354247	13.69220729	13.85982752	0.83963421	15.48227549	0.555344855	0.376644103
1932	5.206859343	24.64354919	12.49637623	0.783634937	16.99683189	1.92341771	20.88136387	12.75575829	0.801201781	17.61360868	1.499454282	16.94002697	12.9435873	0.791011363	18.7691164	0.660135356	0.491716704
1933	4.776930057	27.29026745	14.24752712	0.803721333	16.0658411	1.73803594	23.0354694	14.41805394	0.803529104	16.51821836	1.351562135	18.77606752	14.54484367	0.791268229	17.55342197	0.569932493	0.366028988
1934	5.350334004	23.71300088	13.84466591	0.780518413	17.40728054	2.022421166	19.92655945	14.00408141	0.799657544	17.73201402	1.580822065	16.08217972	14.14491081	0.785698503	18.86974239	0.534947935	0.380889
1935	4.997180969	25.86674991	14.20147228	0.806980014	15.65816402	1.843433112	21.76851474	14.3280344	0.797530055	15.99654198	1.436300188	17.67621372	14.43977165	0.781398177	16.95095444	0.567638141	0.360133466
1936	5.275248624	24.27442427	11.87704868	0.782655823	17.50332565	1.959756263	20.51032628	12.09926923	0.803119739	18.01073074	1.528666385	16.6212232	12.28161573	0.791884005	19.24771976	0.66182859	0.529579345
1937	5.524908267	22.73602892	13.390798	0.826689327	14.75931587	2.096069805	19.22756004	13.57509391	0.817067504	14.96933492	1.63781511	15.53552985	13.69786119	0.811877012	15.99936914	0.599525037	0.396152522
1938	4.88815695	26.42995675	13.8045763	0.780501878	17.28706474	1.808744639	22.20815303	14.00072193	0.800011218	17.62764041	1.410696089	17.99387202	14.17829561	0.788043529	18.83385658	0.5764205	0.412335927
1939	5.424309075	23.42206199	11.94734535	0.79634974	15.90060596	2.042535931	19.72759682	12.0699482	0.787199875	16.33325227	1.596172243	15.93112185	12.14795542	0.765919447	17.29461575	0.629762816	0.495517021
1940	6.257032879	19.45989223	11.66268272	0.805166149	15.18733196	2.453416832	16.53643708	12.00386969	0.800013602	15.48501714	1.924018629	13.28695502	12.28775644	0.785775512	16.54803419	0.639205149	0.484073564
1941	5.450748503	23.09300845	14.99949837	0.8339095	14.77289562	2.077440172	19.41547649	15.1650095	0.823313475	15.00108274	1.624517828	15.66075241	15.32913113	0.820096344	15.9540081	0.439979417	0.260532274
1942	5.076300293	25.08994131	13.16163406	0.802577662	15.9835474	1.904844373	21.12437777	13.34778468	0.806309382	16.36593596	1.487544388	17.0748959	13.50900269	0.796578586	17.4530859	0.60585357	0.461175598
1943	5.435856692	23.24395758	12.54937706	0.78732748	16.93191261	2.050651871	19.64573423	12.77804025	0.806351761	17.19191074	1.60219004	15.87223799	12.96284676	0.797128588	18.33152485	0.648283926	0.474118176
1944	5.334621988	23.72884411	14.22205143	0.842013228	14.62782001	2.025070332	19.90995736	14.38423538	0.8339534	14.72271983	1.583444051	16.05812638	14.51750469	0.836035669	15.66070414	0.547056985	0.332937983
1945	5.389230773	23.60224031	12.94762611	0.804364049	15.72216988	2.014124855	19.96811398	13.20571073	0.793460945	16.13463593	1.571495429	16.17665214	13.39681196	0.775384784	17.17142296	0.618326661	0.453215313
1946	5.382308178	23.71578884	11.84945164	0.771810544	18.05348873	2.002580188	20.08384247	12.12766838	0.809064726	18.41304557	1.562668882	16.26512881	12.32620621	0.805791914	19.72440243	0.689930706	0.540341434
1947	5.396155171	23.59589871	13.58060875	0.785213912	17.39245586	2.002789639	20.06156572	13.91880512	0.808105807	18.15993659	1.561383866	16.27864163	14.17638159	0.801364332	19.46875477	0.613977144	0.423300621
1948	4.204011083	30.92187056	14.12507324	0.806563401	23.46276665	1.504059136	26.65471589	14.30684535	0.844307681	23.32970111	1.170845658	21.68314419	14.46873474	0.839028209	23.27313519	0.580376188	0.427624763

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1949	Chinook_1	0.806 19650 1	0.555 44169 1	0.447 79514 8	0.593 72000 5	126.47	131.98	137.29	133.17	16.63 56979 9	27.83 00489 8	13.77 65119 4	271.8 22123 4	0.782 30298	16.55 23198 3	7.425 13893 5	16.98 66952 8	12.37 05276 5	124.5 61753 8	0.660 95881 5	13.71 31053 9	6.578 64384 4	26.47 05420 4	14.44 64705 8	347.8 95914 7	0.774 57465 7	16.82 37041 6	379.7 36114 5	0.248 99835 5	0.751 00164 5	0.651 26244 5	0.825 45792	0.879 29735 1	4.601 01442	28.48 05468 1	14.52 84124 4	0.777 67484 2	18.64 29103 9	1.642 06989 1	24.35 61461 5	14.62 07971 6	0.827 43010 9	19.03 47118 4	1.275 71310 1	19.89 07444 4	14.71 08779	0.825 67715 6	20.31 59751 9	0.527 14793 3	0.341 63089 6
1950	Chinook_1	0.819 56645 4	0.668 74473 3	0.548 08075	0.509 26005 5	131.94	137.26	143.12	139.44	18.65 27392 3	26.73 04352 6	12.67 20335 8	217.3 73101 4	0.798 11953 6	14.45 27714 6	9.147 23958 1	13.58 08372 7	11.48 23713 3	93.84 89990 2	0.707 62399 4	11.78 39275 4	7.057 49683 8	24.93 11668 7	13.15 50318 4	281.0 62932 3	0.772 59269 4	14.84 95251 3	298.1 42120 4	0.361 45906 6	0.638 54093 4	0.733 18361 7	0.856 72133 6	0.904 96675 1	4.799 38107	27.04 12235 3	13.32 22129 8	0.793 55254 2	16.63 86714 9	1.760 37400 2	22.77 73089 9	13.48 07596 2	0.803 63933 2	17.09 38555 4	1.370 81971	18.51 35881 3	13.58 04548 3	0.792 16489 2	18.20 88213	0.629 81947	0.443 17596 5
1951	Chinook_1	0.824 36319 6	0.625 69752 7	0.515 80201 3	0.522 12336	130.32	133.75	139.12	138.09	18.10 22359 6	26.92 22436 4	13.20 22335 2	260.3 89486 6	0.798 96907 3	16.05 89391 2	8.778 45852 1	14.44 83982 1	11.61 23464 6	106.4 52043 2	0.712 86273	12.91 35644 9	6.803 12997 1	25.40 19558 1	13.84 08101 4	338.7 95979 8	0.770 20899 5	16.29 61119	350.0 30517 6	0.336 21985 3	0.663 78014 7	0.695 28221 3	0.839 34796 4	0.890 22003 4	4.733 91968	27.34 35939 8	14.00 96553 8	0.769 63465 2	18.31 81264 9	1.736 90167 1	23.10 81592 5	14.20 76307 9	0.812 20765 9	18.72 93850 6	1.353 84258 6	18.74 44594 8	14.37 04137 8	0.807 88436 5	20.12 18519 2	0.589 17657 1	0.427 87176 1
1952	Chinook_1	0.849 68530 6	0.732 15883 4	0.622 10460 3	0.604 30885 1	123.27	122.69	130.01	133.22	18.29 31995 2	25.92 60506 9	11.56 58160 6	291.5 44778	0.755 92367 6	17.82 63801 2	8.186 19564 2	16.54 75383 5	10.45 68538 7	161.9 29852 3	0.588 12216 5	16.22 36282 3	7.340 71828 4	23.56 77153	11.84 55561	358.7 42935 2	0.773 72055 3	17.40 44976 2	369.3 27209 5	0.302 42593 8	0.697 57406 2	0.783 06470 2	0.878 88622 9	0.923 04639 1	5.042 80115 7	25.45 48988 2	12.04 83535 8	0.763 91726 7	19.00 33607 5	1.861 96856 2	21.58 26167 9	12.27 70945 2	0.819 70129 4	19.26 50814 1	1.452 58589 1	17.47 96699 3	12.46 69404	0.819 79659 2	20.68 37797 2	0.679 21760 8	0.533 44038 3
1953	Chinook_1	0.818 66753	0.655 18318 4	0.536 37719 9	0.415 83417 3	130.78	133.01	140.07	143.62	20.22 76518 2	25.25 88500 4	12.69 30343 8	209.9 23741 5	0.799 79320 1	14.35 79324	10.34 07482 2	11.73 89778 1	11.10 58446 9	85.41 44424 4	0.714 59538 9	11.55 71199 4	7.400 13225 4	23.43 27310 6	13.32 85369 9	269.4 81084 2	0.770 68821 6	14.73 94955 2	283.8 60534 7	0.447 67703 5	0.552 32296 5	0.722 88812 5	0.851 03909	0.899 81344 1	5.028 72593 7	25.38 05057 9	13.49 1329	0.798 80298 4	16.52 50474 9	1.869 09560 9	21.49 99644 2	13.70 20870 8	0.803 73567 3	16.98 74394 7	1.458 06883 3	17.41 52683 2	13.87 74662	0.792 56710 4	18.11 02724 1	0.589 47746 6	0.467 17099 9
1954	Chinook_1	0.820 23221 1	0.661 45037 1	0.542 5429	0.416 63992	140.53	148.55	149.83	143.71	18.59 07852 1	27.28 10586 4	12.74 72104 3	233.6 88429 2	0.820 55946 8	15.57 03294 6	9.420 80146 8	12.96 56123 6	11.39 06040 2	90.05 16128 5	0.760 76221 5	12.55 01827 2	6.799 56620 9	25.88 05718 6	13.31 05588	302.7 38474 5	0.780 67039 5	15.93 59196	310.4 66125 5	0.448 38089 8	0.551 61910 2	0.727 58365 4	0.855 29533 6	0.903 92064 2	4.617 10614	28.08 08058 9	13.46 76826 5	0.789 41412	17.64 73802 6	1.699 79140 2	23.60 10061 6	13.61 76122	0.809 00087	18.01 31254 2	1.324 35798 6	19.16 04136	13.72 42612 8	0.801 20372 8	0.620 92118 8	0.460 38849 3
1955	Chinook_1	0.810 56769 9	0.649 86265 7	0.526 75767 9	0.583 10561 2	134.83	139.64	145.31	142.74	19.03 70893 9	26.29 34080 2	12.89 12589 2	192.6 18479	0.791 19736 8	13.67 33484 6	9.367 48552 3	12.94 98093 4	11.51 66925 4	86.78 80706 8	0.686 58464	10.93 33549 5	7.260 02309 5	24.02 23665 3	13.41 37374 6	245.0 40969 8	0.773 97370 3	14.23 42501 5	256.9 95971 7	0.286 53882 5	0.713 46117 5	0.718 85374 8	0.849 66188 1	0.898 63239 5	4.938 63961 8	26.02 90513 3	13.57 62418 7	0.806 03385	15.89 02196 9	1.830 68630 8	21.93 36146 3	13.78 08637 6	0.802 90907 6	16.24 90758 9	1.427 22243 8	17.78 76684 9	13.95 58873 2	0.789 63568 8	17.30 91807 4	0.604 68996 6	0.424 14316 4
1956	Chinook_1	0.853 96741 5	0.732 89281 8	0.625 86658 6	0.324 18177 4	116.02	120.66	128.07	134.73	19.55 30979	24.72 32417 6	11.36 94887 8	297.4 12771	0.798 65450 9	18.40 68150 5	9.222 11528 6	14.99 08969 9	10.13 30469 1	144.5 93344 1	0.681 12168 3	15.76 11206 1	7.457 87292	22.91 65646 7	11.68 89933	383.7 40768 4	0.795 92622 3	19.03 08960 3	386.4 56787 1	0.581 85031 2	0.418 14968 8	0.785 58964 2	0.880 72221 3	0.924 49277 3	5.134 65338 2	24.70 43002 1	11.89 66440 2	0.784 53352 5	20.82 32353 2	1.908 27154 4	21.08 70131 5	12.14 46778	0.828 09195 9	20.52 82319 4	1.490 28959 1	17.04 26889 3	12.36 22331 6	0.820 82182 2	21.66 63608 6	0.671 96789 6	0.555 99297 6
1957	Chinook_1	0.828 86637 4	0.716 48260 7	0.593 86834 1	0.378 83067 7	114.52	121.29	128.67	138.28	21.55 51035 2	23.56 77123 3	11.61 58348 5	272.6 32748 2	0.789 7972	16.62 77791 1	11.01 63817	11.70 19175 8	10.35 14219 3	113.4 61831 7	0.685 70966 7	12.92 90832 5	7.742 90605 6	22.35 14158 2	11.94 83176 9	339.4 18406 2	0.771 43573 8	16.87 66844 3	358.0 72296 1	0.512 35123 9	0.487 64876 1	0.779 89159 5	0.878 23521	0.922 38395 5	5.206 09351 2	24.26 15019 3	12.10 67697 5	0.786 56321 8	18.85 40447 2	1.931 45205 8	20.79 94132 1	12.36 27980 6	0.822 19952 3	19.51 98758 4	1.505 99005 1	16.86 77579 3	12.60 60538 3	0.817 24751	20.99 02687 1	0.638 47334 8	0.526 77297 1
1958	Chinook_1	0.824 87932 9	0.647 20626 4	0.533 86706 9	0.556 45249 9	124.93	130.8	136.86	136.83	17.12 83104	28.11 85294 5	12.80 51403 6	275.9 17166	0.793 70389 7	16.84 91975 6	8.059 59543 6	15.57 05885 3	11.52 96987 5	121.3 10063 2	0.696 40680 6	13.90 71104	6.569 45239	27.04 63457 8	13.37 41579 1	353.6 55700 7	0.771 63738	17.09 90542 6	373.9 01092 5	0.314 50321 4	0.685 49678 6	0.723 02643 3	0.855 43047 9	0.904 20792 4	4.498 27371 5	29.31 98449 2	13.50 55851	0.778 14710 1	18.98 51390 8	1.609 72304 6	24.87 26234 1	13.62 39996	0.821 69624 2	19.47 64029 2	1.251 85279 5	20.27 07767 7	13.68 98737	0.819 30160 5	20.66 12491 6	0.595 74589 9	0.452 19994 1
1959	Chinook_1	0.802 96142 9	0.573 86649 5	0.460 79266 1	0.456 93459 5	135.2	140.62	144.77	143.51	18.24 68154 1	27.49 16883 3	13.69 29033 8	227.8 54444 2	0.813 72390 5	14.69 18907 5	9.156 9556	13.37 71561 9	12.07 04450 6	82.75 50231 9	0.754 60676	11.56 32864	6.730 91879 5	25.89 74964 7	14.43 37900 5	304.9 67427 6	0.769 85021 4	15.25 66171 5	318.0 57861 3	0.370 61868 2	0.629 38131 8	0.655 72515 5	0.823 80775 8	0.878 04443	4.646 31262 4	27.96 14240 6	14.56 99405 7	0.783 15678 8	17.31 28498 1	1.704 78314 2	23.53 30358 5	14.70 85453 7	0.803 55807 1	17.76 50521 6	1.328 30134	19.10 36845 9	14.81 27489 1	0.789 91466 8	18.87 71333 7	0.546 32377 3	0.357 19788 8
1960	Chinook_1	0.808 66746 4	0.634 97849 7	0.513 48645	0.480 55075 4	134.02	140.49	144.6	140.04	19.27 82105 1	26.32 13034 7	12.97 83870 2	205.9 89191 3	0.799 79328 2	14.05 40822 2	9.724 78249 7	12.55 14227 4	11.51 40399 9	81.45 13732 9	0.720 10693 6	11.28 56445 3	7.126 16027 9	24.61 39528 4	13.54 61950 3	269.0 37167 9	0.766 09545	14.46 36333	284.2 11608 9	0.371 77454 9	0.628 22545 1	0.708 02241	0.847 63301	0.897 55150 7	4.848 05215 9	26.68 58076	13.69 65293 9	0.794 10986 9	16.35 89435 6	1.785 17805	22.47 26301 6	13.87 08855 3	0.798 83859 6	16.79 36258 3	1.390 74792	18.25 00603 2	14.02 61602 4	0.785 39514 5	17.87 49656 7	0.591 98353 3	0.419 02573 8
1961	Chinook_1	0.800 42247 5	0.622 83332 6	0.498 52979 3	0.195 72402 1	118.85	127.93	134.94	136.21	21.90 97334 6	23.45 24830 3	12.79 25542 4	199.6 54285 7	0.818 25844 7	13.96 83205 1	11.56 10225 7	10.28 20698 2	10.98 00718 3	61.53 87840 3	0.778 91107 8	11.06 95486 1	7.635 33317 3	22.56 96679 2	13.59 59650 7	267.3 03749 1	0.760 17714 5	14.31 76215 5	275.8 21258 5	0.690 14432 8	0.309 85567 2	0.696 50116 2	0.839 56602 8	0.890 47515	5.226 38069 8	24.38 75167 7	13.75 17980 6	0.792 60423 2	16.36 46251 7	1.949 87025 1	20.64 41153 8	13.92 25177 8	0.799 15553 3	16.85 88914 9	1.522 98113	16.68 27217 2	14.05 71003	0.785 82668 3	17.99 53393 9	0.571 46342 8	0.413 42069 5
1962	Chinook_1	0.827 13678 5	0.672 70364 3	0.556 41792 8	0.328 62777 4	119.35	127.21	134.13	130.14	20.57 53360 7	23.87 85749 3	12.27 98123 4	198.2 74013 5	0.792 75834 1	13.81 75395 9	10.02 64440 5	12.27 19225 3	10.79 15689 5	87.19 17495 7	0.706 93653 8	11.40 47290 8	7.776 64101 1	22.40 51098 5	12.82 69098 6	258.5 97808 8	0.760 65595	14.27 41881 2	262.3 38134 8	0.550 68873 3	0.449 31126 7	0.735 02787 9	0.853 31027 3	0.901 23121 5	5.271 39961 7	24.29 36710 6	13.03 41152 2	0.793 53414 8	16.04 82740 4	1.972 89294	20.42 85155 8	13.27 56036 1	0.790 15119 9	16.50 04727	1.542 52606 6	16.47 47451 9	13.44 41332 8	0.770 95255 3	17.50 32825 5	0.638 23171 1	0.455 59998 8
1963	Chinook_1	0.808 80224 3	0.609 00229 5	0.492 56242 2	0.347 47542 4	116.99	125.25	132.42	132.11	22.69 01317 5	22.50 58686 6	12.78 22888 2	166.1 08323 2	0.807 29533 1	13.20 65235 9	11.73 81260 9	10.55 66544 9	10.83 35159 3	71.26 66931 2	0.726 81956 3	10.68 75045 8	8.171 02381 6	20.70 18664 2	13.56 75325 4	211.9 07605 5	0.778 00653 4	13.70 28702 9	219.8 80996 7	0.499 41020 8	0.500 58979 2	0.682 57980 3	0.829 26742 4	0.881 16224 9	5.625 11512 6	22.29 11898 4	13.74 90720 7	0.819 21221	15.28 58415 6	2.140 62652	18.86 00978 9	13.98 05393 2	0.812 47226 4	15.60 44699 4	1.674 80444 9	15.20 04922 6	14.17 26641 7	0.804 47697 6	16.67 77305 6	0.566 41867 5	0.403 81215 7
1964	Chinook_1	0.817 70435 9	0.604 26107 6	0.494 10691 6	0.626 74996 6	133.57	139.9	145.55	141.73	17.49 80354 1	28.25 15829 6	13.45 10835 9	227.4 92797 9	0.785 63382 4	14.83 49563 7	8.440 60624 4	14.94 41151 8	11.83 74465 9	104.9 95489 5	0.673 53706 4	12.11 05701 4	6.716 86551	26.15 42416 6	14.14 30571 9	292.2 18968 7	0.771 86499	15.32 38123 3	303.7 41149 9	0.239 88960 1	0.760 11039 9	0.678 52609 2	0.831 74109 9	0.883 82538 3	4.605 53857 7	28.30 89486 8	14.30 69124 2	0.789 88875 2	17.03 91288 8	1.688 31223 2	23.77 33306 8	14.47 59734 5	0.809 43260 6	17.44 41464 7	1.316 02999 6	19.28 14278 4	14.60 57434 1	0.800 97279	18.48 01597 6	0.587 93264 3	0.371 44606 3
1965	Chinook_1	0.783 43022	0.530 01918	0.415 23304 3	0.652 95879 6	142.46	139.37	140.59	152.61	15.91 37650 7	29.55 45144	14.15 99749 2	257.3 07101 7	0.768 26409 4	16.30 61136 9	7.003 15616 3	18.22 82776 8	12.99 36582 6	135.7 91891 5	0.622 37757 4	14.19 35798 6	6.591 67136 3	26.21 25504 4	14.52 26464 3	324.2 48469	0.773 96836 9	16.39 05777 1	329.3 14147 9	0.193 28389	0.806 71611	0.638 59646 6	0.823 96313 8	0.877 89464 3	4.619 54261 4	28.16 17968 3	14.59 47778 7	0.772 71018	18.13 64498 1	1.699 23041 8	23.65 18266 4	14.79 86663 2	0.808 70477 4	18.33 73158 8	1.326 13642 5	19.13 48072 8	15.05 05657 2	0.799 64008 9	19.58 02888 9	0.483 17807 8	0.339 32717 5
1966	Chinook_1	0.804 56810 1	0.695 00168 7	0.559 17618 8	0.151 46053 9	111.28	123.15	130.79	131.03	24.03 06436	21.50 97823	11.58 89005	162.5 19065	0.823 74325	13.01 78339 8	12.67 66048 5	9.462 20026 3	10.34 91294 9	59.95 98609 9	0.774 05679 2	10.60 29462 8	8.455 14801 9	20.22 26458 2	11.99 58335 6	212.6 16622 9	0.777 02070 3	13.45 12359 3	224.1 71310 4	0.774 03318 5	0.225 96681 5	0.758 71682 4	0.868 93667 9	0.915 07711 6	5.705 07482 4	21.90 55142 1	12.16 15884 8	0.817 43367 9	15.25 28121 9	2.174 30046 9	18.55 88785 6	12.35 92742 3	0.807 26188 4	15.53 74212 3	1.700 10689 6	14.97 97504 8	12.52 16345 8	0.796 30166 3	16.54 34250 8	0.620 11455 8	0.467 04034 5

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas
1967	Chinook_1	0.8114088	0.711071251	0.57696947	0.337977436	125.18	133.49	140.47	136.66	20.88599633	25.16812273	11.99856247	204.4588639	0.825883691	14.25671339
1968	Chinook_1	0.726199985	0.429328731	0.311778518	0.421622013	139.96	143.94	145.41	147.82	17.75972987	27.52727489	15.17311989	180.5182517	0.827332952	13.74077875
1969	Chinook_1	0.839672388	0.649035606	0.544977277	0.351573559	116.32	122.78	130.06	132.82	20.69376125	23.70924218	12.4869662	252.3206313	0.782495209	15.72861477
1970	Chinook_1	0.814999289	0.693159552	0.564924542	0.472144586	123.18	128.25	135.63	142.62	21.26872265	24.35666729	12.121787	188.9479626	0.806733681	14.30667411
1971	Chinook_1	0.832377009	0.601891904	0.501000983	0.664168616	139.01	145.37	147.39	143.04	14.34736547	32.14181796	13.64855358	328.5605632	0.799332018	19.67563309
1972	Chinook_1	0.8380725	0.615981384	0.516237059	0.485151477	122.45	126.96	133.48	137.93	17.89538276	26.81220588	13.21117456	286.4574056	0.803511798	17.55343607
1973	Chinook_1	0.771383756	0.577022679	0.445105922	0.279414466	118.07	126.88	133.63	143.48	23.55343825	22.41008186	12.97225652	128.1104657	0.832915332	12.6239888
1974	Chinook_1	0.830942571	0.579764731	0.481751196	0.536381724	136.65	143.54	147.09	141.87	15.2644124	30.47383866	13.98599843	316.2709416	0.812773096	19.13097852
1975	Chinook_1	0.813868619	0.606235696	0.493396209	0.603084021	144.93	148.17	151.03	155.43	15.92026525	30.37891755	13.71944468	261.9526727	0.794787777	16.68022238
1976	Chinook_1	0.845757551	0.737712874	0.623926234	0.527231396	119.64	125.07	132.31	130.78	19.60467024	24.85727841	11.45569086	264.0278615	0.774962587	15.99412714
1977	Chinook_1	0.728097878	0.504524286	0.367343062	0.23051912	130.87	139.15	144.33	139.37	21.57221708	23.72603553	14.04793378	112.3717066	0.847358499	12.54338132
1978	Chinook_1	0.838348026	0.73584695	0.616895838	0.215481395	109.62	120.42	128.29	128.29	24.01842181	21.66146845	11.04995401	201.604435	0.785129986	13.67166386
1979	Chinook_1	0.830326728	0.729252257	0.605517641	0.184772573	113.3	123.34	131.09	127.83	23.8523908	21.87691749	11.17455373	185.4226954	0.804026923	13.35779326
1980	Chinook_1	0.825443728	0.610549643	0.503974373	0.557795888	134.83	138.68	143.74	146.38	16.58733922	29.11207462	13.45130505	256.6106464	0.8016662	16.00773692
1981	Chinook_1	0.779447324	0.567078414	0.442007752	0.39620999	123.08	123.7	129.18	147.7	21.56412382	23.43173654	13.58551856	189.9821401	0.801794512	13.88115362
1982	Chinook_1	0.811944906	0.529119152	0.4296156	0.577996238	143.26	146.92	146.08	149.44	15.55023273	30.49625837	14.47875752	276.2901508	0.794018005	17.10326815
1983	Chinook_1	0.822123042	0.620957512	0.510503478	0.426219534	119.09	124.44	131.42	145.28	20.33371646	24.67495697	12.93753808	218.688718	0.788452987	14.52998488
1984	Chinook_1	0.814783336	0.599139291	0.48816871	0.614970939	128.42	133.51	139.16	137.91	17.07337358	27.5020056	13.42892585	224.9159584	0.77003938	15.18772343

Year	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv
1967	11.09356941	10.68210572	10.82509174	65.69182892	0.788891733	11.29342098	7.298304357	24.18100014	12.42971134	272.7600937	0.769652516	14.67106533	290.2615967	0.549900514	0.450099486	0.768794078	0.873771437	0.919023218
1968	8.544855148	14.08583533	14.21977062	70.60104675	0.769633031	11.28466549	6.945833422	24.3323395	15.52917449	234.8481216	0.789083024	14.12252371	245.5637207	0.321290066	0.678709934	0.548982588	0.777504268	0.839268372
1969	10.13192678	12.85330069	10.44846668	110.5148819	0.673269379	12.89764881	7.681953743	22.37824609	13.28119135	320.2050273	0.764764339	15.88106036	330.0449524	0.519264181	0.480735819	0.712765427	0.842849498	0.892457054
1970	10.95697234	10.83848188	10.78637695	84.18067169	0.720319617	12.06460323	7.82889916	22.04231249	12.56932036	231.9556758	0.782112588	14.40533074	238.9811859	0.404659438	0.595340562	0.756286755	0.866004875	0.912285429
1971	6.328473069	20.03188923	12.45133934	154.5691193	0.684302902	16.77255592	5.675757043	31.0252024	14.25845273	423.3259786	0.794856101	20.07057746	427.3061523	0.212899941	0.787100059	0.6793581	0.837115513	0.88876558
1972	8.511796653	14.78808563	11.29584427	122.2027084	0.707263052	14.17070084	6.806130111	25.41731807	14.04128011	366.9045308	0.785475363	18.18422079	369.4259644	0.369778379	0.630221621	0.687961919	0.834629993	0.885842174
1973	12.64352118	9.226172456	11.18896999	50.83545151	0.773329735	10.74388561	8.309384771	20.00287703	13.70170164	162.8041611	0.799027999	12.89086143	170.2836914	0.553620037	0.446379963	0.66168166	0.817218217	0.870458309
1974	6.947174877	18.17934599	12.40002213	139.1327087	0.728767073	16.05157204	5.894481689	29.56343384	14.70507765	412.496755	0.789164662	19.6576848	417.1885071	0.308939339	0.691060661	0.65861912	0.824709994	0.877967364
1975	7.402501352	16.39781137	12.43327484	123.0255951	0.686071205	14.03384056	6.34074609	27.87069032	14.14687443	330.9567057	0.782779157	16.84969266	341.1127014	0.258710466	0.741289534	0.684405501	0.837009304	0.888159292
1976	9.370328829	13.87863972	10.22898731	121.7610626	0.644913197	12.94926624	7.427991599	23.62376553	11.88042053	334.3314514	0.77081879	16.39870214	348.7322693	0.374420852	0.625579148	0.787918323	0.880829733	0.924742598
1977	11.15731388	10.28656337	12.85801373	38.23347855	0.803722179	11.213377	7.943378963	20.91417034	14.56494967	150.9123764	0.807401747	12.49984018	156.5999146	0.578006801	0.421993199	0.598919429	0.787735484	0.846002213
1978	12.60053634	10.93437719	9.581760788	91.79468842	0.677812815	10.72316246	8.36720483	20.43978485	11.55547667	259.6797384	0.767126322	14.36391934	267.295929	0.708630665	0.291369335	0.787911154	0.880339967	0.924516388
1979	12.57861821	10.16898327	9.619647026	72.41018906	0.735471833	10.47625751	8.329210266	20.8272532	11.74991926	243.1537832	0.763169994	14.04579433	253.4395905	0.745485729	0.254514271	0.783726803	0.877453235	0.9220489
1980	7.829040311	16.13842814	11.86148777	110.2666275	0.711017632	12.85731125	6.392978586	27.44430575	14.20029608	336.107783	0.778039952	16.52353708	342.1042786	0.300001301	0.699998699	0.682901533	0.833897367	0.885786949
1981	11.01085668	11.21285279	12.1719101	78.67625275	0.714446366	11.0822073	7.904286824	21.18891107	13.96870693	241.3837204	0.775482049	14.27688511	246.7388916	0.42311575	0.57688425	0.652988057	0.81971618	0.873986843
1982	7.099820919	17.79266877	13.13186874	127.9993973	0.695771456	14.42217636	6.166837409	28.34397534	15.06499656	354.9221802	0.772899399	17.37571001	356.2726135	0.252623924	0.747376076	0.616917448	0.806125104	0.862787346
1983	10.06889744	12.64117246	11.04558601	99.522435	0.690011775	11.73475285	7.670114987	22.38408488	13.64627075	278.4022471	0.764713963	14.97254801	284.0406189	0.424953299	0.575046701	0.692542183	0.834867021	0.886106175
1984	7.569891751	16.02425736	12.19494419	122.0301559	0.638447547	13.48502388	7.026777171	25.00312736	13.90531572	277.9971059	0.764719139	15.21613852	285.1039124	0.247130211	0.752869789	0.677717411	0.832022235	0.884103137

Year	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1967	4.913216867	26.29413864	12.59182682	0.798093116	16.63911457	1.798348315	22.31209503	12.75147152	0.813438992	17.11677806	1.401207097	18.11478781	12.87392092	0.807032049	18.25068808	0.635620148	0.480879665
1968	4.906443812	26.01415844	15.5515337	0.814781296	15.92608948	1.837833114	21.84481888	15.66545963	0.816748182	16.11167304	1.432544239	17.72252719	15.82022953	0.811896294	17.13936281	0.414417848	0.211867318
1969	5.280682638	24.14918613	13.51492615	0.776948285	17.76625385	1.959500507	20.53267451	13.80024815	0.806310753	18.41011524	1.529795662	16.60915546	14.01032591	0.795794606	19.76195335	0.61442021	0.44882977
1970	5.303798929	23.87870283	12.74435368	0.81549288	15.98782845	1.989071563	20.24062475	12.96561368	0.819075127	16.33893013	1.553539798	16.36092499	13.14637566	0.814978689	17.54425335	0.618414902	0.488504687
1971	3.938923232	33.49082927	14.36730785	0.775882852	22.06620712	1.393249832	28.77938193	14.42702961	0.846149007	22.01967176	1.084147893	23.44273273	14.4528532	0.845676064	23.15736008	0.579236798	0.41150555
1972	4.697025239	27.42139948	14.21941166	0.790494227	20.27124176	1.714979708	23.41451813	14.42630259	0.823640267	20.56937981	1.337366045	18.97445365	14.57589626	0.814819604	21.49351215	0.590966859	0.433568084
1973	5.77942843	21.43631722	13.84808865	0.844382608	14.47536106	2.225958474	18.15672217	14.0712436	0.834738374	14.55853526	1.742280431	14.62866027	14.26589632	0.837313086	15.48338032	0.508706929	0.375819142
1974	4.122964054	31.80991945	14.84511185	0.770544469	21.54197998	1.471676752	27.23201488	14.99029223	0.841100891	21.46271833	1.145122424	22.17593785	15.09519386	0.840518087	22.69653416	0.565646288	0.377252103
1975	4.331843063	30.21185004	14.29876308	0.788548303	18.76145477	1.565462217	25.58884482	14.51346366	0.821907798	19.06696192	1.217944726	20.83753164	14.72517252	0.816678941	20.35415077	0.560381454	0.417644754
1976	5.021709889	25.64944148	12.08297386	0.778796279	18.20783844	1.836103797	21.86802105	12.28065968	0.813187997	18.73714447	1.43140167	17.73551822	12.40849972	0.804406315	19.96028233	0.682388274	0.549292176
1977	5.589809217	22.33747709	14.65000191	0.856080651	14.14244289	2.147822894	18.79759644	14.76592827	0.849855701	14.19493802	1.680353351	15.1528711	14.86904192	0.859971464	15.09457397	0.463551999	0.281138859
1978	5.656678125	22.13162449	11.74389458	0.793044758	16.06536713	2.157266423	18.70715035	11.9705267	0.790986836	16.44944159	1.687131807	15.09114236	12.15299606	0.772284448	17.49843168	0.670089748	0.529902651
1979	5.577015623	22.63286347	11.9505991	0.798995304	15.70241089	2.107832089	19.13656294	12.17738851	0.792704642	16.13133971	1.648193523	15.43909507	12.33102512	0.774932295	17.16580343	0.675373361	0.497435931
1980	4.46518866	29.56415873	14.35185738	0.772947001	18.46364555	1.616797842	24.80512319	14.48850536	0.810537795	18.68471972	1.259341784	20.14978394	14.57701635	0.80456242	19.90732574	0.574233871	0.416533558
1981	5.471315108	22.75722534	14.11281948	0.805433428	15.98507233	2.102291487	19.19889078	14.36320813	0.807594061	16.38996442	1.644750737	15.47176363	14.62057018	0.798409075	17.59351683	0.522570302	0.357405527
1982	4.280800655	30.56917898	15.19201908	0.768562114	19.18172531	1.554148629	25.83236504	15.32589149	0.818784694	19.40840213	1.211623654	20.94707195	15.44443512	0.811888546	20.73672867	0.524585928	0.32480743
1983	5.262974493	24.16278763	13.84221916	0.789578831	16.71882915	1.974089913	20.40847715	14.11235936	0.794575016	17.20822525	1.54291939	16.47109501	14.33867216	0.77659148	18.39113808	0.577414161	0.432772083
1984	4.807399653	27.07737372	14.06449585	0.788560581	16.7130188	1.766684942	22.73110102	14.25069141	0.796070178	17.14395809	1.377689205	18.42180108	14.3973012	0.77976653	18.28489399	0.560166855	0.391459515

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1985	Chinook_1	0.838304469	0.732456829	0.614021833	0.16441213	110.51	120.88	129.23	128.84	23.84433018	21.40648919	11.02961234	180.5808896	0.775280591	13.59251482	12.11777081	10.67651976	9.565656471	96.22570038	0.645629644	11.52014465	8.715420984	19.7850441	11.50493447	224.8014806	0.770963639	13.9317224	230.2089691	0.771145593	0.228854407	0.78535834	0.87745684	0.921725708	5.798031829	21.51583638	11.7325489	0.809733856	15.45798874	2.219217621	18.21041625	11.98314921	0.802663803	15.76359431	1.737061076	14.66942043	12.16862726	0.789682776	16.82299042	0.67271811	0.517115293
1986	Chinook_1	0.799343142	0.600152281	0.47972761	0.379709311	118.6	122.59	128.73	141.43	21.64545619	23.28077877	12.86944437	200.2873323	0.774292533	14.06758087	10.77390029	12.39563462	11.18143921	102.826561	0.64934926	11.61817837	8.110560343	20.82195581	13.38309463	250.7250748	0.765558372	14.47287917	251.4714355	0.458031204	0.541968796	0.691767278	0.835084112	0.885970082	5.567274734	22.43266602	13.5223011	0.797260523	16.02435226	2.135206237	18.93281916	13.84266504	0.800064524	16.43219344	1.672523692	15.22075451	14.15152645	0.785967469	17.56067228	0.543728663	0.410203203
1987	Chinook_1	0.752780473	0.514094488	0.387000291	0.183745325	118.55	126.92	132.34	128.67	19.96843019	24.29921854	13.91518675	206.0024177	0.83238927	14.24332333	9.888538316	12.3918142	12.63283501	63.06397171	0.805119836	11.3898941	7.297253206	23.3781923	14.47435125	283.4682719	0.77130878	14.74606514	292.5384216	0.658036093	0.341963907	0.614992281	0.80676745	0.863961848	5.149296358	25.03014805	14.54351311	0.789571154	16.80609093	1.916833684	20.99488529	14.65024789	0.797309538	17.25700633	1.49705033	16.96709737	14.75380087	0.782063156	18.29084206	0.472772679	0.296731021
1988	Chinook_1	0.813145579	0.717149131	0.583146645	0.078168449	109.11	121.54	130.02	137.24	26.08168698	20.30974274	11.05061027	137.8521047	0.818678805	12.50893852	14.16767284	8.335810301	9.487900925	57.70135651	0.745287907	10.25380878	8.927055404	19.00721247	11.61586714	176.9800339	0.789177577	12.94031747	184.0838623	0.881265038	0.118734962	0.77541839	0.87209178	0.916741791	5.991816565	20.59597642	11.80001202	0.836215663	14.58339977	2.314117923	17.48453411	12.03029633	0.831051568	14.70464071	1.812109068	14.08070069	12.21282387	0.83281526	15.70590544	0.647489858	0.491231973
1989	Chinook_1	0.793012754	0.514839478	0.408274273	0.429493692	142.63	150.46	154.32	147.54	18.11084146	27.78496585	13.97841883	193.1413798	0.810720342	13.83308128	8.946459435	13.65882367	12.30960369	76.66096039	0.746300483	11.4003046	6.875548825	25.52717783	14.76213884	256.8663305	0.769763837	14.23857236	265.9780273	0.367630783	0.632369217	0.605105929	0.801548913	0.860111874	4.726842627	27.60998517	14.8905138	0.797603214	16.09639778	1.742972299	23.05530682	14.9806455	0.795997421	16.52299468	1.360048637	18.65955148	15.061378	0.78009066	17.48515701	0.521977838	0.296870165
1990	Chinook_1	0.723705074	0.328637338	0.237836509	0.366536786	132.59	140.57	143.69	136.83	18.00453135	26.45661248	15.54028511	170.4298853	0.826058677	13.33021096	8.539077766	13.85687848	14.34180298	61.70345306	0.778706455	10.88265991	7.008840159	24.16869877	16.234025	228.2347285	0.778548429	13.75872644	231.6117096	0.309220128	0.690779872	0.436257938	0.707082021	0.779990029	4.96953018	25.81766521	16.28768768	0.812877059	15.68347034	1.865536585	21.55798119	16.28756777	0.812153419	15.99096457	1.456344023	17.43579672	16.27666378	0.804375261	17.02587605	0.390201777	0.117894704
1991	Chinook_1	0.795999727	0.60504755	0.481617684	0.261854917	121.94	129.21	135.7	142.41	21.52218896	24.06082134	13.03554712	194.9829121	0.823469426	13.98717615	11.39432757	10.33035992	11.2342165	62.03229599	0.78230412	11.00815086	7.549495526	22.72390549	13.79014063	260.9830551	0.76950862	14.38437192	260.7806091	0.595124931	0.404875069	0.680194096	0.830772554	0.882703549	5.18663723	24.52000716	13.95041542	0.797920096	16.39771385	1.947231777	20.70939386	14.14688778	0.813026468	16.83915997	1.523356922	16.67906671	14.31253862	0.807081789	17.97734404	0.556850959	0.395633629
1992	Chinook_1	0.734891452	0.495643432	0.364244121	0.22246058	120.61	128.43	132.77	132.79	21.26608223	23.15002189	13.9562895	161.2661193	0.831240028	13.15179321	10.70319152	11.08393738	12.82763481	50.74970245	0.797990167	10.89844646	7.807459354	21.56358555	14.40597057	219.6813202	0.774568349	13.52082888	225.0682068	0.583534118	0.416465882	0.599909683	0.797735738	0.856055466	5.465345621	23.10327763	14.46665173	0.814571154	15.42682781	2.07946983	19.41604889	14.57946046	0.805300673	15.76310444	1.627581269	15.63081299	14.7021637	0.793064713	16.70861673	0.457135604	0.283095279
1993	Chinook_1	0.825405527	0.722410515	0.596281632	0.483466061	119.8	127.31	134.88	130.37	20.89850312	24.07479098	11.58537681	212.3451336	0.796488021	14.38769879	10.49779464	11.88120734	10.48298454	87.47255707	0.706278849	11.27174835	7.648819901	23.01533732	12.01787647	273.7569021	0.76990662	15.03074567	302.8967285	0.40605806	0.59394194	0.780096677	0.878446138	0.922813606	5.134046055	25.03577096	12.16631298	0.79898988	16.65898304	1.873824306	21.4088924	12.30386957	0.819955925	17.11030293	1.459451951	17.3984332	12.39029408	0.815547675	18.24876213	0.654819027	0.500080907
1994	Chinook_1	0.727468724	0.43808828	0.318695522	0.393193507	128.68	136.47	140.92	134.91	18.67749824	25.93809621	14.44306442	169.9152437	0.824073447	13.23712465	9.015118696	13.29410912	13.34266796	63.1888176	0.773612809	10.79805565	7.16931127	23.79650113	15.00390307	226.2101034	0.77816081	13.69032303	228.5688477	0.350995478	0.649004522	0.554951725	0.784778182	0.846463688	5.058603749	25.47875732	15.02122192	0.812785828	15.55933056	1.893909529	21.26087799	15.03756714	0.804048816	15.88045724	1.479975417	17.16083253	15.11790609	0.791158289	16.84318733	0.403280069	0.215008537
1995	Chinook_1	0.813017903	0.632311486	0.514080559	0.498424228	121.53	124.85	131.7	141.47	21.66732147	23.64425985	12.6919698	193.9384281	0.783534314	13.71384798	11.07874936	11.20287372	10.93120785	88.85022125	0.667364383	10.83722019	7.98387894	21.27294236	13.32102219	240.129509	0.772110264	14.24087667	248.5380096	0.356204538	0.643795462	0.703702344	0.840887862	0.891181398	5.459397644	22.95482807	13.50327225	0.805447853	15.86688366	2.073691487	19.4416967	13.7683328	0.804403365	16.26246866	1.620996386	15.69332486	14.00525856	0.793280691	17.41065598	0.576767549	0.447540424
1996	Chinook_1	0.777950227	0.529837922	0.412187532	0.549623099	137.67	136.42	139.97	152.16	16.2680464	29.15808413	14.48329844	255.4420062	0.794670544	16.32177142	7.393320054	16.59284924	13.45074062	118.4586441	0.692174268	13.91813698	6.602852814	26.07808718	14.80070464	324.2342428	0.777419468	16.31831408	331.9928894	0.269287405	0.730712595	0.622113917	0.80982599	0.866349573	4.636409156	27.99091993	14.9160429	0.779227936	18.22538223	1.704682969	23.53407442	15.09164365	0.80959026	18.53588804	1.328203849	19.10512707	15.26956272	0.801851779	19.91776466	0.489877664	0.317423967
1997	Chinook_1	0.822810846	0.566936856	0.466481794	0.589765234	133.55	136.67	138.93	140.42	14.5735993	30.86006336	14.02331243	355.8677553	0.810372365	21.30541141	6.218795069	20.32503789	12.57098541	164.9328033	0.696520412	18.03925438	5.88448526	29.18772087	14.60327164	460.322703	0.810435236	22.30478907	468.0050659	0.25863463	0.74136537	0.65807125	0.829606483	0.882043051	4.132025138	31.31919498	14.71416759	0.790500855	24.46096802	1.471194282	27.24378558	14.88683987	0.858830432	23.93387922	1.14485468	22.181308	15.06559038	0.85831213	24.48390388	0.539948827	0.389549902
1998	Chinook_1	0.830118257	0.652103518	0.541323036	0.432497669	114.86	122.28	129.2	130.12	21.83103543	23.11151928	12.48782587	253.4907608	0.791404294	15.60346402	11.24867438	11.4202813	10.3432888	96.86665344	0.695256793	11.63876133	7.675337203	22.38407273	13.31529299	327.0002696	0.767229696	16.1803356	347.3634338	0.43461532	0.56538468	0.714994668	0.842429163	0.891655404	5.267502673	24.16355075	13.53921204	0.781516492	18.14945412	1.945525475	20.66028608	13.84708055	0.82123673	18.84963417	1.517652519	16.73982058	14.08113146	0.819854319	20.26788616	0.612481283	0.451634423
1999	Chinook_1	0.826985413	0.633327884	0.523752922	0.350750351	120.18	125.95	132.68	128.76	20.63135607	23.58447224	12.71376583	209.8354618	0.796825102	14.47728845	10.06700762	12.71338025	10.88005943	96.41200409	0.705597687	12.15550842	7.698128574	22.0972893	13.45235427	273.0135295	0.771261632	14.79513693	279.0461121	0.509764406	0.490235594	0.701639697	0.839130383	0.889625826	5.353093736	23.74717636	13.62969818	0.790989506	16.57148037	2.010918133	20.03667486	13.85249074	0.802591304	16.82376258	1.571622662	16.17494658	14.02833652	0.790836841	17.94499588	0.600899424	0.428700144
2000	Chinook_1	0.768556787	0.444334498	0.341496294	0.468362981	131.12	137.71	140.86	138.88	17.89271507	26.63586456	14.42020689	187.714374	0.805533447	13.77406008	8.316447161	14.7240844	13.05079479	84.87336121	0.728323662	11.66225948	7.096651986	24.10015774	15.03594017	241.7542979	0.772641838	14.0858446	251.3130646	0.297037198	0.702962802	0.555390528	0.785949383	0.847873055	4.974102691	25.86031217	15.09058113	0.804678786	15.78463058	1.855784163	21.64444985	15.15267913	0.794860224	16.15724246	1.447147056	17.54524473	15.2750845	0.777376086	17.18997097	0.439176004	0.239530569
2001	Chinook_1	0.801286224	0.602640487	0.482887521	0.127536082	110.58	122.94	130.84	128.54	25.64362327	20.65937781	12.42419645	123.2950807	0.836928474	12.6825428	14.01257826	8.822512025	10.08462772	49.23461227	0.782747078	10.88812084	8.692493588	19.06460152	13.44808563	157.5844777	0.800544302	12.96179978	169.3571472	0.783900358	0.216099642	0.674084656	0.818542541	0.871085518	6.021911055	20.44556553	13.65214691	0.849085951	14.44273682	2.328566849	17.36734104	13.90071774	0.841000636	14.49768035	1.822433531	14.00388923	14.0763793	0.846852779	15.46763849	0.573010783	0.375640293
2002	Chinook_1	0.81146937	0.646636786	0.524725946	0.272374547	119.89	128.91	135.8	132.51	21.20429771	23.93796785	12.56704617	184.7727029	0.819833513	13.66171476	10.87523358	11.11901379	10.93466282	68.81325073	0.768200243	11.1489809	7.679577954	22.44354263	13.1956447	244.3683523	0.772778412	14.04814148	252.625412	0.602024179	0.397975821	0.7129132	0.843152383	0.892719188	5.243250974	24.26645956	13.39510517	0.805847573	15.93601933	1.967614777	20.44056846	13.62964789	0.801875432	16.32662996	1.535542406	16.54874924	13.80179453	0.788226664	17.43509245	0.602627933	0.435064973

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
2003	Chinook_1	0.799488556	0.612664015	0.489817869	0.4203032	129.67	135.71	142.71	141.01	19.45769947	25.87815424	13.18784918	201.581975	0.807107972	14.1004781	9.732663338	12.53373612	11.71673985	79.02853394	0.733775115	11.16656113	7.287060453	23.70505448	13.82201465	259.672894928	0.771772951	14.4842426	283.367126 5	0.421342567	0.578657433	0.690947473	0.838836306	0.890148351	5.006419159	25.59830069	13.95198689	0.801858163	16.28596001	1.847474076	21.68731631	14.10222276	0.809171114	16.73147174	1.437353559	17.66351541	14.23272896	0.800681919	17.92309475	0.558070136	0.405634301
2004	Chinook_1	0.818242183	0.654707281	0.535709115	0.1172319 08	107.17	120.59	128.35	131.88	25.73644032	20.65508733	11.96232101	173.848485 9	0.808715663	13.0887225	14.08890755	8.922495126	9.550630951	61.94462357	0.749564266	10.31717148	8.596956033	19.76909503	12.90394437	226.052719 1	0.762366702	13.63843854	250.341186 5	0.813538684	0.186461316	0.720104273	0.842331584	0.891704125	5.813572899	21.38951627	13.13689423	0.803750288	15.38586597	2.215862766	18.17964882	13.47645411	0.790258547	15.78958225	1.729564592	14.73097251	13.73083973	0.771697074	16.92212 2	0.616650998	0.421454665
2005	Chinook_1	0.779118146	0.558479359	0.435121403	0.3992031402	120.8	127.51	133.91	135.69	20.84549388	23.98250959	13.72402641	178.084131 5	0.811053578	13.5087078	10.46732625	11.72673786	12.21388226	70.02918091	0.739393 21	11.04384041	7.747845717	21.86634079	14.28028075	230.123036 7	0.776297659	13.93168561	241.6 35498	0.414944899	0.585055101	0.643824227	0.811045081	0.866323149	5.387301035	23.48823548	14.43063774	0.812632978	15.64432125	2.028711714	19.84001356	14.63927428	0.804777682	16.04337184	1.583861746	16.05326426	14.80437565	0.792334765	17.08892965	0.529655395	0.330966618
2006	Chinook_1	0.839921627	0.713615985	0.599381 5	0.5695681 55	120.43	125.97	133.03	128.31	19.45147254	24.55935718	11.65633869	241.2180928	0.765203259	15.3632144 2	9.028591119	14.69271789	10.50601768	127.3456268	0.613141465	13.21371574	7.519774795	23.00617591	12.13219865	304.158167 5	0.774523099	15.72800906	318.7 52471 9	0.326582914	0.673417086	0.771067333	0.874505355	0.919884715	5.142026305	24.87594473	12.30521832	0.784966266	17.30783863	1.906636775	21.07478968	12.44550228	0.802074571	17.57131926	1.487088777	17.07880591	12.51731 3	0.788308293	18.58182144	0.677474337	0.502867197
2007	Chinook_1	0.787448894	0.567151295	0.446602665	0.3485697 95	120.18	127.35	132.99	130.45	20.79385462	23.65425711	13.54041965	194.747821 3	0.819239642	13.7081028 7	10.44656114	11.86600031	12.07292881	71.60741577	0.766363394	11.00237007	7.551701047	22.41322404	14.15724643	258.652066 5	0.772923062	14.21691855	267.0 02288 8	0.475884291	0.524115709	0.649272604	0.816047232	0.871044849	5.274040677	24.04437259	14.29278927	0.797460866	16.13457813	1.989 3694	20.23224961	14.44636091	0.793029964	16.52085145	1.553447612	16.36088821	14.55682325	0.775063336	17.56389713	0.529630195	0.350793819
2008	Chinook_1	0.815 42277	0.723 82463	0.590223085	0.1808660 6	103.88	118.23	126.6	132.55	26.59 12621	19.94973911	11.16305746	156.9283883	0.812877276	13.0459834 2	14.51350918	8.786919418	9.662763766	64.03554382	0.730662453	10.34846153	8.942558266	18.80156365	11.59425068	196.1279551	0.787829002	13.50302245	207.2 83371	0.744 24555	0.255 75445	0.777 65598 9	0.871734786	0.916037199	6.030315854	20.33 17254 9	11.78982067	0.830847299	15.02908058	2.335551478	17.31972657	12.09430758	0.827116132	15.33503882	1.828275956	13.95959334	12.36021709	0.825813711	16.55742073	0.645266973	0.498664318
SCN MO1-RESSIM																																																		
1929	Chinook_1	0.798991704	0.640584595	0.511821778	0.3401332 05	126.32	135.47	142.33	132.7	20.43290029	24.64898637	12.76881572	137.573781 7	0.893251095	13.4198438 8	10.44745149	11.79980973	11.54783516	60.80059204	0.850171804	11.26726788	7.462913714	22.32506677	13.34570201	177.518414 8	0.875776251	14.11163219	199.3 95507 8	0.518504739	0.481495261	0.704277263	0.841573725	0.891615098	5.369078837	23.68824055	13.49151993	0.876999009	15.60934105	2.000955544	20.07668718	13.58610598	0.855795244	15.89579169	1.559662513	16.29779466	13.62358856	0.852602065	16.83252239	0.589348765	0.399307245
1930	Chinook_1	0.809163699	0.634401685	0.513334814	0.1043113 7	103.59	117.92	125.55	140.36	25.19658326	20.06456498	12.08391305	126.5542771	0.910617394	13.4336452 8	13.48864452	9.548528465	10.00543633	63.55808563	0.871815836	11.55407257	8.541999593	18.63745665	12.77972953	158.897692 4	0.898260921	13.94746296	165.9 7612	0.826800385	0.173199615	0.698954976	0.829594616	0.878 8999	6.227273241	19.55911301	12.98298969	0.902817178	15.52670231	2.447022274	16.58407832	13.33597342	0.887605429	16.04770788	1.919338778	13.32090901	13.64367533	0.887920648	17.22201824	0.584625359	0.414332594
1931	Chinook_1	0.784335558	0.607174177	0.476228297	0.0746068 68	105.64	120.76	127.88	130.95	26.93944224	19.69720809	12.22792782	116.5355682	0.880853529	12.9016774 4	15.27555725	8.093375373	9.994052887	44.05959778	0.841365087	11.39559784	8.535353534	18.74721296	13.12350019	150.926142 4	0.854187687	13.03632188	162.1 41967 8	0.867568663	0.132431337	0.677328729	0.820892227	0.872 47521 6	6.184397809	19.73405993	13.30969982	0.861711788	14.53333378	2.417764597	16.76278453	13.59764544	0.856319368	14.64647166	1.894655816	13.48 7997	13.83373642	0.864868611	15.65766764	0.553462779	0.372407189
1932	Chinook_1	0.835724059	0.719494743	0.601299068	0.3136840 65	118.19	126.09	132.92	130.45	21.06 74497	23.69080082	11.83302874	227.501162 4	0.859441195	15.1764826 4	10.81074679	12.17596101	10.32807198	87.75 70816	0.825715637	12.33610649	7.382539876	22.85854675	12.34874455	296.363393 1	0.817266643	15.58906722	316.3 09631 3	0.587921297	0.412078703	0.769536073	0.867365101	0.913018514	5.251398213	24.38271584	12.55705261	0.796557629	17.51350212	1.943354316	20.67141891	12.81744512	0.800478247	17.82029724	1.515167989	16.76694923	13.01006848	0.797083378	18.84209633	0.667786668	0.494805578
1933	Chinook_1	0.792413578	0.620247595	0.491496261	0.2611640 21	133.15	141.76	148.05	139.56	19.07094214	26.84704687	13.44336891	188.1833066	0.894 27495	14.2110973 1	9.976447403	12.36260931	11.96478939	60.92562103	0.890630758	11.43342857	6.713476218	25.48748646	14.05033652	250.302833 6	0.844449441	14.70816231	274.3 88397 2	0.601908027	0.398091973	0.688343124	0.833815634	0.885364405	4.793954648	27.20146355	14.20376644	0.827941489	16.70793076	1.742272563	22.97422425	14.38877201	0.814516485	17.11257744	1.354556717	18.73 47416 1	14.53064537	0.809864521	18.06677914	0.584501776	0.379416341
1934	Chinook_1	0.791802275	0.589665547	0.466898521	0.1307055 1	115.09	123.05	128.74	132.5	21.21 176	22.94280369	13.09250614	224.7196067	0.850 38842 9	14.9518292 6	10.72975273	12.65162321	11.54841137	75.71185303	0.839854794	12.43735771 1	7.477118321 1	22.27262459	13.69091241	306.814712 5	0.784357627	15.25375183	313.1 79504 4	0.772029706 3	0.227029365	0.670823773	0.828830285	0.882427977	5.361276367 3	23.65759652	13.81 6292	0.771597493	17.28341541	2.026864626	19.88 39355	13.98150698	0.784608285	17.46 72575	1.584336229	16.04723945	14.13334942	0.779647827	18.33776474	0.545751566	0.390293364
1935	Chinook_1	0.792772526	0.602462584	0.477615784	0.3452562 89	126.98	135.62	142.37	132.99	19.13088447	25.86287566	13.46179226	177.0972688	0.879 82686 9	13.7352324 9	9.694492333	12.65162321	12.04798241	65.66 77597	0.849287379	10.96254253	6.923517533	24.34660100 2	14.07819017	235.305839 5	0.845190048	14.41936807	250.5 53146 4	0.494 49162 1	0.506 50837 9	0.672 87375	0.830 08026 9	0.882 71424 5	5.002041288	25.83 58538 1	14.21 12905 5	0.831626761	16.35939331	1.845276333	21.74 67137 8	14.34 09214	0.812 54698 8	16.59 10040 5	1.437 7257	17.65886215	14.45839262	0.805476099	17.41 96867 9	0.577808342	0.365872037
1936	Chinook_1	0.849525456	0.724675203	0.615 62938	0.3341659 84	115.8	122.34	129.63	129.97	19.73750024	24.04225201	11.41781834	240.1967752	0.812239651	15.8264808 3	9.232847579	14.08663916	10.06430206	124.4521362	0.705107093	14.03302536	7.610735334	22.23842356	11.84913667	297.631184 9	0.807636698	15.82159861	310.7 47161 9	0.568 26006 6	0.431 73993 4	0.780 23590 1	0.877 28845 1	0.922 29301 3	5.359 47100 1	23.80 11782 8	12.05 18920 9	0.789 05050 8	17.43 08954 2	1.998 88024 5	20.11 93762 1	12.28 28477 2	0.790 35838 4	17.64 34818 9	1.559 66047 2	16.29 66064 2	12.47 36557	0.785 83857 4	18.59 50698 9	0.668 48682 2	0.535 30462 2
1937	Chinook_1	0.800756515	0.629424892	0.504016083	0.3389659 05	123.81	132.42	138.44	131.56	22.11238133	22.81190748	12.59796831	138.2971111	0.877440533	13.1629601 5	11.64289881	10.34230648	11.00617561	59.23182831	0.814913213	10.75796281	7.736543454	21.19641232	13.29521942	178.028630 6	0.868 26702	13.80597043	190.8 15246 6	0.514 28041 8	0.485 71958 2	0.691 28407 1	0.829 37786 8	0.880 15817 4	5.587 58310 2	22.41 34240 5	13.46 89737 3	0.867 89411 3	15.36 38448 7	2.127 43897	18.95 53435 5	13.64 11708 2	0.852 41701 2	15.70 17809 5	1.662 92298 6	15.30 65563 6	13.75 69932 9	0.852 06335 8	16.71 69971 5	0.603 02421 8	0.393 33732
1938	Chinook_1	0.820866611	0.619461522	0.508495323	0.5223389 69	128.93	134.24	138.14	140.21	17.88914402	26.69763432	13.15585252	230.8236761	0.814537031	15.2459671 5	8.404975779	15.13663999	11.71385803	108.2884338	0.728571796	13.00029244	6.947875805	24.46763333	13.67595371	296.911834 7	0.793 44358	15.42 25862	305.8 08837 9	0.333 33933 2	0.666 66066 8	0.690 83929	0.836 35710 3	0.887 85182 7	4.932 21718 8	26.13 90171 1	13.83 34232 3	0.779 44130 9	17.19 63184 4	1.829 38981 8	21.96 49815 3	14.03 43955 4	0.796 92653 8	17.41 7401	1.427 16581 4	17.78 81333 9	14.22 01271 1	0.789 93368 1	18.52 23732	0.583 63383 3	0.415 64004 8
1939	Chinook_1	0.823024927	0.700778094	0.576 75784	0.3546594 15	114.68	122.93	130.38	127.9	21.14606853	23.01389847	11.45845338	186.6232311	0.827182152	13.6000045	10.38677186	12.46615076	10.61002731	89.22 82196	0.735725951	10.93693027	7.842260495	21.36108626	11.76217655	238.758672 1	0.816987038	14.24289902	245.3 55011	0.530550219	0.469449781	0.761 58936	0.871 66094 5	0.917 83988 4	5.533 53156 1	22.82 01798 5	11.87 47425 1	0.810 95769 4	15.86 53860 1	2.098 37569 3	19.22 40919 7	11.97 61219	0.802 57044 2	16.23 08451 3	1.640 97307 6	15.50 55408 5	12.04 23293 1	0.788 31461 1	17.23 34156	0.627 4252	0.491 6864

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1940	Chinook_1	0.820 71190 7	0.724 92383 9	0.594 95362 7	0.065 05389	95.01	111.1 4	119.3 7	138.7	28.00 80522 1	18.50 42844	10.89 52482 1	166.5 34957 9	0.857 00230 1	13.61 74889 6	15.54 35049 3	9.299 90026 4	9.240 03448 5	81.62 60864 3	0.752 63247 5	10.60 60083 4	8.744 52811 5	18.20 14546 7	11.35 05428 6	208.7 55521 1	0.872 47854 5	14.54 38862 6	218.8 68347 2	0.902 30512 3	0.097 69487 7	0.774 86070 1	0.867 88490 2	0.912 24921	6.336 40271 4	19.14 47349	11.55 78315 7	0.863 29512 6	16.18 43593 6	2.494 84345 3	16.27 56418 8	11.89 23835 8	0.841 24535 3	16.66 33230 8	1.957 35171 4	13.06 91954 3	12.17 30938	0.835 31910 2	17.68 49613 2	0.648 70289	0.495 02706 7
1941	Chinook_1	0.749 14818 9	0.474 54503 6	0.355 50455 4	0.284 22035 3	132.75	138.23	138.72	142.36	19.43 79004 9	25.20 88991 8	14.53 42861 6	145.6 55464 4	0.895 16841 9	13.55 36211 2	9.679 38191 4	12.61 05317 5	13.32 58932 1	59.29 86152 6	0.866 56682 5	11.53 92927 2	7.285 61043 7	22.46 03926 3	15.03 33499 9	190.2 50544 2	0.866 58773 8	13.91 62191 5	197.4 86312 9	0.498 23126 5	0.501 76873 5	0.569 62453 6	0.775 45659 1	0.836 09838 4	5.348 77193	23.59 92024 3	15.10 57928 1	0.861 19735 2	15.64 43040 8	2.033 83436 8	19.82 05386 1	15.23 68129 1	0.844 71414 5	15.91 74388 2	1.589 98161 6	15.99 32565 1	15.36 71870 2	0.843 42995 3	16.87 03274 7	0.447 52662 4	0.262 11503 2
1942	Chinook_1	0.811 70848 3	0.667 74256 2	0.542 01230 2	0.516 59634 1	133.72	136.68	142.53	146.16	19.65 27019 7	25.75 03714	12.63 79992 6	185.8 75114 4	0.836 50137 3	13.88 36839 5	9.968 88823 3	12.39 32848	11.32 06394 2	84.66 63360 6	0.748 01766 9	11.24 59102 6	7.299 26621 9	22.94 60613 7	13.07 50408 2	233.8 47071 3	0.828 48885 7	14.40 68624 2	242.6 61224 4	0.352 46705	0.647 53295	0.729 33467 2	0.853 90398 8	0.902 41305 2	5.181 76949	24.46 80953 5	13.24 94985 6	0.823 3868	16.07 59618 8	1.950 70630 3	20.63 66290 2	13.44 93875 5	0.821 95194 6	16.50 91123 6	1.523 67734 9	16.67 61693 5	13.62 53261 6	0.813 7815	17.60 12144 1	0.611 16302 7	0.463 71276 7
1943	Chinook_1	0.834 77076 5	0.688 26635 1	0.574 54462 8	0.417 36215 2	120.77	123.72	129.05	130.25	21.43 32939 5	23.19 28733 9	11.87 17716 1	229.5 36246 2	0.805 56233 9	15.40 98134 4	10.74 78905 5	13.12 25317 4	10.41 97734 8	118.3 48120 1	0.683 01384 4	13.41 20355 6	7.708 61249 4	21.67 50815 5	12.36 67254 4	291.0 44362 4	0.810 46831 6	13.55 40009 3	304.6 50116	0.459 96393 2	0.540 03606 8	0.743 22444 8	0.856 73282 3	0.904 25633 6	5.456 65579 3	23.12 60548 4	12.56 31456 4	0.796 09700 4	17.28 84456 6	2.060 99789 6	19.55 11546 7	12.78 76215	0.811 94484 2	17.54 53319 5	1.610 49210 3	15.79 20558 9	12.97 26638 8	0.805 91714 4	18.63 35773 5	0.658 13162 5	0.480 17721 3
1944	Chinook_1	0.792 55436 1	0.585 00774 3	0.463 65043 8	0.412 84411 6	130.57	138.19	144.96	139.11	19.67 26621 5	25.34 45619 6	13.43 20886 5	133.6 89637	0.867 83611 3	13.01 05225 4	9.808 89131 9	12.12 85457 9	12.01 98164	66.29 36607 4	0.817 61344 7	11.45 64792 6	7.492 10833	22.07 09892 8	14.03 14377 1	167.5 90665 2	0.843 60676	13.18 38274 8	170.7 64831 5	0.417 08386 2	0.582 91613 8	0.654 84578 6	0.813 78211 1	0.867 27770 9	5.401 72694 6	23.37 82229	14.19 04192	0.849 69406 1	14.62 51483 9	2.054 99379 3	19.62 95258 1	14.35 83758 7	0.843 27495 1	14.75 56193 7	1.607 28131 2	15.82 51687 2	14.50 31805	0.845 77098 5	15.72 89485 9	0.560 40106	0.340 87437 8
1945	Chinook_1	0.815 31164 2	0.673 60975 5	0.549 20187 5	0.448 58486 9	117.84	125.8	132.89	130.31	21.76 61102 8	23.27 90872 6	12.26 38592 7	175.8 02066 8	0.847 23151 6	13.86 44582 9	11.30 61825 8	11.41 85748	10.70 72275 2	76.24 81704 7	0.780 38382 5	11.58 51894 4	7.688 29067 8	21.71 12319 9	12.83 65205 1	223.0 30586 2	0.826 55406	14.29 01635 2	238.9 43512	0.422 03649 7	0.577 96350 3	0.732 41740 1	0.850 02346 3	0.898 13212 3	5.476 29531 5	23.11 73329 9	13.02 93211	0.822 30770 6	15.77 61400 2	2.058 09640 1	19.55 84026 5	13.27 26570 8	0.810 85856 8	16.11 65771 5	1.606 71522 5	15.82 91762 6	13.45 22814 8	0.801 75969	17.13 50016 6	0.618 23823 8	0.451 40067
1946	Chinook_1	0.856 54332 3	0.745 25263 7	0.638 34117	0.202 65909 3	111.36	120.2	127.74	127.04	21.69 44866 3	22.94 58805 8	11.18 10024 8	258.2 99548	0.801 34776	15.94 82754	10.83 41563 6	13.17 06481 2	9.587 07809 4	119.3 49964 9	0.700 56008 7	13.24 84716 4	7.756 37964 2	21.92 74154 5	11.68 90071 2	328.6 80501 3	0.786 01169 6	16.16 31305 2	342.9 23339 8	0.730 33432 9	0.269 66567 1	0.792 20303 4	0.877 30426 4	0.921 67713 5	5.415 37503 2	23.53 85597	11.90 9869	0.766 84142 4	17.92 88085 9	2.017 64244 6	19.93 68246 4	12.19 01966 7	0.793 87547 6	18.13 31558 2	1.574 52393 3	16.14 49226 7	12.39 02421	0.800 14574 5	19.17 23403 9	0.698 35914	0.543 95049 5
1947	Chinook_1	0.835 04541 2	0.645 13684 8	0.538 71856 5	0.264 86899 2	110.45	121.08	128.23	128.4	22.25 05635 5	22.80 44915	12.43 39355 1	239.2 28252 4	0.813 75565 3	14.83 06481 8	11.57 65881 2	11.86 95249 2	10.05 04821 8	95.47 76199 3	0.733 33289 6	11.22 75844 6	7.676 09056 8	21.96 00640 2	13.36 15117 1	306.1 16923	0.787 65296 9	15.39 35913 2	329.7 93853 8	0.619 47952 5	0.380 52047 5	0.709 27450 1	0.836 73471 1	0.886 97329 1	5.417 82626 5	23.47 60892 9	13.59 27679 1	0.779 13202	17.20 82271 6	2.013 64070 2	19.95 66790 2	13.93 46129 1	0.801 03617 9	17.92 23467 5	1.569 99856 2	16.19 09454 2	14.19 52447 9	0.794 90891 1	19.18 22748 2	0.621 93293 5	0.425 31490 5
1948	Chinook_1	0.829 75911 4	0.617 92337	0.512 72754 8	0.527 38881 9	132.21	136.8	140.55	141.37	15.56 33769 9	29.85 76169 2	13.53 39360 2	328.8 39012 1	0.834 60824 8	19.55 33534 5	7.124 93357 8	17.49 52166 9	12.17 01505 7	142.6 00729 4	0.758 52565 8	16.20 46463	6.022 16403 9	28.63 16753 8	14.07 02621 1	425.1 73334 8	0.815 31494 9	20.59 29384 2	447.9 06005 9	0.330 72170 6	0.669 27829 4	0.697 65546 6	0.843 19390 2	0.893 35038 1	4.221 21291 6	30.75 17271 4	14.20 21961 2	0.796 30547 8	22.90 03242 5	1.512 27038 4	26.51 14264 2	14.37 70767 8	0.834 31164 4	22.69 28424 8	1.177 33132 1	21.56 24848 7	14.53 60245 7	0.830 92361 7	22.77 13308 3	0.587 06025 1	0.430 27597 3
1949	Chinook_1	0.809 12085 3	0.564 20305 1	0.456 50845 4	0.597 18651 5	126.5	132.39	137.61	132.94	16.47 35761 6	28.00 39938	13.78 62197 3	271.9 92415 8	0.797 51411 5	16.53 31736	7.379 79762 3	17.27 90865 6	12.37 18332 3	125.6 82060 2	0.694 21107 8	13.94 41776 3	6.457 44054	26.67 33049 1	14.45 17863 6	348.1 16790 8	0.782 35737 5	16.66 25360 6	377.7 5354	0.250 02743 8	0.749 97256 2	0.657 08365 8	0.825 30401 3	0.879 29692 4	4.596 38290 1	28.51 81545 8	14.53 74958	0.764 87041 7	18.44 16889 2	1.642 52953 2	24.35 66396	14.63 73119 4	0.817 99320 4	18.73 79360 2	1.276 43780 4	19.87 94342 2	14.73 65789 4	0.820 28096 9	19.97 73893 4	0.537 36127 9	0.347 28887 9
1950	Chinook_1	0.818 39159	0.674 27649 2	0.551 82221	0.533 90218 5	130.94	136	141.83	139.62	18.63 23579 4	26.66 91076 9	12.69 18921 5	213.0 90675 9	0.831 39022 3	14.47 92749 2	9.262 95809 4	13.61 84508 5	11.43 87630 5	92.44 73190 3	0.752 70041 2	11.96 76473 6	6.931 81026	24.64 55881 4	13.17 45214 5	273.4 02359	0.812 66061 5	14.86 20204 1	289.1 69647 2	0.340 84624 6	0.659 15375 4	0.735 13624	0.856 37328 7	0.904 78272	4.899 33121 2	26.37 92287 9	13.34 57214 4	0.803 19528 6	16.67 88385 4	1.803 84209 8	22.23 98478 5	13.51 73705 4	0.806 87212 9	17.11 19092 3	1.405 21553 2	18.06 36261 6	13.63 31038 5	0.793 37230 3	18.22 81770 7	0.636 31995 3	0.445 58341 5
1951	Chinook_1	0.824 74622 6	0.635 40018 5	0.524 04390 5	0.537 33524 6	130.5	134.48	139.71	137.66	18.06 48568 9	26.94 45211 4	13.20 42568 1	259.7 42085	0.809 19483 3	15.95 82430 6	8.823 71583 6	14.52 69989 3	11.60 64243 3	106.6 15655 5	0.730 50708 8	12.84 57202 9	6.709 52276 1	25.49 72969 5	13.83 56073 7	337.4 80326 3	0.779 36558 9	16.20 78077 8	348.5 71777 3	0.326 13831 2	0.673 86168 8	0.701 37327 2	0.838 91236 4	0.889 86056	4.735 98567 4	27.30 58427 6	14.01 59057 6	0.762 62136 7	18.17 87838	1.738 38315 2	23.08 95543 8	14.22 64881 1	0.802 77419 1	18.50 66076 9	1.355 05396 9	18.72 77680 4	14.39 96138 6	0.803 49624 2	19.76 60570 1	0.598 43029 7	0.435 78461 5
1952	Chinook_1	0.854 38296 1	0.730 34382 8	0.623 99332 2	0.575 71850 6	123.6	123.26	130.39	133.31	17.93 61870 4	26.16 82008 9	11.73 52292 2	288.9 92601 7	0.780 79001 4	17.86 75852 5	7.959 83628 2	16.94 12533 2	10.50 70592 9	161.6 88269	0.655 19927 7	16.77 93685 9	7.214 90953 1	23.76 44755 3	12.10 23243 3	355.1 10366 8	0.775 84434 5	17.21 00742 7	366.1 55151 4	0.328 56061 5	0.671 43938 5	0.781 41418 6	0.875 42639 4	0.920 53954 5	5.028 36535 1	25.54 70487 6	12.30 87814 3	0.754 4765	18.68 85135 7	1.856 30235 8	21.64 6927	12.52 53063 8	0.803 61330 5	18.85 05923	1.448 09392 8	17.53 32908 3	12.69 93746	0.811 9075	20.00 51269 5	0.683 91913	0.531 18672 7
1953	Chinook_1	0.819 15018 3	0.665 10560 2	0.544 82137 6	0.439 54909 8	131.82	133.53	140.21	143.3	20.08 64096 4	25.29 24635 5	12.67 78335 6	207.0 56004 1	0.835 79232 9	14.46 55892 5	10.42 22599 4	11.96 31695 1	11.08 07500 8	85.75 77789 3	0.763 48787 5	11.59 17821 9	7.155 38727 5	23.54 77807 8	13.30 13580 6	264.6 03187 6	0.813 94265 1	14.91 68982 5	279.3 69354 2	0.427 77573 4	0.572 22426 6	0.725 95367 7	0.849 88573 3	0.898 64266	5.061 86138 8	25.15 50395	13.47 37674 7	0.804 52376 6	16.68 48976 1	1.884 54618 3	21.32 79493	13.69 79173	0.806 53520 4	17.01 10092 2	1.470 31661 1	17.27 19463 9	13.88 54327 2	0.802 69396 3	18.06 32448 2	0.598 46205 8	0.474 50134 6
1954	Chinook_1	0.821 95984 5	0.668 98489 8	0.549 87872 3	0.436 78537 8	139.92	146.31	147.08	144.63	18.41 35349 9	27.26 93678	12.75 11357 6	230.6 11096	0.850 90560 6	15.65 26763 1	9.378 39280 1	13.18 98013 1	11.35 51189 4	90.41 79718	0.802 93119	12.81 16575 2	6.665 40391	25.65 87056 2	13.30 14011 4	296.5 67606 6	0.816 33726 8	15.96 27954 2	303.7 23144 5	0.431 76474 3	0.568 23525 7	0.731 99854 7	0.855 05171 4	0.903 57313	4.696 48511	27.49 18140 1	13.46 57339 1	0.800 51441 2	17.73 82997 5	1.734 82225 1	23.13 37937 9	13.63 62222	0.815 13579 7	18.10 88724 1	1.352 10970 8	18.76 84979 4	13.76 54552 5	0.807 48748 8	19.46 50068 3	0.630 48932 6	0.467 63829 8
1955	Chinook_1	0.816 80906 8	0.651 80651 1	0.532 40146 9	0.537 17547 4	135.9	141.61	147.42	143.66	18.44 62373 5	26.79 61664 5	12.96 09221 7	191.3 31873 8	0.853 31782 3	14.25 43497 4	9.164 46772 2	13.55 82935 1	11.58 57322 7	87.57 69424 4	0.782 56453 3	11.67 96009 1	6.876 70206 3	24.63 87609 9	13.52 06006 4	243.7 5693	0.838 93789 8	14.80 20525 8	256.3 20770 3	0.330 18527 6	0.669 81472 4	0.714 86269 5	0.846 48332 1	0.895 74413 9	4.901 25643 5	26.27 87790 7	13.67 54697 8	0.826 24090 9	16.51 11738 2	1.813 72188 8	22.13 47183 9	13.85 47178 9	0.815 96454	16.69 51793	1.413 82118 3	17.95 46675 9	14.00 83136 6	0.812 79718 9	17.61 34543 4	0.613 21525 4	0.428 14678 9
1956	Chinook_1	0.856 80092 8	0.732 72901 5	0.627 8029	0.319 21267 1	116.12	120.62	127.95	134.95	19.35 11777 6	24.76 88148 9	11.49 53975 7	293.6 89688 5	0.810 38180 4	18.16 13596 5	9.086 15768 7	15.19 82705 8	10.13 83913	144.6 75500 5	0.721 58577 4	16.07 36595 2	7.383 90952 3	22.91 16022 5	11.89 05765 2	377.1 42547 6	0.789 56962 6	18.34 86150 1	380.7 48901 4	0.588 16175	0.411 83825	0.785 12241 4	0.877 74102 2	0.922 28280 3	5.159 88618 1	24.57 36565 9	12.10 44183 7	0.764 57185 7	20.06 06144	1.920 62872 6	20.95 31139 8	12.34 67219 7	0.815 18530 8	19.77 53855 4	1.499 98861 6	16.93 40253	12.55 52749 6	0.814 50071 9	20.99 07226 6	0.676 10084 2	0.563 17809
1957	Chinook_1	0.830 68884 9	0.716 99590 5	0.595 60050 3	0.371 57303 1	114.75	121.55	128.62	137.92	21.28 55541 4	23.70 45840 3	11.74 03503 8	268.9 17184 6	0.814 37436 2	16.67 64087	11.00 26027 1	11.97 19342 3	10.38 37685 5	114.5 22016 9	0.722 12257 4	13.37 03790 7	7.480 04819 5	22.50 30850 9	12.14 13310 4	330.4 63831 6	0.798 43820 1	16.72 72310 3	351.9 98077 4	0.521 03072 4	0.478 96927 6	0.778 65723	0.875 02688 2	0.919 73772	5.222 52942 6	24.12 67647 8	12.30 60146 3	0.787 47683 8	18.56 85390 5	1.936 90018 4	20.73 48046 7	12.55 50588	0.822 22622 6	19.20 95661 2	1.509 80003 2	16.82 58131 1	12.78 81870 3	0.819 90474 5	20.68 70269 8	0.639 96750 5	0.527 49817 8

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1958	Chinook_1	0.830324559	0.655291224	0.544104397	0.543679918	124.98	130.7	136.65	137.04	16.85357386	28.30010243	12.85158014	273.5977184	0.834653011	17.09108543	7.933767445	15.98548745	11.50954971	122.1039032	0.77808044	14.72420235	6.424538665	27.0836357	13.42997042	349.5563049	0.799123426	17.08290005	370.5079346	0.329725815	0.670274185	0.727953462	0.854632832	0.903600011	4.531682543	29.06917759	13.57205944	0.775524986	18.90803261	1.62283989	24.67118984	13.71148141	0.814481477	19.25602659	1.262050532	20.10648032	13.79890871	0.813948095	20.44269753	0.609726647	0.460028984
1959	Chinook_1	0.806441499	0.576414573	0.464844632	0.442863556	136.37	142.83	146.34	142.79	17.96723995	27.71129998	13.72732891	228.0287601	0.846741391	14.88634406	9.08218991	13.72609078	12.08905048	83.26851654	0.809543002	11.77640915	6.507852949	26.32573984	14.48579995	305.2885081	0.801110903	15.47224132	318.4584351	0.387080492	0.612919508	0.655778562	0.821942767	0.876697982	4.618025459	28.15420376	14.615135	0.784078729	17.56593952	1.693033762	23.69380385	14.74966113	0.799060444	17.80676746	1.319026269	19.23769017	14.84723854	0.79437393	18.76182365	0.553052555	0.360676557
1960	Chinook_1	0.809216491	0.646227065	0.522937598	0.504428234	132.15	137.53	142.09	140.5	19.10081885	26.45609095	12.98461403	205.3476552	0.837496834	14.16151554	9.770656615	12.76435826	11.46466522	81.78309326	0.770603347	11.38828583	6.91690845	24.59899776	13.53346872	267.8484472	0.811990162	14.62356385	281.9978027	0.354347364	0.645652636	0.711975558	0.84687946	0.896697751	4.908416934	26.28515657	13.70097542	0.801271105	16.57518559	1.812378563	22.14538922	13.9045976	0.803578397	16.96352673	1.412442155	17.97203501	14.09222269	0.79145509	18.03920364	0.603071263	0.426878226
1961	Chinook_1	0.800644033	0.630874832	0.50510617	0.230181752	118.64	127.67	134.53	132.6	21.82476571	23.37682312	12.78722886	192.5687831	0.855591527	13.96453725	11.68088888	10.43835614	10.95025864	61.95190048	0.821582246	11.00496197	7.393874802	22.57435157	13.58660189	256.6638133	0.811728438	14.39935676	266.79422	0.647238039	0.352761961	0.696834857	0.836674597	0.887720116	5.289307512	24.00320033	13.75148811	0.803144968	16.41305122	1.978678145	20.34963989	13.93536822	0.808160007	16.78844452	1.545715667	16.44136876	14.08186054	0.803479791	17.86370373	0.5792849	0.416865737
1962	Chinook_1	0.830946201	0.678303182	0.563633452	0.317595658	119.52	127.16	133.77	131.38	20.12027099	24.07202749	12.31954275	192.2580158	0.857898891	14.21734265	9.905917786	12.67440842	10.7824852	87.12950592	0.807017612	11.95483894	7.451336145	22.44476007	12.86555926	249.0604477	0.82924968	14.6771183	252.8318787	0.56710946	0.43289054	0.734139055	0.85058037	0.898674974	5.351669073	23.84048837	13.07950668	0.81142714	16.48875866	2.009506762	20.06582406	13.33266068	0.799988111	16.66831366	1.571558207	16.17598208	13.51726484	0.788549989	17.65372372	0.649890985	0.46154463
1963	Chinook_1	0.809383715	0.616841666	0.499261599	0.356747121	117.17	125.3	132.14	131.68	22.39389317	22.64104127	12.7883232	164.0609807	0.849086885	13.40480168	11.75951053	10.79172807	10.83060455	71.57802429	0.775847411	10.80666771	7.840034582	20.93086064	13.56880395	208.2247518	0.834663381	13.9714102	216.3615112	0.493664408	0.506335592	0.682335514	0.827139785	0.879015985	5.652154066	22.14852514	13.75485325	0.833716071	15.54502239	2.153646298	18.74953564	13.99410915	0.826675852	15.91475519	1.685140796	15.10962172	14.19373178	0.823174864	16.96776962	0.575021312	0.412247469
1964	Chinook_1	0.819178926	0.612478798	0.501729724	0.624090645	133.08	139.6	145.21	141.73	17.35869345	28.35909018	13.4607236	225.8376754	0.819688597	15.01672275	8.451969169	15.11404448	11.8253685	103.9835281	0.727175283	12.65057049	6.577904291	26.1264115	14.13995075	288.4319814	0.806627671	15.33609168	299.8666382	0.245303619	0.754696381	0.683270939	0.832227764	0.884197367	4.648819275	27.98494742	14.30624828	0.798037803	17.07613888	1.706071354	23.52761749	14.48687267	0.815571467	17.5616045	1.329947926	19.08012553	14.63319111	0.80562678	18.62657642	0.596895844	0.377182144
1965	Chinook_1	0.791211556	0.534439624	0.422854807	0.646191434	142.76	140.78	140.92	152.02	15.74914832	29.71392697	14.15471002	255.2522212	0.790659228	16.31137105	6.923926584	18.56801404	12.93759613	136.7977234	0.669485211	14.53137207	6.504844569	26.31815704	14.55377372	321.1133575	0.786967208	16.27753973	326.4178772	0.200497787	0.799502213	0.637421581	0.821535958	0.875968042	4.622622393	28.13121812	14.63672638	0.768178475	17.94909267	1.701361082	23.62539559	14.83531602	0.801372568	18.0669686	1.327960037	19.10859976	15.08505106	0.796383977	19.19895172	0.492592144	0.345018537
1966	Chinook_1	0.809507753	0.697800092	0.564874585	0.133168218	111.45	123.06	130.34	132.29	23.29964757	21.7026463	11.66806861	159.8151384	0.902235448	13.80691842	12.36711948	9.915526643	10.34065952	60.268853	0.893944788	11.88169022	8.016101904	20.42753509	12.11127869	207.7494634	0.860262553	14.0646286	219.4624634	0.801440913	0.198559087	0.755834526	0.865536602	0.911696801	5.760881014	21.63317344	12.28127785	0.852799678	15.936166	2.200206853	18.34649119	12.48917039	0.832889696	16.37682247	1.720606662	14.80612634	12.66338921	0.822859406	17.47929287	0.635587812	0.475033302
1967	Chinook_1	0.813355152	0.716793467	0.583007659	0.335829845	125.37	133.76	140.32	136.04	20.5505873	25.3240935	11.99490588	200.2433493	0.871355559	14.46318551	11.02439487	11.06518455	10.84351559	66.52450256	0.854135418	11.57373466	7.02241087	24.32391426	12.42397944	266.3103714	0.821383546	14.91618077	282.6847534	0.555651297	0.444348703	0.770472735	0.872419156	0.917909849	4.951207876	26.05296391	12.58341713	0.807902837	16.82262478	1.817190409	22.08868948	12.73727894	0.814801991	17.15103436	1.416295707	17.92342935	12.85198641	0.817098409	18.13005209	0.642511284	0.485132512
1968	Chinook_1	0.727191676	0.438149814	0.318618897	0.438982489	138.74	141.94	143.16	149	17.73706087	27.46292	15.13114064	174.9940093	0.859617889	13.65640817	8.576511279	14.08566052	14.15386219	69.56837616	0.809645486	11.22614059	6.916953996	23.86426525	15.45645968	223.5327581	0.831070691	14.03460884	231.6487427	0.311118064	0.688881936	0.551384296	0.778074729	0.839665857	5.038619474	25.17940621	15.47927856	0.828952467	15.85409527	1.898079738	21.16851394	15.61185964	0.825549126	16.16464456	1.48030822	17.15759213	15.79571962	0.815666139	17.33253241	0.422997215	0.217202257
1969	Chinook_1	0.839945634	0.656098009	0.551086658	0.357386318	116.39	122.77	129.9	132.43	20.57067648	23.77604936	12.51831858	249.4609337	0.795604595	15.56960794	10.16978408	12.97506426	10.4615263	110.916835	0.689643204	12.87803078	7.514711395	22.48065931	13.32136313	315.6601003	0.781708141	15.68039401	325.098877	0.516357386	0.483642614	0.716074093	0.84149106	0.891350641	5.297711864	24.04727319	13.55848522	0.771356797	17.53584328	1.968417898	20.44302758	13.8472058	0.800709685	18.13210424	1.53693001	16.53332201	14.05819845	0.790590644	19.45545483	0.621204148	0.451457586
1970	Chinook_1	0.817875417	0.693914989	0.567536011	0.469064793	123.17	127.88	134.98	142.16	20.79283133	24.35214255	12.16961493	180.5374985	0.865014992	14.5156249	10.69814648	11.16917367	10.75830555	84.21237183	0.807093728	12.61997738	7.602206774	21.855012	12.64489667	219.3782374	0.845790366	14.57671285	224.3562012	0.408614242	0.591385758	0.752518157	0.861959238	0.908481849	5.414468355	23.25731396	12.82639236	0.843243444	16.18167381	2.044260032	19.71579504	13.05843735	0.839240253	16.63951683	1.597789861	15.91667716	13.2498107	0.83457467	17.89084148	0.622034116	0.490989879
1971	Chinook_1	0.836662532	0.6002969	0.502245924	0.642444788	138.9	145.49	147.59	143.07	14.23722995	32.27676202	13.72560263	327.6707371	0.80753221	19.51081814	6.257735558	20.25246499	12.46452694	154.9473572	0.718431818	17.04387894	5.639584243	31.11864125	14.38085826	421.7277374	0.785548791	19.57148981	425.8627625	0.229965517	0.770034483	0.68036897	0.835124748	0.887561323	3.937448442	33.52672801	14.48073654	0.758415681	21.51444626	1.39226757	28.79956612	14.53285599	0.835835358	21.46618334	1.08337225	23.45981409	14.54921103	0.84036684	22.6409483	0.587452009	0.410772649
1972	Chinook_1	0.840577383	0.621338169	0.522282812	0.481463789	122.48	126.85	133.07	138.36	17.67347342	26.89191996	13.20776258	283.2029364	0.836500585	17.56492867	8.428413987	15.08006422	11.29211388	121.6445038	0.769412208	14.46718559	6.666825175	25.3672182	14.03236405	361.0910034	0.810657978	17.98873154	362.5066223	0.375879727	0.624120273	0.690594207	0.833068901	0.884631378	4.752823114	27.0473844	14.20951805	0.787517929	19.99468803	1.740296513	23.07900368	14.42391904	0.818047067	20.14605522	1.357344896	18.69625914	14.57952118	0.81756261	21.18376255	0.598587232	0.43822344
1973	Chinook_1	0.775607374	0.580706449	0.450400204	0.242074441	119.51	127.85	134.23	141.77	22.88851692	22.69095182	13.03369617	130.985696	0.883210753	13.21678417	12.36935528	9.660800985	11.26461887	52.02982483	0.841993618	11.37050648	7.88712132	20.58909439	13.77090693	166.8007075	0.859164208	13.50979082	174.7462158	0.606989956	0.393010044	0.657565705	0.813671609	0.867070627	5.710012317	21.72371859	13.91846752	0.863995516	15.15013409	2.19552961	18.39779538	14.13402335	0.852803946	15.24226062	1.717933744	14.82972744	14.3208766	0.858322114	16.17495632	0.515423022	0.382297529
1974	Chinook_1	0.832200435	0.582523118	0.484775993	0.555690699	136.5	143.5	146.7	141.67	15.24202463	30.47449371	13.98501955	314.9765908	0.815120797	18.86505011	6.919242926	18.37647641	12.40306511	140.6512024	0.739253438	16.04244118	5.899934076	29.40124011	14.71016566	410.7868195	0.785904075	19.22161055	415.8928833	0.293765867	0.706234133	0.662656527	0.823889058	0.877573465	4.148742102	31.57273426	14.84518318	0.75986405	21.15286598	1.483336113	27.02057066	14.98639774	0.831880093	21.06679153	1.154357783	21.99635251	15.08760405	0.83439827	22.25462532	0.571139538	0.376096855
1975	Chinook_1	0.816776926	0.606515928	0.495388215	0.599435247	145.45	149.91	152.95	154.62	15.64960003	30.62635631	13.76575756	260.3813733	0.817425051	16.60910443	7.293849848	16.95125584	12.48393993	124.9134445	0.731204498	14.22295036	6.165377058	28.16456657	14.2226998	329.2683462	0.797988286	16.66438452	338.7079773	0.26230996	0.73769004	0.682712347	0.833687865	0.885441526	4.32151822	30.27511697	14.37008266	0.778921711	18.51996155	1.563858457	25.62203293	14.56533209	0.816749255	18.70174154	1.217004605	20.85374341	14.75790405	0.818428725	19.94856834	0.563954448	0.417704375

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1976	Chinook_1	0.849979288	0.738996133	0.628131407	0.511220293	119.82	125.2	132.21	130.85	19.1594921	25.091209	11.57583482	262.2896767	0.81568755	16.26987873	9.169804715	14.33083836	10.25247536	122.4242244	0.725237024	13.56309834	7.183315655	23.79290196	12.05213022	331.6445211	0.798906783	16.54177284	344.7332764	0.391172077	0.608827923	0.787556756	0.877656115	0.922218345	5.043356091	25.51649978	12.25997524	0.776332593	18.29163132	1.847647935	21.73780001	12.45927525	0.806163967	18.54297702	1.440745324	17.62166483	12.59201097	0.808275878	19.65977097	0.687599387	0.548509994
1977	Chinook_1	0.730529562	0.507410339	0.370678253	0.149973397	131.28	140.43	146.16	134.05	21.0848832	23.8606114	14.06497812	106.2079852	0.91547644	12.80593089	10.91946001	10.71283566	12.90733891	38.24018936	0.89070847	11.18320637	7.672403894	21.09492534	14.60275888	141.5417531	0.893854946	13.12 45815	147.594101	0.701100418	0.298899582	0.592264777	0.783198979	0.841435614	5.632985435	22.12 93065	14.67844563	0.903026247	14.86956196	2.167424791	18.63205532	14.77007008	0.888988912	15.17838701	1.695855282	15.01796368	14.85039759	0.890879840	16.31496525	0.468865780	0.280233395
1978	Chinook_1	0.842229990	0.738080099	0.621633195	0.220384376	109.62	120.05	127.66	128.42	23.4759070 1	21.7846818 1	11.12037893	202.9378112	0.85308755 7	14.49679627	12.40097075	11.28211249	9.563560486	91.55380402	0.793485487	12.06071987	7.991464011	20.65946507	11.66676346	260.3812281	0.829300265	14.98 48915 7	270.4839478	0.703827032	0.296172968	0.786178253	0.877634789	0.922085135	5.691583033	21.96 74119 6	11.86 26201 6	0.812647655	16.73746357	2.170180522	18.59407241	12.09359614	0.798763136	16.93486055	1.696970813	15.00580664	12.28282785	0.789325327	17.85151577	0.678231292	0.532421887
1979	Chinook_1	0.829908810	0.729855957	0.605713889	0.205827952	113.32	123.24	130.76	127.44	23.6501840 7	21.9244346 5	11.25232329	182.4694307	0.83398533 3	13.37316278	12.67778607	10.38750459	9.631550026	72.55851898	0.768378246	10.39999256	7.999175556	20.96423915	11.86992725	237.5987167	0.805651198	14.09 09310 2	249.4879303	0.720239653	0.279760347	0.780278673	0.873812451	0.918724901	5.616313942	22.43 14817 9	12.07 45597 8	0.803200126	15.67439632	2.124897905	18.98519153	12.30077457	0.800846647	16.10362879	1.661568291	15.31771761	12.45985937	0.787112176	17.17086458	0.678271519	0.498126411
1980	Chinook_1	0.827668625	0.619159024	0.512458498	0.567383041	134.21	136.64	142.05	146.91	16.54 18897	29.11 29226 9	13.43 96556 4	254.3 33659 6	0.81727188 8	16.03 47151 1	7.800 64870 4	16.24 27300 4	11.85 11022 6	110.6 74585	0.740 79221 5	13.27 20615 4	6.385 42689 4	27.25 08006 8	14.17 76590 3	333.0 68456	0.789 64122 1	16.43 58460 1	339.2 33551	0.295 44189 9	0.704 55810 1	0.688 67356 3	0.834 33996 7	0.886 23026 5	4.508 78430 9	29.24 01313 2	14.33 71730 8	0.772 97402 6	18.35 48408 5	1.635 12350 6	24.53 08631 7	14.48 10702	0.803 23616 7	18.53 64290 9	1.273 81272 6	19.92 03797 8	14.57 87730 2	0.797 64375 1	19.60 14137 3	0.583 76148 8	0.428 19278 3
1981	Chinook_1	0.780176202	0.571572148	0.445926987	0.389164793	124.41	124.06	129.06	148.31	21.25 24284	23.61 55507 4	13.59 43987	188.5 11274 1	0.83682548 6	14.02 16704 4	10.98 40227 8	11.54 01891 3	12.20 23164 7	78.79 60998 5	0.764 55390 5	11.41 30119 3	7.605 68852	21.46 93537 7	13.98 38724 1	238.8 12571 2	0.815 46516 2	14.32 77240 6	244.2 40890 5	0.433 36705 6	0.566 63294 4	0.652 80097 1	0.818 73219	0.873 19336 1	5.479 11471 9	22.70 91381 9	14.11 71737 7	0.809 56295 7	15.99 21176 9	2.106 62860 4	19.16 12727 2	14.35 48739 8	0.810 97726	16.38 19427 5	1.648 25219 7	15.43 96319 6	14.60 39972 3	0.805 63598 9	17.53 75642 8	0.528 21894 2	0.358 76525 2
1982	Chinook_1	0.813467892	0.527589828	0.429177384	0.591290213	143.11	146.47	144.87	149.26	15.48 52797 7	30.44 55807 7	14.47 99351 7	271.3 66021 8	0.81397435 9	16.99 03809 7	7.070 25060 8	18.02 89468 6	13.14 29212 6	128.4 20961	0.733 60776 9	14.58 03798 7	6.129 69499 1	28.05 01535 8	15.06 54880 2	346.4 86282 3	0.787 93395 6	17.11 13084 2	346.9 67071 5	0.242 20471 8	0.757 79528 2	0.615 50001 4	0.803 02639 7	0.860 33399 7	4.353 01476	30.00 46362 2	15.18 24022 3	0.764 11855 2	18.85 01705 2	1.587 21684 7	25.30 39029 6	15.31 37277	0.812 84558 8	18.99 05084	1.237 91488 3	20.49 97544 8	15.43 39633	0.811 57654 5	20.28 76148 2	0.527 64848 7	0.322 43719 7
1983	Chinook_1	0.822545193	0.631608510	0.519526544	0.440895529	118.91	124.3	131.07	143.28	20.1515450 4	24.7514969 7	12.92709323	217.5503791	0.81549798 6	14.55046817	10.12110407	12.82524725	11.02841454	100.3159698	0.724733555	11.78179817	7.413381264	22.61774169	13.63383023	277.0966848	0.798884104	15.00 23088 5	283.3162231	0.414 67083	0.585 32917	0.696 55388 6	0.833 93132 9	0.885 10132 5	5.270 03972 2	24.11 10963 5	13.83 64587 8	0.788 94828 6	16.74 16616 4	1.977 68412 5	20.37 25779 8	14.11 46278 4	0.797 48030 5	17.13 68408 2	1.545 78836 3	16.44 09928 8	14.34 51867 1	0.783 72335 4	18.33 29992 3	0.586 83335 9	0.442 83722 4
1984	Chinook_1	0.821191278	0.600963678	0.493506131	0.582365378	128.33	133.77	139.14	138.04	16.69 88507	27.85 76934	13.49 02097 2	223.5 75364 2	0.82392566 1	15.49 18092 3	7.480 28136	16.53 24908 3	12.19 77045 1	122.2 91641 2	0.731 68945 3	13.95 54817 2	6.756 47056 1	25.25 70404 4	13.99 42838 4	275.3 91433 7	0.812 75210 8	15.47 47662 5	282.9 37194 8	0.275 80437 2	0.724 19562 8	0.675 63306 4	0.829 39685 6	0.881 87922 8	4.823 83012 8	26.94 78958 4	14.15 16643 5	0.796 68599 4	16.98 53794 1	1.773 83247	22.63 96951 8	14.33 60077 5	0.801 99384 7	17.29 00568 6	1.383 25467 7	18.34 81841 5	14.48 48575 6	0.788 36610 9	18.43 87426 4	0.567 00267 4	0.395 18098 9
1985	Chinook_1	0.837694968	0.732299676	0.613443753	0.179148931	110.51	120.83	128.76	128.17	23.5477201 6	21.4246624 4	11.11 91182 1	177.4 03980 3	0.80667194 7	13.56 63294 5	12.18 24488 5	10.83 42096 8	9.568 13793 2	96.17 35183 7	0.679 23798 6	11.44 61221 7	8.321 86947 8	19.91 99176 8	11.65 11828 1	220.4 63371 3	0.816 20322 7	13.90 50686 4	225.2 04895	0.752 67438 3	0.247 32561 7	0.780 97999	0.873 59443 8	0.918 23829 6	5.847 39862 4	21.27 92027	11.88 12015 5	0.815 29802 1	15.46 13027 6	2.244 86972 4	18.01 21782 3	12.12 83391 3	0.810 80667 2	15.79 02202 6	1.757 70418 3	14.50 20906 2	12.31 29358 3	0.801 22298	16.86 31515 5	0.675 00328 1	0.515 45130 6
1986	Chinook_1	0.806222848	0.609864747	0.491686893	0.372621377	119.16	122.7	128.43	142.63	21.1238156 8	23.5166154 5	12.85 80193 5	197.1 80571 4	0.84318788 1	14.67 75893 8	10.63 54936 5	12.84 00648 7	11.18 05351 3	103.1 46002 2	0.748 84415 9	12.34 46580 9	7.722 23771 4	21.04 53752 1	13.35 52505 2	245.3 97875 5	0.843 40222 7	15.17 83607	245.7 56835 9	0.472 07452 7	0.527 92547 3	0.693 45093 3	0.833 27377 4	0.883 97353 7	5.618 70277 7	22.16 69141 8	13.49 73291 4	0.827 61097	16.78 98834 2	2.159 62553 8	18.72 49256 7	13.82 74202 3	0.820 89181 7	16.98 25471 2	1.691 90184	15.05 09526 1	14.14 69512	0.816 28817 3	17.99 01552 2	0.556 96068 1	0.420 96494 6
1987	Chinook_1	0.750068702	0.508434972	0.381361166	0.218783949	118.36	126.77	131.97	127.42	19.9958622 5	24.0678451 5	13.87 93715 7	199.3 83029 1	0.85650142 2	14.01 39197 3	9.940 16461 8	12.52 24085 8	12.67 08259 6	62.81 40373 2	0.830 10764 1	11.14 54608 9	7.215 36268 3	23.19 13713	14.45 74111 3	272.2 54804	0.806 74724 8	14.58 39860 4	280.7 29187	0.603 84488 1	0.396 15511 9	0.607 32974 6	0.804 40860 7	0.862 24939 3	5.223 95052	24.56 82714 8	14.50 18503 2	0.797 11859 2	16.64 17394 6	1.953 30478 3	20.61 44269 7	14.56 02331 2	0.797 24556 2	17.03 35454 9	1.526 09403 4	16.64 89424 4	14.63 15407 8	0.783 91104 9	17.99 91102 2	0.469 85156	0.287 66536 7
1988	Chinook_1	0.817545182	0.720144047	0.588750296	0.065572626	109.19	121.28	129.09	141.44	25.1042929 6	20.4671036 5	11.09 64251 2	138.2 48673 6	0.90646929	13.36 02517 3	13.69 84417 1	8.805 70419 3	9.472 88398 7	57.70 76232 9	0.874 73048	11.28 21445 5	8.363 68376 8	19.37 00160 5	11.69 10220 8	180.3 37455 7	0.886 15305 2	13.82 39292 3	185.4 78179 9	0.900 58487 9	0.099 41512 1	0.772 39670 8	0.868 70813	0.913 16532 7	6.022 96621 4	20.46 93401 9	11.87 95358 7	0.882 15791	15.68 18546 3	2.334 56859 7	17.34 92054 9	12.11 30914 7	0.864 33665	16.14 48418 3	1.829 51203 7	13.95 10019 7	12.30 23905 8	0.864 91904 5	17.21 56343 5	0.654 17604 3	0.483 83071 6
1989	Chinook_1	0.796470761	0.516422932	0.411315766	0.357170828	143.3	151.44	155.78	145.78	17.6836026 4	28.1044613 5	14.06 66523 7	192.7 27534 2	0.87565439 9	14.42 24506 8	8.814 45895 1	14.11 61829 5	12.41 19089 1	75.84 95163	0.846 51491 6	11.97 78778 1	6.562 36942 9	26.10 76104 6	14.89 59366 5	254.6 22680 7	0.837 76478	14.82 18795 5	262.6 53228 8	0.444 73305 7	0.555 26694 3	0.598 12352 6	0.795 86854 5	0.855 04926 7	4.694 83312 2	27.85 14277 4	15.02 33200 1	0.821 14197	16.83 89154 4	1.728 11537 2	23.24 90744 5	15.08 56291 5	0.810 29015 8	17.07 31611 3	1.348 24853 4	18.82 20657 5	15.12 90879 2	0.804 85785	17.98 21834 6	0.526 82961 3	0.296 87388 6
1990	Chinook_1	0.729091517	0.347268247	0.253190333	0.326451473	131.77	139.62	143.06	139.62	17.8463546 9	26.7302066 7	15.54 16367 4	164.4 47721 2	0.87053546 3	13.62 42944 9	8.560 79646 9	13.95 92162 2	14.25 05050 7	61.31 14166 3	0.848 43457 9	11.65 89336 4	6.896 53939	23.98 99180 7	16.17 59576 8	218.1 64065	0.824 22092 6	13.81 42776 5	220.4 45922 9	0.366 16979 7	0.633 83020 3	0.447 98331 1	0.711 46105 4	0.783 46512 2	5.064 60851 4	25.24 26041 6	16.24 14981 8	0.819 85837 2	15.71 05552 7	1.907 42108 2	21.09 63639	16.29 92617 3	0.818 83396 7	15.93 75327 4	1.489 57192 9	17.05 20788	16.35 53972 2	0.814 46382 4	16.97 58067 1	0.411 15930 8	0.132 90601 5
1991	Chinook_1	0.796807281	0.613520938	0.488857951	0.258360661	122.37	129.36	135.59	143.02	21.2387447 2	24.2439973 2	13.03 48199 4	194.3 62460 8	0.85851101	14.12 19009 7	11.37 88170 1	10.60 52499 6	11.23 87723 9	62.31 27265 9	0.832 90355 2	11.21 41775 1	7.276 34340 5	22.97 18747 8	13.78 40991	259.8 98307 8	0.809 90024 4	14.48 17252 2	259.2 33184 8	0.604 02459 7	0.395 97540 3	0.682 63068 8	0.829 88542 8	0.881 92750 2	5.201 57939 2	24.43 58985 4	13.94 58881 4	0.801 12727 9	16.50 37826 3	1.953 90096 3	20.64 10997 5	14.14 49228 9	0.814 19140 1	16.90 26355 7	1.528 69013	16.62 18221 4	14.31 34017	0.813 99762 6	17.96 12450 6	0.565 11352 3	0.399 71289
1992	Chinook_1	0.741296207	0.509805332	0.377916759	0.182164805	121.4	128.6	132.66	136.27	20.7054933 8	23.4200677 5	13.95 24598 1	154.0 19505 6	0.89938283 8	13.62 46554 9	10.43 57400 1	11.46 18977 1	12.79 37330 2	51.09 75235	0.902 01119 2	11.66 70091 6	7.543 33893 2	21.63 45949 2	14.37 27614 1	208.8 17601 5	0.846 88427 1	13.92 18889 1	214.3 37631 2	0.654 60952 6	0.345 39047 4	0.603 98810 5	0.797 43444 1	0.855 29069	5.537 39325	22.72 37692 1	14.44 24001 7	0.840 76628 7	15.84 04615 4	2.113 40174 8	19.11 40329 3	14.57 88765	0.825 59706 8	16.14 66455 5	1.654 56981 2	15.38 19787 7	14.72 99203 9	0.819 64671 6	17.09 96990 2	0.472 96956 2	0.294 48527 7
1993	Chinook_1	0.825270499	0.730988776	0.603263472	0.505139858	119.74	127.24	134.6	130.1	20.7280059 1	24.0620899 4	11.55 75836	206.0 53439 5	0.82620401	14.26 44476 5	10.54 14826 8	12.08 1581	10.48 95118 7	87.72 32208 3	0.745 62912	11.26 02058 4	7.413 86565 6	22.99 17908	11.97 32227 3	264.3 27977 5	0.806 45226 4	14.89 63242 4	292.7 64892 6	0.388 36895 7	0.611 63104 3	0.784 34557 7	0.877 84614 7	0.922 37249 2	5.195 90339 1	24.66 19025 7	12.12 33541 5	0.798 77142 9	16.44 45869 4	1.903 77381 4	21.08 26170 6	12.26 05810 2	0.817 50293 6	16.80 51430 4	1.483 31591 5	17.12 19980 4	12.34 34481 6	0.818 92287 7	17.84 02485 8	0.662 53044 7	0.506 14922 2

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1994	Chinook_1	0.737061861	0.454007499	0.334631612	0.350194614	128.31	135.75	140.73	136.58	18.47317878	26.1606524	14.40233449	157.026332	0.874207292	13.4716553	8.950748973	13.57823453	13.26508274	63.86974716	0.85187552	11.72777233	7.0960906	23.37859747	14.94168425	207.287852	0.829920967	13.64432875	209.0910797	0.409271895	0.590728105	0.562015705	0.785935127	0.846849119	5.195743605	24.63665691	14.96891727	0.82569797	15.37279148	1.958151922	20.58253444	15.01191394	0.817728778	15.62752374	1.531062767	16.59704016	15.12442207	0.810034454	16.5925684	0.42085372	0.22473977
1995	Chinook_1	0.814294458	0.641055703	0.522008107	0.505370198	122.58	124.87	131.43	141.45	21.40425221	23.78775834	12.69561611	191.6943294	0.818114451	13.82862357	11.11857767	11.41865095	10.9303896	89.19897156	0.714529014	10.98633194	7.67334339	21.49914093	13.31888103	236.4968389	0.813493381	14.33763901	244.7812958	0.354112916	0.645887084	0.705288593	0.839389122	0.889741375	5.480256766	22.83750835	13.50774975	0.808357012	15.92522736	2.084108621	19.34822156	13.7804985	0.806375265	16.24763362	1.629328042	15.61487765	14.02402163	0.801976651	17.33539581	0.585781672	0.452640987
1996	Chinook_1	0.783246145	0.540184991	0.423097812	0.541425675	137.91	136.8	140.18	152.24	16.07057168	29.36056428	14.46521398	254.8568578	0.816973197	16.34929923	7.310156666	16.94702959	13.43143349	119.969429	0.733275807	14.15568466	6.487347774	26.26994305	14.78731521	322.9503021	0.795207808	16.28119993	330.5181885	0.281018555	0.718981445	0.628216138	0.810496748	0.866945589	4.632532649	28.02237514	14.9051342	0.776861286	18.18252811	1.703155361	23.55582628	15.07769998	0.805112461	18.37099361	1.32704889	19.1217078	15.25396633	0.801969409	19.64260483	0.503109852	0.328918542
1997	Chinook_1	0.828819343	0.573768296	0.475550262	0.56285806	134	138.04	140.32	139.56	14.42497415	31.10420069	14.04792452	356.0365437	0.81673319	20.99191584	6.149629131	20.57853024	12.56354065	165.3274078	0.729304779	18.22027283	5.800859801	29.5894933	14.65310256	461.3331655	0.797957212	21.52773444	470.4274597	0.283827206	0.716172794	0.663250475	0.829029747	0.881701051	4.083983533	31.72451015	14.77227974	0.769400597	23.62327423	1.450793169	27.62420136	14.94090716	0.851613561	23.15073204	1.128764413	22.50181286	15.11581993	0.854435116	23.9979763	0.5501611	0.397217025
1998	Chinook_1	0.83460307	0.661354969	0.551968887	0.418069088	114.97	122.18	128.88	130.31	21.29948626	23.2639743	12.47549241	249.3199588	0.843997151	15.97972468	10.92975769	11.87868428	10.34212589	97.14177704	0.8003232	12.98555241	7.448899992	22.46164528	13.28537766	321.0707397	0.802391022	16.11243121	338.6766968	0.4536063	0.5463937	0.720561704	0.842002337	0.891384368	5.314597614	23.91094723	13.50999908	0.782009876	18.03597908	1.971998431	20.39595171	13.82526429	0.815719763	18.65702883	1.539029755	16.51103812	14.06746674	0.819469452	20.01299763	0.625232075	0.459724082
1999	Chinook_1	0.826398599	0.642418374	0.530893644	0.388717219	119.87	125.44	132.11	128.24	20.60818642	23.55757527	12.70279925	206.3455544	0.820986854	14.34662032	10.18552375	12.84162973	10.83832455	97.01820526	0.721024144	11.80488567	7.524970882	22.16829739	13.44241063	266.5809072	0.8147841	14.8333892	273.8771362	0.47231562	0.52768438	0.704171296	0.837667354	0.888122043	5.382734887	23.57019939	13.63050289	0.805515683	16.63276806	2.024508379	19.90468249	13.86529541	0.809633315	16.95929337	1.582326911	16.06754941	14.05058289	0.799560487	18.02812099	0.610087999	0.435603664
2000	Chinook_1	0.773095153	0.464926954	0.359432775	0.472035065	130.34	136.65	140.27	141.47	17.64819656	26.91441434	14.37306643	189.6717082	0.845450891	13.99504004	8.319582775	14.89354373	12.98115559	84.77818298	0.787552619	11.79867306	6.873681694	24.35131876	14.95704381	244.4070485	0.816424986	14.3677903	253.692276	0.305403049	0.694596951	0.568978427	0.792143821	0.852850281	4.99337998	25.7674879	15.01841717	0.806877899	16.13110809	1.86206612	21.57280254	15.10676225	0.796816965	16.38813273	1.452100247	17.48613654	15.26159191	0.780822664	17.44205761	0.45867146	0.25712247
2001	Chinook_1	0.800696305	0.605482248	0.484807399	0.127518161	110.67	122.98	130.59	127.11	25.34695001	20.69220087	12.44687067	117.7461469	0.878530272	12.90715109	13.99228915	9.047100222	10.11106949	49.34661789	0.829777408	11.10432625	8.383933477	19.18853248	13.4690388	149.678655	0.858422945	13.25701952	160.7003937	0.786323747	0.213676253	0.669289047	0.813950577	0.866636907	6.073529415	20.21515493	13.67445393	0.868469369	14.6917696	2.356679522	17.17155727	13.92529011	0.863021215	14.79044787	1.84515103	13.83727652	14.10124445	0.872621238	15.77877283	0.576853739	0.375428749
2002	Chinook_1	0.814016755	0.651665482	0.530466621	0.253780974	120.2	128.96	135.45	137.04	20.80071402	24.12069332	12.60724299	179.4593822	0.882726699	14.10889803	10.7692314	11.44297639	10.93130379	68.16046753	0.865398335	11.95082569	7.397550739	22.45857642	13.2284797	235.2476756	0.83853056	14.37892866	242.9380798	0.628758637	0.371241363	0.711568476	0.840414967	0.890122847	5.323446907	23.81894413	13.43501453	0.826171398	16.35467968	2.004503436	20.07594416	13.68441963	0.814870159	16.60706329	1.564884312	16.24406921	13.875916	0.805228174	17.68974113	0.609731323	0.438389636
2003	Chinook_1	0.804772414	0.62574714	0.503584037	0.393173886	130.94	137.22	144	140.94	18.95998783	26.30140769	13.19947754	205.7595602	0.858244828	14.53901448	9.592008583	13.0283541	11.72634792	80.61084442	0.809470987	11.51269131	6.91818805	24.40570249	13.82544359	264.7954305	0.828012307	14.97765001	289.7671204	0.457166984	0.542833016	0.695877925	0.838868615	0.889883268	4.942444518	25.99960459	13.96490822	0.815165007	16.87441826	1.816445097	22.04488755	14.12207317	0.818413556	17.33653959	1.412554815	17.97053332	14.2608366	0.814806312	18.48495579	0.573057882	0.419328599
2004	Chinook_1	0.822826223	0.66659312	0.548490299	0.102447625	107.25	120.31	127.68	134.88	24.84322141	20.75088372	11.90772397	168.0426576	0.901036556	13.98064028	13.61863745	9.365372539	9.532502747	61.89799347	0.88745178	11.67262917	8.129648544	19.92370495	12.81033262	217.4722977	0.862875899	14.37608401	240.9525909	0.838854673	0.161145327	0.722482947	0.840446554	0.889304604	5.897631027	20.99863902	13.04464741	0.849218643	16.27541447	2.257979341	17.8552484	13.39936002	0.821512361	16.77242756	1.763275512	14.45741717	13.667099	0.80904749	17.86694431	0.630203922	0.434513602
2005	Chinook_1	0.781915407	0.55948171	0.437467369	0.388870903	121.68	127.92	133.88	134.69	20.46318538	24.11222002	13.750222	172.3787182	0.856697423	13.75284355	10.33899636	12.10824189	12.27453938	70.94256744	0.801286709	11.40434227	7.475109577	22.02266533	14.30967776	220.8836924	0.831221998	14.16519507	231.4837646	0.429047412	0.570952588	0.637955294	0.807065655	0.862846913	5.424730301	23.25961858	14.45315685	0.826285493	15.81379852	2.049874932	19.64393203	14.64336395	0.815060695	16.11339537	1.600860417	15.88627022	14.79646349	0.810488224	17.07933521	0.533829004	0.332925216
2006	Chinook_1	0.843654298	0.715119965	0.603314032	0.556221355	120.55	126.07	132.85	128.41	19.09369608	24.77225871	11.77072498	241.2065473	0.802733875	15.69762298	8.887657546	15.03106654	10.51168613	127.4897705	0.682270247	13.58465633	7.309215426	23.17351012	12.2895174	303.2254639	0.804487358	15.99778732	317.0925293	0.340183773	0.659816227	0.769910876	0.871381245	0.917289556	5.157690644	24.78954369	12.4711771	0.788154495	17.52712021	1.913580894	21.00084772	12.62247658	0.800138772	17.66318003	1.492631555	17.01627441	12.70586443	0.794743836	18.63988876	0.684045377	0.507707852
2007	Chinook_1	0.78703704	0.569889963	0.44852451	0.355481527	120.21	127.62	132.89	129.29	20.6364043	23.63689124	13.5292947	189.0126926	0.850731871	13.72722602	10.44897343	12.04924646	12.09113731	71.15097198	0.808127224	11.10634441	7.357201107	22.49834444	14.15724325	250.6386388	0.811601887	14.23087398	259.0120544	0.469991427	0.530008573	0.646666139	0.813706681	0.869061753	5.306984194	23.83018266	14.28634586	0.803950787	16.13650322	2.007498987	20.05512612	14.4190925	0.795890609	16.39541531	1.56787426	16.21301891	14.51373625	0.785040706	17.34919262	0.533156873	0.35132336
2008	Chinook_1	0.818762924	0.727236523	0.595434302	0.159376862	104.56	118.05	125.87	134.75	25.54580382	20.05178867	11.17772572	151.8203441	0.897839955	13.75391313	13.89930552	9.227661197	9.662739182	63.94364929	0.843443239	11.05725231	8.464068748	18.97473066	11.60940568	188.2651418	0.892090917	14.38598601	198.3598938	0.77411972	0.22588028	0.775386683	0.868313284	0.912239888	6.103219844	20.01865788	11.80989265	0.890554047	16.06308193	2.373685427	17.05587049	12.11888218	0.875063201	16.76895777	1.859012552	13.73657171	12.39096355	0.870710164	18.15582275	0.651169812	0.502471567
SCN MO2-RESSIM																																																		
1929	Chinook_1	0.790022568	0.636877405	0.503147523	0.451650053	125.92	134.4	141.75	133.93	21.41811717	23.99467939	12.65973718	137.1067423	0.74825768	10.73168676	10.86943062	10.91843513	11.408078	59.17801666	0.709981918	9.609666443	8.004658751	21.74557846	13.24119616	178.1838353	0.654283077	9.814913511	201.0079498	0.398752214	0.601247786	0.71733153	0.851164207	0.902754699	5.381666951	23.61861321	13.39780483	0.688406724	10.62871761	2.006110631	20.02633521	13.50513617	0.692603022	11.41720645	1.563734852	16.25608544	13.5497036	0.720950261	12.65120411	0.589472663	0.392120113
1930	Chinook_1	0.796583804	0.622151643	0.495595922	0.167542694	103.28	117.81	125.97	133.68	26.58521528	19.94177314	12.20362936	131.2113062	0.729532438	10.56102504	14.29255808	9.108636062	10.1457777	65.09058609	0.641703397	9.150851631	9.196609735	18.26233913	12.86458667	165.5820948	0.66749001	9.85782218	172.8067017	0.72822955	0.27177045	0.705578212	0.836154446	0.88778215	6.182552814	19.75999032	13.08070393	0.708451241	10.68594475	2.421653479	16.74968394	13.46190166	0.701260298	11.58580716	1.898979098	13.45865856	13.78611755	0.724269375	12.92763186	0.575154765	0.396237995

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1931	Chinook_1	0.778361705	0.610276822	0.475016108	0.121552081	105.34	119.89	127.6	133.31	27.32929865	19.51762058	12.21747821	121.6811262	0.765462901	10.59617461	15.13856396	7.794689985	10.04583206	44.14291382	0.730279911	9.465764809	9.094739437	18.3638439	13.02627977	157.7126846	0.677514007	9.65551734	170.3040314	0.791685253	0.208314747	0.695953587	0.832677861	0.885081552	6.16873908	19.81694788	13.22705822	0.716553897	10.65678444	2.404400587	16.84766289	13.55668481	0.706645995	11.56094297	1.883554757	13.56467123	13.82346582	0.728796199	12.92193985	0.554476868	0.387863246
1932	Chinook_1	0.829318296	0.715230662	0.593153874	0.418117997	117.23	125.22	132.57	128.76	22.11050615	23.08166457	11.62710994	230.2835835	0.72201735	12.67406603	11.34939279	11.56422858	10.11970425	91.78301086	0.601169688	9.768552017	7.824700139	22.41476921	12.17904409	300.7567698	0.683733692	12.33319195	321.3575134	0.470192934	0.529807066	0.776474414	0.872892491	0.91867733	5.253964446	24.37131008	12.38144855	0.697380221	13.74099369	1.944089405	20.66392669	12.62690989	0.754123529	14.28779697	1.515766375	16.76025579	12.79970884	0.756669581	16.49774551	0.665723659	0.496783244
1933	Chinook_1	0.78415533	0.613723182	0.481254304	0.457102114	132.6	141.09	147.83	139.43	20.14670885	25.99841179	13.28787756	185.4979853	0.755695203	11.57479739	10.50308497	11.38640731	11.78261395	60.614711	0.700867492	9.43563633	7.222840898	24.75754203	13.91518672	251.5419744	0.67923293	10.9919498	278.6760864	0.382230863	0.617769137	0.698850059	0.841299617	0.8929139	4.815228336	27.01146524	14.07289181	0.715798473	12.31760273	1.754315637	22.82524465	14.26968575	0.747321288	13.58580939	1.364391349	18.60034402	14.41881275	0.734036386	15.58433533	0.578565274	0.370689339
1934	Chinook_1	0.787960291	0.59747685	0.470788033	0.212161842	113.8	122.07	128.32	131.6	21.6848707	22.75435602	12.98104177	227.6410746	0.769481759	13.21578022	10.9824767	11.83931005	11.47536335	79.37520294	0.719746995	11.58554993	7.698289268	21.91844336	13.52605104	310.1110382	0.695668861	12.2510124	316.1737671	0.653109028	0.346890972	0.685280447	0.836291518	0.889143109	5.398704402	23.47782226	13.65523262	0.691637594	13.55408859	2.041662715	19.74361951	13.84787114	0.754422863	13.91308339	1.596063666	15.93171515	14.02281046	0.756061345	16.24936438	0.551947563	0.388178268
1935	Chinook_1	0.781163376	0.597247033	0.466547508	0.502216105	126.4	134.59	141.95	133.92	20.21417467	25.03291127	13.36632095	176.4547081	0.7455908	11.21218552	10.19896219	11.63891259	11.94258766	63.68861847	0.679228359	9.268697929	7.469336458	23.58105271	13.96342166	235.4219589	0.67368874	10.5710295	250.4723816	0.33341111	0.66658889	0.685834647	0.8393088	0.891939409	5.036362119	25.62779819	14.10285416	0.713193947	11.82683105	1.85983441	21.58069716	14.25259622	0.735810091	13.13493601	1.449269421	17.51968197	14.38875914	0.710662082	15.15398455	0.563938618	0.359060783
1936	Chinook_1	0.843417584	0.717672943	0.60529798	0.405403446	115.55	122.4	130.1	129.28	20.68452638	23.77533161	11.33672489	241.8987792	0.696012144	13.94186452	9.873483419	13.43638079	9.890331268	123.3254868	0.528447115	12.88443642	7.918293528	22.14907257	11.82612387	301.3690745	0.683655977	12.57124575	314.6485596	0.489036907	0.510963093	0.78238503	0.879758414	0.9252584	5.312305979	24.08664955	12.03295498	0.688890076	13.58645687	1.976376258	20.34280227	12.26723131	0.748853644	14.11756357	1.541864477	16.48132727	12.46040106	0.752845377	16.48109484	0.65360666	0.520217465
1937	Chinook_1	0.790006045	0.625294878	0.493986733	0.448016598	123.01	130.86	137.39	131.96	23.57999402	22.27409145	12.46891989	140.2010563	0.72997678	10.61301255	12.51376352	9.535816768	10.88364429	58.15942078	0.664650941	9.227529144	8.336512938	20.58432567	13.1384004	180.9658152	0.649404531	9.726572593	193.970108	0.396995814	0.603004186	0.706098082	0.840859738	0.89289419	5.605886593	22.32271086	13.31492481	0.687236875	10.69754333	2.135068431	18.88897351	13.50280794	0.691908628	11.60593605	1.668920204	15.25296432	13.63335562	0.713547602	12.97111893	0.588247826	0.382166731
1938	Chinook_1	0.816020143	0.631796923	0.515559015	0.614113657	127.11	131.54	135.42	139.12	18.39324739	26.23678627	12.92189401	235.6534756	0.730761151	13.58627888	8.572364949	14.87169553	11.45715656	114.9403397	0.604481208	12.0675272	7.260862112	23.84533877	13.40157143	303.257665	0.701375321	12.78950636	310.7805481	0.256916668	0.743083332	0.709839033	0.847053461	0.897710997	4.994557858	25.74862185	13.56826077	0.706226891	14.02462368	1.856295556	21.65862188	13.80339972	0.753807753	14.49721591	1.448777467	17.52552951	14.02162457	0.744782582	16.60127783	0.593020315	0.420121727
1939	Chinook_1	0.816302173	0.707721701	0.577714762	0.484894677	113.61	121.87	129.87	127.92	22.27281558	22.53189776	11.28402581	193.5573365	0.70305698	11.6788528	10.94227	11.91974616	10.4154808	92.57553864	0.567931348	9.663195419	8.38940534	20.87032323	11.55835946	247.7368774	0.667190502	11.258075	254.1728821	0.39807421	0.60192579	0.78218406	0.884035709	0.929844815	5.553076118	22.75454791	11.68019638	0.695554674	12.28362503	2.103701621	19.17661697	11.8132054	0.723975301	13.19559415	1.645186454	15.46667398	11.90134621	0.699375808	15.23228645	0.637833165	0.48220407
1940	Chinook_1	0.802188084	0.708961721	0.568720644	0.101018741	94.9	111.43	120.64	134.78	29.75704999	18.31105533	11.10626725	166.4513964	0.655410609	10.31545401	16.55694735	8.498575933	9.468544006	79.27417908	0.443481964	7.488469505	9.618439384	17.75507974	11.50885439	208.8390986	0.659722731	10.19731426	219.4308929	0.846507469	0.153492531	0.778177885	0.872837513	0.918975082	6.285765834	19.35728795	11.73253689	0.701932484	11.24025269	2.465152271	16.45895829	12.10488129	0.703904182	12.4333245	1.933153458	13.22703968	12.41359568	0.700410381	14.14924908	0.628077349	0.468850532
1941	Chinook_1	0.734631728	0.489426966	0.359548578	0.456768355	128.89	131.8	135.66	145.55	20.63762869	24.45281045	14.32687671	145.0393333	0.735339825	10.69776498	10.23691075	11.40988378	13.09319096	57.07112885	0.690682834	9.430356979	7.963733882	21.31670802	14.72728411	189.5167643	0.640223955	9.661218723	197.2718048	0.320175317	0.679824683	0.603995114	0.794798816	0.854980647	5.471063584	22.97451451	14.8183979	0.677618974	10.7310585	2.085442841	19.34017871	15.02328873	0.684629887	11.625844	1.630646914	15.60326585	15.22613668	0.711094424	12.93898869	0.44432883	0.259360095
1942	Chinook_1	0.796316216	0.661692533	0.526916494	0.62294916	133.52	134.94	140.76	145.56	21.35360225	25.00637255	12.53367547	185.0327753	0.700235818	11.26849324	11.09446497	11.22246585	11.1954134	81.57685699	0.574547839	9.01054039	7.866248496	22.27736796	12.95917845	235.1302312	0.655094951	10.58468596	243.7241669	0.254868066	0.745131934	0.736994891	0.860106163	0.909728831	5.215378173	24.28280092	13.1458807	0.681515408	11.67104702	1.966438688	20.47850204	13.36093998	0.709409177	12.60182985	1.53633336	16.54110935	13.54995394	0.7267057	14.36472464	0.596922631	0.453109446
1943	Chinook_1	0.833528048	0.685450257	0.571342015	0.463115177	120.15	122.58	128.52	131.18	22.2220541	22.9006787	11.74193668	226.2297211	0.724282882	13.86345458	11.18427702	12.71679264	10.23009853	121.1619995	0.589194965	13.47687035	8.08873494	21.12957936	12.22515376	288.0040538	0.699000349	12.50924468	300.9777832	0.413210697	0.586789303	0.751830975	0.863050065	0.910601325	5.515077665	22.83195021	12.42678623	0.710158062	13.49889011	2.089019135	19.30175038	12.68091075	0.757752101	14.10745557	1.633112833	15.57827654	12.8955431	0.75091061	16.2759428	0.646417535	0.484702292
1944	Chinook_1	0.782622399	0.574026304	0.449245843	0.56700387	130.61	138.29	145.24	138.1	20.74685992	24.49279264	13.32315207	135.511025	0.727438865	10.4996045	10.36841021	11.17467896	11.81187401	65.2077774	0.648560333	9.161431694	7.938177437	21.63005453	13.96202739	170.6012853	0.656890407	9.617989858	174.523407	0.269931549	0.730068451	0.661880178	0.820037848	0.875144236	5.392707676	23.40457568	14.1312254	0.696102148	10.58260727	2.051002771	19.66346974	14.32189782	0.698072463	11.39879545	1.603898019	15.85757277	14.48160553	0.725339904	12.64594841	0.552809086	0.334286148
1945	Chinook_1	0.807110385	0.680911579	0.549570806	0.564088899	117.03	124.54	132.19	130.11	23.0305493	22.56065525	12.01270165	182.0126452	0.729369332	11.60473715	11.99444566	10.3111327	10.42149143	74.04655457	0.650299609	9.957484245	8.232668914	21.21778973	12.57054408	232.2979304	0.659945602	10.80673234	250.0804443	0.315085587	0.684914413	0.752682809	0.863116732	0.911223256	5.483055867	23.09929167	12.77311745	0.689190406	11.79011402	2.057282038	19.56295866	13.03969034	0.713000307	12.70443344	1.605856277	15.83734441	13.24239683	0.71023272	14.51722956	0.625570294	0.456845949
1946	Chinook_1	0.856260397	0.739498157	0.633202985	0.229281549	111.19	120.03	127.82	126.49	22.10006002	22.9322736	11.06524229	264.640576	0.708382643	14.13160668	11.03502501	13.24052112	9.378501892	130.4897003	0.53423965	12.3562479	7.964775056	21.81258255	11.62909349	333.6990153	0.707693363	12.96565779	346.5384521	0.69633001	0.30366999	0.793887191	0.880184136	0.924603161	5.394344777	23.64838591	11.8516964	0.701400775	14.08316135	2.0080356	20.03162055	12.13366095	0.770550152	14.62077904	1.567054003	16.22043658	12.33578253	0.777963012	17.30753899	0.690012038	0.541511605
1947	Chinook_1	0.832068917	0.637607708	0.530533555	0.289036671	110.26	120.78	128.27	128.23	22.58875887	22.75258489	12.45726504	246.3753902	0.717472428	13.3553399	11.62572419	11.88639299	10.12596588	100.6507507	0.583279175	10.23128681	7.968729131	21.800097	13.34660562	314.6918538	0.68803665	12.87330492	339.5052185	0.586338397	0.413661603	0.71179348	0.839287317	0.88988144	5.390036218	23.64149932	13.58078785	0.703929317	14.20636997	1.997284912	20.11329321	13.93595632	0.761839072	15.2125419	1.556879841	16.32484492	14.20281887	0.768828511	17.44009638	0.613001457	0.441935657
1948	Chinook_1	0.818397874	0.624442557	0.511042461	0.617465676	130.73	134.43	139.32	140.94	16.34002175	29.00833967	13.3977125	320.8367146	0.770080226	17.74234377	7.623494752	16.11175913	12.00320435	138.2984589	0.65363642	14.78387108	6.29105635	27.90329221	13.91931407	414.2433472	0.752157211	18.02986113	434.8553772	0.252942578	0.747057422	0.706217314	0.847124275	0.897119698	4.292501047	30.23423322	14.06994133	0.751033092	19.89734001	1.543086663	25.98333771	14.27408091	0.801295439	19.9320844	1.201488599	21.12522741	14.4536624	0.805048734	20.7682066	0.580285769	0.438090724

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1949	Chinook_1	0.796	0.568	0.452	0.688	126.05	130.71	136.39	132.26	16.94	27.43	13.69	271.5	0.736	15.38	7.571	16.67	12.23	126.4	0.585	12.89	6.705	26.11	14.34	349.1	0.729	15.25	383.5	0.180	0.819	0.668	0.831	0.885	4.639	28.19	14.44	0.735	16.72	1.655	24.15	14.58	0.788	17.16	1.286	19.72	14.70	0.794	18.57	0.535	0.357
1950	Chinook_1	0.803	0.670	0.538	0.660	130.24	134.45	140.48	139.12	19.94	25.71	12.53	211.4	0.726	12.18	10.04	12.41	11.27	91.57	0.601	9.857	7.425	23.77	13.01	270.7	0.692	11.62	286.6	0.228	0.771	0.742	0.862	0.910	4.970	25.89	13.19	0.714	12.87	1.836	21.85	13.36	0.755	13.80	1.430	17.74	13.48	0.744	16.10	0.623	0.442
1951	Chinook_1	0.820	0.633	0.519	0.596	130.89	131.76	137.27	138.07	18.54	26.48	13.08	260.7	0.754	14.52	9.017	14.21	11.45	108.7	0.643	12.00	6.984	24.80	13.70	337.3	0.725	13.88	348.9	0.272	0.727	0.706	0.843	0.894	4.814	26.77	13.88	0.725	15.38	1.771	22.66	14.11	0.777	16.03	1.381	18.37	14.30	0.776	18.31	0.596	0.418
1952	Chinook_1	0.848	0.733	0.622	0.653	122.11	121.71	129.17	133.3	18.82	25.51	11.50	288.0	0.720	16.55	8.488	16.23	10.22	163.3	0.546	16.17	7.560	22.95	11.84	352.7	0.725	14.97	362.1	0.259	0.740	0.788	0.880	0.925	5.152	24.84	12.06	0.716	15.88	1.910	21.04	12.31	0.778	16.33	1.491	17.03	12.53	0.788	18.50	0.682	0.546
1953	Chinook_1	0.808	0.654	0.529	0.518	128.15	128.37	135.66	142.49	21.16	24.66	12.61	206.9	0.734	12.43	10.99	11.19	10.99	84.52	0.625	10.16	7.660	22.73	13.23	264.1	0.693	11.88	278.7	0.344	0.655	0.729	0.854	0.903	5.142	24.69	13.41	0.719	13.20	1.919	20.94	13.65	0.745	14.23	1.498	16.95	13.85	0.734	16.17	0.592	0.456
1954	Chinook_1	0.812	0.656	0.533	0.504	140.43	147.5	147.65	144.08	19.16	26.89	12.78	230.6	0.760	13.54	9.791	12.65	11.43	90.82	0.678	11.25	6.989	25.34	13.32	296.8	0.708	12.70	303.6	0.359	0.640	0.729	0.856	0.906	4.682	27.60	13.49	0.716	13.86	1.728	23.21	13.65	0.761	14.78	1.347	18.83	13.76	0.754	17.27	0.604	0.449
1955	Chinook_1	0.797	0.647	0.516	0.712	133.48	133.92	140.6	142.82	20.19	25.37	12.78	186.9	0.703	11.49	10.15	11.79	11.32	84.65	0.579	9.422	7.629	22.90	13.30	234.7	0.658	10.85	245.4	0.182	0.817	0.724	0.852	0.902	5.114	24.90	13.48	0.683	11.91	1.911	21.03	13.72	0.708	12.73	1.491	17.03	13.93	0.722	14.44	0.596	0.423
1956	Chinook_1	0.853	0.734	0.627	0.400	114.89	119.79	127.41	133.47	20.10	24.36	11.31	292.0	0.759	16.91	9.562	14.74	9.884	146.8	0.624	15.14	7.654	22.37	11.71	374.4	0.752	16.61	375.7	0.499	0.500	0.790	0.881	0.926	5.237	24.16	11.94	0.740	17.87	1.955	20.59	12.21	0.785	17.77	1.527	16.63	12.44	0.788	19.54	0.674	0.562
1957	Chinook_1	0.823	0.716	0.590	0.432	113.27	120.43	128.36	138.02	22.39	23.46	11.66	273.0	0.721	14.90	11.62	11.64	10.32	115.3	0.555	11.19	7.988	22.03	12.00	335.0	0.720	14.54	359.0	0.455	0.544	0.784	0.879	0.924	5.246	24.07	12.19	0.744	16.03	1.939	20.69	12.47	0.778	17.37	1.511	16.81	12.74	0.779	19.35	0.632	0.537
1958	Chinook_1	0.820	0.644	0.528	0.632	124.66	130.42	136.64	135.83	17.45	27.71	12.78	271.9	0.755	15.30	8.255	15.20	11.43	119.5	0.653	13.23	6.652	26.85	13.41	349.8	0.717	14.51	370.4	0.248	0.751	0.723	0.855	0.904	4.514	29.18	13.56	0.723	15.85	1.618	24.74	13.67	0.781	16.49	1.258	20.16	13.74	0.789	18.55	0.597	0.447
1959	Chinook_1	0.793	0.582	0.461	0.607	134	137.17	141.18	142.88	18.95	26.81	13.52	227.2	0.748	12.67	9.586	12.92	11.91	84.00	0.655	9.769	6.979	25.00	14.23	304.3	0.701	12.56	316.9	0.241	0.758	0.669	0.829	0.883	4.771	27.06	14.38	0.711	14.16	1.761	22.78	14.54	0.757	14.70	1.373	18.47	14.67	0.752	16.66	0.549	0.361
1960	Chinook_1	0.794	0.642	0.510	0.641	132.01	136.01	140.58	139.82	20.56	25.60	12.83	203.7	0.718	11.73	10.70	11.65	11.31	80.87	0.596	9.164	7.405	23.92	13.36	266.8	0.680	11.30	282.8	0.233	0.766	0.722	0.854	0.904	4.939	26.08	13.52	0.708	12.69	1.825	21.98	13.73	0.745	13.72	1.422	17.84	13.93	0.729	15.85	0.591	0.410
1961	Chinook_1	0.796	0.618	0.492	0.324	117.65	126.06	133.57	131.7	22.85	22.93	12.78	191.4	0.751	11.88	12.15	10.11	10.94	63.95	0.690	9.608	7.931	21.93	13.55	255.2	0.678	11.28	264.3	0.525	0.474	0.701	0.841	0.893	5.324	23.83	13.73	0.713	12.70	1.994	20.19	13.93	0.738	14.03	1.558	16.30	14.09	0.717	15.99	0.565	0.417
1962	Chinook_1	0.821	0.671	0.551	0.476	118.73	126.33	133.67	129.33	21.65	23.24	12.09	192.0	0.707	11.54	10.78	11.62	10.46	87.43	0.581	9.422	8.040	21.87	12.73	248.8	0.666	11.14	253.0	0.396	0.603	0.743	0.858	0.907	5.353	23.83	12.95	0.697	12.37	2.009	20.06	13.18	0.729	13.28	1.571	16.17	13.34	0.703	15.38	0.631	0.452
1963	Chinook_1	0.798	0.606	0.484	0.427	116.38	124.18	131.59	132.17	23.37	22.11	12.76	163.8	0.728	11.17	12.12	10.08	10.85	69.29	0.631	9.433	8.463	20.26	13.49	208.6	0.674	10.44	217.1	0.413	0.586	0.690	0.834	0.887	5.691	21.97	13.68	0.716	11.47	2.170	18.60	13.94	0.725	12.74	1.697	14.99	14.15	0.710	14.61	0.564	0.406
1964	Chinook_1	0.805	0.610	0.491	0.738	133.25	139.42	144.99	140.87	18.25	27.47	13.32	225.0	0.724	12.81	8.950	14.03	11.72	104.4	0.592	10.82	6.939	25.42	13.97	288.1	0.696	12.13	299.7	0.156	0.843	0.690	0.838	0.890	4.687	27.62	14.14	0.711	13.27	1.727	23.24	14.32	0.757	14.14	1.347	18.83	14.46	0.755	16.21	0.587	0.367
1965	Chinook_1	0.784	0.565	0.443	0.729	141.36	134.31	137.67	153.57	16.32	29.09	13.98	256.7	0.717	14.94	7.204	17.81	12.66	138.7	0.558	14.04	6.805	25.48	14.33	322.4	0.708	13.82	325.2	0.151	0.848	0.664	0.829	0.883	4.718	27.47	14.47	0.706	14.92	1.742	23.07	14.75	0.759	15.26	1.360	18.65	15.06	0.758	17.27	0.509	0.381
1966	Chinook_1	0.801	0.692	0.555	0.231	111.02	122.39	130.51	130.67	24.68	21.39	11.59	167.7	0.733	11.06	13.17	9.158	10.20	61.81	0.678	9.392	8.618	20.16	12.05	218.4	0.645	10.23	231.6	0.671	0.328	0.766	0.873	0.921	5.695	21.97	12.23	0.676	11.34	2.164	18.63	12.45	0.694	12.22	1.691	15.05	12.64	0.711	13.82	0.617	0.475

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1967	Chinook_1	0.80369135	0.70951803	0.57023351	0.46154107	124.58	132.24	139.47	135.9	21.6821905	24.4738646	11.8969792	194.876444	0.76481634	12.0838058	11.5416162	10.1617274	10.7739423	63.8632141	0.71124223	9.92161674	7.60642180	23.3964514	12.3026862	259.544273	0.69186993	11.4309469	276.896118	0.41880428	0.58119571	0.77678124	0.87872456	0.92444007	5.02944956	25.5554301	12.4641365	0.72298036	12.8085807	1.85190082	21.6825243	12.6227919	0.75265505	14.0293690	1.44369448	17.5866105	12.7441506	0.74273182	15.9517264	0.63328165	0.48490965
1968	Chinook_1	0.71426877	0.44733938	0.31952055	0.56269303	137.91	140.33	142.19	147.95	18.4774831	26.7894570	15.0556761	173.393584	0.75577354	11.5310955	8.94755993	13.1661711	14.1003147	68.9848526	0.68093569	9.68447265	7.27006887	23.2655372	15.3298675	221.614214	0.69602552	10.8088269	229.337951	0.21548034	0.78419565	0.57017789	0.78623251	0.84778730	5.07223700	24.9635778	15.378828	0.72187056	11.9845476	1.91416043	20.9969446	15.5548909	0.73790186	12.7744229	1.49316840	17.0118881	15.7698302	0.73681378	14.6266384	0.40874871	0.22117603
1969	Chinook_1	0.83576627	0.64842030	0.54192782	0.41370252	115.4	121.97	129.4	131.35	21.2479487	23.3200138	12.4142832	247.520314	0.72432952	14.1357853	10.4413279	12.6482219	10.2973268	112.647865	0.59386594	12.3560602	7.89574245	21.8754204	13.2259217	311.957183	0.69521438	13.1890714	321.602691	0.45065922	0.54934077	0.71861328	0.84466698	0.89487336	5.37278298	23.6762498	13.4689569	0.70510495	14.5864280	2.00114057	20.1157659	13.7775414	0.75727804	15.1464220	1.56275159	16.2648821	14.0029473	0.75308048	17.3322887	0.61485178	0.45685558
1970	Chinook_1	0.80096602	0.68555902	0.54910549	0.55513436	121.27	127.05	134.8	141.25	22.4676445	23.5235283	12.1023196	177.080823	0.75567511	12.1160060	11.7951430	9.67973530	10.6611711	76.1797409	0.66310676	10.4067777	8.17354749	21.2290562	12.5814286	216.320643	0.71065319	11.2232585	222.383453	0.32127848	0.67872151	0.75753827	0.86813597	0.91530836	5.45019816	23.0900320	12.7757482	0.74724212	12.3214353	2.05697336	19.5910807	13.0148112	0.75498611	13.6615419	1.60741572	15.8233990	13.2115974	0.73670773	15.7552061	0.60405697	0.47390648
1971	Chinook_1	0.82688289	0.60200199	0.49778515	0.72565532	139.16	145.58	147.32	142.82	14.4942852	31.9340437	13.6494831	329.400628	0.78743010	19.0686885	6.41853170	19.8189896	12.4276487	155.173272	0.65330718	16.4045394	5.72251423	30.8338549	14.2704261	424.540486	0.79291460	19.2416722	429.267211	0.16712364	0.83287635	0.68351396	0.83910884	0.89115587	3.95295067	33.3303762	14.3761041	0.77996814	20.9700130	1.39852225	28.6694339	14.4394912	0.81933279	21.1484438	1.08823575	23.3531182	14.4659438	0.82422176	22.2675228	0.58516520	0.40468736
1972	Chinook_1	0.82688314	0.61625035	0.50956703	0.53716472	120.86	126.79	133.56	136.99	18.5213860	26.2341482	13.1873946	277.636192	0.75964944	15.6315299	8.96007060	13.8118374	11.3158653	114.535069	0.65468521	12.5835241	6.97890958	24.9366344	13.9804013	356.495707	0.72694453	15.5175999	359.431213	0.31969219	0.68030780	0.69416171	0.83743192	0.88909628	4.75715282	26.9996448	14.1600933	0.73369606	17.2049835	1.74113515	23.0665458	14.3774887	0.77947409	17.7595062	1.35792535	18.6882995	14.5345225	0.77482146	19.5088863	0.58149372	0.42887142
1973	Chinook_1	0.76337960	0.58280623	0.44490239	0.35695307	116.99	125.23	132.26	143.05	23.8731323	22.1250190	12.9194942	130.976359	0.75858437	10.6609592	12.7430888	8.94746789	11.1922565	49.5024414	0.70721588	9.38476390	8.52097079	19.6504100	13.5699741	165.449735	0.68068396	8.70918828	173.170394	0.46600590	0.53399409	0.67526960	0.82562530	0.87972776	5.83758875	21.1601359	13.7294872	0.71736300	10.7685089	2.25171533	17.9512141	13.9913202	0.71278610	14.4622136	1.76233914	14.4671835	14.2216129	0.73682864	12.9850540	0.50777357	0.37866574
1974	Chinook_1	0.82289494	0.59081629	0.48617974	0.63595010	135.33	141.82	145.65	143	15.7048249	29.8938280	13.8656488	310.310581	0.78629595	17.7178463	7.22439716	17.4459920	12.3197206	136.425640	0.67006532	14.8352867	6.05706078	28.8269080	14.5378160	405.854034	0.77630283	17.9468913	412.649719	0.22941808	0.77058191	0.67156898	0.82946989	0.88240445	4.21147067	31.0732308	14.6845418	0.76383217	19.5183605	1.50762537	26.581547	14.8569634	0.80978339	19.6729768	1.17321328	21.6389789	14.9829711	0.81408986	21.0283126	0.57604516	0.38764262
1975	Chinook_1	0.80776136	0.61844507	0.49946465	0.681727	144.62	146.48	149.43	155.5	16.4480105	29.7827971	13.5905195	259.061949	0.75492079	15.0656306	7.74134502	15.4525864	12.2274269	119.823414	0.63531932	12.7832696	6.51708035	27.4350150	14.0224863	327.941543	0.73204929	14.5576409	339.821929	0.19975760	0.80024239	0.69969276	0.84359055	0.89446609	4.37827091	29.8854034	14.1932855	0.74303747	16.0613252	1.58099191	25.3330060	14.4340060	0.77831105	16.8323542	1.22985457	20.6346512	14.6657671	0.77291700	18.6704311	0.56995117	0.42564699
1976	Chinook_1	0.83701880	0.73379578	0.61420087	0.62354711	118.58	123.94	131.56	129.7	20.5296696	24.2537795	11.3937544	259.789192	0.71471439	14.2388047	10.0632117	13.1874504	10.0181839	120.261109	0.54294847	11.1233377	7.61127522	23.1786404	11.8987787	329.099324	0.71521041	14.3234884	343.987731	0.28369607	0.71630392	0.79075176	0.88197529	0.92651821	5.09192159	25.2364295	12.1123960	0.72311304	15.8070411	1.86731338	21.5092153	12.3167263	0.77182751	16.2592315	1.45602148	17.4387072	12.4541840	0.76925018	17.9383111	0.67244026	0.52395069
1977	Chinook_1	0.72422708	0.50054649	0.36250933	0.23912908	130.59	138.94	144.24	138.93	21.6410044	23.5169505	14.0203372	108.845766	0.78255941	10.3994375	11.0296534	10.2672518	12.8863840	38.1377578	0.76771552	9.64704399	8.12613488	20.5840956	14.5114482	145.436508	0.68620935	9.24568104	151.110839	0.56030577	0.43969423	0.60571968	0.79388777	0.85348041	5.63999296	22.0885377	14.5885345	0.72837124	10.4042337	2.17168711	18.5983362	14.7047821	0.71706238	11.1271705	1.69937284	14.9877737	14.8089070	0.74398438	12.2813501	0.45638231	0.27940090
1978	Chinook_1	0.83045389	0.72951547	0.60582897	0.23740750	109.31	120.64	128.65	129.49	24.6773468	21.6246933	11.1710254	202.564325	0.71148618	11.7300458	13.2066673	10.4778527	9.62252216	89.0394043	0.58549401	9.51181526	8.45695027	20.4836971	11.7042099	260.863629	0.67222513	11.2782886	270.773284	0.67796219	0.32203780	0.79079159	0.88271032	0.92791623	5.63073381	22.2824031	11.9070764	0.69273535	12.5042211	2.13939747	18.8496540	12.1492128	0.72695577	13.2067389	1.67224127	15.2222087	12.3440296	0.71510216	15.2487778	0.65276591	0.50969621
1979	Chinook_1	0.82422044	0.72218695	0.59524125	0.24511764	113.26	123.18	131.09	127.09	24.4784130	21.7848692	11.242661	187.230523	0.74246094	11.6722240	13.1200277	9.93291826	9.63098506	71.3305732	0.67553110	9.69667682	8.40632289	20.8633546	11.8526732	246.066299	0.66946718	11.0658830	257.398407	0.66932084	0.33067915	0.78685001	0.88052673	0.92603691	5.55467528	22.7584861	12.0635112	0.69954919	12.1439493	2.09559891	19.2444399	12.2958828	0.72812081	13.2054316	1.63824445	15.5306034	12.4561333	0.70949141	15.2803249	0.66185786	0.48428483
1980	Chinook_1	0.81877098	0.60785750	0.49769608	0.63982963	136.01	141.97	146.35	143.65	16.8268975	28.8755030	13.4865288	257.249127	0.75941998	14.5724386	7.98133485	16.0734828	11.935602	110.668046	0.65045404	12.0098915	6.44049426	27.3897870	14.2206045	335.205251	0.72993506	14.2007163	340.939971	0.23140401	0.76875698	0.68475436	0.83392951	0.88649794	4.45736524	29.5927483	14.3794448	0.72565860	15.6476032	1.61388134	24.8509344	14.5207525	0.77295557	16.1370611	1.25701016	20.1872910	14.6058688	0.77209055	18.0967207	0.57512534	0.41623925
1981	Chinook_1	0.77102006	0.58199182	0.44872736	0.47893142	120.15	121.73	128.08	146.48	22.3490921	22.9705198	13.4400275	185.735074	0.72521059	11.7861508	11.4818143	10.6211040	12.0591033	76.7184036	0.60986086	9.60213584	8.22232013	20.5639089	13.7375476	234.940443	0.68394090	11.0964981	240.600205	0.34737970	0.65262029	0.67453346	0.83121548	0.88510834	5.58297640	22.2224302	13.8966152	0.71301578	12.2189872	2.15179309	18.7700977	14.1898555	0.72831655	13.3180961	1.68402379	15.1199815	14.4916472	0.71826733	15.3576679	0.52076959	0.35968624
1982	Chinook_1	0.79824598	0.53310176	0.42554634	0.68589507	143.9	145.21	144.49	149.3	16.0614045	29.7823932	14.3912223	268.569624	0.74507172	15.3016275	7.36260365	17.3340327	13.0558553	127.545181	0.60934497	12.9240392	6.39536571	27.3000782	14.9379905	343.199127	0.73071336	15.0166398	341.986480	0.17316596	0.82683403	0.62541989	0.80911205	0.86607308	4.41950619	29.4730484	15.0720167	0.72773399	16.3880029	1.61784002	24.8368738	15.2369022	0.77290169	16.7390222	1.26239532	20.1008842	15.3799386	0.76883542	18.6172556	0.51618925	0.31510446
1983	Chinook_1	0.81192658	0.62595550	0.50822991	0.50056435	117.32	123.38	130.72	144.21	21.1925802	24.1811474	12.8780007	214.535106	0.71715053	12.4519888	10.6789754	11.9252033	10.9822811	95.875598	0.59914863	10.1765884	7.91860958	21.8306030	13.5512210	274.053385	0.67406121	11.9031303	279.199310	0.35179754	0.64820245	0.70377841	0.83990898	0.89154371	5.36368748	23.6546735	13.7616956	0.69467915	13.1756805	2.01697737	19.9863124	14.0633986	0.73257189	13.9738973	1.57696148	16.1221279	14.3122897	0.71991826	16.0986309	0.56477406	0.43121127
1984	Chinook_1	0.80095667	0.59769645	0.47872896	0.75403391	127.96	132.87	138.68	136.41	17.7272329	26.8644497	13.315509	221.716742	0.69392165	12.839479	8.01984444	15.3021896	12.0367116	120.919922	0.52668868	11.2910121	7.17475987	24.6844351	13.8490168	274.763987	0.68024344	12.0543667	282.223419	0.14350430	0.85649569	0.68423399	0.83576273	0.88841870	4.83837390	26.8414989	14.0065572	0.70109993	13.0268520	1.78163922	22.5447395	14.1757936	0.74132179	13.9050569	1.38956467	18.2653477	14.3016672	0.72907859	15.9803929	0.56186656	0.37940892

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1985	Chinook_1	0.83424581	0.72307017 3	0.60321826 2	0.24847115 1	110.3	120.74	129.24	127.41	24.90 51154 8	21.36 12888 9	11.04 41235 1	180.2 53575 5	0.683 44743 1	11.18 19925	12.97 32200 4	10.67 79936 8	9.387 29724 9	98.26 40579 2	0.505 36126 5	9.122 68219	8.924 65919 3	19.64 97476 7	11.62 87929 2	225.2 90301	0.673 57741 8	10.76 96309 9	227.6 82800 3	0.664 81100 3	0.335 18899 7	0.788 37983 8	0.880 92707 2	0.926 02594 1	5.804 29881 8	21.49 82901 8	11.86 64886 5	0.711 76733 4	11.80 29226 3	2.225 06222 1	18.17 14781 4	12.12 12819 4	0.729 78386 3	13.04 22849 7	1.742 31371 3	14.62 65204 9	12.31 22258 2	0.701 06016 1	15.05 55138 6	0.663 22112 2	0.504 53355 4
1986	Chinook_1	0.78987978 9	0.60777882 3	0.48007220 9	0.47479373 9	116.78	121.24	128.18	141.04	22.88 21712 7	22.90 47427 1	12.82 30128 3	195.5 26276 7	0.687 40241 2	11.90 67701 6	11.73 10132	11.74 07257 5	11.10 16038 9	102.3 70101 9	0.514 94933 4	9.690 98587	8.418 23057 1	20.25 42837 8	13.29 29932 3	242.9 16008	0.674 81563	11.48 58733 8	242.2 87109 4	0.364 98055 1	0.635 01944 9	0.703 30149 1	0.840 09245 2	0.891 45100 8	5.675 69474 1	21.93 69891 6	13.46 41016	0.705 43946 6	12.58 06444 2	2.183 44215 3	18.52 69455 7	13.83 68314 1	0.726 56733 8	13.55 16503 7	1.710 81356	14.88 92733 9	14.18 82448 2	0.707 41982 8	15.52 27379 8	0.542 36311 4	0.407 99414 1
1987	Chinook_1	0.74912439 1	0.51509657 1	0.38587140 5	0.27778949 8	117.75	126.09	131.86	127.71	20.28 02446 6	23.94 79617 2	13.79 66833 1	205.6 92926 4	0.771 29554 7	12.28 1722	9.993 92886 5	12.36 14261 9	12.57 43152 6	65.49 02061 5	0.743 52263 2	10.55 40205	7.444 78410 5	23.05 71249 2	14.34 46242	281.3 67665 6	0.680 08774 5	11.35 27228	291.2 00592	0.526 79998 8	0.473 20001 2	0.626 96732 6	0.813 58431 1	0.870 74379 9	5.192 35962 6	24.78 51058 4	14.39 75742 3	0.695 19425 6	12.79 14070 1	1.934 54286 5	20.80 53040 5	14.49 57462 9	0.743 92964 4	13.54 55271 4	1.510 95849 3	16.81 30671 2	14.59 58638 2	0.738 80797 6	15.71 93555 8	0.470 78434 7	0.300 02523 5
1988	Chinook_1	0.80436609 3	0.70631696 2	0.56813741 5	0.11543563 6	108.98	121.45	130.01	134.07	26.83 12115 1	20.30 98412	11.17 73371 7	138.3 02622 4	0.727 80106 5	10.46 89708 1	14.76 32155 9	8.169 10695 7	9.571 92516 3	57.76 56623 8	0.652 56822 7	9.022 07698 8	9.106 70842 2	18.96 12952 1	11.75 22942 2	180.1 93527 2	0.654 39738 8	9.614 75412 1	185.6 25030 5	0.826 63996 2	0.173 36003 8	0.777 13255 9	0.875 23463 3	0.921 85797 8	5.977 74709 8	20.67 78686 5	11.94 96696 5	0.694 93180 5	10.72 44611 7	2.309 86879 8	17.52 39120 7	12.19 41458 4	0.697 31485 8	11.62 02767 7	1.809 46974 5	14.10 06931 7	12.38 94496	0.717 59176 3	12.98 61011 5	0.632 86854 5	0.454 99278
1989	Chinook_1	0.78420949 6	0.53170693	0.41696962 4	0.58907582 2	142.71	149.76	152.31	147.49	18.66 02399 6	27.44 4631	13.81 16179 9	195.7 08763 1	0.723 50115 4	11.58 12510 8	9.307 98944 1	13.28 95710 5	12.15 11304 9	79.32 79083 3	0.630 56559 6	9.651 24340 1	7.058 51465 5	25.09 93616 2	14.52 20470 4	260.7 46871 9	0.662 69837 8	10.88 78692	271.7 61871 3	0.238 15121 7	0.761 84878 3	0.628 09380 5	0.813 68797	0.871 69086 3	4.772 91852 2	27.27 76383 1	14.66 05547	0.684 62286	12.14 40078 7	1.762 13035	22.80 68129 7	14.79 01700 3	0.720 98825 4	12.89 43602 2	1.375 07417 8	18.45 68212 7	14.91 73855 8	0.724 35262 8	14.76 73268 3	0.527 58415 4	0.299 41765 1
1990	Chinook_1	0.71438210 7	0.32386337 4	0.23136219 9	0.46788006	132.61	140.65	143.8	136.95	18.38 93313 4	26.10 16991 7	15.47 33707 6	167.2 49568 7	0.745 37709 8	11.22 35061 8	8.757 67550 6	13.46 73062 6	14.29 70508 6	60.71 01966 9	0.701 75238 3	9.681 93035 1	7.157 60906 8	23.84 7278	16.17 78318 1	224.2 2288	0.654 41997 3	10.30 86177 5	228.5 68811 1	0.223 98525 8	0.776 01474 2	0.443 25704 9	0.713 83040 1	0.787 72631 4	5.002 91498 8	25.60 25052 4	16.20 85641 9	0.683 92496 7	11.56 99466 7	1.880 02281 6	21.39 25074 4	16.19 84529 5	0.708 54366 8	12.52 63055 2	1.467 62549 1	16.18 06902 9	0.718 50304 3	14.17 77677 5	0.373 74438 7	0.121 41626 2
1991	Chinook_1	0.78740387 3	0.60092124 2	0.47316771 3	0.33879789 5	120.68	127.87	134.76	141.09	22.16 43333 3	23.71 48432 2	13.02 42481 9	191.3 85789 9	0.762 81835 4	12.10 12378 8	11.80 54225 9	9.860 39948 7	11.24 76707 5	59.28 29032 9	0.712 41745 9	9.914 71862 8	7.779 85668 2	22.31 37585 8	13.75 71015 4	256.3 92995 2	0.686 22846 4	11.36 101	256.0 85632 3	0.500 72297 8	0.499 27702 2	0.685 61909 1	0.834 67889 9	0.887 31245	5.241 34039 9	24.21 80315 4	13.92 25555 4	0.716 96724 9	12.81 3727	1.971 51249 6	20.45 97985 4	14.13 03278 6	0.745 87367	14.08 30526 4	1.542 56033 9	16.47 49424	14.30 47623 6	0.731 80648 7	16.08 20317 3	0.538 72344 1	0.398 78788
1992	Chinook_1	0.73008163 9	0.49934076	0.36455952	0.32274143 6	119.69	127.1	132.02	132.25	21.68 85803 4	22.79 40892 7	13.82 24826 5	159.8 78758 8	0.740 96722 9	10.94 79695 7	10.86 55250 9	10.80 87310 4	12.72 50316 6	52.30 84953 3	0.720 51075 7	9.564 53609 5	8.046 67018 4	21.13 53165 9	14.24 28255 1	216.1 45502 7	0.628 49818 2	9.914 94814 6	222.2 16781 6	0.459 89695 8	0.540 10304 2	0.617 17353 1	0.808 55469 1	0.867 46507 4	5.528 28787 3	22.78 34466 1	14.29 10997 4	0.659 42571 2	11.15 60512 5	2.106 95718 2	19.16 86020 4	14.41 32992 4	0.681 14815 2	11.96 80875 1	1.649 30008 4	15.42 97184 8	14.55 03654 5	0.705 32733 2	13.41 35131 8	0.446 18863 8	0.282 86285 5
1993	Chinook_1	0.81745395 4	0.72244623 5	0.59056653 1	0.57914905	119.21	126.45	134.48	129.88	21.70 37757 2	23.44 71535 8	11.47 85485 3	202.4 35116 9	0.742 56001 6	12.40 27696 7	10.95 39332	11.26 53832 5	10.40 17036 4	84.24 74899 3	0.638 10889 7	10.05 66146 9	7.953 83732 8	22.42 86807 9	11.89 23034 7	262.2 32172 6	0.700 88350 8	12.07 87354 3	291.5 57464 6	0.315 93305 6	0.684 06694 4	0.788 98402 3	0.883 27603 9	0.927 94328 1	5.216 75818 4	24.54 15443 8	12.04 81367 1	0.735 47217 8	13.24 08681 9	1.914 08913 6	20.97 37602 6	12.18 85188 4	0.763 6922	14.51 96622 2	1.491 61233 8	17.02 80135 1	12.27 34627 7	0.753 21915 7	16.23 99158 5	0.648 53445 1	0.490 00022 6
1994	Chinook_1	0.71454693 4	0.42313994 7	0.30235335 2	0.52214056 8	128.38	136.48	140.5	134.86	19.12 12520 7	25.46 51484 9	14.45 64826 1	166.3 36825 5	0.735 58486 4	11.11 18548 6	9.225 49371 4	12.92 51417 2	13.36 71842 6	63.09 46342 5	0.680 75171 7	9.546 29554 7	7.369 44326 8	23.33 65772 1	15.01 18543 3	220.0 82743 3	0.649 07170 3	10.25 32072 9	223.3 90869 1	0.235 13603 7	0.764 86396 3	0.555 23613 8	0.787 09138 5	0.850 36081 8	5.118 12934 3	25.11 90262 1	15.01 51521 7	0.679 90815	11.47 28712 1	1.919 79455 9	20.98 05436 1	15.03 91330 7	0.700 86901 4	12.19 97826 9	1.500 47075 7	16.92 96661 4	15.13 16351 9	0.707 22968 9	13.76 51209 8	0.401 38591 2	0.199 63356 7
1995	Chinook_1	0.79861965 7	0.63293880 5	0.50547737 2	0.57349777 9	118.86	123.06	130.37	140.37	22.92 14556 2	23.14 18674 5	12.65 30114 6	189.5 42196	0.711 42309 5	11.70 21642 8	12.00 87893 4	10.46 93695 8	10.88 02463 5	85.37 97088 6	0.571 13452	9.583 19397	8.314 40147	20.65 03215 6	13.24 68557 4	233.3 04000 9	0.684 04273 2	11.04 73851 4	241.5 99105 8	0.286 71850 9	0.713 28149 1	0.711 82192 7	0.844 55787 6	0.895 43503 8	5.572 30623 8	22.41 18539 8	13.45 14436 7	0.718 07974 6	12.12 31109 6	2.122 50991 9	19.00 46995 1	13.75 64497	0.734 56784 1	13.31 85863 5	1.659 50345 2	15.33 77947 5	14.02 20265 4	0.719 70474 7	15.42 91997	0.568 05638 2	0.446 79998 4
1996	Chinook_1	0.77708642 3	0.55906028 2	0.43443815 5	0.65042346 5	137.44	134.64	138.35	151.28	16.52 41078 2	28.91 45045 9	14.27 82593 5	259.5 30577	0.742 70648 4	14.84 22006 2	7.516 77635 3	16.70 87456 6	13.22 27029 8	123.2 21907	0.617 11005 6	13.07 45826 7	6.704 76541 7	25.78 69274	14.54 55524 1	331.7 59251 9	0.718 72348 6	13.98 58768 8	339.1 87774 7	0.202 24483 9	0.797 75516 1	0.651 60652 3	0.822 66856	0.877 81928 1	4.677 04401 2	27.74 13383 6	14.67 83700 9	0.714 24386 5	15.28 27217 1	1.721 21752 1	23.31 90892 7	14.89 41806 2	0.766 67137 9	15.63 46174 9	1.341 65594 7	18.91 41784 1	17.76 83739 7	0.510 60545 5	0.342 84626 5
1997	Chinook_1	0.82174667 5	0.58506936 2	0.48077880 3	0.64146646 4	132.9	135.33	137.96	140.63	14.79 56344 5	30.57 89082 2	13.93 53516 4	354.3 25095	0.795 30412 8	20.30 93453 8	6.355 45142 7	19.90 78696 4	12.40 56251 5	164.7 26245 1	0.665 11299 6	17.51 334	5.972 78962 3	28.84 99529 6	14.51 60600 3	457.6 42776 5	0.801 44905 1	20.79 04860 2	464.7 69500 7	0.223 70113 5	0.776 29886 5	0.671 79692 2	0.832 72114 7	0.884 95544 4	4.170 53411 2	31.01 62702 9	14.65 87875 4	0.785 47667 3	22.59 36916 4	1.487 75271 3	26.93 99510 5	14.87 33441	0.828 94643 1	22.31 49337 8	1.157 79639	21.93 03595 1	15.07 90939 3	0.835 30381 3	23.05 20029 1	0.557 40693 1	0.397 58606 6
1998	Chinook_1	0.82135752 6	0.65215386 6	0.53565148 6	0.48443392 5	114.21	121.71	128.81	129.64	22.45 07942 9	22.80 22802 2	12.48 05613 2	251.3 44557 6	0.730 48051 3	13.77 08486 8	11.67 55679	11.06 48878 3	10.38 28937 5	94.76 07025 1	0.607 30028 2	10.33 67397 3	7.849 11689 9	22.10 08414 6	13.26 34450 6	325.1 72119 1	0.698 37154 9	13.43 00216	344.6 01348 9	0.381 30777 4	0.618 69222 6	0.721 42151 1	0.844 50152 2	0.894 39428 4	5.311 48205	23.96 16423 2	13.49 35226 4	0.712 27737 7	14.95 39663 3	1.966 34069 8	20.44 99349 2	13.82 06876 1	0.765 48701 5	16.14 12420 3	1.534 33192 5	16.56 07214 2	14.06 58345 2	0.778 69689 5	17.98 99821 3	0.605 63284 9	0.458 96365 9
1999	Chinook_1	0.81789828 9	0.63442687 6	0.51889665 7	0.45587594 5	118.8	124.05	131.13	128.86	21.45 85030 9	23.09 44007 1	12.66 54931 5	204.7 17613 2	0.722 58041 6	12.20 01303 9	10.60 04417 5	12.30 17115 3	10.83 4375	95.61 78558 3	0.600 25588 3	10.24 83997 3	7.961 46854	21.52 86299	13.36 71703 3	265.6 91182 5	0.685 80899 6	11.70 81433 9	272.0 98724 4	0.398 49345	0.601 50655	0.710 17980 4	0.843 10832 4	0.894 02911 9	5.443 80053 1	23.25 46909	13.55 86259 8	0.705 57744 5	12.95 75098	2.053 53277 2	19.63 44509 2	13.81 54656 1	0.742 58707	13.67 39374 8	1.605 59143 9	15.83 95143 6	14.01 66163 4	0.722 83124 9	15.78 09562 7	0.594 68904 2	0.418 42024 4
2000	Chinook_1	0.75850887 6	0.44500732 7	0.33754200 7	0.56377609 3	131.75	137.17	140.15	137.55	18.00 03846 5	26.42 20532 5	14.37 76645 7	192.2 98043 9	0.736 65112 9	12.04 54774 9	8.305 89997 8	14.76 05811 8	13.03 13221	87.48 85421 8	0.651 43738 4	10.68 77687 5	7.169 06549 8	24.03 69239	14.98 0714	247.9 0227	0.675 98840 6	11.23 92847 5	256.8 74359 1	0.220 90611 1	0.779 09388 9	0.565 59314 4	0.792 08243 9	0.854 30059 9	4.970 72317 5	25.88 99280 4	15.03 47106 9	0.701 27979 5	12.43 71660 2	1.854 95951	21.65 85284 4	15.11 10076 9	0.729 05858 4	13.24 72779	1.446 78338 6	17.54 95107 7	15.24 19242 9	0.706 40343 4	15.32 50627 5	0.433 32146 7	0.244 73740 7
2001	Chinook_1	0.79419884 9	0.59752052 4	0.47455011 3	0.17291792 4	110.47	122.51	130.55	127.75	25.78 75503 2	20.38 78191 7	12.43 61704 4	118.5 49229 5	0.765 39093 3	10.59 39973 4	13.91 06653	8.700 14005	10.18 07621	48.73 82392 9	0.726 40575 2	9.597 92060 9	8.911 88975 4	18.72 58227 6	13.39 94245 5	151.1 16478	0.680 57425 8	9.625 42438 5	162.3 60534 7	0.716 40221 7	0.283 59778 3	0.679 09955 2	0.823 40266 6	0.877 54573 3	6.085 24771 8	20.17 32998 4	13.60 29977 8	0.720 19416 1	10.54 54561 2	2.360 80776 9	17.14 14931 8	13.86 10709 5	0.710 21560 8	11.38 79722	1.848 32441 1	13.81 43900 1	14.04 43201 1	0.734 62891 6	12.67 31772 4	0.557 49862 8	0.369 41917
2002	Chinook_1	0.80789298 8	0.64516716 9	0.52122603 2	0.40668239 9	119.17	128.09	135.21	131.33	22.03 56264 9	23.40 20524 6	12.41 92278 7	182.4 57274 8	0.739 53332 2	11.49 06310 4	11.42 50122 7	10.64 66035 1	10.70 17780 3	70.42 98172	0.654 61858 5	9.326 41105 7	7.912 99716 4	22.01 42819 3	13.10 57100 3	240.1 87347 4	0.680 06262 2	10.98 02327 2	247.2 96249 4	0.451 76526 3	0.548 23473 7	0.720 67223 2	0.848 51231 4	0.898 57700 3	5.305 77389 2	23.92 6082	13.30 99887 8	0.712 04930 5	12.33 93596 6	1.996 56764 4	20.15 47630 7	13.53 83145	0.735 31846 2	13.41 00167	1.558 68712 8	16.30 72272 4	13.70 19448 3	0.712 87673 7	15.45 63980 1	0.591 39494 2	0.429 71049 4

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
2003	Chinook_1	0.790847649	0.614904979	0.486296157	0.54270131	129.32	134.23	141.5	140.01	20.23376305	25.31668526	13.11441115	198.5286947	0.727089488	11.9541832	10.23521435	11.9409677	11.62418652	78.95196075	0.626034093	9.585574913	7.530480042	23.20569315	13.71995815	257.0451533	0.674847389	11.32580686	281.2910156	0.306621338	0.693378662	0.701068187	0.843759833	0.89554778	5.066452876	25.21100857	13.8670578	0.705835253	12.59658241	1.875890955	21.37085178	14.0504144	0.734374454	13.64041106	1.460107341	17.39131783	14.21124935	0.734387591	15.45995569	0.555858597	0.413221929
2004	Chinook_1	0.804401947	0.645811658	0.519492155	0.167580167	107.09	120.43	128.44	130.55	26.59654866	20.49722526	12.05930758	168.7542795	0.72876077	11.05235962	14.76732877	8.465584262	9.708488083	57.49445343	0.674142355	9.419010735	8.810582653	19.55925203	12.95202605	221.0545451	0.638657843	10.08323757	244.9500427	0.739408899	0.260591101	0.722816769	0.844507208	0.895532781	5.838523403	21.28583644	13.18958874	0.675423664	11.20209045	2.227183387	18.0907877	13.54391575	0.68896996	12.38092454	1.738573298	14.6570082	13.80780458	0.698455885	14.06129837	0.603912268	0.418048238
2005	Chinook_1	0.769339259	0.567043688	0.436248971	0.494993971	120.04	126.14	133.11	135.22	21.64931384	23.34518586	13.56467635	169.9946572	0.726067803	11.21710001	10.91451962	10.97041118	12.06336613	66.20447998	0.658192724	9.724025917	8.089646183	21.14481146	14.07815075	218.7299703	0.645664637	10.21170346	230.5228882	0.326923055	0.673076945	0.660811843	0.820087269	0.875818512	5.508028828	22.85800975	14.23830299	0.67749427	11.32691689	2.082648002	19.33929862	14.47321256	0.695995162	12.26064968	1.626516096	15.64121389	14.66682911	0.712343618	13.86310673	0.517029278	0.346141493
2006	Chinook_1	0.833899808	0.712389159	0.594061183	0.635118351	119.78	124.56	131.99	128.51	20.13303026	24.21876026	11.60203048	241.2827143	0.697974976	13.34416141	9.563519455	14.23358644	10.26811981	127.7042099	0.516117871	11.4910944	7.651865289	22.70281397	12.1500624	302.9241892	0.69851018	12.86823662	313.8285522	0.267395126	0.732604874	0.775518672	0.876289941	0.922390257	5.196981952	24.59773576	12.34009228	0.701424706	14.01017303	1.932757869	20.8014497	12.50349299	0.753561685	14.34164969	1.508076623	16.84446496	12.59716368	0.747012243	16.32868195	0.662030336	0.512946086
2007	Chinook_1	0.776955696	0.582107142	0.452271459	0.478743209	119.05	125.4	131.77	131.66	21.72158737	23.15013885	13.37355178	195.7767408	0.747344935	11.7738596	11.14434952	11.06364926	11.9109314	68.46040268	0.676163459	9.600769424	7.771778293	21.98438365	13.94209671	259.4086914	0.680335765	11.14883065	269.9198914	0.349615546	0.650384454	0.669711572	0.826719452	0.881154875	5.33534617	23.71558382	14.0899765	0.700830477	12.49520969	2.01245857	19.99937716	14.27192656	0.733343691	13.31781928	1.571261533	16.17882336	14.41311646	0.722564444	15.40923452	0.534270237	0.364334352
2008	Chinook_1	0.805100921	0.719227689	0.579050874	0.228308727	103.05	117.09	125.93	131.75	27.07167547	19.64416222	11.15890864	149.2167617	0.731389471	11.12887887	14.65654982	8.439727388	9.693622971	60.92283249	0.596496433	8.967477989	9.280795321	18.37205987	11.54784457	185.6971766	0.709495073	10.69378916	195.6660156	0.681703616	0.318296384	0.784280634	0.87724893	0.922158552	6.110672221	19.99773752	11.75217323	0.756054199	11.71699448	2.375880137	17.03922475	12.07395713	0.744355222	13.03739643	1.860600784	13.72554715	12.35724401	0.727593154	14.97187328	0.641868407	0.499592242
SCN MO4-RESSIM																																																		
1929	Chinook_1	0.805477118	0.63819796	0.514053853	0.059651404	126.47	135.8	142.17	132.76	19.37822355	25.99874533	12.88271087	161.2657215	0.965089257	15.80181214	9.898089454	12.28528912	11.60869141	61.44042511	0.963879192	13.1862627	7.094070755	23.62903756	13.44424725	211.7849808	0.948642741	16.45539546	225.2425232	0.89807628	0.10192372	0.702265084	0.838512285	0.887544336	5.136944376	25.03633684	13.58477039	0.950081956	18.75816212	1.905943207	21.07480745	13.69437949	0.937066317	19.92588425	1.486001723	17.09245016	13.75922298	0.933472693	21.16991615	0.591747383	0.403619606
1930	Chinook_1	0.807398054	0.621278818	0.501619308	0.017271738	103.88	118.41	125.38	136.28	24.40487488	20.19198087	12.07502822	141.5476071	0.9573434	15.02719453	12.8343777	9.862959281	10.18334446	63.09501877	0.960365641	13.57071075	8.313425027	19.23019556	12.78446356	179.5710526	0.933496654	15.07663973	190.5870972	0.968968462	0.031031538	0.69011256	0.82935734	0.87880812	6.071142875	20.17974816	12.9479948	0.938787377	17.01456852	2.368009858	17.10551438	13.1985321	0.923866947	18.01585102	1.855485611	13.76137102	13.41233158	0.920332998	19.49207497	0.569821266	0.404683466
1931	Chinook_1	0.792175166	0.617624551	0.489266831	0.015978474	105.78	120.78	127.59	141.59	25.90776424	19.98801146	12.14021015	140.1397136	0.948998132	14.46857933	14.48827878	8.34406947	9.989022636	44.30315781	0.94177922	11.4868578	8.239484973	19.54626545	13.02312756	185.5048548	0.929513196	15.26013239	200.7868042	0.97083738	0.02916262	0.685356457	0.82563538	0.875682211	5.987371154	20.57167673	13.20464268	0.938876593	17.4919363	2.315019585	17.46924346	13.45910327	0.924598694	18.46710809	1.812098779	14.07978934	13.65958977	0.921708584	19.83452511	0.563203128	0.383507233
1932	Chinook_1	0.843655355	0.700210997	0.590736758	0.03617485	118.88	128.05	134.56	133.08	19.7385337	24.68751263	12.09240954	234.6967648	0.965048343	18.89493605	9.839314222	13.14126434	10.45269279	91.44445343	0.976993978	16.45102119	7.102549933	23.76946478	12.69539913	304.9463399	0.937617898	19.6002322	323.861908	0.944249017	0.055750983	0.751629907	0.857818826	0.903149216	5.095472477	25.28743877	12.90228844	0.929691708	22.22054672	1.87470793	21.41162609	13.15266927	0.905741215	22.92687607	1.460949682	17.38069363	13.33485222	0.885875195	23.40587711	0.65685015	0.485546468
1933	Chinook_1	0.797084876	0.610559396	0.486667661	0.073902252	132.77	141.86	148.08	138.25	18.60762662	27.39713167	13.49622652	192.2338442	0.963285914	16.64342305	9.658027858	12.66866799	12.00282249	61.57546387	0.965715289	13.28716965	6.639871508	25.69553416	14.12680022	253.3499527	0.942904582	17.65073514	275.0798035	0.869034521	0.130965479	0.679115876	0.828083961	0.878975766	4.768790275	27.36352499	14.27111359	0.940146041	20.25267563	1.733003885	23.09720671	14.43019644	0.921736618	21.33746656	1.347370952	18.83427145	14.54589176	0.909997046	22.24786186	0.579601913	0.374917918
1934	Chinook_1	0.795382373	0.584880065	0.465203294	0.027137821	115.74	124.01	129.13	137.3	20.50487022	23.06743378	13.04498986	223.9313927	0.970016901	18.59079344	10.15710404	12.28218049	11.55792809	75.15562286	0.981469417	15.40462532	7.302491449	22.5689634	13.66038736	305.4480794	0.945481916	19.84912769	311.5804138	0.94822742	0.05177258	0.661325973	0.822507399	0.874803154	5.334012769	23.78338583	13.78141117	0.937531066	22.79845886	2.017036788	19.98007968	13.91167831	0.914374371	23.02284114	1.576681189	16.12346918	14.02795553	0.893890053	23.40657997	0.541886647	0.393083677
1935	Chinook_1	0.80031153	0.59666051	0.477514285	0.052178584	127.24	135.95	142.64	133.04	18.38287298	26.79518196	13.46272979	180.8990716	0.969890905	16.74760039	9.189346202	13.1223997	12.10771332	65.97494431	0.973227143	14.06311779	6.816539682	24.68688591	14.09580978	238.5254898	0.952056428	17.44327076	251.9691925	0.904350301	0.095649699	0.666709717	0.824849531	0.876407373	4.956211604	26.13308319	14.21438751	0.949983478	20.03939896	1.825431474	21.97773172	14.30439727	0.934535305	21.08381526	1.422008432	17.85231461	14.37944889	0.926466912	22.07848358	0.576110913	0.367411025
1936	Chinook_1	0.857204918	0.695616056	0.596285505	0.046498757	116.86	124.83	131.36	136.98	18.4102748	24.92642526	11.6503627	242.0338952	0.958448116	19.84033523	8.268083222	15.11801992	10.313307	125.012204	0.950250387	18.47284012	7.301267847	23.03053573	12.16157643	300.2895355	0.944503417	20.16772	313.0396729	0.928470477	0.071529523	0.754724734	0.86500946	0.909985997	5.22308515	24.51144122	12.32940102	0.937120163	22.48118324	1.94253923	20.69053174	12.4927117	0.914265056	22.96342468	1.515230641	16.76636761	12.61930513	0.8947936	23.41302109	0.647769007	0.513716362
1937	Chinook_1	0.811236074	0.621156129	0.503904259	0.043259604	125.05	133.73	139.65	131.53	20.60479926	24.23851253	12.84482425	163.3163817	0.964512301	15.87361101	10.71301553	11.25570908	11.1163578	61.06142731	0.962798393	13.04017944	7.271507941	22.76703052	13.59959284	216.1960347	0.948196729	16.66979019	226.5746613	0.923706332	0.076293668	0.683498184	0.824331101	0.87466042	5.286509596	24.04852457	13.77743092	0.949658525	19.10306358	1.987193666	20.25688931	13.9606123	0.936429441	20.11840439	1.551909409	16.37736124	14.08924723	0.932758063	21.32979107	0.600196689	0.392537057
1938	Chinook_1	0.835335699	0.584282155	0.488071742	0.078058088	130.18	137.76	141.91	149.16	16.69897939	27.88537178	13.4851502	231.0780754	0.962114641	19.20903059	7.630432986	16.15368416	11.92387257	108.3128555	0.964267516	17.62974434	6.606386468	25.63664176	14.16033077	294.370285	0.941378047	19.53532068	304.4046326	0.860133616	0.139866384	0.657128671	0.819132073	0.871497457	4.763783857	27.23920576	14.30933571	0.934643495	22.0140686	1.754199043	22.87775125	14.45898787	0.91541034	22.49421247	1.367148712	18.56299093	14.58558989	0.900970429	23.12535095	0.562988447	0.39360098
1939	Chinook_1	0.835835297	0.693983013	0.580055498	0.029140767	117.28	125.73	132.41	128.34	19.6348067	24.06686552	11.64837265	186.8131834	0.973600724	17.84618483	9.338073753	13.19544226	10.6710598	89.06170959	0.976952541	16.30354652	7.524542496	22.07286514	11.99374294	239.2167689	0.957608004	18.10652979	246.3783264	0.953737813	0.046262187	0.750856119	0.86115495	0.906280471	5.422070667	23.39834089	12.12376938	0.955594659	20.45562897	2.046245649	19.69519679	12.24618944	0.942885617	21.41384443	1.599267319	15.90130614	12.33484554	0.938328207	22.27021694	0.62823859	0.49032616
1940	Chinook_1	0.826714449	0.712961921	0.589415922	0.006887419	95.15	110.77	118.91	134.45	26.8712903	18.40077801	10.80687339	167.4478683	0.968951711	16.78424209	14.34605028	9.596336949	9.32011528	81.46828918	0.974139822	15.83757706	8.671760641	18.30490717	11.27884197	210.3842163	0.949103723	16.56813304	220.9721527	0.989257586	0.010742414	0.765490333	0.863254977	0.90705296	6.30778154	19.21851238	11.45046864	0.949392915	18.64844837	2.48684343	16.32766513	11.69540056	0.93588088	19.8079586	1.951212727	13.10781494	11.89217424	0.931845397	21.14442158	0.641068487	0.48791775

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1941	Chinook_1	0.756 40713 6	0.471 62865 7	0.356 74328 2	0.041 77414 2	133.51	139.98	140.75	143.7	18.64 50986 6	25.93 79120 2	14.54 41066 9	160.2 34868 2	0.965 22546 2	15.88 32607 3	9.184 69817 9	13.17 43820 9	13.38 34730 1	60.14 24179 1	0.964 71180 9	13.35 50561 9	7.000 37857 1	23.55 42104 3	15.07 43823 1	212.9 18416 3	0.948 26616 8	16.56 37939 8	220.0 67611 7	0.901 58090 6	0.098 41909 4	0.568 20285 9	0.774 15082 2	0.833 85001 3	5.153 09592 3	24.74 92180 5	15.13 22391 5	0.948 93709 4	19.02 59456 6	1.942 14337 3	20.73 15518 8	15.21 84149 4	0.935 33132 5	20.00 48669 2	1.517 30819 8	16.74 48204 1	15.29 75540 2	0.931 29783 9	21.17 63601 3	0.447 81672 4	0.265 38899 4
1942	Chinook_1	0.829 81731	0.645 37394 7	0.535 54247 2	0.056 27623 9	136.4	144.2	149.19	147.65	17.67 34063	27.70 97681	12.96 86051 8	203.6 37081 1	0.969 62713 8	18.19 41258 2	8.687 30653 8	14.40 17341 1	11.63 54835 5	90.19 74990 8	0.973 69550 5	16.24 66926 6	6.614 91356 8	25.69 59191 6	13.56 55571 6	263.3 82415 8	0.951 05055	18.68 52969 3	271.2 67944 3	0.905 97521 4	0.094 02478 6	0.708 87548 3	0.843 01529 1	0.891 44755	4.736 29938 1	27.37 79056 4	13.70 78371	0.947 20403	21.15 46787 3	1.751 92405 3	22.92 66915 5	13.82 09285 7	0.929 75376	21.91 36714 9	1.366 43089 4	18.57 27657 3	13.90 10663	0.918 04963 4	22.63 18874 4	0.605 17601 7	0.457 04324 2
1943	Chinook_1	0.846 10392 7	0.655 43677 3	0.554 56762 8	0.045 09489 5	124.09	130.71	135.53	130.09	19.47 32461 2	23.93 50331 9	12.28 53774 3	218.5 93959 3	0.958 46355 4	18.78 48400 4	9.166 84938 2	13.81 80519 8	10.68 54457 9	111.4 20996 1	0.953 77730 1	17.73 07819 4	7.391 59573 6	22.38 04550 6	12.92 77760 2	273.6 24008 2	0.941 60074	18.82 87893 9	284.4 77356	0.925 49014 9	0.074 50985 1	0.712 42043 4	0.839 63585 7	0.887 90118 4	5.352 87250 6	23.67 08561 8	13.11 82094 6	0.935 79915 8	21.16 81091 3	2.016 26850 7	19.97 36178 5	13.31 83641 4	0.915 69336 3	21.67 54194 9	1.575 07856 2	16.13 99622 1	13.46 95363	0.901 15824 3	22.51 45435 3	0.639 70816 5	0.457 33431
1944	Chinook_1	0.804 72794 5	0.594 50871 7	0.478 41777 8	0.047 44646 8	131.41	139.65	145.97	136.41	18.33 31037 6	26.95 31927 1	13.50 70714 3	158.5 65122 9	0.966 52144 6	15.95 912	9.109 97862 4	13.01 09997 8	12.10 11783 6	67.90 70632 9	0.970 38492	14.09 91155 6	6.933 35477 3	24.13 25916 8	14.10 26326 8	207.7 83200 6	0.946 56215 1	16.34 57282 4	211.8 65478 5	0.912 58492 1	0.087 41507 9	0.662 35093 5	0.817 24397 4	0.869 08781 1	5.038 42309 9	25.53 16830 1	14.25 23025 5	0.946 76551 8	18.68 52882 4	1.884 57108 3	21.35 16083 2	14.39 54696 7	0.932 60322	19.60 08307 1	1.471 80420 9	17.25 52726	14.51 01733 2	0.928 44650 1	20.80 71527 5	0.569 86597 3	0.360 20645 3
1945	Chinook_1	0.832 21293 9	0.640 35925 3	0.532 91525 6	0.036 23953 9	119.89	128.84	135.28	130.62	19.71 64967 1	24.85 29080 8	12.65 41756 2	182.1 70106 1	0.966 98937 7	17.27 36626 4	9.784 62415 2	13.02 83014 1	10.95 54918 3	82.78 56170 7	0.964 48253 4	15.04 56359 9	7.306 60522 7	22.76 34851 7	13.32 60259 6	231.9 69866 4	0.952 57389 5	17.82 82396	244.9 61212 2	0.938 16737 9	0.061 83262 1	0.702 19466 9	0.832 70777 4	0.881 43788 1	5.296 39352 1	24.08 53085 7	13.51 14164 4	0.953 37115 5	19.92 49054	1.980 68548	20.30 64119	13.73 64365 3	0.940 57611 6	21.01 32897 7	1.545 70216 7	16.44 19536 8	13.90 05503 7	0.936 18446 6	22.07 05938 3	0.602 29989 1	0.434 25064 4
1946	Chinook_1	0.864 02540 3	0.731 33397 5	0.631 89113 2	0.016 02106 9	111.83	120.68	128.01	128.15	20.23 89333	23.32 24121	11.28 72777 7	256.1 75788 9	0.960 46398 8	20.07 16349 4	9.588 27864 4	13.79 93362 4	9.639 43996 4	118.2 56246 9	0.969 36985 3	18.55 75786 6	7.552 73006 1	22.24 37014 8	11.85 06156 6	326.2 07204 2	0.933 27499 4	20.45 71824 9	339.8 32000 7	0.976 24816 8	0.023 75183 2	0.778 54128 1	0.870 44469	0.913 93662 7	5.376 48103 4	23.70 80682 5	12.06 70166	0.922 85209 9	22.96 36867 5	2.004 74942 5	20.06 56775 4	12.33 24705 8	0.896 36498 7	23.19 40326 7	1.564 59877 6	16.24 54184 5	12.51 66678 4	0.872 42677 8	23.60 70194 2	0.536 58304 5
1947	Chinook_1	0.843 92753 9	0.628 06902 6	0.530 04474 7	0.054 21326 1	111	121.95	128.61	130.09	20.68 41744	23.33 19469 2	12.46 76006 2	240.8 16546 8	0.960 86795	19.04 13581 3	10.26 83518 5	12.89 91978	10.22 75047 3	97.99 30938 7	0.969 10789	16.71 74873 4	7.398 84489	22.46 52037 3	13.40 33983 5	308.1 72037 8	0.934 43565 6	19.65 23491 5	328.1 52435 3	0.908 57000 5	0.091 42999 5	0.693 36377 3	0.831 65310 2	0.881 47600 1	5.346 30578	23.79 39978 3	13.60 50783 2	0.926 30945 4	22.14 66617 6	1.991 13654 3	20.18 63489 8	13.86 92827 2	0.902 08208 6	22.92 55498 3	1.552 90331 7	16.36 58135 3	14.06 37421 6	0.881 86177 6	23.42 89808 3	0.612 79116	0.418 26444
1948	Chinook_1	0.839 12973 1	0.605 56971 6	0.508 15155 3	0.199 77103 5	132.62	137.34	141.69	146.88	15.02 90601	30.75 94640 5	13.68 15422 6	336.5 60759 4	0.934 46072 9	22.02 42169 2	6.789 69682 8	17.99 78446 3	12.22 38977 4	137.9 52279 7	0.925 77563 5	19.05 54435 7	5.930 90584 1	29.08 59060 6	14.24 94429	422.6 96502 7	0.908 92882 1	22.83 43044 9	440.7 89764 4	0.686 27814 3	0.313 72185 7	0.685 64649 8	0.838 03876 1	0.888 18628 9	4.200 01139 5	31.15 08422 9	14.38 43141 6	0.896 98215 7	25.59 81159 2	1.489 84240 7	26.87 18729 9	14.56 21697 1	0.889 78417 7	25.83 63933 6	1.158 19986 9	21.92 22006	14.72 83582 7	0.875 27287	25.82 19318 4	0.585 56985 8	0.424 49711 5
1949	Chinook_1	0.831 31804 1	0.573 91125 9	0.477 10278 4	0.137 18584 5	126.78	132.77	138.22	136.23	15.56 16132 9	29.39 97743 5	13.75 19729 5	284.4 87266 5	0.941 23112 3	20.30 13832 9	6.840 77609 3	18.22 01735 6	12.42 75764 5	126.0 68325 8	0.946 82028 3	18.64 30992 1	6.256 24503 9	27.46 56665 6	14.43 86245 4	360.6 41250 6	0.907 18931	20.63 56989 5	385.0 66497 8	0.763 98670 1	0.236 01329 9	0.659 50769 4	0.828 71137 1	0.881 72904 3	4.502 11753 7	29.25 62526	14.52 35948 6	0.895 69693 8	23.00 25966 6	1.600 38744 7	24.98 94906 7	14.57 49842 3	0.870 63429 8	23.26 87409 7	1.243 23611 7	20.41 17810 1	14.61 95430 8	0.846 41960 3	23.62 85247 8	0.557 84952 1	0.365 27577 6
1950	Chinook_1	0.835 47232 9	0.654 57097 6	0.546 87593 8	0.048 87198 2	132.97	139.84	145.57	139.53	16.97 67546 3	28.42 55948 9	13.03 98756 4	224.5 84725 5	0.967 50826 9	18.81 08901 6	8.141 86327 9	15.13 77614 1	11.70 21560 7	95.62 95288 1	0.977 60125 4	16.92 38239 3	6.484 10150 4	26.51 87018	13.57 72848 1	289.0 98765 1	0.942 85162 3	19.23 94656 3	305.9 96185 3	0.918 90015 6	0.081 09984 4	0.716 21345 8	0.845 36836 8	0.893 52989 5	4.630 26127 2	28.31 90442 5	13.73 91206 7	0.936 32506 1	21.82 51152	1.682 30032 9	23.80 82969 4	13.90 07663 7	0.913 04991 6	22.49 05815 1	1.308 78341 2	19.38 80174 7	14.00 49905 8	0.893 79888 8	23.09 31272 5	0.631 48952 8	0.438 78844 8
1951	Chinook_1	0.841 98473 1	0.626 84154	0.527 79100 5	0.064 50147 4	131.53	138.09	143.43	139.31	16.43 38612 2	28.69 72568 5	13.37 18630 2	265.3 11873 8	0.956 35483 9	19.95 97146 2	7.726 44189	16.11 91947	11.83 02883 1	108.7 38432 3	0.973 64305 3	18.04 98661	6.255 13260 8	27.45 23220 4	14.04 47912 2	348.2 74826	0.920 12585 2	20.49 04120 8	360.0 87677	0.890 19200 9	0.109 80799 1	0.692 51923 1	0.836 97096 2	0.887 14944 1	4.473 87962 8	29.29 66227 2	14.20 29493 3	0.908 76095 3	23.17 93178 6	1.620 78448 4	24.73 54730 8	14.34 60830 1	0.884 72159 7	23.29 60154 2	1.262 03804 5	20.10 66646 1	14.45 37935 3	0.861 42769 5	23.63 12046 1	0.602 08160 3	0.436 77762
1952	Chinook_1	0.871 02585 8	0.704 39966 2	0.613 55032	0.212 83260 3	125.69	131.18	136.52	134.21	16.37 63535 7	27.70 91380 3	12.12 16844 8	292.5 71091 8	0.927 3085	20.98 02842 8	7.011 59633 7	18.30 98256 1	10.84 95288 8	158.7 77407 8	0.900 16940 8	19.80 24601	6.665 85075 1	25.68 77400 1	12.63 76047 1	362.1 11902 9	0.913 57776 5	21.32 99964 3	375.4 16534 4	0.705 02490 3	0.294 97509 7	0.759 01534	0.867 40396 2	0.912 79858 6	4.730 58389 9	27.46 92960 5	12.80 94118 1	0.900 58004 9	23.43 60988 6	1.723 24039 8	23.27 91664 2	12.95 12939 5	0.874 66869 8	23.45 79035 4	1.342 57053 6	18.90 10644 7	13.04 16278 8	0.849 08735 8	23.73 83184 4	0.673 55199 7	0.520 23302 7
1953	Chinook_1	0.832 77788 8	0.660 53639 9	0.550 08010 7	0.048 68286	132.76	140.44	146.79	148.28	18.33 60317 6	26.80 52299 8	12.79 74172 3	218.9 7335	0.961 88341 7	18.30 80903 1	9.183 06031 1	13.45 39846	11.30 16309 7	88.50 18081 7	0.969 44594 4	16.14 82452 4	6.691 07473 6	25.35 61644 6	13.44 61552 3	282.2 68000 3	0.936 52311	18.78 35120 4	297.5 58654 8	0.920 23860 2	0.079 76139 8	0.721 60936	0.848 01069 7	0.895 51088 1	4.775 52676 9	27.03 68583 8	13.59 24924 9	0.932 53822 3	21.31 84478 8	1.753 71778 8	22.87 76788 2	13.74 99313 4	0.913 39574 3	22.01 70847 6	1.366 42510 4	18.57 27402 9	13.87 19558 7	0.899 82819 6	22.72 58291 2	0.605 28119 2	0.478 37651
1954	Chinook_1	0.834 61877 1	0.659 02969 6	0.550 03855 5	0.080 97287 1	140.43	146.26	149.89	143.79	17.10 21579 2	28.57 39711	12.94 44094 4	238.6 61634 2	0.960 09865	19.10 01339	8.452 56275 7	14.50 77763 9	11.55 26933 7	95.46 88171 4	0.967 87684	16.71 42570 5	6.308 36542 7	27.27 94543 7	13.54 88921 8	312.1 18988	0.933 66634 8	19.90 67767 5	322.0 92315 7	0.868 90423 9	0.131 09576 1	0.721 72455 7	0.849 98974 9	0.897 82488 6	4.475 47849 3	29.19 18969 9	13.69 78899	0.925 36436 3	22.32 75482 2	1.634 41573 8	24.52 89480 9	13.82 68957 1	0.902 51570 9	22.65 67789 7	1.272 65404 9	19.93 85417 5	13.91 41764 6	0.883 0733	23.22 18418 1	0.629 71261 8	0.467 32244 5
1955	Chinook_1	0.832 98919 3	0.640 20020 4	0.533 27985 1	0.053 30457 5	135.88	143.14	149.24	144.93	17.13 93079 7	28.35 05609 4	13.11 13794 9	199.8 62250 2	0.969 79442 7	18.08 71285 7	8.261 20010 8	14.74 11681 7	11.69 61624 1	89.95 91491 7	0.973 77762 8	16.35 52078 2	6.601 00330 4	25.79 62780 9	13.73 55736 1	254.7 46210 7	0.951 37271 3	18.38 13951 8	265.7 07000 7	0.910 17357 9	0.089 82642 1	0.703 57220 2	0.838 66633 7	0.887 13026 4	4.740 23546 3	24.08 53085 7	13.51 14164 4	0.953 37115 5	19.92 49054	1.980 68548	20.30 64119	13.73 64365 3	0.940 57611 6	21.01 32897 7	1.545 70216 7	16.44 19536 8	13.90 05503 7	0.936 18446 6	22.07 05938 3	0.602 29989 1	0.434 25064 4
1956	Chinook_1	0.861 87011	0.714 05292 7	0.615 42087 4	0.083 06611 2	117.78	124.04	130.4	147.02	18.21 67565 4	25.46 34093 5	11.71 4771	298.3 35893 9	0.930 90724 1	20.95 17917 6	8.283 01711 4	15.73 92519 4	10.37 62432 1	139.5 44091 8	0.920 18075	19.03 59142 3	7.074 95337 7	23.90 90314 2	12.18 61707 4	382.0 81385 3	0.905 29985 2	21.42 32947	390.8 76007 1	0.878 12551	0.121 87449	0.769 78478 3	0.871 76175 1	0.916 12302 7	4.984 92389 9	25.58 33504 4	12.36 73011 8	0.895 62721 3	23.75 33840 2	1.838 17809 8	21.85 87794 1	12.55 17009 1	0.885 7343	23.81 86092 4	1.433 94208	17.70 42831 7	12.70 10583 9	0.868 11938 9	24.29 31919 1	0.662 44997 4	0.545 44358 7
1957	Chinook_1	0.841 00043 9	0.697 58313 6	0.586 66772 4	0.158 82707 4	116.52	124.56	130.48	142	19.49 48460 2	24.54 61763 5	11.87 55462 5	276.7 61080 1	0.936 90800 7	19.76 78129 3	9.551 75014 6	13.45 54457 7	10.60 14362 3	119.4 14471 4	0.934 13999 1	17.89 83554 8	7.117 07449 7	23.41 41199 5	12.32 95434 3	344.1 20091 8	0.907 66902 8	19.81 15566 6	363.6 17340 1	0.768 06889 5	0.231 93110 5	0.764 72927 2	0.869 13080 7	0.913 84953 8	5.063 94935 4	24.93 36004 8	12.45 86999 9	0.899 70622 1	22.09 57908 6	1.872 25673 3	21.44 71952 5	12.63 90988	0.886 37389 7	22.83 87680 1	1.459 52651 6	17.39 7341	12.79 55179 2	0.871 55601 4	23.62 34073 6	0.630 47906 4	0.516 74539 4
1958	Chinook_1	0.844 27873 9	0.646 27409 1	0.545 63547 5	0.173 79336 7	126.78	132.64	138.25	144.33	15.95 88806 3	29.58 44105 8	13.02 62610 6	280.1 10835 5	0.941 67916 7	20.22 75045 3	7.329 21109 3	17.15 45054 7	11.66 83801 7	124.9 72937	0.937 91372 8	18.21 89449 3	6.257 16696 7	27.78 72485 9	13.59 12192 7	354.2 90110 3	0.915 65663 6	20.72 30083 1	371.9 19677 7	0.734 70633 2	0.265 29366 8	0.718 21632 5	0.851 01421 4	0.899 50610 8	4.450 63661	29.74 95525 2	13.72 70490 6	0.904 58509 9	23.09 53826 9	1.587 81065	25.20 81005 8	13.86 19410 2	0.882 10167 5	23.56 07191 7	1.234 41658 9	20.55 81823 8	13.95 23353 6	0.859 44691 3	23.92 43907 9	0.612 10055 5	0.462 56630 5

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1959	Chinook_1	0.8186008055	0.5659862011	0.46331676	0.0440370777	137.02	144.25	148.17	144.71	16.9363861	28.75378423	13.86163153	232.1705148	0.965677794	18.72808562	8.350413948	14.68559959	12.19106998	84.86482544	0.978350186	16.0827713	6.260514997	27.36716607	14.64041678	308.2422434	0.93795679	19.53071904	320.0209351	0.915584545	0.084415455	0.64425386	0.816187945	0.870233616	4.490656279	29.17096173	14.76403065	0.930559623	22.42586021	1.63542857	24.51027782	14.8743089	0.910688996	22.96546618	1.273274325	19.92880615	14.95343637	0.893338233	23.38432693	0.55465771	0.359813332
1960	Chinook_1	0.8248289511	0.6150335299	0.5072974611	0.0497573611	135.36	142.13	147.61	139.16	17.60967076	27.70293863	13.24569723	205.931197	0.970056696	18.10247251	8.67368526	13.99266364	11.69746475	83.84408264	0.976981163	16.0047493	6.579726152	25.84996949	13.97433805	267.4721832	0.949315031	18.56842184	279.86026	0.912135734	0.087864266	0.681835451	0.831068687	0.881456088	4.737918906	27.4936769	14.11673393	0.944720411	21.269767	1.737624131	23.07871151	14.22975763	0.92717435	22.00117747	1.353322111	18.75177023	14.31881571	0.915908396	22.74875641	0.591261936	0.409389696
1961	Chinook_1	0.8095179399	0.6320587699	0.5116629122	0.04189382	119.72	129.43	136.16	132.85	20.70294017	24.09350501	12.77934231	199.2942619	0.963137946	16.95893237	10.87064009	11.16006743	11.0264637	63.78773956	0.969579041	13.79946079	7.11648722	23.35683791	13.58525674	266.8532308	0.939339687	17.88720759	278.0116882	0.927231935	0.072768065	0.696349419	0.835498571	0.885040576	5.1583056	24.71148557	13.73779602	0.935488975	20.62541008	1.919515982	20.96069791	13.88107904	0.919813832	21.56507746	1.498814359	16.94752065	13.9848237	0.909841508	22.38562107	0.585258652	0.423172292
1962	Chinook_1	0.8363104844	0.6509444799	0.5443916922	0.0259377311	120.19	128.92	135.21	129.31	19.05969067	24.88117666	12.57854046	191.9976076	0.974049066	18.03252237	9.138767481	13.35937629	10.91844997	87.69832458	0.980187094	16.59090786	7.243788257	23.02484475	13.21481848	249.3744965	0.95595927	18.27719871	252.6494751	0.956704567	0.043295433	0.70893149	0.83565174	0.88376415	5.252878085	24.36761729	13.41876869	0.953040254	20.81759377	1.968679532	20.47470893	13.65219116	0.938809911	21.64920998	1.539410546	16.50779941	13.8214736	0.93186301	22.38346004	0.629247735	0.442199582
1963	Chinook_1	0.82182735	0.6050845633	0.4972750433	0.0308191433	119.18	128.4	134.77	136.7	20.40513486	23.98152232	12.91420977	182.1781218	0.967479169	16.95925307	10.33674822	12.12361408	11.12138901	75.76622162	0.97017417	14.6974617	7.327655338	22.50479692	13.73497852	236.146848	0.948973397	17.50638588	244.9419708	0.944201582	0.055798418	0.672393181	0.823867465	0.875059804	5.344198965	23.73130061	13.88473969	0.948225236	19.89779816	2.011939012	20.02698075	14.02827199	0.933042089	20.89785639	1.572426789	16.16725059	14.13658428	0.92580694	21.88720894	0.570354563	0.409381773
1964	Chinook_1	0.8425820644	0.5891967099	0.4964465799	0.1037308022	134.18	141.31	147.01	144.21	15.87325036	30.27168152	13.75569446	236.8913977	0.959669054	19.21778468	7.442938246	17.02489792	11.98825607	109.6990631	0.96231035	17.43545914	6.187251404	27.95600923	14.57099708	302.4235636	0.937302778	19.70166731	312.778656	0.820799199	0.179200801	0.660248195	0.82066765	0.872938569	4.426957086	29.85763488	14.72584743	0.92984606	22.03398972	1.603388503	25.00223332	14.87215614	0.907432934	22.6331412	1.248400733	20.32684277	14.9813323	0.888127714	23.10979366	0.594321156	0.369269769
1965	Chinook_1	0.8102965944	0.5077194711	0.4114033588	0.1667741999	144.54	147.61	147.06	159.06	14.76941525	30.98362909	14.22096218	260.7909066	0.946605465	20.21058907	6.334083691	19.66169399	13.3106245	132.5500183	0.935337877	18.83486443	6.145674504	27.99338464	14.64475012	326.7000834	0.929298192	20.52759409	334.3716736	0.688306803	0.311693197	0.613898671	0.816964429	0.871425945	4.409945764	29.85026722	14.664324	0.920586145	22.87206535	1.599352308	25.09011577	14.69133631	0.899881542	23.13684527	1.246399082	20.35965509	14.78704977	0.881359071	23.52747536	0.483601558	0.331321688
1966	Chinook_1	0.8108639556	0.6774769433	0.5493416344	0.0223757776	111.86	124.32	130.95	127.39	22.60178429	22.00154451	11.73936238	166.2583286	0.966612288	16.11510134	11.85755083	10.3135671	10.47914467	61.28872528	0.967513239	13.57199478	7.80316034	20.97365806	12.23458878	219.0303446	0.949168235	16.6855553	230.0355225	0.963491991	0.036508009	0.738319149	0.856163561	0.902134731	5.649594218	22.15258258	12.37539902	0.949725437	19.17106152	2.152692109	18.74227099	12.51842276	0.936120848	20.25407918	1.683205128	15.12593241	12.6329031	0.931591809	21.38210297	0.615869824	0.457129787
1967	Chinook_1	0.82404389	0.7047244441	0.5807238699	0.0740582811	126.25	135.92	142.16	134.15	19.40206604	26.41704027	12.14370196	212.7432949	0.955901316	17.15488795	10.22877035	12.05179377	10.94037342	71.22447815	0.960820067	13.75696907	6.726392522	25.46322693	12.62041457	283.1636531	0.929753492	18.30642843	298.8913574	0.886660849	0.113339151	0.759704234	0.866613807	0.911421478	4.772218123	27.23235114	12.77370167	0.925090766	20.90571136	1.739148661	23.06157632	12.91070366	0.905059695	21.72390048	1.354678228	18.7330175	13.00779533	0.889734864	22.37873363	0.641526982	0.481840647
1968	Chinook_1	0.748755521	0.4244070224	0.3177771022	0.0448151446	140.66	146.82	149	148.44	16.63043121	28.79183174	15.21015528	192.5179482	0.966654288	17.26613021	7.958729863	15.33077569	14.24062386	73.47927704	0.971552682	14.79207344	6.410007633	26.15200904	15.68997049	253.8029633	0.945899655	17.9436996	264.8443604	0.883060208	0.116939792	0.531532933	0.767681887	0.829913676	4.687840022	27.61115191	15.70341053	0.943229127	20.57589493	1.737852968	23.07698118	15.73095894	0.926427146	21.27290662	1.353567936	18.74847337	15.79156494	0.917048663	22.09349728	0.424440452	0.21585773
1969	Chinook_1	0.8525284644	0.6518461966	0.5557174366	0.0657557755	117.63	125.5	131.99	137.15	18.73688373	24.97944027	12.60033165	260.2804941	0.956144571	19.86967414	8.840399876	14.39003069	10.68161869	114.0841751	0.965322077	18.24981422	7.054742172	23.7674158	13.41829109	332.6554108	0.926570038	20.2092905	341.9213867	0.893596207	0.106403793	0.711117963	0.841309063	0.890015667	5.076851442	25.23722919	13.62321548	0.916923916	22.79102478	1.87202473	21.47706352	13.83582783	0.895793676	23.18882879	1.461034998	17.37957985	13.9812479	0.876596928	23.51447105	0.625512161	0.455873669
1970	Chinook_1	0.8339943266	0.6743738155	0.5624239355	0.1035427622	126.84	133.97	140.08	148.86	18.70802657	26.45227898	12.46536691	209.7661994	0.952860313	17.80921538	9.375037514	13.18621429	11.14080715	94.71482239	0.948551404	15.76514168	6.89281597	24.52719379	13.01626174	265.1364594	0.932881514	18.30930956	273.2392883	0.838948548	0.161051452	0.738949949	0.856019642	0.902318927	4.923295401	26.13500768	13.15165577	0.931055129	20.51410446	1.820930921	22.0701981	13.30442969	0.912469586	21.27177366	1.420777999	17.86749762	13.41846991	0.900335819	22.07615185	0.61729289	0.484878038
1971	Chinook_1	0.8553972466	0.6017348988	0.5147223755	0.2883378977	139.39	145.79	148.38	140.82	13.84683193	32.88236582	13.77457271	329.8789771	0.910104773	21.49266856	5.9853452	20.74168206	12.41216316	154.0036591	0.893829024	19.55844994	5.57769578	31.4570937	14.43295034	425.2906647	0.878720482	21.9907697	429.0464783	0.573456455	0.426543545	0.680199763	0.836162944	0.888076188	3.904594831	33.86665462	14.54597569	0.866566956	24.26941032	1.37573991	29.14140371	14.6246109	0.86114649	24.2105999	1.070245482	23.75282171	14.66726303	0.844544709	24.38244247	0.601260492	0.421724755
1972	Chinook_1	0.8519773551	0.6230993777	0.5308665566	0.1269633411	125.09	130.94	136.74	153.04	16.41016116	28.50639115	13.3233116	299.9977897	0.940042168	20.81192098	7.647842348	16.26909752	11.46492519	123.2128357	0.949063849	18.62586517	6.291845761	27.0702448	14.14226453	386.9389852	0.902545502	21.26828416	389.7806702	0.795132138	0.204867862	0.692127511	0.836098139	0.886570307	4.488495313	28.88280853	14.30587673	0.891284335	23.85118103	1.619653814	24.77065902	14.47883034	0.886230926	24.09588814	1.262007527	20.10716059	14.60736609	0.873231947	24.38252258	0.607855594	0.447315466
1973	Chinook_1	0.7847334999	0.5857752911	0.4596774933	0.0360102777	121.61	131.11	136.48	138.19	21.5502629	23.45458843	13.05009447	149.41575	0.954412958	15.17776149	11.42304	10.40530273	11.38893642	54.37293472	0.950405002	12.59022579	7.472298034	21.95805755	13.7922891	197.2988485	0.93495971	15.88929415	205.771637	0.931348492	0.068651508	0.663035773	0.816495955	0.868479098	5.426801808	23.17452754	13.91945305	0.940966094	18.20280247	2.062993564	19.54580042	14.0798947	0.926334719	19.03305308	1.612972386	15.76944939	14.20716333	0.922547966	20.19972038	0.522684213	0.390868258
1974	Chinook_1	0.8469256866	0.5787659933	0.4901717866	0.1725078599	136.6	143.6	146.83	148.38	14.68845176	31.25756648	14.05204282	314.0355399	0.926033007	21.18924509	6.555556141	18.87118627	12.43044243	137.7177002	0.924665427	18.97457085	5.788007945	29.9461991	14.79346514	409.5044607	0.890189221	21.92914899	411.0448608	0.714630759	0.285369241	0.65820277	0.824949259	0.878397953	4.095131606	32.09892715	14.9248291	0.878078842	24.23675613	1.461620122	27.42783487	15.04529317	0.867805004	24.1259524	1.137583703	22.32457733	15.13519669	0.849244058	24.32813835	0.578930923	0.380168571
1975	Chinook_1	0.8348602966	0.5864077888	0.48956858	0.1898270555	144.97	150.43	154	163.36	14.79121236	31.96504479	13.89586605	268.0051956	0.941697695	19.94613293	6.733926699	18.30621614	12.64439983	126.5483429	0.932435119	18.26169281	5.928359799	29.32019668	14.41855192	338.2342631	0.920265357	20.25898234	345.0531616	0.690066546	0.309933454	0.665149245	0.827396674	0.879169132	4.193299107	31.44100096	14.53721256	0.911953247	22.67331505	1.509231158	26.54591975	14.66994667	0.893942197	23.02775256	1.174178816	21.62037973	14.80526924	0.877115875	23.53640842	0.560234745	0.408627662
1976	Chinook_1	0.8640622444	0.7231002477	0.6248036222	0.1139645533	121.47	128.7	134.87	135.29	17.43989657	26.86324823	11.89297152	278.6686145	0.946730541	20.38518899	8.033378527	15.92008337	10.4914526	127.318898	0.95310849	18.89573784	6.743594289	25.3842922	12.44126908	354.402125	0.914780945	20.72793468	365.2261047	0.837460734	0.162539266	0.774016689	0.872688071	0.916977034	4.780255198	27.15314336	12.6284235	0.903644001	23.10296783	1.73194769	23.16746098	12.80095641	0.8818899	23.40756989	1.349628001	18.80262754	12.90877008	0.86044538	23.66306782	0.684025905	0.541272452

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1977	Chinook_1	0.736984641	0.521889648	0.384624655	0.08991942	130.97	139.53	144.21	140.05	20.67355902	24.39650962	14.02102184	120.3680815	0.945730942	13.29778065	10.76167938	10.79038104	12.83691463	38.26717437	0.940370965	10.79437466	7.466771759	21.78220165	14.55126921	163.8360265	0.923063348	13.94452031	168.8567963	0.812724488	0.187275522	0.603899749	0.790033129	0.847199331	5.490952529	22.85152947	14.63872222	0.928382826	16.10786247	2.102024324	19.19601360	14.73533636	0.911442796	16.84683000	1.644103535	15.47850789	14.81992912	0.908194989	18.23390484	0.483346298	0.292874118
1978	Chinook_1	0.847032004	0.716153818	0.606605203	0.01571840 2	110.35	121.35	128.63	129.74	21.93248484	22.17085116	11.25872741	201.1873845	0.973700481	18.39369658	11.06194239	11.93710867	9.738740921	91.81815796	0.979866493	16.79133492	7.767212853	21.14847006	11.86456394	258.1840159	0.955412904	18.64856927	268.3821716	0.975975555	0.024024448	0.766711173	0.865789782	0.909738283	5.596480355	22.38620628	12.03600597	0.951713657	21.12798958	2.131437644	18.92306838	12.21188545	0.936088443	21.91341 4	1.666350469	15.27426471	12.34 41	0.926850259	22.69603250	0.660121008	0.515594261
1979	Chinook_1	0.837340663	0.719284622	0.602286262	0.013 8146	113.47	123.8	131.1	129.21	22.29142424	22.46 59442	11.31604753	182.4161189	0.967810111	17.04719901	11.60086033	11.07981567	9.690938759	73.43456345	0.968879092	14.37266312	7.757443193	21.35866886	11.94390249	238.6437658	0.950824330	17.83068124	250.2554932	0.979105725	0.020894275	0.769630558	0.865188645	0.908964954	5.567677975	22.66444995	12.13818607	0.951546586	20.20229149	2.103825063	19.16951276	12.35158888	0.937299768	21.23058128	1.644 82823	15.46997267	12.49720955	0.930799365	22.11085796	0.672685894	0.496609882
1980	Chinook_1	0.843628878	0.611433639	0.515823075	0.065 68604 1	137.13	143.99	148.5	144.85	15.57780509	30.27341708	13.55181408	247.5754787	0.962853138	19.89265135	7.142541721	17.31640188	11.99237423	111.0926819	0.974071622	18.22 06337	6.156156331	28.15846184	14.28406668	323.0065867	0.934931477	20.41755279	325.7151184	0.885 60865	0.114 39135	0.679 66576 7	0.829 95621 1	0.880 91771 2	4.400 66674 4	30.09 04797 4	14.43 18460 5	0.926 04826 7	22.97 79644	1.596 57463 4	25.12 66554 3	14.55 02907 4	0.905 29904 8	23.09 26418 3	1.243 90351 8	20.40 06455 4	14.63 20166 6	0.886 95636 4	23.43 19019 3	0.586 82011	0.431 40410 7
1981	Chinook_1	0.796355192	0.537044742	0.427678369	0.046526056	128.38	134.63	134.3	151.43	19.34814923	24.62517495	13.84979282	196.3556486	0.961936989	17.48608725	9.544567645	13.15190286	12.58694763	83.36640015	0.964531028	15.36 69178	7.054077849	23.23668664	14.38 71851	254.9595057	0.940744023	18.00309499	261.8888245	0.904503228	0.095496772	0.620596913	0.803163682	0.858590101	5.140 15983	24.49059754	14.47988338	0.938 91968 7	20.36 38473 5	1.956 82598 7	20.59 00963	14.58 31184 4	0.922 47585 5	21.04 28473 2	1.529 66024	16.61 09428 2	14.68 45803 3	0.913 49667 3	21.94 52190 4	0.509 59028 4	0.347 33807 9
1982	Chinook_1	0.833028073	0.531657597	0.442885703	0.153 28698 8	142.85	146.81	147.81	166.21	14.64855701	31.76725768	14.51312201	280.2673912	0.942 36332 6	20.44711406	6.561 15822 5	18.91 76128 2	13.15 78960 4	127.5 42976 4	0.943 06086 3	18.71 83990 5	5.877 05560 8	29.45 11547 8	15.10 51481 6	359.9 08035 3	0.912 96407 6	20.92 34856	362.8 19122 3	0.722 99604 7	0.277 00395 3	0.617 58902 3	0.806 69368 1	0.862 72825 4	4.182 46492	31.50 87552 1	15.21 62338 3	0.902 81189 7	23.26 67366	1.504 90853 9	26.65 90685 1	15.32 71980 3	0.885 98396 4	23.46 99236 6	1.172 32350 3	21.65 50960 7	15.43 53599 5	0.868 16456 9	23.72 96991 3	0.541 56148 1	0.334 94386 3
1983	Chinook_1	0.834603836	0.607223256	0.506790859	0.081 58841 1	122.79	129.4	135.12	154.12	18.32917776	26.03368069	13.12778091	221.4143851	0.963 95878 7	18.84576757	8.765 82799 9	14.49 13514	11.44 15317 5	103.0 93200 7	0.963 22861 9	17.11 75678 3	6.976 51592 6	23.93 79864 5	13.86 72382	280.7 61118 6	0.946 54686 3	19.19 23834 5	285.9 48242 2	0.858 93601 1	0.141 06398 9	0.674 29596 1	0.824 00627 3	0.875 03571 6	5.047 92217 2	25.35 79797 6	14.02 88707 7	0.941 94732 9	21.63 24436 2	1.882 13301 5	21.38 31149 3	14.19 48671 3	0.926 68167 8	22.32 67250 1	1.470 17998 2	17.27 33491 2	14.32 25956	0.916 52092 3	22.97 56403	0.574 75366 1	0.431 30815 4
1984	Chinook_1	0.837581719	0.583624249	0.488832994	0.149429515	129.12	135.59	140.79	149.96	15.83393493	29.28072745	13.73401267	230.2793934	0.955 95358 1	19.45503787	6.977 94692 2	17.45 90292 8	12.26 45759 6	123.7 05212 4	0.942 34746 7	18.38 20884 7	6.549 85116 4	26.05 71669	14.28 99996 4	281.7 99031 6	0.945 26927 7	19.54 80847 4	289.5 88989 3	0.748 27154 2	0.251 72845 8	0.657 34584 5	0.818 37335 2	0.870 53890 4	4.720 31568	27.71 86609 3	14.45 30782 7	0.940 43167 8	21.60 32932 3	1.724 13347 7	23.27 32592 1	14.65 35965 6	0.922 21075 3	22.38 90349 1	1.343 58342	18.88 71609 4	14.82 50989 9	0.908 61415 9	23.04 15468 2	0.563 39166 4	0.388 12755 2
1985	Chinook_1	0.847468671	0.718088928	0.608557787	0.010998872	110.93	121.38	128.96	133.81	21.85438101	21.78352282	11.18855653	178.908432	0.967 12939 7	17.45757174	10.72605024	11.71856391	9.675050354	97.02052002	0.967 24078 7	16.88758583	8.042 99223 4	20.30566678	11.75 79735 1	223.0121791 1	0.950 60151 8	17.22 92411 3	228.2754822	0.983 29453 1	0.016 70546 9	0.767 77323 2	0.864 81739 8	0.908 75884 5	5.796 16892 3	21.47 61678 5	11.96 52397 2	0.948 82910 3	19.36 32858 3	2.225 03539 9	18.16 94450 2	12.17 25893	0.934 14276 8	20.24 20056 7	1.742 12771 7	14.62 76341	12.31 71954 2	0.928 13184 9	21.42 16909 4	0.667 03032 5	0.507 99395 2
1986	Chinook_1	0.814585336	0.588235756	0.479168221	0.065 06880 9	123.45	128.87	132.7	153.91	19.29493824	24.26125468	13.00853927	206.3031513	0.965 32805 9	18.48316523	9.150 35552 5	14.00 72742 3	11.50 30605 3	103.0 88612 4	0.966 16877 3	17.50 30319 2	7.305 93267 1	22.39 86370 3	13.60 13625 5	259.0 15324 9	0.947 29168 2	18.49 96980 8	260.5 98663 3	0.881 33642	0.118 66358	0.674 89413 5	0.825 14734 4	0.875 92383 6	5.329 10421 5	23.59 29301 4	13.70 05945 2	0.943 48564 1	20.77 51110 1	2.027 92593 8	19.90 28981 3	13.88 87259 2	0.928 60519 9	21.55 44751 5	1.587 19843 6	16.01 93812	14.05 95760 3	0.920 33579 9	22.39 11171	0.542 25078 6	0.408 49865 6
1987	Chinook_1	0.762967653	0.529204616	0.403766004	0.037 83782 7	119.17	127.15	132.46	141.69	19.22411805	24.79663393	13.83240536	200.8179795	0.969 59659 9	17.39146105	9.455 38748 8	12.83 39739 6	12.53 93692	63.00 44174 2	0.972 79456 9	13.71 74137 1	7.058 57799 2	23.55 7742	14.37 06601 5	275.3 46928 9	0.951 73007 2	18.76 24494 6	282.6 92810 1	0.919 70919 3	0.080 29080 7	0.617 69399 2	0.803 89664 1	0.859 17271 5	5.180 26540 4	24.81 15379 2	14.45 25133 1	0.947 27499 5	21.76 51096 3	1.934 67343 6	20.80 77177 6	14.56 09143 6	0.928 46854 5	22.45 51474 3	1.511 29204 8	16.80 97862 7	14.67 73266 8	0.914 27362	22.94 93274 7	0.489 60379 4	0.308 66383 6
1988	Chinook_1	0.818857108	0.712898069	0.583761651	0.014 67497 1	109.41	121.31	128.88	131.42	24.41515109	20.67140116	11.09 65538	152.1647399	0.963 71151 7	15.41454346	13.16523405	9.112 93470 9	9.544 90661 6	58.24 85824 6	0.964 56692 2	13.29 61118 7	8.156 28791 6	19.93 75423 5	11.71 48842 8	200.6 97809 9	0.944 85480 6	15.81 34866 6	208.1 94061 3	0.977 26418 8	0.022 73581 2	0.766 87607 7	0.865 29889 9	0.909 22631 3	5.887 44903 4	21.06 24676 5	11.88 16989 9	0.946 23900 7	18.15 79393 4	2.266 89950 4	17.84 24554 7	12.06 84715 9	0.931 96574 8	19.23 85412 9	1.775 17820 1	14.36 34679 4	12.21 14939 7	0.927 67074 7	20.59 02977	0.646 39120 1	0.489 98960 9
1989	Chinook_1	0.805828002	0.514177836	0.414338898	0.048 25255 5	142.8	150.61	154.72	148.82	17.06283072	28.61851089	14.13768339	191.0840153	0.971 42014 8	17.61784298	8.313 86360 5	14.62 69857 6	12.41 58557 9	77.39 14947 5	0.975 99480 2	15.46 92060 5	6.495 85140 5	26.22 62806 9	14.96 53735 2	252.1 22589 1	0.953 31818 9	18.17 94238 9	257.9 12506 1	0.898 61882 2	0.101 38117 8	0.593 26489 7	0.788 96042 5	0.846 77816 8	4.691 97345 5	27.87 11047 7	15.10 52505 5	0.950 48317 9	20.85 96122 7	1.729 28128 4	23.24 09499 8	15.19 34986 1	0.935 36599 5	21.65 04726 4	1.349 55406 9	18.80 39769 8	15.25 90928 1	0.927 11901 7	22.36 08627 3	0.529 30682 6	0.300 70394 3
1990	Chinook_1	0.739758304	0.346266403	0.256153447	0.058 23098 6	132.39	140.49	143.01	138.86	17.11478717	27.73816596	15.58847461	178.904944	0.970 35010 8	16.65926044	8.226 45275 3	14.47 50935 9	14.31 40010 8	62.33 52012 6	0.974 04590 8	13.91 21894 8	6.541 04449 6	25.43 56297 8	16.22 98076 9	243.0 86507 2	0.952 44549 7	17.51 89774	245.8 40499 9	0.822 69332 5	0.177 30667 5	0.443 46102	0.711 64013 6	0.782 59611 9	4.838 74895 4	26.70 74722 9	16.28 51776 1	0.949 22341 1	20.29 38434 6	1.808 60992 5	22.23 30842 4	16.30 44509 9	0.934 85760 7	21.14 62237	1.411 92173 2	17.97 87383 3	16.33 34312 4	0.928 23368 3	22.05 92727 7	0.413 80526 5	0.134 83603 7
1991	Chinook_1	0.807522351	0.605559746	0.489000302 9	0.044 80277 8	124.52	134.05	139.45	134.08	20.03 30421	24.93288162	13.11495147	199.6868341	0.961 91196 4	16.95522922	10.49884003	11.60 94440 8	11.38 23967	66.04 04449 5	0.969 50018 4	13.86 45462	6.901 60474 2	24.20 21631 1	13.89 33819 1	271.8 83707 7	0.936 54456 7	18.05 73054 9	273.0 70678 7	0.918 62897 4	0.081 37102 6	0.674 6419	0.826 03273 6	0.877 24734 5	4.991 36361 5	25.64 26375 2	14.03 65734 1	0.930 80421 7	20.78 47145 1	1.864 23867 9	21.61 72738 9	14.18 41386 2	0.912 33656 8	21.43 50751 2	1.458 02438 3	17.41 54839 6	14.29 69040 9	0.899 4762	22.07 69233 7	0.564 68403 6	0.403 32217 1
1992	Chinook_1	0.746902451	0.505476865	0.377541905	0.048 4815	122.26	130.13	134.04	139.17	20.23 20527 1	23.84769627	13.95 60766 9	161.5465527	0.964 73372	15.65632623	10.19 34619 4	11.71 10319 2	12.81 06065 8	51.24 73823 5	0.961 08855	12.27 71934 5	7.323 16665 4	22.32 95826 4	14.42 47773 5	220.5 40603 6	0.950 13862 8	16.81 37418 4	225.0 98037 7	0.892 53393 5	0.107 46606 5	0.595 49037 9	0.791 64586 1	0.848 74328 9	5.399 98428 5	23.41 84195 3	14.49 36824 8	0.951 21935 6	19.48 59371 2	2.052 24104 2	19.66 49363 5	14.59 17199 5	0.937 72274 3	20.48 51328 5	1.605 86066 5	15.83 76418 8	14.70 45617 1	0.932 9741	21.44 59199 9	0.471 25567	0.294 73811 3
1993	Chinook_1	0.842904668	0.719508605	0.606477162	0.058 85103 8	121.93	130.19	136.69	137.54	18.60 60066	26.24386476	11.80742121	239.2368755	0.954 55371 5	18.57179005	9.154 08930 2	13.73 93166 2	10.69 07569 9	94.08 63388 1	0.965 70445 3	16.28 37417 6	6.883 28183 4	24.88 01658	12.25 71827 6	306.1 46497 1	0.922 53882 7	19.09 01947 8	326.5 54443 4	0.912 56818 1	0.087 43181 9	0.774 18829 2	0.873 77314	0.917 65887	4.885 26678 8	26.60 56028 2	12.40 03204 3	0.916 34831 4	21.49 06456	1.765 9005	22.70 14584 6	12.53 20981 3	0.894 51720 3	22.35 76424 9	1.374 85740 3	18.45 94050 7	12.62 53724 1	0.877 02614 1	22.93 19095 6	0.662 54644 7	0.507 12417 9
1994	Chinook_1	0.750955526	0.464164663	0.348566895	0.057 04271 3	129.37	136.71	141.59	137.59	17.72 23186 5	27.15 37165 9	14.36 33309 1	168.7997984	0.969 97585	16.42 24989 8	8.565 73564 6	14.00 42214 4	13.23 87304 3	64.42 86964 4	0.971 48811 8	13.85 64098 4	6.804 88853 9	24.50 79051 9	14.91 05768 2	225.1 50484 7	0.953 70374 1	17.17 96124 8	230.8 14819 3	0.865 03935 3	0.134 96064 7	0.563 80217 8	0.783 56977 8	0.842 97543 3	5.012 74567 1	25.78 54782 8	14.94 82666	0.952 69517 9	19.77 25353 2	1.867 29335	21.54 05294 2	14.96 62720 4	0.939 57779 8	20.73 67490 1	1.457 87131	17.41 79710 7	15.03 83229 3	0.935 22721 5	21.74 64971 5	0.431 69767 5	0.239 90167 8

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1995	Chinook_1	0.835 54450 5	0.622 42125 4	0.520 06065 8	0.052 89307	128.3 9	134.7 7	140.2 4	144.6 3	18.66 72317 2	25.76 60613 9	12.96 48554 7	205.5 11996 1	0.967 20558	18.32 47456 2	9.119 32181 6	13.87 93492 3	11.40 40424 3	96.88 71139 5	0.971 00951 7	16.81 64653 8	6.938 83471 2	24.03 73044 7	13.66 32262 9	260.5 38678 5	0.947 63846 2	18.55 14641 6	269.9 09057 6	0.908 03791	0.091 96209	0.689 38482 4	0.833 71500 2	0.883 52560 3	5.016 0449	25.46 69962 7	13.80 23876 2	0.944 29365 4	20.89 08119 2	1.874 78245 8	21.45 18407 2	13.93 43258 5	0.926 51488 4	21.66 50301 6	1.463 54796	17.35 05760 4	14.04 12893 3	0.915 08314	22.42 49115	0.583 50068 8	0.451 27945 6
1996	Chinook_1	0.799 52433 8	0.523 84408 6	0.418 82609 6	0.167 10433 6	140.9 1	143.6 7	145.6 3	152.3 9	15.09 45691 9	30.65 70457 9	14.56 52866 4	262.4 73653	0.946 49981 6	19.88 84322 3	6.709 90804 6	18.40 13712 2	13.66 24794	121.5 46131 9	0.938 17342 5	17.99 16599 3	6.119 23087 4	27.98 63577 9	14.93 33965	333.5 71589 2	0.926 68868 1	20.38 11540 6	342.8 36425 8	0.693 27009 2	0.306 72990 8	0.612 62445 3	0.804 64269 1	0.860 84873 8	4.392 32433 6	29.82 27193 9	15.01 92457 2	0.917 76913 4	22.90 88008 9	1.598 00884 9	25.07 60136 8	15.10 50090 8	0.896 74111 2	23.13 73036 7	1.243 71913 8	20.40 36703	15.19 62046 6	0.877 99793 5	23.60 07261 3	0.498 28799 6	0.325 28783 8
1997	Chinook_1	0.837 17588	0.552 96895 2	0.462 93226 9	0.260 64842 3	133.3 2	135.7 2	138.7 3	143.5	14.06 47067 3	31.70 06126 1	14.07 90446 8	363.0 41204 2	0.902 43582 2	22.41 37524 2	5.931 19487 2	20.80 07354 7	12.79 93507 4	159.4 93624 9	0.886 24249 7	19.74 97764 6	5.737 54604 2	29.94 85107 3	14.68 68244 8	468.0 00549 3	0.867 14837	23.13 02715 9	478.4 10980 2	0.583 55689 9	0.416 44310 1	0.649 53837 8	0.830 25795 7	0.883 49490 2	4.055 58843 9	32.07 67956 8	14.75 72475 4	0.851 87639	25.45 66230 8	1.427 66206	28.05 38080 9	14.82 00197 2	0.861 56121 9	25.24 19719 7	1.109 95505 8	22.88 86579 5	14.90 80753 3	0.852 92720 8	25.35 50100 3	0.538 77800 6	0.384 17126 6
1998	Chinook_1	0.848 01997 2	0.643 00293 4	0.545 27933	0.098 31365 3	116.5 2	125.1	131.3 1	131.9 3	19.54 66488 8	24.71 60283 6	12.68 5087	255.9 83872 5	0.948 56589 6	19.11 45846 2	9.673 71539 8	13.54 82394	10.66 56797 4	105.7 21310 4	0.953 61477 1	16.62 81990 1	7.025 23963 9	23.90 01825 2	13.56 17680 5	331.9 41970 8	0.918 64187 5	19.85 12931 7	345.1 56738 3	0.842 13899 8	0.157 86100 2	0.704 57039 4	0.838 71369 6	0.888 04592 2	5.056 46281 7	25.38 13484 2	13.75 14240 3	0.909 45998 4	22.32 28794 1	1.862 85009 2	21.57 34968 6	13.96 22910 8	0.885 79672 6	22.83 15124 5	1.453 34433 8	17.47 04667 5	14.11 08012 2	0.864 58012 5	23.30 55763 2	0.615 55309	0.452 32195 3
1999	Chinook_1	0.835 95861 7	0.629 23541 5	0.526 01476 7	0.037 32659 9	121.7 3	128.8 4	135.4 7	132.6 6	19.08 39444	24.61 52184 4	12.80 12322 7	203.8 33747 3	0.967 95441 4	18.22 47334 2	9.058 35874 4	13.66 79471 8	11.05 65624 2	95.06 22360 2	0.974 03705 1	16.93 82232 7	7.280 03823 8	22.73 48495 1	13.57 56454 5	260.2 74018 8	0.946 86304 5	18.34 83382 9	267.9 91546 6	0.935 72367 7	0.064 27632 3	0.691 08463 5	0.831 77161 8	0.881 68892 1	5.305 83655 8	23.99 20136 8	13.73 80014 4	0.942 41428 4	20.77 89753	1.987 54864 9	20.25 86328	13.89 64589 4	0.925 38082 6	21.44 07564 8	1.552 57159 5	16.37 00833 5	14.01 09539	0.914 82839	22.32 85923	0.604 68613 7	0.428 12446 5
2000	Chinook_1	0.785 75568 2	0.435 89752 2	0.342 50895 5	0.036 26953	131.8 7	138.9 5	141.1 2	139.9 9	16.84 29284 9	27.75 66957 8	14.44 08525 1	187.6 28549 8	0.973 46416 1	17.73 68352 1	7.761 79000 7	15.65 89217	13.14 01454 9	85.19 15039 1	0.979 89699 8	16.25 10889 1	6.705 69443	24.80 76241 2	15.12 24861 1	240.9 44290 2	0.954 83574 3	17.91 81685 4	250.0 07461 5	0.909 09768 2	0.090 90231 8	0.534 09009 1	0.771 32076 4	0.833 42485	4.935 07730 2	26.10 10832 2	15.16 73852 9	0.951 84941 3	20.38 95576 5	1.840 41350 3	21.82 31321 8	15.15 55544 5	0.937 13345 1	21.19 46207 7	1.435 09163 7	17.69 12217	15.20 32141 7	0.930 05824 1	22.19 04306 4	0.442 80646	0.236 58617 2
2001	Chinook_1	0.808 74910 3	0.618 19955 9	0.499 96833 9	0.018 37877 4	110.8 5	123.2 7	130.5 3	130.1	24.17 87552 2	21.25 67835	12.38 91788 2	140.1 87287 7	0.950 58252 6	14.52 05489 6	13.17 88998	9.406 12888 3	10.09 44908 1	49.65 49293 5	0.943 20372 3	11.80 59499 7	8.040 19673 9	20.12 75998 3	13.40 74147 5	184.2 09246 3	0.932 02281	15.24 66165 2	196.2 06115 7	0.967 22251 1	0.032 77748 9	0.679 81234 6	0.819 56837 6	0.870 60530 6	5.860 11298 7	21.17 39957 1	13.61 21658 3	0.939 11541 7	17.31 00788 1	2.250 50973 1	17.95 05325 9	13.84 69187 4	0.924 42967 5	18.29 51583 9	1.760 62011	14.47 92196 4	14.00 41098 6	0.921 26697 3	19.72 07765 6	0.586 86181 5	0.387 30675 1
2002	Chinook_1	0.819 93088	0.629 73285 6	0.516 33741 5	0.040 36615 2	121.0 5	130.5 4	136.8 1	133.6	19.92 85066 4	24.69 17463 4	12.79 33468 1	178.6 73415 6	0.966 10831 4	16.54 95390 2	10.11 19138 7	12.04 01593 8	11.04 35201 6	70.19 27841 2	0.972 34345 7	14.49 44829 9	7.226 08007 5	22.88 93617 4	13.49 95468 5	233.9 09078	0.943 96663 7	16.97 12910 7	243.6 93206 8	0.930 19841 5	0.069 80158 5	0.691 01899	0.828 71219 6	0.878 49325 2	5.244 70581 1	24.18 93374 7	13.69 51158 5	0.940 87467 2	19.41 43886 6	1.971 93436 3	20.39 54522 8	13.91 23729 1	0.924 00586 6	20.25 75664 5	1.538 85377 9	16.51 39279 8	14.07 25593 6	0.915 1555	21.39 31026 5	0.594 25870 3	0.423 60617 5
2003	Chinook_1	0.815 20534 7	0.624 08742 7	0.508 75940 8	0.074 63199	131.0 9	139.1 7	145.6 5	148.7	17.83 21766 7	27.51 72825 9	13.23 98278 4	219.3 08003	0.961 17301 5	17.95 74448 7	8.857 72504 7	13.97 02448 3	11.82 42736 8	83.26 60125 7	0.967 64445 3	15.41 99512 5	6.594 82642 3	25.69 56182 9	13.89 63082 6	282.6 97654 7	0.936 36658 8	18.51 48302 7	305.1 58660 9	0.872 65176 2	0.127 34823 8	0.693 48007 4	0.837 53137 3	0.887 42842 9	4.741 73339 5	27.32 99314	14.02 13905 3	0.930 69695 2	21.08 34964 8	1.730 17930 2	23.12 56734	14.13 00239 6	0.911 19410 6	21.95 65073 6	1.344 67046 7	18.87 18816 9	14.21 57702 4	0.897 33919 5	22.83 12263 5	0.579 60967 5	0.423 43023 5
2004	Chinook_1	0.824 48273 9	0.655 33691 8	0.540 31397 7	0.010 62152 6	107.5	120.8 7	128.0 3	130.7 5	24.16 01334 5	20.92 33436 3	11.92 11594	171.5 37910 7	0.969 29871 2	16.31 72785 2	13.04 35797 3	9.702 80371 2	9.653 79524 2	63.05 86311 3	0.970 48648 6	13.56 15881	7.982 07074 4	20.30 35895 9	12.84 39067 2	223.1 47234 6	0.952 95856 4	16.79 12190 8	245.8 91250 6	0.982 15286 9	0.017 84713 1	0.712 98199 8	0.834 26123 6	0.882 37960 9	5.809 01175 7	21.37 55529 3	13.05 71092 6	0.952 84527 5	19.25 94522 5	2.220 56016 3	18.14 87856 7	13.34 42389 2	0.940 95450 6	20.53 59350 8	1.733 85483	14.69 51670 2	13.54 56878 8	0.938 62161	21.98 22111 1	0.622 11107 4	0.427 34635 7
2005	Chinook_1	0.799 02575 4	0.543 58880 8	0.434 34145 7	0.039 32093 4	124.0 2	132.0 1	137.1 2	136.4 8	18.87 06147 6	25.46 08746 1	13.93 05958 1	185.0 71867 3	0.968 25010 4	17.06 66371 8	9.228 91649 6	13.56 75091 8	12.49 97261	77.07 36801 1	0.969 61658	14.60 08012 8	7.046 22008 7	23.45 87294 2	14.54 05770 9	240.6 89987 2	0.951 23682 4	17.77 27704	249.1 99569 7	0.920 53300 1	0.079 46699 9	0.622 62422 7	0.798 23815	0.853 62588 8	5.170 20692 7	24.68 84846 7	14.66 41065 6	0.949 14704 6	20.18 73710 6	1.938 30152 6	20.75 33020 3	14.80 48804 6	0.933 38280 9	21.07 74459 8	1.513 07883 1	16.79 05255 6	14.90 74711 8	0.924 81198 9	22.03 88336 2	0.525 64272 7	0.328 26904 5
2006	Chinook_1	0.859 99311 7	0.699 79649 5	0.601 82016 9	0.094 55563 2	122.1	129.0 8	135.6 9	129.0 1	17.49 51802 3	26.32 20287 3	12.08 15555 7	250.1 00484 6	0.958 62196 2	20.07 11977 1	7.827 21333 2	16.10 90846 1	10.70 61189 7	126.5 51535	0.957 29302 2	18.87 42683 4	6.974 51025 2	24.23 56957 7	12.64 88466 3	307.3 78189 1	0.939 04067 1	20.25 91424	322.4 17999 3	0.859 19801 5	0.140 80198 5	0.754 76072 6	0.863 24629 3	0.908 69954 6	4.999 27967 8	25.79 47428 5	12.82 38658 9	0.931 49402 1	22.46 42189	1.833 38367 9	21.87 69630 2	12.97 46542	0.912 06181	22.94 36817 2	1.427 86669 7	17.77 92061 7	13.05 97500 8	0.896 75509 9	23.43 06364 1	0.682 83489 2	0.505 57384 7
2007	Chinook_1	0.800 12690 7	0.567 17035 3	0.453 80826	0.029 80813	122.2 6	129.8	135.0 2	133.4 5	19.31 53772 5	24.83 70855 1	13.67 13444 8	193.2 76809 1	0.970 83107 1	17.35 31904 6	9.543 68715 7	13.04 92083 5	12.22 51293 2	73.52 05490 1	0.975 41779 3	14.61 86500 5	7.080 54115 6	23.30 66839	14.28 02599 3	254.6 7571	0.952 42450 6	18.16 50372 3	264.7 84240 7	0.941 75158 8	0.058 24841 2	0.640 54503 2	0.807 52224 8	0.861 49255 7	5.189 95728 3	24.53 27115 7	14.41 61277 8	0.948 54847 2	20.82 47585 3	1.947 67697 9	20.64 45818 9	14.55 93166 4	0.931 50621 7	21.59 74667 9	1.519 76566 8	16.71 75416 3	14.66 46618 8	0.920 69977 5	22.44 90108 5	0.534 60008 5	0.356 83418 8
2008	Chinook_1	0.826 09651 5	0.706 62687 7	0.583 74200 1	0.031 26734	106.0 4	120.1 4	127.3 4	144	24.65 49868	20.39 39601	11.34 94039 9	156.3 52327 9	0.950 55795 1	15.19 01227 4	13.19 80927 4	9.741 76559 3	9.819 89955 9	67.32 47352 6	0.951 03569	13.51 25574 1	8.249 82960 5	19.49 80623 5	11.88 96225 3	195.9 34265 1	0.925 43934 8	15.36 16229 7	208.2 85476 7	0.951 49220 1	0.048 50779 9	0.758 95707 1	0.861 30782 6	0.905 96042 8	5.957 54368 6	20.56 43720 7	12.06 83439 3	0.928 30243 1	17.13 29410 6	2.308 68415 5	17.51 67795 4	12.31 05506 9	0.911 19196	18.01 94765 7	1.807 19308 6	14.11 65280 8	12.51 14712 7	0.904 87217 9	19.51 37281 4	0.640 83679 1	0.491 07775 8

5515 **Table 4-4. Snake River MO3 Spring Chinook Raw Data**

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
SCN MO3-RESSIM-GRNIMN																									
1929	Chinook_1	0.919511973	0.638048933	0.586693634	126.83	130.81	138.15	0.017974229	10537.4319	9.743078521	7.370251149	12.34669697	11.45311565	55.73202591	0.930641329	0.77368741	7.875960998	20.82836748	13.19818894	154.7387466	0.899445405	14.25688744	169.6061249	0.703600959	0.446626489
1930	Chinook_1	0.85109864	0.537451123	0.45742392	116.72	123.3	129.65	0.019348745	8841.234705	9.895050389	14.58520593	7.931149343	11.20225487	64.07468109	0.957388365	0.82858772 3	8.099128067	19.70082833	13.87704817	159.2095795	0.919699311	14.58239619	164.6813049	0.580770862	0.3328846
1931	Chinook_1	0.843254873	0.535859223	0.451865901	116.03	122.97	129.98	0.019647335	8868.888405	9.907198259	15.39320278	7.433159115	11.10623589	44.93143616	0.936234808	0.80398607 3	8.163071893	19.62186485	13.96460946	157.7758789	0.909666747	14.54994313	169.6083679	0.573176003	0.344175328
1932	Chinook_1	0.900458399	0.708319902	0.637812605	122.07	126.2	133.14	0.01927782	12286.00755	12.138401	9.403517164	10.50647433	10.71308517	86.22854919	0.98334198	1.15374555 6	7.167587757	23.72482263	12.66726383	298.3464661	0.861278633	17.84263833	318.0845642	0.729093978	0.503422993
1933	Chinook_1	0.922237901	0.622287049	0.573896702	132.93	136.91	143.86	0.016083425	9220.061307	11.39999495	7.18113213	12.42427171	11.65093021	57.09509354	0.980460215	1.09603853 2	6.957645364	24.15106069	13.84887362	225.513148	0.903342515	17.04767211	238.6426392	0.693131112	0.438218997
1934	Chinook_1	0.888780731	0.543879287	0.483389431	120.59	125.02	130.57	0.019430871	9383.072508	12.02940331	10.59905711	9.855413337	12.35942211	73.92218323	0.96766001	1.20884542 5	7.130280644	23.39934672	14.31887706	304.6672872	0.84752363	17.9106698	310.1675415	0.594107663	0.380586466
1935	Chinook_1	0.926822579	0.585395456	0.542557726	128.29	131.9	139.08	0.017299582	9376.868587	11.29817625	6.701038234	13.35622665	12.00406742	63.64140091	0.979392707	1.07433271 4	7.030059002	23.72206327	14.18151363	227.6010488	0.899793208	16.86041403	240.0293427	0.663070626	0.404719576
1936	Chinook_1	0.909432885	0.690205881	0.627695925	120.81	124.91	131.73	0.019477493	12214.40479	12.07627273	8.384572811	11.89785148	10.61216812	121.4522919	0.979020476	1.18672056 2	7.233424574	23.45387978	12.27579562	297.8064931	0.857927243	17.87996244	311.2555542	0.716969105	0.521001625
1937	Chinook_1	0.90236196	0.63993745	0.577455211	126.51	130.33	137.16	0.018180744	10487.16607	10.46011676	9.245874785	10.31604917	10.95651207	58.35632324	0.956416214	0.87134494 8	7.654515639	21.49801377	13.35160764	182.9737345	0.910421292	15.48795931	196.8638458	0.692155321	0.435820299
1938	Chinook_1	0.931793895	0.602252036	0.56117477	131.46	135.02	139.34	0.016428377	9210.642899	11.98740111	6.196380213	14.53266365	11.71657505	108.1774048	0.970465553	1.17467603 7	6.698758304	25.39898709	14.00273546	289.1795705	0.858782967	17.75047239	296.8853455	0.667031185	0.452266873
1939	Chinook_1	0.906558671	0.694399636	0.629514011	121.7	125.5	132.48	0.019296292	12135.84029	11.39395336	8.643538237	11.37461317	10.63416214	91.46031189	0.985970807	1.07283926	7.522693574	22.08047011	12.11909548	235.9698105	0.89914451	17.09998433	241.6286621	0.707797989	0.512596771
1940	Chinook_1	0.798033571	0.612939366	0.489146191	110.48	120.92	127.55	0.019621486	9587.344051	11.20062634	20.78241126	5.982274204	10.29674759	80.41598511	0.979333878	0.98790674 2	7.890700758	20.51213185	13.15060155	222.7095922	0.904414048	16.7723937	232.9519958	0.600233491	0.369492114
1941	Chinook_1	0.923474475	0.461368311	0.426061859	134.74	138.12	139.2	0.015573475	6628.894719	10.66149112	6.981969513	12.98160412	13.65693626	59.14681778	0.966293478	0.93775863 6	7.21792952	22.64385981	15.14574512	190.2967707	0.911767532	15.89438248	197.4971924	0.567847247	0.297982594
1942	Chinook_1	0.919774431	0.656727716	0.604041362	137.6	141.32	147.09	0.014333783	8648.693085	11.22132805	7.521632284	12.33261075	11.42599773	86.14080963	0.969195926	0.99987125 4	6.787986279	25.09539511	13.46010828	245.951383	0.879054467	16.58357509	257.348053	0.706017664	0.496974492
1943	Chinook_1	0.898995952	0.658289608	0.591799693	126.46	129.96	135.89	0.018416027	10887.55656	11.61690961	9.707586177	10.27669205	10.75125122	110.0913391	0.974280179	1.14878664	7.294648282	22.87696701	13.19957272	258.1103923	0.880459696	17.35169029	262.3994446	0.696288625	0.466707025
1944	Chinook_1	0.925958779	0.591292802	0.547512761	132.37	136.03	143.18	0.015956362	8728.502212	10.19293526	6.843088195	13.15676686	11.71622028	65.95204163	0.959100044	0.89084110 3	7.362133294	22.3766323	13.98226134	169.0211105	0.918545643	15.12384653	174.6496735	0.673698091	0.396078816
1945	Chinook_1	0.906048373	0.657554373	0.595776071	122.69	126.62	133.46	0.018832071	11209.28868	11.12650166	8.750090428	11.37754655	11.09074974	78.4650528	0.966844321	0.92085351 9	7.416728534	22.46377724	13.11489407	232.5920563	0.890179177	16.52865442	248.4925537	0.696770048	0.482643763
1946	Chinook_1	0.885920466	0.716730018	0.634965792	118.14	122.54	129.76	0.019905616	12628.90809	12.39100163	10.84315068	10.06753073	10.38854332	118.7723907	0.962278903	1.09720764 2	7.331889488	23.344818	12.40705252	333.629125	0.834960788	18.05752611	349.0971375	0.725117667	0.513907754
1947	Chinook_1	0.889213736	0.58966778	0.524340689	118.47	123.13	129.7	0.019716931	10329.14734	12.34954844	10.43961915	10.5165081	11.26440849	101.7924637	0.977306616	1.12215929	7.155025803	23.57363847	14.04377826	321.3206889	0.845903565	17.97119315	343.0419922	0.635817802	0.392630562
1948	Chinook_1	0.941605112	0.609939034	0.574321713	134.75	137.96	141.43	0.015844272	9091.688201	14.94340897	5.254172601	16.84075717	12.25742149	139.0600067	0.973168206	1.38611640 9	5.877599895	30.08736367	14.17747386	426.8891246	0.839024216	22.08883476	447.7481384	0.664363301	0.464948738
1949	Chinook_1	0.942000372	0.559400553	0.526955529	127.72	130.85	136.59	0.017537158	9234.515506	12.94945104	5.198311031	16.87570109	12.38969002	120.5164642	0.967298961	1.21154499 1	6.432933338	26.94011805	14.56415224	348.1750488	0.828657081	18.48368025	375.0756836	0.654847707	0.392682514
1950	Chinook_1	0.928576577	0.676266122	0.627964881	133.92	137.07	143.16	0.016429105	10306.04221	11.75168593	6.582142174	13.75754345	11.37401638	91.47819061	0.979718511	1.11813993 5	6.660977289	25.79198251	13.31589651	277.3087845	0.869211962	17.3755029	295.1929321	0.736015241	0.493992436
1951	Chinook_1	0.926886352	0.629619214	0.583585456	132.46	135.59	141.77	0.016492583	9614.729479	12.69264017	6.761418253	13.60946011	11.56440849	106.2475845	0.962379003	1.18683548	6.311955489	27.66956288	14.05937449	346.9119212	0.825911174	18.36056487	362.5084229	0.682512611	0.460117974
1952	Chinook_1	0.927263613	0.701128219	0.650130685	128.1	131.08	136.7	0.017930073	11645.78668	12.73722036	6.736227177	14.10368204	11.03817692	159.6092651	0.952764869	1.10578517 9	6.573213719	26.72161721	12.84536997	362.3434397	0.812759966	18.36394135	374.9149788	0.725388215	0.536382743

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1953	Chinook_1	0.911897114	0.654167354	0.596533323	135.46	139.19	145.99	0.014705731	8762.806923	11.86233888	8.310674816	11.52920858	11.32862549	88.83659515	0.975392222	1.084403229	6.632722433	25.82464734	13.59121561	281.8044357	0.866138905	17.44076316	297.3147278	0.692360508	0.494086118
1954	Chinook_1	0.922574265	0.675024034	0.622759802	141.28	144.28	148.99	0.01373757	8546.658305	12.17390398	7.236205108	12.89355536	11.42132835	98.67952271	0.9631935	1.124915028	6.304457039	27.66953762	13.45789115	314.7511037	0.840987474	17.81955544	326.6013794	0.713830504	0.512664237
1955	Chinook_1	0.929906421	0.648177994	0.602744879	136.84	140.36	146.38	0.014973614	9015.730534	11.42092211	6.429598212	13.9405412	11.37709293	88.4086853	0.97803303	1.05502367	6.743965469	25.17353664	13.63694318	245.5205256	0.888633341	16.98496771	256.5126343	0.712570721	0.481173701
1956	Chinook_1	0.906133693	0.697463847	0.631995491	122.85	126.91	132.9	0.018123427	11442.39662	13.25276559	8.808096752	11.58526579	10.76030407	138.3050171	0.966805625	1.306995201	6.79120408	25.43286515	12.57335504	364.3822327	0.828549753	19.43841267	375.5515747	0.703769236	0.536374071
1957	Chinook_1	0.893339143	0.678638308	0.606254165	124.48	128.66	133.35	0.017154189	10388.49071	13.55484813	10.19157058	10.46273715	11.20806351	125.598822	0.966902637	1.135985565	6.524390794	26.77976734	12.78352737	385.42217	0.816754232	19.31088352	410.7419739	0.666248665	0.515012875
1958	Chinook_1	0.939178492	0.65522653	0.615374664	129.05	132.12	137.04	0.016911182	10399.38282	12.88507894	5.45395501	16.15490511	11.60430222	121.9439301	0.970582187	1.154717731	6.365319476	27.5624409	13.44754855	354.4240316	0.827302625	18.6006004	375.657074	0.704563601	0.506928404
1959	Chinook_1	0.927685893	0.586954387	0.544509305	137.88	141.2	146.27	0.01460657	7946.030817	12.13008451	6.619180784	13.72166113	12.13734379	83.29364471	0.979535532	1.203538513	6.367312796	27.06465894	14.44059674	297.7823537	0.857791076	17.94772418	308.4461365	0.657048202	0.426673762
1960	Chinook_1	0.925295688	0.62760858	0.580723512	136.05	139.16	144.53	0.01558199	9039.469196	11.72261773	6.923245594	13.07176348	11.39951496	84.55063477	0.979423833	1.160501385	6.670934319	25.50935491	13.9031024	261.7273966	0.880183806	17.46096881	271.8879395	0.695524332	0.454909777
1961	Chinook_1	0.895946799	0.607677799	0.544446979	123.41	127.49	134.77	0.017865012	9717.220352	11.73511944	9.849876508	9.984995959	11.42545509	62.3269577	0.976623905	1.092525959	7.117362283	23.48153871	13.94940964	262.4614207	0.880164305	17.33185228	273.1824036	0.637186369	0.437397764
1962	Chinook_1	0.912245832	0.672306129	0.613308464	122.02	126.07	133	0.019032317	11660.41318	11.57837319	8.143001921	11.66511708	10.84412975	86.22023621	0.985022473	1.149559116	7.351481594	22.75646516	12.99183957	251.0541738	0.886989931	17.33767239	256.1709595	0.718465039	0.468362644
1963	Chinook_1	0.896580765	0.574516687	0.515100611	122.97	126.92	133.87	0.018193594	9361.208348	10.95920784	9.807044894	10.38159926	11.62855854	75.14878693	0.967859614	0.95895319	7.416600794	22.18532549	14.13773648	217.6136703	0.899022082	16.28691419	226.8298344	0.630147911	0.407795359
1964	Chinook_1	0.936426246	0.609347576	0.570609063	135.29	138.57	144.41	0.015312177	8728.04168	11.86279212	5.783794835	15.35983009	11.67931919	101.2356598	0.974354732	1.105082798	6.352858052	27.30035613	14.36171373	291.8307393	0.859381417	17.46334791	305.9496155	0.711355688	0.419394153
1965	Chinook_1	0.944744319	0.497828892	0.470321017	146.36	149.43	148.21	0.01300828	6112.78482	12.33477572	4.968125656	17.73091952	13.62976742	135.2108521	0.958056331	1.181816101	6.149210326	28.29269537	14.7521855	325.539327	0.822197835	17.99597122	332.7698669	0.572586705	0.38138443
1966	Chinook_1	0.871501107	0.670544651	0.584380406	118.74	124.57	131.52	0.01965926	11476.82599	10.93972591	12.25987186	8.531453612	10.66532478	58.73991699	0.965168262	0.915812969	7.756333426	21.3169436	12.3492926	219.4164098	0.893023682	16.20354605	236.4047089	0.675214291	0.465105698
1967	Chinook_1	0.910851918	0.710139328	0.646831768	128.01	132.01	138.8	0.017566125	11351.44096	11.53518966	8.291448459	11.2603182	10.86968231	62.52724228	0.969860578	0.999725628	7.016275726	24.29462028	12.44458246	260.0910467	0.877389411	16.9295942	276.5617371	0.735702393	0.526233183
1968	Chinook_1	0.937565747	0.408110945	0.382630843	141.54	144.55	145.9	0.014106951	5393.086405	10.9969323	5.615753599	15.62775173	14.79137745	71.10960236	0.956375873	1.006910706	6.663950138	24.89832647	15.67375008	232.7833023	0.874175608	16.19824251	243.932724	0.552925443	0.253497621
1969	Chinook_1	0.902436718	0.623429557	0.562605723	121.58	125.47	132.36	0.018880455	10611.90831	12.69261166	9.202322118	11.12789181	11.0805151	113.386087	0.973386145	1.221264553	6.89298138	24.73873978	13.96745682	334.0370382	0.837221195	18.42740568	346.5262451	0.668496946	0.440468058
1970	Chinook_1	0.913740141	0.671385961	0.613472302	130.14	133.7	139.87	0.015975565	9791.469898	11.25051144	8.024923407	12.04062043	11.23813343	94.77518463	0.955091608	0.925585365	6.980564818	24.2949341	13.01663303	252.3484421	0.870297223	16.51757256	262.0503235	0.692861075	0.526162192
1971	Chinook_1	0.94914256	0.618053417	0.586620803	139.54	142.58	145.84	0.014461049	8476.242527	13.93855844	4.538954891	18.99980906	12.47486534	153.8974213	0.958529794	1.268523216	5.647075713	32.03135534	14.2178305	423.0275625	0.784229567	19.98452075	427.6967773	0.714901711	0.481277618
1972	Chinook_1	0.927067046	0.611353837	0.566765996	127.65	130.88	136.87	0.016675407	9442.89908	13.85228263	6.670724474	14.17220295	11.90922947	123.3926147	0.976343942	1.308959484	6.236855924	27.83003917	14.30636215	387.0840302	0.830152889	20.2781353	393.1380312	0.667285026	0.453390758
1973	Chinook_1	0.88885457	0.548733634	0.487744398	126.22	130.8	137.19	0.016088301	7838.703164	10.21624395	10.62034435	9.602387417	11.83526173	54.35994339	0.939919651	0.9034132	7.553182669	21.6597862	14.14437946	176.7596181	0.893845281	15.08821217	186.2350159	0.568599073	0.386582683
1974	Chinook_1	0.944071447	0.578793798	0.546422698	137.29	140.71	144.88	0.014752441	8054.615132	13.77100512	5.015065014	17.47272012	12.66381779	137.8013763	0.959726834	1.296234417	5.859670542	30.25790181	14.73461119	403.0603333	0.805182864	20.03444783	406.5570984	0.670092468	0.403607966
1975	Chinook_1	0.944490532	0.588835357	0.55614942	147.11	150.56	153.56	0.011210102	6229.503422	12.58894035	4.965929739	17.4883015	12.59099846	127.7710251	0.966871297	1.219190598	5.967390075	29.41899212	14.34786574	334.2131958	0.824848125	18.27005005	342.1758118	0.64579236	0.45877565
1976	Chinook_1	0.921274994	0.723050685	0.666128515	124.38	127.77	134.15	0.018664266	12421.0924	12.87717359	7.257619441	13.23277822	10.7641531	125.5688583	0.973415685	1.188414863	6.727562062	25.94914785	12.51071548	353.3695984	0.825597992	18.57297421	366.9285278	0.756186103	0.560776593
1977	Chinook_1	0.911862878	0.49929769	0.455291029	132.54	136.53	142.24	0.015328032	6971.79978	9.450152022	8.214044109	11.20883701	13.14298668	38.55773315	0.945009112	0.823343754	7.659936383	21.07548437	14.75990661	142.788147	0.909552753	13.89306445	148.3406219	0.583046014	0.327960921

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1978	Chinook_1	0.869989138	0.711901829	0.619346858	118.09	123.08	130.4	0.019198332	11877.21616	11.62720254	12.59326241	8.708083506	10.38503952	94.29417725	0.980024517	1.079886341	7.531386115	22.14946813	12.12932984	267.6116638	0.875553826	17.36266152	274.8617249	0.694180188	0.507525743
1979	Chinook_1	0.875991487	0.721360655	0.631905793	117.9	123.01	130.42	0.019624834	12387.97749	11.15217829	11.85167457	8.9058697	10.31484909	72.77512589	0.970816755	0.879457664	7.709854893	21.66618592	11.94682455	246.8464228	0.882419566	16.55053266	260.4804688	0.726531818	0.482045825
1980	Chinook_1	0.93991957	0.623472754	0.586014243	138.08	141.4	146.98	0.013791463	8075.936106	12.35049663	5.399966009	16.32364847	11.93231602	111.2781433	0.958391964	1.180757141	6.236740068	28.11891937	14.17053032	331.0133921	0.828378717	18.14845864	334.5569153	0.674249405	0.477476145
1981	Chinook_1	0.900192263	0.499438603	0.449590764	132.67	137.11	137.27	0.015536482	6977.808471	11.35453081	9.555914775	10.72119083	13.38823948	85.48097687	0.962440968	1.026318932	6.876742929	24.06418914	14.9556551	257.0675151	0.868207196	16.8061889	262.5525513	0.601491997	0.330339289
1982	Chinook_1	0.943886299	0.522807638	0.493470967	144.71	147.57	148.32	0.012764822	6294.037365	13.03008958	5.041922167	17.50081675	13.46438522	128.2789444	0.96732111	1.258992767	5.86477492	29.96628415	15.16337077	361.0802917	0.816505641	18.92292039	364.9697571	0.644556709	0.364643549
1983	Chinook_1	0.912235771	0.589763998	0.538003816	126.71	130.27	136.36	0.015611425	8391.101238	11.8879994	8.209963776	12.13898892	11.97725792	105.9490158	0.974818206	1.156180573	6.813040696	24.80909892	14.21512699	284.8371277	0.856303453	17.53405825	291.5667419	0.638027451	0.442856938
1984	Chinook_1	0.943318872	0.587335192	0.554044371	130.86	134.21	138.83	0.016094411	8910.027308	11.78775549	5.068282306	17.08178325	12.34697399	123.1325699	0.976578987	1.145207596	6.673440479	25.46470265	14.08726867	275.2105662	0.865318179	17.49943463	281.9351196	0.666289881	0.439044433
1985	Chinook_1	0.870488156	0.705943214	0.614515207	118.04	123.39	130.99	0.019365278	11888.67757	11.23055727	12.45754977	8.730164665	10.10659237	92.3706131	0.979445267	1.055748653	7.819456428	21.07637593	12.12232335	218.0826569	0.907713165	16.88529619	223.8692169	0.695462422	0.490003517
1986	Chinook_1	0.898020396	0.540958789	0.485792026	127.64	131.72	135.4	0.016658896	8084.753116	11.63381423	9.758089416	10.4639178	12.04646282	103.4543228	0.974118423	1.101505375	7.050440215	23.50996958	14.29731242	254.5388565	0.879280984	17.3092262	258.1813354	0.584277663	0.397132418
1987	Chinook_1	0.91485856	0.49971266	0.457166405	121.74	125.63	131.14	0.019493826	8905.648857	11.66559345	7.812431037	12.28298768	13.12041416	63.16126862	0.978138721	1.135641766	7.180689178	23.05160128	14.56090403	268.5461655	0.872782369	17.36440198	276.5710754	0.588271415	0.336076163
1988	Chinook_1	0.850889159	0.691161886	0.588102156	116.74	122.93	130.7	0.019357969	11372.48608	10.31989721	14.60244667	7.532225755	10.2402977	57.27506256	0.968094265	0.881466579	8.142564349	19.95885462	11.9684871	176.5716832	0.919927289	15.31967163	180.3801422	0.683119718	0.460307736
1989	Chinook_1	0.932490043	0.538117312	0.501789035	143.66	147.14	151.76	0.013133271	6585.179631	11.60422438	6.124598064	14.43064719	12.12050991	75.94868774	0.981603098	1.161755466	6.585004777	25.91268739	14.82100232	246.3459167	0.888988088	17.3304135	252.93013	0.655122	0.354336633
1990	Chinook_1	0.937939556	0.399101619	0.374333195	132.3	135.82	139.84	0.017161879	6418.920605	11.09339234	5.571617745	15.53719995	14.07530346	62.48364182	0.977507198	1.135574818	6.974780381	23.48421567	15.71195857	211.1404673	0.908140808	16.64465396	210.0681915	0.588613535	0.249601963
1991	Chinook_1	0.899317841	0.591592275	0.532029488	128.2	132.39	138.96	0.016657544	8853.245697	11.63087967	9.521862343	10.34831985	11.69287987	64.33817596	0.970375407	1.085660934	6.888060369	24.47311891	14.14747016	268.5400518	0.868234247	17.17609088	271.1170349	0.629436896	0.424705098
1992	Chinook_1	0.910411948	0.485355513	0.441873458	124.25	128.27	132.59	0.018980949	8378.460151	10.97966514	8.249876574	11.33125286	13.320401	50.94631577	0.969634175	0.979882052	7.431112863	21.93159293	14.59220235	210.6557261	0.905782392	16.41995716	216.4525146	0.562765233	0.344449968
1993	Chinook_1	0.914574886	0.714940321	0.653866462	123.84	127.48	134.63	0.018910629	12354.14991	11.60901407	7.905177757	12.12949287	10.74484444	87.90304108	0.964895976	0.876413345	7.239695139	23.54121715	12.22653866	269.2114563	0.871506065	16.83012795	292.7973938	0.743943145	0.526308105
1994	Chinook_1	0.934269144	0.455236774	0.425313666	129.4	132.84	137.85	0.017766331	7549.861199	11.15805251	5.915153168	14.80606142	13.13755341	61.05918503	0.976181746	1.093953323	7.064849511	23.36063654	14.8508625	214.4558055	0.905860394	16.7173934	220.9073334	0.570382168	0.305089951
1995	Chinook_1	0.905557242	0.610222343	0.552591262	131.64	135.24	141.6	0.015459903	8534.399464	11.50233214	8.968438603	11.03083773	11.63440666	96.75101929	0.970095873	1.052272797	6.824834332	24.75212459	13.96780952	263.1435572	0.869932761	17.00245825	275.2388611	0.645185947	0.453328524
1996	Chinook_1	0.941996149	0.509598544	0.480039866	142.48	145.12	147.27	0.012745749	6112.984685	12.41856074	5.230404035	16.96101494	14.07700405	122.1772705	0.957944131	1.182934475	6.117490284	28.30317574	15.09226036	329.8155212	0.823770801	18.03076315	339.9545288	0.615747921	0.360428156
1997	Chinook_1	0.946483089	0.545813906	0.516603632	135.34	137.94	140.26	0.015470678	7986.065159	15.54184324	4.791926585	18.32558962	12.90720158	161.2550079	0.96183145	1.454152775	5.643941194	31.7458262	14.82599624	466.9888865	0.802331487	22.55190325	477.5127258	0.641513992	0.410694697
1998	Chinook_1	0.897520841	0.616904132	0.553684315	121.4	125.16	131.65	0.018807835	10403.29145	12.40403012	9.720274307	10.83891049	11.33827896	108.0198166	0.963042951	1.070991135	6.891332634	24.86088313	14.00749095	341.8098043	0.824360291	17.93805154	355.5706482	0.647388977	0.439121395
1999	Chinook_1	0.910314767	0.603042468	0.548958463	124.08	127.41	134.46	0.018645182	10226.49111	11.68676703	8.407989465	11.63040329	11.50208092	96.98786316	0.977349925	1.15023365	7.260104343	22.83742931	13.99814749	254.5374934	0.886873225	17.4841164	257.638031	0.662074213	0.429007093
2000	Chinook_1	0.939129692	0.444206267	0.417167294	132.87	136.43	138.75	0.017118998	7136.000561	11.6743084	5.46339988	16.04267226	13.15479259	85.86859283	0.983289921	1.237781048	6.794367	24.42740991	15.05314976	243.4088593	0.892071575	17.53062073	251.6460419	0.578700319	0.290036662
2001	Chinook_1	0.866582629	0.569371644	0.493407572	118	123.26	131	0.019279807	9503.974415	9.683152028	12.85289158	8.470676395	10.97311344	51.79628448	0.941249418	0.800977234	8.183424525	19.58016227	13.95881287	151.4381994	0.908760846	14.20861101	160.840744	0.620695634	0.374770511
2002	Chinook_1	0.907167293	0.651018825	0.590582985	123.39	127.53	134.42	0.018333961	10816.17539	11.45933758	8.665487133	11.11645865	10.99778099	68.43727264	0.982338631	1.135490227	7.325115487	22.59505424	13.29346832	233.6345444	0.900170207	17.17268342	239.8310852	0.692218387	0.48447093

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
2003	Chinook_1	0.922419221	0.613440121	0.565848959	132.44	136.2	143.41	0.015697272	8873.612551	11.7033611	7.172438771	12.77779744	11.74065323	79.32934418	0.975928009	1.075335503	6.838541475	24.63302515	13.93913349	254.4398193	0.884607742	17.19712782	275.8760986	0.658540896	0.450808519
2004	Chinook_1	0.857281573	0.609956515	0.522904481	116.72	122.82	129.96	0.019316241	10090.06253	11.1859107	13.85596245	8.164782722	10.67100582	64.00260229	0.977384746	0.977604866	7.730462141	21.09205076	13.67416636	222.7172724	0.899199078	16.63413207	247.6680145	0.637184921	0.386016776
2005	Chinook_1	0.913500082	0.535140771	0.488851138	125.9	129.56	135.24	0.017985912	8783.006571	11.14835531	8.044193149	12.0675182	12.76865902	73.70869293	0.975040579	1.026327229	7.200680412	22.85319336	14.6706473	226.0914027	0.89683342	16.57814709	237.0324249	0.607109311	0.360889378
2006	Chinook_1	0.9220316	0.70461293	0.649675388	123.43	126.76	133.69	0.019099115	12395.55074	12.14241372	7.201533936	13.23062203	10.84738789	128.2048233	0.975634634	1.15542841	7.118512742	23.78443816	12.5982097	293.9065145	0.864635895	17.95979023	302.4699097	0.744255513	0.520579903
2007	Chinook_1	0.907253244	0.558401658	0.506611715	124.07	127.7	133.7	0.018318887	9270.186426	11.65544173	8.722811095	11.39217949	12.55857658	74.40320435	0.981365502	1.157709789	7.106451534	23.26193083	14.50571998	255.9834391	0.884328038	17.42003934	265.168335	0.620780108	0.379962908
2008	Chinook_1	0.841167728	0.677696541	0.57005646	117.74	123.79	131.21	0.01896472	10801.45058	10.78834159	15.89177936	7.332983187	10.52701874	73.00832138	0.961367249	0.850131035	7.793945424	20.98398131	12.57913319	213.8724162	0.896374792	15.76177502	229.9109497	0.656095578	0.469412555
SCN MO3-RESSIM-SAL																									
1929	Chinook_1	0.928357245	0.663241138	0.615724715	124.99	127.68	135.22	0.018773299	11550.51369	9.438097358	4.620796092	18.69584258	11.09575596	54.09363785	0.926754498	0.753186752	8.239862502	19.73869295	12.64982144	143.4582901	0.897204896	13.82458091	155.3191376	0.721357667	0.479128455
1930	Chinook_1	0.905715686	0.669794688	0.606643556	103.93	109.4	117.55	0.018480173	11199.03957	9.315341473	7.829573594	11.69708146	9.682554626	59.33450851	0.933146691	0.663420486	9.006323993	17.48631561	11.43564685	148.2828293	0.905412883	13.47640864	156.6886139	0.667089083	0.493489616
1931	Chinook_1	0.897166759	0.673322238	0.60408233	106.55	111.67	119.89	0.018933895	11425.90796	8.909744757	8.50026194	10.74549776	9.566019058	42.97081604	0.917611587	0.655017328	9.133262418	17.29348145	11.54120938	133.7082278	0.888176262	12.97230148	142.1733398	0.68359845	0.506085085
1932	Chinook_1	0.929680119	0.738292445	0.686375809	117.64	120.5	127.92	0.019415569	13315.93128	11.64225657	4.995455891	17.43620728	10.32642632	82.57201233	0.970048988	1.024285984	7.953401983	20.77201338	11.68748871	272.6408437	0.863793353	17.21590281	287.9810181	0.775746599	0.561399976
1933	Chinook_1	0.927657514	0.618050463	0.573339156	131.16	133.78	140.84	0.017058653	9769.590473	11.26841576	4.46476157	19.48336896	11.63727741	56.05530777	0.977275312	1.101433849	7.218110833	22.94945364	13.71609894	217.1445516	0.905762891	16.87788757	226.0842591	0.689152871	0.452978439
1934	Chinook_1	0.921984172	0.63430988	0.584823669	114.54	117.26	123.05	0.019012535	11107.61216	11.93448608	5.161730133	16.98495696	11.14434586	78.89875641	0.962951398	1.109517002	7.910318844	20.61534151	12.78478209	307.4966736	0.842089842	17.69121091	314.8917542	0.655469419	0.491222539
1935	Chinook_1	0.928366336	0.589334152	0.547117987	125.64	128.12	135.22	0.018355195	10032.63339	11.14251763	4.243967913	20.44746447	11.80034485	62.74397888	0.97624929	1.038751221	7.412624091	22.16636332	13.94932238	216.542689	0.904879669	16.62836742	228.7690125	0.665206852	0.41529457
1936	Chinook_1	0.94292368	0.725787635	0.684362348	116.42	118.93	126.3	0.019637061	13426.18374	11.86870698	4.132692635	20.95292767	10.02758312	127.4037766	0.977493989	1.1084198	7.855603978	21.14027477	11.43790976	291.1034139	0.861323029	17.60401789	302.5303955	0.747185788	0.578085168
1937	Chinook_1	0.919801304	0.671146326	0.617321266	124.7	127.36	134.41	0.018664225	11509.30278	10.07727953	5.835220024	15.54447275	10.68247204	54.94858475	0.945712519	0.810753727	8.065014698	20.20556713	12.69368696	171.4309845	0.902765075	14.81843249	185.1851654	0.718340843	0.486177493
1938	Chinook_1	0.9428013	0.629521195	0.5935134	129.62	131.99	136.6	0.017071435	10122.72197	12.00351555	3.458891086	24.76891889	11.4953577	108.5496277	0.969272459	1.14256773	6.970343128	24.20331774	13.50309261	294.8815918	0.855849624	17.72454214	304.1505737	0.68442386	0.500519153
1939	Chinook_1	0.932663434	0.731213437	0.681976035	116.26	119.3	126.59	0.019587993	13345.93513	11.16653105	4.777873665	18.23326605	10.25021286	84.20984497	0.97961868	0.95206461	8.087913424	20.14072318	11.32936859	227.6637472	0.901059459	16.67254194	237.4466248	0.743088443	0.565992173
1940	Chinook_1	0.897181013	0.742712704	0.666347736	95.01	101.29	110.51	0.016450009	10949.51181	9.802108662	9.067651533	10.05293569	8.90916481	83.4686203	0.863576818	0.572818279	9.460835293	16.85600007	10.30773735	196.2595113	0.822981685	14.14470164	207.3538208	0.727145559	0.527705986
1941	Chinook_1	0.918098565	0.493396161	0.452986307	132.94	135.1	136.13	0.016191668	7327.563683	10.41049198	4.073638529	21.23039188	13.41648827	57.05632095	0.962566257	0.892770291	7.492185284	21.56433934	14.66070016	182.6404419	0.910226603	15.48247911	189.6040039	0.579117487	0.338307767
1942	Chinook_1	0.935438284	0.671149153	0.627818612	135.78	137.98	144.35	0.015228612	9550.248597	11.05712261	4.391121432	20.29452976	11.22541373	82.89598694	0.965047085	0.956099224	7.113450147	23.64040405	13.06001177	235.5717392	0.881979436	16.31633027	248.7467804	0.714020939	0.532304464
1943	Chinook_1	0.935659055	0.711297359	0.665531815	122.41	124.62	130.88	0.01863345	12388.47748	11.72582323	4.952138975	18.10939747	10.18534355	122.8862	0.960627377	1.063215733	7.834138677	21.07599561	12.05594778	286.7305196	0.853049695	17.32240311	291.9794312	0.749021977	0.563169822
1944	Chinook_1	0.931310454	0.590925301	0.55033491	130.65	133.04	140.48	0.016981049	9336.897777	10.07594139	4.167114973	20.84824354	11.71320038	62.59826965	0.951079655	0.863035774	7.579258025	21.58965751	13.79551586	165.8682454	0.913728426	14.90815695	173.5161591	0.672283972	0.423043543
1945	Chinook_1	0.924807161	0.689729067	0.63786638	118.92	122.12	129.29	0.01933525	12321.88067	10.52537233	5.181002282	17.04313545	10.72434158	67.20752563	0.950236261	0.799880028	8.039165817	20.33454015	12.31391048	203.0233793	0.891943653	15.49829809	220.8336029	0.725533353	0.532332943
1946	Chinook_1	0.935184073	0.771101909	0.721122224	110.64	113.62	121.65	0.019541975	14080.43201	12.05360048	5.259769082	16.71379025	9.310554695	114.8619568	0.964967299	0.97758646	8.329153091	19.90520286	10.59236765	320.6518351	0.841193825	17.63082536	335.6883545	0.784962064	0.571880426
1947	Chinook_1	0.927380933	0.690091069	0.6399773	110.45	113.93	121.7	0.019445428	12433.51031	11.49793938	5.478531554	16.12173416	9.992050362	86.89625397	0.975447917	0.955011559	8.201914877	19.67619356	12.03587262	258.8485896	0.881453454	17.00418901	274.0377502	0.712865347	0.532115202

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1948	Chinook_1	0.945119325	0.630634255	0.596024622	132.96	134.96	138.86	0.016586742	9877.411462	14.36502644	3.100323163	27.59181269	12.01188374	133.5401215	0.973454964	1.3467103	6.212298058	28.01236613	13.74781593	402.7114919	0.841107508	21.22118648	422.3431396	0.682546329	0.501276969
1949	Chinook_1	0.941611146	0.57467434	0.541119764	126.06	128.17	134.11	0.018041006	9755.164467	12.70623715	3.166792646	26.95728627	12.16335049	118.1861816	0.971138489	1.203732204	6.761429861	25.21350864	14.31419945	330.6573639	0.840229799	18.30280765	355.2485352	0.647447379	0.424858619
1950	Chinook_1	0.94036978	0.687996791	0.646971392	132.28	134.4	140.46	0.01730984	11187.14059	11.58511996	3.772573136	22.84777049	11.26592464	89.06238098	0.978500319	1.076886272	6.988166861	24.20840262	12.89646228	267.0198491	0.874024898	17.15627495	283.9216003	0.746000954	0.524038509
1951	Chinook_1	0.940750052	0.646071863	0.607792138	130.78	132.73	139	0.017169196	10424.32708	12.55734726	3.752009198	23.14820785	11.39031487	105.1453979	0.962851048	1.160851383	6.658380553	25.74358342	13.61442757	341.0569051	0.828355054	18.19307852	356.8728027	0.700071326	0.507302038
1952	Chinook_1	0.948563121	0.724390861	0.687130455	125.29	127.26	133.33	0.018497978	12698.39637	12.59995409	3.539834403	24.41712368	10.65001907	157.7332123	0.952232862	1.073069286	7.074994273	24.33571603	12.19411977	355.3974406	0.815536181	18.17764521	369.6945496	0.766291828	0.569664985
1953	Chinook_1	0.932248763	0.670684269	0.625244585	132.34	134.84	141.54	0.01581472	9877.144243	11.33277103	4.667881675	18.88274721	11.04626389	82.66471863	0.963035846	1.003823853	7.136217594	23.47014072	13.06417243	255.5237986	0.868219296	16.66242027	270.4333191	0.700204153	0.530137758
1954	Chinook_1	0.942225263	0.690524188	0.650629334	139.47	141.18	145.81	0.014798377	9618.560258	12.09317327	3.857077681	22.60513913	11.16204472	101.815036	0.961155427	1.094530773	6.591175959	26.00215234	12.97707033	310.8389537	0.843387206	17.71063169	320.8485107	0.739217437	0.548357117
1955	Chinook_1	0.939907352	0.649376869	0.610354094	135.09	137.18	143.15	0.016044114	9782.246571	11.21886454	3.834919341	22.61800312	11.27868443	84.46255035	0.973273134	1.015513134	7.003823698	23.97905391	13.45767927	236.9499054	0.889005661	16.6441342	249.4746857	0.710309469	0.498224031
1956	Chinook_1	0.942830813	0.730517814	0.688754705	117.66	119.99	126.59	0.018336651	12616.7358	13.54564531	4.175037801	20.7840104	10.15770817	138.2622681	0.960046601	1.195939445	7.436139166	22.84295589	11.65557337	391.1296692	0.815131992	19.64155881	407.0189819	0.74529955	0.598098587
1957	Chinook_1	0.93420003	0.712891317	0.665983093	117.2	120.63	126.48	0.017264897	11485.62665	12.4783505	4.874808751	18.01972988	10.44516907	121.3573898	0.958111489	1.010146332	7.471507877	22.06259203	11.87573687	318.8364512	0.847169886	18.07206059	334.7771301	0.724474882	0.586036635
1958	Chinook_1	0.945098289	0.677484047	0.640289013	127.42	129.53	134.74	0.017588408	11253.74243	12.62359684	3.369606204	25.33954533	11.32692077	118.6450653	0.971179339	1.122543433	6.706416637	25.75250368	12.97368447	334.4650167	0.838060091	18.29690504	355.6206055	0.721605223	0.541177968
1959	Chinook_1	0.937574189	0.618540239	0.579927363	136.17	138.11	143.74	0.015487596	8973.340495	11.9423462	3.689203463	23.2951907	11.81298332	81.67079468	0.978894567	1.168298054	6.679508828	25.37194204	13.89189736	285.24322	0.864681234	17.72503026	295.7714539	0.680907938	0.472769548
1960	Chinook_1	0.939273595	0.643443154	0.604369164	134.4	136.23	141.46	0.016560174	9998.075631	11.64194281	3.949062288	21.99997941	11.22958927	87.2541687	0.973897505	1.129856777	6.921292625	24.31964034	13.52531926	263.1848272	0.874287566	17.33599822	272.0845642	0.708676601	0.488229596
1961	Chinook_1	0.919747768	0.655184248	0.602604254	118.75	121.99	128.36	0.01847832	11124.42424	11.24106373	5.695669383	15.68269351	10.75580101	61.61362991	0.969704497	0.983410835	7.83823806	20.7723757	12.90828292	236.7375488	0.886421273	16.64094766	246.0447544	0.689868878	0.505605335
1962	Chinook_1	0.936064364	0.702404429	0.657495756	119.62	122.22	129.44	0.019364029	12718.34469	11.51017186	4.443298809	19.54585256	10.53264713	89.14200134	0.982349348	1.115723515	7.789803714	21.19423823	12.25125249	248.4126867	0.886856963	17.22060442	254.2181549	0.742019176	0.527336656
1963	Chinook_1	0.922118709	0.634666021	0.585237412	118.22	121.31	127.76	0.018618624	10884.29018	10.52154963	5.453058347	16.24292243	10.84863815	68.49351196	0.95689857	0.851952267	8.091965444	19.92364453	12.95043262	198.5020243	0.901066542	15.5339032	208.074707	0.671159652	0.489117992
1964	Chinook_1	0.942494274	0.626186666	0.590177347	133.63	135.81	142.01	0.01631529	9618.75833	11.59098104	3.510752045	24.59205289	11.49808865	92.38935547	0.971550941	1.038137913	6.662766531	25.67829191	13.98245637	273.5558395	0.866659204	17.07802057	288.6371155	0.714211087	0.451514877
1965	Chinook_1	0.941251681	0.531608693	0.500377576	144.43	145.95	145.77	0.013674135	6836.316417	12.33659666	2.765829861	30.83941682	13.28970165	135.6426117	0.959360541	1.166245174	6.334494241	27.24293899	14.34512521	328.1638082	0.822462718	17.99944291	335.7718811	0.597366596	0.418367164
1966	Chinook_1	0.917763411	0.710897239	0.652435474	111.14	115.02	123.11	0.019398043	12643.02082	10.34324799	6.198017053	14.27082342	10.03481083	60.78222275	0.964766836	0.850830936	8.59162011	18.60154749	11.3954277	186.8302892	0.908937355	15.27993361	197.0668335	0.716803651	0.550772086
1967	Chinook_1	0.927480631	0.721887857	0.669537006	125.08	128.22	135.24	0.018387265	12299.13864	10.91832117	5.019380093	17.31911221	10.62183495	56.82792053	0.961050284	0.904004383	7.594456963	21.87951701	11.98006455	224.894165	0.889247576	16.05786689	238.1805573	0.744087681	0.550486151
1968	Chinook_1	0.921347794	0.433878443	0.399752947	139.77	141.64	143.16	0.014983956	5984.704386	10.72303346	3.302830435	25.87403081	14.55237217	69.4795929	0.95501703	0.969315243	6.919244632	23.69058379	15.31413603	219.2219823	0.877092779	15.81810188	229.0761261	0.574595784	0.283075587
1969	Chinook_1	0.937039861	0.679561201	0.636775933	117.41	119.97	126.7	0.019067885	12130.12997	12.24131935	4.547307834	19.23751374	10.33544292	112.4046646	0.969492793	1.145501614	7.639783129	21.72053702	12.68086195	315.5476278	0.841802905	17.97409534	322.7494507	0.724912853	0.536266298
1970	Chinook_1	0.933650678	0.691826851	0.645924608	127.1	129.39	135.9	0.016863251	10882.2678	10.68209999	4.516891666	19.27573168	10.89266911	86.61368408	0.948676729	0.861142731	7.501571	22.1127754	12.47384771	224.7757111	0.874355048	15.67931422	233.5615387	0.712595866	0.547157878
1971	Chinook_1	0.950421234	0.635299045	0.603801702	138.89	140.6	144.3	0.015043949	9076.155237	13.86327008	2.661568828	31.93759469	12.33267479	152.385495	0.95882988	1.256460953	5.781855084	31.1080233	13.9498388	419.086085	0.786630968	19.87769381	424.659668	0.701578178	0.504828537
1972	Chinook_1	0.942491373	0.648699162	0.611393364	125.5	127.69	133.13	0.017308821	10573.35491	13.41639478	3.54624708	24.20599601	11.46660709	119.6628113	0.975463521	1.250487137	6.699467972	25.29543562	13.53708685	365.7953695	0.837643961	19.73050499	367.8673706	0.691404906	0.518435254

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1973	Chinook_1	0.913193272	0.61408111	0.560774738	121.06	124.33	129.92	0.016860847	9445.15459	9.583750248	6.078401223	14.72326771	11.07201538	50.61755295	0.925488114	0.808424759	8.168217577	19.74445656	13.03069035	158.1300176	0.880983684	14.15889899	165.07901	0.637086951	0.479877248
1974	Chinook_1	0.945961269	0.60341346 2	0.570805765	135.51	137.44	142.07	0.015602157	8898.67147 5	13.60699507	2.917803772	29.21484027	12.35430679	135.994458	0.959305787	1.263627911	6.121632688	28.68479882	14.3066783	396.8688456	0.806306402	19.77745104	401.187439	0.67070397	0.45585484
1975	Chinook_1	0.946763035	0.60951038 5	0.5770619	145.26	147.18	150.99	0.012031773	6937.527592	12.46792262	2.866186619	29.72577534	12.36120605	125.9185928	0.968297374	1.197625542	6.140501022	28.30116526	14.07195505	326.4931183	0.831149876	18.15639861	333.5541992	0.671157847	0.48701996
1976	Chinook_1	0.944512814	0.74312619	0.701892206	121.33	123.77	130.81	0.019166434	13440.05953	12.45662083	3.954241969	21.83101861	10.26920013	120.8968262	0.974516821	1.160975838	7.361222409	23.04344136	11.80036942	323.5615031	0.843233585	18.17840799	334.282074	0.782579656	0.600045344
1977	Chinook_1	0.909786448	0.52927718 1	0.481529207	129.65	132.32	137.5	0.016659357	8014.015434	9.314323766	5.047585279	17.38200224	12.73987713	37.89460449	0.933469534	0.80447979	7.985307954	20.08758073	14.26131884	138.8086065	0.900080781	13.67112811	144.9246216	0.592638734	0.363757509
1978	Chinook_1	0.923525729	0.74789709 1	0.690702206	109.73	113.34	121.59	0.018712171 1	12910.09117	11.25560365	6.247914135	14.36029351	9.533019066	87.91951752	0.969607198	0.940094376	8.417582348	19.16923826	11.06944895	243.0313288	0.879905781	16.72838721	256.3052368	0.756154021	0.564197621
1979	Chinook_1	0.916696722	0.74606971 2	0.683919659	112.4	115.78	124.12	0.019499401	13321.95754	10.46386387	6.556150682	13.72775406	9.737675476	61.28513336	0.945919383	0.732594442	8.617976129	18.82313951	11.0458498	200.5341899	0.888174961	15.30992802	223.416626	0.753047969	0.538413724
1980	Chinook_1	0.946236822	0.64251912 9	0.607975257	136.29	138.34	144.08	0.014791721	8986.253791	12.32258064	3.151192054	27.12809575	11.69546432	110.1160034	0.959941113	1.145692348	6.437539287	26.9974705	13.81822348	330.3928019	0.830715111	18.0730621	336.8589783	0.699804957	0.510350432
1981	Chinook_1	0.916968267	0.55128142	0.505507568	128.43	130.94	130.37	0.016070381	8115.252008	10.83142836	5.086183272	17.48265757	12.68612442	78.56468964	0.946115041	0.917032146	7.46695824	21.72565671	13.92365456	233.9461085	0.867104063	15.89580504	243.1517181	0.614237855	0.40212988
1982	Chinook_1	0.942309848	0.54725359 9	0.515682456	142.91	144.55	146.01	0.013721793	7070.428308	12.8958684	2.856555156	29.84335955	13.15684605	125.3093582	0.968404937	1.232223797	6.099171758	28.41383437	14.73233239	351.9441427	0.823171328	18.77408663	356.706543	0.654313961	0.402114933
1983	Chinook_1	0.934794136	0.64097775 7	0.599182248	123.11	125.5	130.4	0.016274931	9742.44478	11.69193765	4.240389757	20.52435274	11.36320229	101.2793457	0.969927776	1.057750702	7.302077278	22.68159313	13.23401642	278.8687744	0.858584056	17.22675276	286.9714355	0.669317688	0.512554673
1984	Chinook_1	0.944005160	0.61126674 2	0.577038959	129.19	131.42	136.5	0.016842334	9711.059592	11.73099286	3.102400057	27.42957441	12.14361057	123.3448364	0.97795428	1.134802437	6.91223751	24.35974867	13.65117757	269.8986257	0.870067110	17.458378	275.0627747	0.674789431	0.472922856
1985	Chinook_1	0.929962644	0.75249312 5	0.699790496	109.72	112.84	121.24	0.018983114	13271.2559	11.24351518	5.816444643	15.33226732	9.259793091	107.2824631	0.968920612	1.007415676	8.597940758	18.76483995	10.82669671	237.3315506	0.889238606	16.85472155	239.8343658	0.756317351	0.567001846
1986	Chinook_1	0.930119178	0.61181790 9	0.569063571	122.65	125.02	127.55	0.016737174	9515.06624	11.44802196	4.704209402	18.72195743	11.27041702	104.3336731	0.968245518	1.040338707	7.66722165	21.1335347	12.96167421	254.2948914	0.870465845	17.00908756	256.8279724	0.639497506	0.492320634
1987	Chinook_1	0.916999568	0.55806189 5	0.511742517	117.95	120.58	126.56	0.019739132	10094.24443	11.37784488	4.629806578	18.81898763	12.31899204	57.82825012	0.972962296	1.033363342	7.704874985	21.12582988	13.7583677	250.3982417	0.880652914	16.8565189	264.8221741	0.615427684	0.405420252
1988	Chinook_1	0.907851691	0.73467383 7	0.666974885	109.15	112.86	121.19	0.019048416	12691.42797	10.26950611	7.910556566	11.72246198	9.335994148	59.47561111	0.953155231	0.779426765	8.818678841	18.08733034	10.89493942	183.342308	0.910386682	15.20033487	190.3459778	0.728215020	0.543624293
1989	Chinook_1	0.940908683	0.56967737 9	0.536014393	141.85	143.9	148.51	0.014250797	7632.885911	11.56877116	3.409482844	24.97608008	11.81730518	78.12469025	0.982060456	1.162176704	6.814088196	24.73973231	14.29627609	242.4506811	0.893027226	17.32799371	246.5485077	0.668755265	0.409037777
1990	Chinook_1	0.923189594	0.43560972 9	0.402150369	131.6	133.82	138.24	0.017697939	7111.312131	11.13120954	3.431225017	24.8303309	13.88313637	62.96385422	0.979002941	1.137556171	7.10595274	22.97903123	15.33722814	212.4357808	0.908875664	16.71885204	211.2241821	0.590973204	0.275269244
1991	Chinook_1	0.921113165	0.64141759 5	0.590818188	123.59	126.65	131.76	0.017505447	10331.94377	11.31997476	5.417795964	16.39552016	11.0617485	60.4889595	0.965980363	1.000993538	7.508171231	21.89041704	13.11829869	250.6120046	0.877359817	16.75914784	252.1783447	0.676031145	0.504924243
1992	Chinook_1	0.910810052	0.54607624 9	0.497371737	121.11	123.73	128.33	0.019110675	9495.234416	10.49478633	4.775075763	18.23057276	12.79803829	49.30284119	0.960463846	0.874329376	7.924595751	20.20892302	13.72724899	192.4604289	0.906869034	15.59798845	198.3365326	0.592840117	0.406568109
1993	Chinook_1	0.933821883	0.72958478 3	0.681302236	120.74	123.53	131.05	0.019401013	13206.33739	10.82718524	4.602341816	18.79821446	10.44984303	78.15470886	0.951518726	0.757965136	7.924098767	20.89588734	11.63792626	221.8816961	0.889297575	15.80519867	240.2672272	0.763356593	0.558999401
1994	Chinook_1	0.924724046	0.47990910 4	0.443783488	128.68	130.92	136.18	0.018204273	8071.91086	11.13473667	3.671446666	23.33482813	12.9633976	60.64072266	0.976173246	1.078376007	7.224264994	22.74149917	14.63220263	213.3206762	0.906580091	16.6626579	221.3425751	0.567297063	0.346396058
1995	Chinook_1	0.931189519	0.64961319 9	0.604913002	127.36	129.61	135.21	0.016315072	9859.270229	11.06041428	4.729979694	18.64473668	11.09065399	92.08553772	0.959877551	0.969075108	7.436397344	22.11887845	13.06872327	240.9718882	0.874117325	16.31101433	250.9286652	0.677863385	0.520884012
1996	Chinook_1	0.936483339	0.53655690 2	0.502476599	140.7	142.07	143.9	0.013551144	6803.033687	12.41554291	2.894296721	29.45435112	13.74603443	122.2700714	0.958481181	1.168589115	6.343264647	27.05190433	14.66326014	331.6008403	0.824040045	18.04080296	342.4441833	0.632749284	0.404299767
1997	Chinook_1	0.946430549	0.56620245 4	0.535871299	134.64	136.19	138.76	0.015900943	8514.320101	15.36325966	2.685642488	31.70962641	12.71912651	161.8798187	0.961773491	1.424841691	5.846291997	30.33602254	14.50329383	462.8523	0.801067054	22.30143468	471.9979858	0.649493542	0.431130159

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1998	Chinook_1	0.926089561	0.674060213	0.624240126	116.01	118.99	125.79	0.019044151	11876.3433	11.57161025	5.388713598	16.47037562	10.52623863	89.67572021	0.954813766	0.901768494	7.788991205	21.14025883	12.71329308	281.4712499	0.854088823	16.76849063	300.2525635	0.718533039	0.532163184
1999	Chinook_1	0.933498789	0.644595396	0.601729022	121.06	123.27	129.54	0.019079447	11470.63029	11.65958217	4.460633345	19.59851642	10.97312603	99.10372162	0.972421694	1.083430195	7.731935576	21.20799847	13.11705494	269.2231191	0.872255584	17.36833064	273.2650757	0.704899032	0.494131822
2000	Chinook_1	0.934128531	0.492768224	0.460308857	131.06	133.15	136.31	0.017667173	8126.110157	11.68465846	3.307569943	25.86380102	12.75286827	87.11137543	0.982615006	1.214183807	6.992782906	23.6628869	14.55346775	248.8222631	0.888805687	17.53608322	256.7334595	0.582181795	0.365186945
2001	Chinook_1	0.901998114	0.67206265	0.606199243	110.85	115.27	123.45	0.019318235	11699.83556	9.157339334	7.732205547	11.81471181	9.812289238	40.84489517	0.90403831	0.642381001	8.965012729	17.79765763	12.16131115	138.6550992	0.887004584	13.33443483	150.5421448	0.696145273	0.497621998
2002	Chinook_1	0.930664983	0.692929399	0.644885127	119.9	122.82	129.67	0.018946646	12205.32944	11.39143671	4.828399539	18.02926746	10.54598541	70.11482849	0.979590333	1.072222712	7.813864246	20.95505902	12.28302606	234.8389867	0.897038917	17.06477912	242.4254303	0.719674477	0.543354184
2003	Chinook_1	0.933996581	0.626327312	0.584987568	130.58	133.05	140.06	0.016512626	9650.253336	11.4670261	4.058642268	21.32613473	11.54360847	76.90997314	0.97288202	1.041740992	7.188043348	23.06658436	13.57679001	240.7525558	0.88894245	16.90704155	260.4354248	0.678322582	0.480427483
2004	Chinook_1	0.911677585	0.722304189	0.658508539	107.4	111.8	120.13	0.018887318	12424.54253	10.65682731	7.491854139	12.13189929	9.239259338	60.71099243	0.961347878	0.831694698	8.730858922	18.23702933	11.31112766	202.0129801	0.901996771	15.75253987	219.833252	0.726250121	0.547512194
2005	Chinook_1	0.920659327	0.57965492	0.533664709	122.67	125.34	131.02	0.018584484	9907.254586	10.75238126	4.737477459	18.55627983	12.15538731	67.1325058	0.966418314	0.95613308	7.713847525	20.96974997	13.88730796	206.5040741	0.901550005	15.9283212	216.1983643	0.655532076	0.435535704
2006	Chinook_1	0.944676789	0.728140899	0.687857806	121.51	123.64	130.8	0.01938774	13322.36212	11.98670939	3.853836223	22.4557847	10.42948494	127.8444931	0.971383309	1.132489204	7.556248277	22.15573469	11.94847743	291.8438721	0.861277779	17.78990555	297.8026123	0.779831681	0.558928451
2007	Chinook_1	0.920351544	0.606394036	0.558095687	120.87	123.23	129.44	0.018750351	10452.76811	11.46105872	4.957941048	17.81328382	11.89204922	68.44199371	0.977652192	1.094354916	7.633205943	21.27814302	13.61476469	243.7468211	0.889269928	17.13241227	253.0018616	0.659055521	0.452165632
2008	Chinook_1	0.902274752	0.733048509	0.661411162	107.41	112.13	120.28	0.018295779	12090.38546	9.85547282	8.151316971	11.1369262	9.57006855	60.82829208	0.919988394	0.678269243	8.810917564	18.10950351	11.03706344	180.9872665	0.886600057	14.23927522	192.7246399	0.723946129	0.558159279
SCN MO3-RESSIM-SNK																									
1929	Chinook_1	0.962424743	0.675583555	0.650198329	124.39	126.06	133.8	0.019061883	12384.69791	9.328083192	3.076438069	27.82545858	10.96659279	53.89043503	0.926580679	0.745209455	8.389128581	19.33560307	12.38733641	140.0000661	0.896045784	13.67394821	150.7934875	0.760483824	0.519006702
1930	Chinook_1	0.946263564	0.685712909	0.648865142	103.15	107.07	116.13	0.018420397	11939.73308	9.244197982	6.600279972	14.06158322	9.508746338	59.92483444	0.938794482	0.659881687	9.10141369	17.28912861	11.18712505	146.2621028	0.90724057	13.30879092	154.9381409	0.715919107	0.517816522
1931	Chinook_1	0.939109899	0.700955782	0.658274513	104.78	108.72	117.59	0.018705003	12300.43878	8.754546489	7.236006804	12.74677987	9.241340446	43.26747131	0.921512961	0.64471488	9.274365216	16.99421615	11.05499013	130.8810501	0.890999913	12.75777887	137.5868683	0.730867351	0.518581738
1932	Chinook_1	0.968616015	0.744601902	0.721233327	117.02	118.91	126.46	0.019557983	14094.83118	11.63456065	3.853102796	22.82406266	10.25762863	82.30306396	0.972295213	1.010477448	8.062687472	20.3600587	11.49437634	269.799291	0.872459789	17.27289883	283.7765503	0.806725557	0.583827519
1933	Chinook_1	0.957294733	0.613677582	0.587470317	130.71	132.5	139.54	0.017490432	10263.77984	11.27388399	3.233978346	26.72252364	11.6545454	55.92011414	0.977692127	1.104915333	7.284412928	22.63738058	13.7372872	216.7235413	0.907823602	16.90461699	224.4298553	0.702806592	0.45579895
1934	Chinook_1	0.954275738	0.650984934	0.621219128	113.85	115.54	121.58	0.019043326	11817.97401	11.960009	4.180176362	21.22674697	10.97957001	79.73236084	0.964723146	1.103514576	8.018654071	20.29498776	12.53807608	308.3286641	0.845037222	17.74212122	315.4052734	0.696174848	0.522363181
1935	Chinook_1	0.958820559	0.59410214	0.569637346	125.13	126.81	133.87	0.018638495	10606.81482	11.09687124	2.92802614	29.36740524	11.73857784	62.65988464	0.975755823	1.026963425	7.540729344	21.6986452	13.83089304	213.3431727	0.906727274	16.5578502	225.6035461	0.679296021	0.435377871
1936	Chinook_1	0.97827349	0.738446943	0.722403068	114.88	116.37	124.14	0.019601437	14146.77387	11.79110595	2.983179316	29.26639315	9.832967567	127.4787598	0.977879167	1.073259735	8.051729813	20.5002663	11.16410192	289.9698792	0.861924867	17.47874451	301.8942871	0.790045018	0.578760868
1937	Chinook_1	0.955979356	0.688563047	0.658252058	123.12	124.97	132.24	0.019039974	12519.47493	9.900802272	4.291338429	20.58939113	10.52247734	52.17864384	0.939910054	0.766208458	8.287573636	19.56633758	12.33362214	165.3180415	0.903218667	14.52060366	178.7708282	0.756260273	0.515551543
1938	Chinook_1	0.973999932	0.638088854	0.621498501	129.12	130.6	135.38	0.017309748	10748.00738	12.00509378	2.452711992	34.92962174	11.44972744	108.9635391	0.969390821	1.134627724	7.052783713	23.87155451	13.35458771	296.4898885	0.855222672	17.72214381	305.6914673	0.707352291	0.526664851
1939	Chinook_1	0.969058481	0.737464973	0.714646686	115.55	117.4	125.03	0.019606187	13998.29839	11.12238404	3.433638498	25.43368731	10.20979671	82.761409	0.978917825	0.928366375	8.196721308	19.78636084	11.20244026	225.3101603	0.902983656	16.60069784	235.2405243	0.780209361	0.577832359
1940	Chinook_1	0.941168181	0.750786898	0.706616739	96.19	102.64	111.85	0.017117549	12082.39243	10.19640037	10.00564554	9.502721513	8.747035789	81.27045898	0.880177927	0.566097736	9.255906209	17.03940292	10.25226514	197.7233098	0.878077249	14.95264077	210.5924683	0.760571427	0.537065544
1941	Chinook_1	0.932841218	0.510653033	0.476358244	131.47	133.01	134.14	0.016572037	7886.649129	10.31493163	3.279897623	26.37398257	13.28403778	55.98124313	0.96174686	0.874302578	7.611461625	21.14092634	14.45078945	179.5908915	0.910517484	15.33053525	186.381134	0.593444274	0.363752266
1942	Chinook_1	0.967370597	0.677350373	0.655248835	134.35	135.87	142.33	0.015846804	10372.12299	10.9825339	3.313043065	26.45399181	11.13455906	80.83401337	0.96468848	0.940382862	7.284119315	22.91793748	12.87841161	227.4595668	0.888618608	16.21822582	240.963089	0.744164705	0.555680541

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1943	Chinook_1	0.977807275	0.720409109	0.704421267	121.9	123.25	129.65	0.018855694	13268.75464	11.82366974	3.882913448	22.97603046	10.12936344	124.9120224	0.961201179	1.056078053	7.893754572	20.92175503	11.88482269	294.8545074	0.851883312	17.4582777	300.7654419	0.794905717	0.578625257
1944	Chinook_1	0.958182091	0.584174487	0.559745532	129.23	130.83	138.47	0.017632197	9860.711402	9.980652605	3.048504509	28.34612071	11.75212288	59.15698776	0.943910837	0.849004459	7.729481488	21.06412816	13.78422991	161.8312378	0.911280066	14.73135098	170.6989746	0.677200802	0.437793389
1945	Chinook_1	0.961709967	0.698320045	0.671581347	118.2	120.29	127.78	0.019407304	13021.48685	10.33911525	3.663500771	23.87253594	10.63175945	64.73920135	0.945817494	0.77232933	8.216576487	19.79774714	12.08190997	194.3174795	0.892609258	15.19070347	211.8741302	0.747974142	0.55933852
1946	Chinook_1	0.978327348	0.778163006	0.76129815	110.02	111.95	120.25	0.019438441	14786.13129	12.03391354	4.063319944	21.98405599	9.205426598	114.2905258	0.969034421	0.965983391	8.44511389	19.54885118	10.33722862	319.6123149	0.844072709	17.5894076	335.6716614	0.821566395	0.61165332
1947	Chinook_1	0.96774498	0.710414629	0.68750019	108.7	111.13	119.52	0.019229841	13208.69782	11.35111356	4.383506298	20.37900432	9.694306946	84.48561554	0.975447404	0.921551609	8.409847997	19.06180019	11.58595626	248.8662313	0.888183365	16.82047796	262.2990112	0.762848173	0.565651385
1948	Chinook_1	0.973659701	0.638393402	0.621577929	132.54	133.78	137.76	0.016823143	10447.70397	14.20151302	2.150860436	39.64016482	11.9538332	132.1752411	0.974315572	1.336288643	6.328112707	27.36218985	13.5940431	395.6791331	0.842406611	20.98513556	414.8632507	0.717074026	0.528242351
1949	Chinook_1	0.970768105	0.582433907	0.56540826	125.65	127	133.09	0.018226354	10297.73823	12.60760679	2.165617034	39.24898154	12.09289188	117.8052505	0.972261691	1.198187733	6.894232914	24.58375048	14.18464947	323.9129588	0.844444185	18.22808552	347.2767944	0.692479985	0.435473588
1950	Chinook_1	0.971485699	0.692744175	0.672991059	130.9	132.48	138.6	0.017894873	12030.36913	11.48146571	2.745291494	31.37176478	11.22142067	85.63347321	0.978779149	1.046961308	7.175825514	23.38387706	12.70776065	259.0284195	0.879111369	17.01640558	275.8941345	0.773534161	0.546245286
1951	Chinook_1	0.974348912	0.647404636	0.630798003	130.39	131.7	137.97	0.017436862	10987.56008	12.52026715	2.743834965	31.53960446	11.37215195	104.7436081	0.96441083	1.159157753	6.751477346	25.2737785	13.55122407	338.0545298	0.831213226	18.16790899	353.8452454	0.730723163	0.52486093
1952	Chinook_1	0.984914017	0.729560387	0.718554252	124.86	126.09	132.34	0.018666226	13399.88526	12.58974859	2.573674098	33.70973344	10.58706093	157.8141846	0.953981721	1.071937943	7.17498716	23.91044421	12.05127954	354.1391856	0.818267077	18.18291966	368.4886475	0.793534141	0.606813215
1953	Chinook_1	0.965057303	0.672311483	0.648819106	130.85	132.48	139.24	0.016383159	10617.97706	11.21481189	3.765216932	23.36934333	10.95955276	80.14260101	0.961151266	0.984882545	7.300484136	22.77671354	12.93923775	246.9138082	0.873731891	16.49672731	262.0638733	0.727191116	0.556801764
1954	Chinook_1	0.975067368	0.697619981	0.680226478	138.15	139.35	144.01	0.015388223	10456.92253	12.07644067	2.885284878	30.1524882	11.0333252	103.8382614	0.961036277	1.082496071	6.712480657	25.38815217	12.78124444	309.5106557	0.844716191	17.68726714	319.6470947	0.767049198	0.587949923
1955	Chinook_1	0.970502541	0.651422995	0.632207671	133.73	135.1	141.11	0.016729733	10565.51698	11.11413319	2.813577816	30.70988364	11.2197773	81.32626343	0.971830285	0.987962818	7.172431715	23.26792281	13.34560299	230.0126038	0.892495145	16.47750187	243.7009583	0.718668169	0.508501649
1956	Chinook_1	0.978907118	0.739157057	0.723566105	116.13	117.49	124.32	0.018423419	13317.13302	13.62485014	3.351969726	26.35002478	10.00577679	137.4758942	0.960739756	1.172539711	7.59543661	22.27061894	11.42792114	395.6449483	0.816176891	19.66749239	414.5856934	0.782100735	0.606681795
1957	Chinook_1	0.970518925	0.718765316	0.697575342	116.37	118.32	124.8	0.017359585	12096.44979	12.38880553	3.998136304	22.28043657	10.35209484	121.1076309	0.962962782	1.005328562	7.572331294	21.6519237	11.76366409	311.515274	0.855042795	18.00007772	326.0296326	0.753678157	0.601122702
1958	Chinook_1	0.976549801	0.685469849	0.669395444	126.93	128.25	133.57	0.017807856	11912.10978	12.51533335	2.22694803	38.14290298	11.23929157	117.8062119	0.971467066	1.112685871	6.856097847	25.01687363	12.78115018	325.6503906	0.842806776	18.18177319	346.2767029	0.745298002	0.574911267
1959	Chinook_1	0.966063507	0.628228462	0.606908591	134.86	136.22	142.05	0.016035815	9723.258048	11.88345238	2.787673518	30.86775449	11.68436661	80.60951385	0.979920614	1.16081953	6.809950501	24.73887243	13.72037999	280.836202	0.867863675	17.66130129	291.2876282	0.706110211	0.511639501
1960	Chinook_1	0.972011332	0.655921371	0.637563006	133.09	134.38	139.59	0.017229565	10973.53996	11.6335785	2.918840341	29.65684016	11.13532276	88.31979218	0.972487593	1.117083931	7.047677517	23.77567872	13.30161158	263.5530294	0.874884715	17.32555008	272.5137024	0.740988571	0.519493506
1961	Chinook_1	0.957605421	0.667466629	0.639169663	117.98	120.08	126.49	0.018629099	11895.72518	11.18995803	4.264121704	20.63997354	10.63119736	61.4711113	0.97028358	0.963421822	7.977113999	20.30908564	12.65578731	231.9804128	0.892112315	16.59412432	240.7607574	0.717530835	0.5350691
1962	Chinook_1	0.973974707	0.717702394	0.699023979	118.07	119.66	127.18	0.019531271	13638.40782	11.49822858	3.140833966	27.56120738	10.35104313	91.05131683	0.982871556	1.101163769	7.997104883	20.52092152	11.87810421	247.722379	0.888783524	17.20689106	253.6599731	0.770928052	0.562588262
1963	Chinook_1	0.959613413	0.64877624	0.622574382	117.46	119.44	126.01	0.018738843	11653.44721	10.47385754	4.165358879	21.25520022	10.71478386	67.68595886	0.958147526	0.837293533	8.213894986	19.55078352	12.68242375	195.0167262	0.906034023	15.46192161	204.4720001	0.706218712	0.522752941
1964	Chinook_1	0.972905328	0.632490434	0.615353313	133.17	134.65	141.03	0.016676129	10250.88735	11.49788894	2.501711577	34.29846607	11.45431366	89.87354431	0.97050966	1.014392376	6.780628607	25.12509191	13.84780582	265.4561717	0.871222963	16.94982274	281.4285889	0.741876206	0.479032731
1965	Chinook_1	0.960053676	0.542881433	0.521195313	143.99	144.66	144.81	0.013898757	7237.706731	12.33075823	2.055825211	41.42637728	13.21187	135.6701233	0.959948957	1.162129402	6.399116486	26.89596893	14.22004159	328.4667511	0.822900116	17.99584214	335.9306946	0.622498353	0.441484923
1966	Chinook_1	0.956909876	0.721898371	0.690791681	109.41	112.01	120.5	0.019250364	13284.38463	10.24880665	4.893348061	18.19707947	9.875900078	62.07195053	0.967522418	0.837686634	8.766036756	18.10680844	11.19332329	181.3747228	0.914555411	15.13791577	189.2084351	0.755255036	0.535748881
1967	Chinook_1	0.962973264	0.724758643	0.697923196	124.39	126.43	133.65	0.018677414	13022.89356	10.74979779	3.541137062	24.48726788	10.5695322	55.62074661	0.960273767	0.876155186	7.768562771	21.24020882	11.84402577	214.7318166	0.894409994	15.81732798	227.0217285	0.777171929	0.570384326

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1968	Chinook_1	0.925722204	0.447030517	0.413826076	139.35	140.51	142.24	0.015246253	6303.847757	10.63380068	2.574606679	33.07039162	14.47885361	69.16559296	0.95460217	0.954838085	7.004005753	23.33216823	15.18473816	214.9273809	0.87819917	15.69053491	224.3396759	0.569177083	0.293626626
1969	Chinook_1	0.976329277	0.696530482	0.680043102	115.81	117.37	124.37	0.019164775	13020.16008	12.15130721	3.526262619	24.93735521	10.11755772	111.2936615	0.97122720 5	1.128944683	7.8536257	20.99680657	12.28361273	311.2852987	0.84583408 6	17.89880975	318.1035461	0.778596347	0.562158842
1970	Chinook_1	0.967261739	0.699534198	0.676632665	125.62	127.2	133.76	0.017220266	11640.98833	10.47805837	3.389840685	25.67923168	10.74397907	83.03631744	0.94694677 6	0.836582475	7.708235584	21.37038314	12.26720365	213.799324	0.87757594 4	15.38992977	222.4225159	0.747739675	0.579866585
1971	Chinook_1	0.981297489	0.649022488	0.636884137	137.58	138.66	142.48	0.015604773	9930.32369	13.81980961	1.902315982	44.62933711	12.16764736	150.8889526	0.95914487 8	1.245929623	5.907239161	30.32385914	13.71728277	416.663915	0.78840643 2	19.80690606	423.2371521	0.744931314	0.548471907
1972	Chinook_1	0.977528775	0.657169243	0.642401845	125.02	126.46	131.73	0.017463534	11208.91898	13.30568041	2.489203408	34.39617627	11.38232956	118.9892838	0.97531887 3	1.238094711	6.823647618	24.70450005	13.3394653	360.3856455	0.83971363 3	19.59305191	361.6990356	0.725898005	0.543198278
1973	Chinook_1	0.943512229	0.631833185	0.596142336	120.04	122.06	127.51	0.017050623	10153.8706	9.46119925	4.697526552	18.95628726	10.91391258	50.12578125	0.92574909 9	0.792501354	8.305462256	19.37018498	12.74210612	154.0918554	0.88121652 6	13.9816103	160.4857941	0.673166734	0.509883319
1974	Chinook_1	0.977017864	0.609216458	0.595215362	135.13	136.34	140.98	0.015849321	9426.215625	13.58222423	2.056521125	41.35162399	12.29675312	135.866748	0.95917326 2	1.258013344	6.203716338	28.22356739	14.18590482	395.8225199	0.80662014 1	19.73462168	400.5730286	0.692895764	0.482253765
1975	Chinook_1	0.973506365	0.614652699	0.598368315	144.93	146.21	150.03	0.012297134	7352.322273	12.42323429	2.069251619	41.04641787	12.31477337	125.2439102	0.96855977 8	1.188864422	6.208675109	27.88582517	13.97206036	323.3693136	0.83330161 4	18.10695473	330.5731812	0.687031782	0.507395705
1976	Chinook_1	0.982040236	0.751310988	0.73781762	119.77	121.3	128.68	0.019352061	14264.82344	12.28533231	2.795132071	30.93200065	10.05826454	119.1614883	0.97601574 7	1.152206707	7.622832686	22.03140851	11.50657527	311.000885	0.85152991 6	18.02884467	320.0139465	0.810691644	0.596855452
1977	Chinook_1	0.929149967	0.541354457	0.502999475	129.1	130.89	135.98	0.017011151	8548.113701	9.277527315	3.887568854	22.35009893	12.62968922	37.7428772	0.93099814 7	0.794720411	8.084738903	19.80854052	14.08457756	137.1634954	0.89920488	13.62095579	143.3311615	0.612611123	0.399251265
1978	Chinook_1	0.967515497	0.754057999	0.7295628	108.01	110.61	119.26	0.018647155	13589.06466	11.23634682	5.345894106	16.92106459	9.31665554	87.27789917	0.97093659 6	0.926433468	8.573553458	18.68903854	10.88521655	235.9754105	0.89012079 4	16.74399773	248.4212189	0.786444541	0.584107533
1979	Chinook_1	0.958069601	0.750151015	0.718696884	110.87	113.29	121.75	0.019357448	13897.4542	10.22468703	5.195953935	17.23282962	9.525765419	58.93657608	0.94579581	0.733610439	8.856134132	18.11330514	10.86256075	184.0818253	0.89816168	14.89309843	204.7370911	0.789389886	0.531671004
1980	Chinook_1	0.976747574	0.648142003	0.633071129	135.89	137.2	142.9	0.015076355	9537.234307	12.29728692	2.198007874	38.7253614	11.63881054	109.622963	0.96008197 1	1.132299232	6.51848641	26.56251563	13.68764512	328.8865306	0.83188614 2	18.02635511	336.5259705	0.719206672	0.538581702
1981	Chinook_1	0.944124644	0.568169233	0.536422569	126.77	128.07	127.95	0.016380479	8777.721075	10.71682855	4.393078585	20.33765665	12.4481987	76.41648712	0.94524525 4	0.894377899	7.632432908	21.15063462	13.62437391	225.8523636	0.87316352 1	15.69653813	235.7782135	0.635126524	0.449166852
1982	Chinook_1	0.969819105	0.552715846	0.536034388	142.58	143.65	145.2	0.013964858	7479.668738	12.84703442	2.088694751	40.72100229	13.10602875	124.8902679	0.96889203 8	1.226760769	6.176067404	27.93132105	14.61310848	348.453481	0.82541015 7	18.72086302	353.3137817	0.670403305	0.410442633
1983	Chinook_1	0.968244523	0.656694119	0.635840483	121.57	123.1	127.96	0.016523475	10496.37964	11.64487215	3.364596143	26.03320539	11.15461693	99.07701721	0.97046107 1	1.030388355	7.453206666	22.09913612	12.9262379	276.1948547	0.86184198 7	17.14750671	286.1812744	0.707126713	0.557099671
1984	Chinook_1	0.973884085	0.620293451	0.60409392	128.69	130.07	135.29	0.017105774	10325.39824	11.71126498	2.099855319	40.40383801	12.09085941	123.5104095	0.97842108	1.130325031	7.010592505	23.93223199	13.46986723	268.2984314	0.87158779 3	17.44533841	272.6393433	0.698407282	0.49295742
1985	Chinook_1	0.973076973	0.760829531	0.740345697	108.21	110.37	119.02	0.018822881	13921.83676	11.27211557	4.758156188	18.92519284	9.123599434	110.7584595	0.96974425 3	0.987187386	8.711574979	18.44298806	10.60680628	245.4334691	0.88667535 8	16.89835342	246.1019287	0.800005285	0.592725725
1986	Chinook_1	0.960398275	0.624929214	0.600180939	121.95	123.23	125.95	0.01695547	10166.25905	11.49323702	3.958842427	22.42654303	11.1570488	104.3798416	0.97082299	1.042172432	7.738016382	20.88838569	12.785405	253.7538325	0.87742037 6	17.12267399	256.1033631	0.672250022	0.519352694
1987	Chinook_1	0.936366822	0.581781422	0.544760822	117.21	118.81	125.06	0.019737773	10744.81487	11.27329476	3.346586302	25.74385318	12.11186848	56.67033691	0.97130821 9	1.002728367	7.877602659	20.56292591	13.45970027	242.4218267	0.88468885 4	16.67179394	258.4049377	0.642704652	0.448655734
1988	Chinook_1	0.95241487	0.744626497	0.709193348	107.39	110.15	118.73	0.018780235	13304.76738	10.25216128	6.374025106	14.41781218	9.047337914	58.11177368	0.94819856 9	0.73808713	8.953062601	17.7444977	10.68965419	185.5111771	0.91022508 3	15.1571939	193.5841522	0.769387513	0.551088528
1989	Chinook_1	0.968211405	0.585859264	0.567235621	140.49	141.9	146.48	0.014902502	8446.869755	11.58006716	2.495933518	34.0845975	11.6666626	79.92866211	0.98265061 4	1.165359306	6.896332912	24.35602935	14.05866607	244.2552719	0.89266518 8	17.35581207	247.2679291	0.690563771	0.448108931
1990	Chinook_1	0.939747254	0.468118761	0.439913318	130.16	131.6	136.36	0.01821392	8005.878783	11.18829966	2.523396447	33.62629527	13.668116	63.66827774	0.98048585 7	1.136962891	7.206402533	22.63302159	15.0197045	216.4153112	0.90769251 2	16.81665389	215.3007965	0.620465435	0.297188258
1991	Chinook_1	0.955211447	0.650449155	0.621316478	122.87	124.86	129.61	0.017698183	10984.91463	11.30005888	4.13899523	21.37198071	10.96573181	59.64234924	0.96726906 3	0.988136768	7.62884602	21.43563154	12.90162214	247.1540476	0.88275904 5	16.75191482	249.4724731	0.704234783	0.542103351
1992	Chinook_1	0.925976826	0.564625689	0.522830304	120.46	122.09	127.06	0.019203894	10029.94393	10.40654155	3.74903594	23.25258749	12.70559845	49.1496666	0.95998457 7	0.851242447	8.026915327	19.90126072	13.53492689	189.3792013	0.90809837	15.45431519	195.2182465	0.633872579	0.431657121

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1993	Chinook_1	0.970161933	0.734355582	0.712443831	120.1	121.86	129.58	0.019538492	13907.82912	10.61138448	3.196071483	27.02021870	10.38737202	75.98688507	0.949289036	0.730037451	8.117640585	20.26857997	11.45279662	209.2527491	0.893578142	15.51587399	225.9549561	0.790198248	0.570526391
1994	Chinook_1	0.933495604	0.506935716	0.473222262	127.14	128.57	134.26	0.01862353	8805.606243	11.10503813	2.636229388	32.27060961	12.72140622	59.84096375	0.976140523	1.062592602	7.398284473	22.10792582	14.40300179	210.7636083	0.90845873	16.60228427	219.9912262	0.606396107	0.37205572
1995	Chinook_1	0.965732078	0.655728331	0.633257884	126.87	128.34	133.66	0.016582436	10490.37272	11.04377948	3.836777486	23.12477528	11.01353359	91.86577148	0.962525725	0.963567066	7.517440006	21.76969986	12.92861001	236.9959793	0.882352332	16.31572935	246.2431641	0.712034361	0.543214069
1996	Chinook_1	0.956043995	0.546598386	0.522572105	140.37	141.1	142.92	0.013801151	7205.633482	12.41216956	2.175539725	39.11530068	13.66725368	122.1839935	0.9589064	1.1641078	6.415893599	26.67073961	14.51917235	331.4060415	0.825073858	18.04365762	342.3174438	0.646929222	0.411695955
1997	Chinook_1	0.973038794	0.580713706	0.565056964	133.3	134.21	137.06	0.016269731	9186.258608	15.19295689	1.941562518	43.81388535	12.54105625	161.8484192	0.961574924	1.403820324	6.014833808	29.28578761	14.28409147	457.7881775	0.800327152	22.04173565	466.2925415	0.668511219	0.470431269
1998	Chinook_1	0.966528546	0.685593346	0.662645534	115.22	117.09	124.26	0.019090731	12637.84947	11.41592591	4.135110132	21.46587723	10.39778633	86.93986511	0.955300415	0.876528746	7.957105426	20.54427293	12.432947	268.1246465	0.863870253	16.57309659	286.8570862	0.738968967	0.554749754
1999	Chinook_1	0.972243454	0.661865886	0.643494775	119.59	121.03	127.36	0.019296747	12406.43219	11.67798734	3.436526105	25.572545	10.73585835	99.89380493	0.971055901	1.052360821	7.888787903	20.74067257	12.80949958	275.4956055	0.868905097	17.37536494	280.2846069	0.745712855	0.534787103
2000	Chinook_1	0.951894865	0.51280803	0.488139331	130.52	131.63	135.15	0.017894826	8728.45792	11.68897431	2.317107551	36.73170358	12.63043594	87.40397491	0.982404792	1.206114578	7.081131592	23.3402125	14.34030072	250.7513987	0.887766838	17.53925339	258.4676514	0.618879909	0.388927264
2001	Chinook_1	0.944621229	0.700982539	0.662162987	108.95	112.1	120.91	0.019234693	12724.69416	9.010232636	6.263781503	14.45518427	9.490882683	38.41899261	0.897302532	0.622909403	9.19450821	17.34474225	11.58442291	133.1039696	0.883077264	13.04939421	146.4464722	0.741992122	0.532176222
2002	Chinook_1	0.968223055	0.704450137	0.682064864	119.18	121.02	128.02	0.019085433	13003.5973	11.39406548	3.35388048	25.86508512	10.45298519	70.82566528	0.979902256	1.060209561	7.940039165	20.56248798	12.00143623	235.7026622	0.897519886	17.07587767	243.1914825	0.763629851	0.566448589
2003	Chinook_1	0.963146531	0.628893591	0.605716679	129.1	130.74	137.64	0.017078713	10334.76383	11.41030216	3.072021663	28.18401344	11.46944065	75.65307159	0.974128008	1.037363625	7.341107689	22.42171741	13.47223425	235.1595815	0.894455731	16.88146035	253.4386292	0.701305052	0.498967104
2004	Chinook_1	0.957223823	0.739856322	0.708208096	105.75	109	117.77	0.01864667	13192.00441	10.58925649	6.209587879	14.69764318	8.944190025	60.75370636	0.961658669	0.806788254	8.886649147	17.84065877	10.88166571	199.9128621	0.906918257	15.64323362	215.9125977	0.780762741	0.557988644
2005	Chinook_1	0.952261264	0.592647869	0.564355609	122.11	123.88	129.6	0.01870086	10542.65166	10.65293762	3.510306165	24.87765812	12.02039719	65.85439072	0.965573728	0.93745594	7.849608973	20.52947742	13.65663958	201.2120234	0.903696587	15.76337115	210.7763367	0.668019957	0.457171954
2006	Chinook_1	0.981848293	0.735613685	0.722261035	121.01	122.31	129.62	0.019519335	14083.62641	11.97057646	2.662064426	32.51236644	10.32623062	127.798349	0.971661901	1.133655453	7.678260744	21.75540679	11.75197474	292.5411326	0.860939721	17.78680722	297.5411682	0.806219548	0.577676915
2007	Chinook_1	0.954032767	0.618876962	0.5904289	120.3	121.88	128.03	0.01885572	11120.48447	11.43095619	3.746062875	23.4897271	11.75896301	67.26343689	0.978688037	1.081844616	7.756776929	20.85958778	13.38700294	240.2484233	0.893162837	17.09642204	249.5858612	0.692323685	0.484188308
2008	Chinook_1	0.945454944	0.739642867	0.699299003	106.26	109.54	118.12	0.018405047	12859.30123	9.911109277	7.257305197	12.94079352	9.410076714	60.08734283	0.927540946	0.673353577	8.842917301	17.94550524	10.87600597	180.6781184	0.90320461	14.40157231	190.9911041	0.757006338	0.562772076

5516 **Table 4-5. Snake River MO1, MO2, MO4, Steelhead Raw Data**

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
SCN NAA-RESSIM																																																		
1929	Steelhead	0.698879773	0.563074481	0.393521366	0.39321841	126.8	133	140.14	144.26	21.9023343	27.1735563	12.7240446	143.828058	0.88605604	12.9849142	12.1321716	10.3574126	11.3035272	65.4197738	0.81002048	10.9678754	7.82126944	22.0089359	13.2440247	178.999338	0.89244689	13.3596039	191.203689	0.40429885	0.59570115	0.63173437	0.81746928	0.86092959	5.87745969	23.0694804	13.4316112	0.90630172	14.8130975	2.06110229	19.4085354	13.6314846	0.90712068	14.9261735	1.59954693	15.9021452	13.7781486	0.92442065	15.8999347	0.49592268	0.28382907
1930	Steelhead	0.506299952	0.444075889	0.224835409	0.31630763 8	141.56	141.04	142.29	146.78	18.2233821 4	28.6925871 4	14.8690930 8	137.709089 8	0.88349742 1	12.6236504 8	8.96772906 2	12.7945215	13.4068780 9	63.3788658 1	0.80917223 7	10.3654504 8	7.33289545	23.0791098 6	15.4026385 9	176.480178 8	0.88718400 4	13.1378978 1	181.688644 4	0.36784286 4	0.63215713 6	0.52064944 5	0.76136778 4	0.81524950 9	5.60135751 2	23.9440813	15.5643119 8	0.90553617 5	14.664291	2.01444017 1	19.9110161 4	15.7171297 1	0.90858928 4	14.8904959 4	1.56767284 1	16.2185925 2	15.8815083 5	0.92755156 8	15.8576936 7	0.32193029 7	0.15056093 4

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1931	Steelhead	0.533779955	0.417758463	0.222991094	0.342126036	139.57	144.05	147.1	142.15	17.583307884	29.10840179	15.025440766	133.692064	0.894388991	12.77565602	8.616512351	13.23378584	13.4051096	58.06997528	0.833843505	10.7699585	7.039977059	23.75233136	15.92562151	172.8701833	0.892038037	13.16503843	177.03125	0.335461477	0.664538523	0.493070741	0.743184275	0.799957765	5.435976848	24.45370839	16.0790247	0.909091187	14.75380554	1.972632095	20.35197596	16.10000579	0.911045551	14.93365542	1.536776558	16.53835162	16.07340288	0.930582881	15.8691144	0.349198694	0.134585286
1932	Steelhead	0.782343057	0.651946403	0.510045742	0.410933216	118.19	124.02	130.23	136.39	18.393682877	30.12592845	11.81111847	228.6621633	0.84997172	14.85814377	9.796539709	12.65671264	10.36088829	94.63326874	0.747203028	12.02863808	6.619740181	27.45307669	12.19045591	291.3940938	0.860598594	15.04000751	302.3262939	0.444805631	0.555194369	0.710415969	0.856241899	0.892343761	4.942182235	29.07214767	12.3847168	0.871571958	16.90807934	1.646728776	24.2140084	12.6961511	0.884641767	17.54715856	1.275573723	19.89270334	12.9764142	0.892585695	18.83281803	0.604530142	0.378444172
1933	Steelhead	0.715958744	0.578423573	0.414127415	0.282661651	126.67	129.92	135.56	147.03	19.03000352	29.65972744	13.15247216	200.2119206	0.878386983	14.19195853	10.40826794	11.8337571	11.44514656	71.10921021	0.817384362	11.38665619	6.675316341	26.53812285	13.7777799	261.1518453	0.86841615	14.51432729	273.0314026	0.540999347	0.459000653	0.646255003	0.827048897	0.868740336	5.02183307	27.91783347	13.96120892	0.883011627	16.39809723	1.711936928	23.32070275	14.21833801	0.892678857	16.94750214	1.327677943	19.11298018	14.42592239	0.902862608	18.16796446	0.507657578	0.314698633
1934	Steelhead	0.446903919	0.484879791	0.216694679	0.168725911	140.82	139.37	138.8	142.13	15.58042991	31.86644797	15.14862238	205.1271008	0.893158159	14.39642314	7.692378454	14.39111502	14.27977333	58.16246796	0.863228333	11.84218731	5.948189147	29.44705097	15.46128178	285.769455	0.86467884	14.7864186	291.7187195	0.57232988	0.42767012	0.562243019	0.790865227	0.840345695	4.564489491	30.64271135	15.54226265	0.870026994	16.79944534	1.582963564	25.28281361	15.61433442	0.883331895	17.12813314	1.230542339	20.62262339	15.71929359	0.890385419	18.15503788	0.297604174	0.146525369
1935	Steelhead	0.70593546	0.556111367	0.392578733	0.304679173	125.41	131.39	137.97	139.08	18.65444504	29.35396873	13.29328707	177.8836888	0.880411825	13.34148901	9.885128714	12.13556674	11.58473759	68.27279968	0.815417731	10.67862186	6.819060579	25.63769155	14.03375053	232.859759	0.874779811	13.86774516	244.0797729	0.500536316	0.499463684	0.625903377	0.817648139	0.861321506	5.163591519	26.84202757	14.20097885	0.890610778	15.67407227	1.786925271	22.36287798	14.37724113	0.893833081	16.03128497	1.386916474	18.30102723	14.50802279	0.904488653	17.06724167	0.500696228	0.273756626
1936	Steelhead	0.694389721	0.653012429	0.453445118	0.362063537	118.66	118.59	124.47	140.28	17.98634975	30.8231366	11.7967545	242.0082817	0.814239221	15.48240076	9.366136536	14.37485594	10.84244423	119.4199112	0.646904993	13.01717606	6.639207065	27.70844583	11.79605881	303.4479167	0.860804518	15.6366717	313.9924316	0.476560533	0.523439467	0.711023029	0.859121838	0.895192527	4.908585966	29.49729736	12.01174889	0.866025436	17.24081039	1.62723057	24.51191093	12.32095305	0.886003057	17.7882328	1.260854796	20.125254	12.65122318	0.894701034	19.09313583	0.527268081	0.370727816
1937	Steelhead	0.726860753	0.573338268	0.416737086	0.272950876	119.5	129.04	136.04	134.23	23.54519695	26.84602089	12.40985802	143.7304769	0.886805807	12.85307435	13.74438743	9.46994815	10.76116314	56.47238007	0.819697821	10.67489101	7.832101904	22.31319522	13.06563139	186.2272161	0.88613236	13.2614181	199.6436157	0.554168279	0.445831721	0.641220346	0.82072363	0.863148073	5.840962015	23.51401422	13.26848183	0.902961159	14.81824589	2.023456387	19.74983534	13.50818602	0.904379229	15.01764043	1.569136195	16.20371185	13.67851114	0.920707405	16.05198383	0.521986898	0.295484516
1938	Steelhead	0.774502212	0.652165367	0.50510352	0.394401063	119.41	120.34	125.26	139.25	16.20606209	32.01263979	12.01587425	247.0623872	0.827113194	15.54335863	8.005193777	15.82766904	10.81778603	114.7133987	0.683949387	12.86042786	6.222968049	29.22169735	12.25076739	320.3707275	0.85997353	15.83811307	332.3378296	0.460312215	0.539687785	0.710290715	0.856929087	0.893244486	4.667154975	30.8915379	12.42026081	0.861045635	17.64016094	1.552516364	25.70817556	12.70827293	0.88842986	17.89781221	1.203598909	21.08692663	12.98922062	0.901403785	19.10377693	0.588805612	0.392063977
1939	Steelhead	0.553949358	0.512736095	0.284029831	0.374374097	138.62	140.62	141.59	141.06	17.4940033	29.70376164	13.62070826	173.4437746	0.867335822	13.36708709	8.708200485	13.5203216	12.75235348	74.4692749	0.784653354	11.10898457	6.831578046	25.36746734	14.01740344	224.3399099	0.86990581	13.76366091	229.1525574	0.360963659	0.639036341	0.58472401	0.798553364	0.846681695	5.192411572	26.47873971	14.13496685	0.889186549	15.45835953	1.826445818	21.94082901	14.15470823	0.89372009	15.87366517	1.42125994	17.86271807	14.19124842	0.9059003	16.89164734	0.378387748	0.201262791
1940	Steelhead	0.636907744	0.555394416	0.353735005	0.342867796	125.06	125.5	130.61	143.25	18.45985508	29.31610102	13.31516811	182.9446744	0.852400384	13.21422597	9.460174181	12.75969048	11.71305695	81.1811264	0.746959996	10.49414387	7.048032247	25.05343963	13.7664849	234.6994603	0.866467863	13.83324877	241.7814331	0.436342263	0.563657737	0.625671542	0.817627662	0.861531031	5.299648009	26.34941779	13.9532835	0.885970998	15.50617352	1.828498773	21.86563618	14.23734665	0.890319506	15.89134375	1.419732325	17.88174567	14.5191617	0.901118726	16.92981911	0.446669952	0.259518685
1941	Steelhead	0.617741454	0.499014032	0.308261654	0.291295682	127.79	130.55	136.14	141.82	18.41400931	28.71272327	14.25077077	142.831965	0.894045902	12.86973463	9.230864666	12.46225036	12.92066879	57.47232132	0.837377489	10.82706833	7.246753767	23.6352664	14.76876879	187.0725327	0.88829277	13.21079985	194.7940063	0.463433749	0.536566251	0.574974031	0.789521066	0.837952629	5.5154223	24.61102184	14.90998917	0.904633474	14.82738609	1.95334129	20.51589342	15.08065923	0.90556399	15.0451444	1.519324616	16.72495594	15.21083975	0.922103643	16.00093889	0.411834914	0.207168104
1942	Steelhead	0.774751882	0.633615452	0.490894763	0.302345551	116.21	122.03	129.06	143.7	19.9520716	28.15748479	11.58971201	175.0513627	0.861764691	13.32913974	10.38813783	11.9763364	10.30036144	83.84542694	0.758682764	10.63942356	7.588677324	23.39242427	11.9201568	219.0449193	0.87854894	13.8854026	224.2719116	0.552790169	0.447209831	0.693528482	0.847500217	0.885413153	5.654058374	24.71379325	12.14217854	0.895028889	15.46762657	1.949303068	20.53747166	12.41236115	0.899327079	15.81915919	1.514754392	16.77452282	12.64445972	0.913090676	16.91750383	0.584452006	0.371922068
1943	Steelhead	0.767913647	0.624252651	0.47937213	0.461498489	126.46	128.1	131	133.76	15.88768395	31.66543464	12.2635169	232.3701145	0.828176119	15.38001217	7.548302323	15.93412323	10.93571301	114.4320053	0.680680144	13.3674551	6.364949398	28.26596931	12.66404899	295.2809143	0.865177731	15.41440455	311.8178406	0.379885041	0.620114959	0.68507751	0.845589348	0.883876189	4.790390305	29.79436403	12.84878273	0.870752573	17.11729546	1.602523096	24.88946117	13.09147644	0.890796403	17.44972992	1.241663255	20.43718825	13.31420755	0.902635425	18.61890411	0.578677458	0.363216485
1944	Steelhead	0.698122384	0.517334014	0.361162455	0.271542357	120.58	129.96	137.33	137.8	22.67608242	26.91618462	13.17015518	129.1791594	0.900466655	12.81258024	12.92462443	9.792691479	11.17358112	55.05769196	0.845960522	11.05704842	7.799733527	21.92668677	14.09403531	165.8907623	0.896122257	13.09687932	175.5675659	0.522392494	0.477607506	0.589867118	0.795178826	0.842235035	5.888162859	22.91443066	14.28426723	0.910757327	14.61121826	2.083347149	19.22853094	14.46177546	0.91141963	14.66987769	1.61879582	15.71733618	14.57804632	0.930854917	15.58940077	0.46560677	0.25619742
1945	Steelhead	0.717017911	0.590028945	0.423061322	0.546258338	124.62	128.27	134.36	139.47	19.13867821	29.6624691	12.89421974	196.2510027	0.852862626	13.90236354	10.34769777	12.46253604	11.35718632	84.55473633	0.744968545	11.30154324	6.838735498	26.11826344	13.41831811	250.5713755	0.869205534	14.41434121	267.150177	0.279719604	0.720280396	0.6567126	0.831393506	0.872166615	5.097695626	27.61153631	13.61260242	0.882662392	16.02675056	1.726510055	23.1012063	13.87446562	0.887506942	16.46670659	1.337668099	18.97075988	14.08897972	0.895516396	17.52116919	0.523302012	0.312059655
1946	Steelhead	0.790432737	0.665244407	0.525830957	0.370878227	119.85	121.08	126.45	133.14	16.50316801	32.09513682	11.67052405	260.7195631	0.833892256	15.99631146	8.415232792	15.25146139	10.34538937	113.170166	0.702815259	12.90893459	6.10023845	30.05260773	12.00667302	337.1733042	0.86006994	16.30003023	348.7549744	0.493964755	0.506035245	0.720677079	0.861354916	0.896863026	4.565733559	31.83066313	12.19136333	0.857278717	18.17966099	1.503243126	26.52225712	12.47153441	0.888891101	18.5428985	1.163975544	21.8109936	12.72027922	0.903014868	19.90803051	0.605815877	0.410126042
1947	Steelhead	0.597868556	0.549651707	0.328619473	0.541922079	135.08	128.35	130.6	139.09	16.68287004	31.38723647	13.91129582	236.4999689	0.829489061	15.12026715	8.363922916	14.74702482	12.5226656	108.2712021	0.693115497	12.27346935	6.373494253	28.12626585	14.28481436	297.9213155	0.857878457	15.31876349	305.6019287	0.245578739	0.754421261	0.620358126	0.818415105	0.862778892	4.782364711	29.66967664	14.45010509	0.864700842	17.14703064	1.617435381	24.66923473	14.68434811	0.886472861	17.63819059	1.253702179	20.24032882	14.93720627	0.89955005	18.99520206	0.418848343	0.243069863
1948	Steelhead	0.75155583	0.63420347	0.476639315	0.567608731	133.04	135.04	140	141.3	14.42668704	34.26701885	13.1476903	340.2825372	0.831837692	20.19315897	7.043952905	17.33463724	11.75646	149.5616119	0.708831286	16.42404823	5.435743704	32.71410192	13.64422099	434.6273397	0.850262096	21.43474293	453.220459	0.287046437	0.712953563	0.693540676	0.852925414	0.888710721	4.082305923	34.45822369	13.82012901	0.847975314	23.88214455	1.3395987	29.82123935	14.03534857	0.90968885	23.72186661	1.038256064	24.49758327	14.20880222	0.918129802	23.56048679	0.571816232	0.358499895

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1949	Steelhead	0.7896 73617	0.6308 41149	0.4981 58611	0.4129 27839	117.7 3	120.4 6	126.3 3	135.9	16.77 92820 8	31.49 00039 5	12.21 74545	254.8 94928	0.822 11406 7	16.03 42067	8.399 12813 2	15.41 57846 2	10.35 67325 6	124.1 38861 1	0.666 75529 5	13.33 47869 9	6.407 18966	28.26 43105 9	12.78 07498	313.9 00014 2	0.862 63663 6	16.05 22932 2	323.0 88195 8	0.436 98368 8	0.563 01631 2	0.690 44887 1	0.845 95176 8	0.883 70508 4	4.797 41626 2	29.88 26048 5	13.01 94358 8	0.867 40704 8	17.78 63950 7	1.592 62394 2	25.02 93210 6	13.39 21947 5	0.888 97750 8	18.40 92760 1	1.233 24852 4	20.57 71838 9	13.69 56067 1	0.897 81865 5	19.97 90344 2	0.593 30884 9	0.391 67893 9
1950	Steelhead	0.7662 19902	0.6395 96166	0.4900 71312	0.3641 90496	123.2 7	127.1 2	133.4	138.9 7	18.76 17293 1	29.41 58723 1	11.79 27146	205.4 22538 2	0.851 20710 3	14.20 13140 7	9.809 83761 7	12.77 58417 1	10.55 93029	92.21 80435 2	0.742 11795 3	11.60 53949 4	6.975 89626 9	25.67 45014 4	12.12 17379 6	260.6 80150 3	0.867 71838 9	14.52 98958 6	272.8 29254 2	0.485 38799 5	0.514 61200 5	0.699 33941 5	0.852 15240 2	0.889 46226 4	5.214 1954	27.12 27713 2	12.31 28917 7	0.880 49796 8	16.23 91750 3	1.766 51954 7	22.59 99100 4	12.55 27019 5	0.889 67742 5	16.70 75265 2	1.369 88416 3	18.52 69299 8	12.75 79565	0.898 99295 6	17.89 92905 6	0.580 23331 4	0.383 26993 9
1951	Steelhead	0.7629 40361	0.6210 11048	0.4737 94393	0.3831 88102	120.9 4	123.4 4	128.7 7	135.0 2	16.59 04683 5	31.55 31338 3	12.56 47593 2	244.7 50339	0.847 93497	15.49 33521 4	8.379 72418 2	14.56 23959 4	11.00 27395 2	100.9 37027	0.741 51839	12.66 58992 8	6.237 93014 9	29.12 06544 5	13.05 99254	316.7 81779	0.860 58311 7	15.63 25904 5	328.8 23303 2	0.457 8386	0.542 1614	0.683 23234	0.845 48880 9	0.883 88613 1	4.683 77003 1	30.76 58465 5	13.24 72896 6	0.863 46267 5	17.59 65288 2	1.554 54385 3	25.65 59595	13.52 30334 6	0.886 93555 2	18.10 12080 5	1.204 30681 1	21.07 44443 3	13.76 42822 3	0.897 40386 6	19.44 68183 5	0.571 68478 3	0.357 90924 8
1952	Steelhead	0.8142 77512	0.6960 22213	0.5667 55236	0.5686 67503	119.9 2	120.1 4	125.6 4	134.9 7	14.78 50943 4	33.56 13118 1	11.19 57998 3	289.0 93098 2	0.786 87868 8	17.76 09742	6.708 22661 4	19.13 86500 5	10.14 09431 5	162.6 86633 3	0.574 49404	16.20 24078 4	6.087 52509 2	30.26 11194 8	11.31 00264 9	354.1 78110 8	0.857 30557 6	17.27 71177 3	362.7 93212 9	0.316 92901 9	0.683 07098 1	0.746 03700 3	0.873 01866	0.906 16811 6	4.539 64241 6	32.11 74569	11.53 39607 2	0.852 31488 9	18.80 11974 3	1.482 36810 4	26.90 82261 1	11.83 66699 2	0.892 92045 4	19.10 23966 5	1.148 24845 6	22.11 30382 3	12.12 68844 6	0.907 63434 8	20.59 57250 6	0.647 36060 4	0.454 51203 6
1953	Steelhead	0.7600 17113	0.5891 66992	0.4477 76996	0.3894 16475	122.4 4	126.4 2	132.9 8	145.3 2	17.67 83006 5	30.61 89892 2	12.84 68962 4	215.0 28571 5	0.855 24918 4	14.63 62432 8	9.207 74811 5	13.62 14800 1	11.00 58301 9	91.90 33096 3	0.754 66400 4	11.87 42031 1	6.524 86959 1	27.27 42094 9	13.65 20992 9	272.7 43540 4	0.866 69523 5	14.97 49641 4	284.2 64343 3	0.438 04594 3	0.561 95405 7	0.655 38786 6	0.831 15978 1	0.872 02899 2	4.908 82590 4	28.71 01377 5	13.83 62123 5	0.879 75045 4	16.71 68256 8	1.662 48892 2	24.00 95066 2	14.05 68691 9	0.889 40864 8	17.27 10984 5	1.289 11115 2	19.68 37483 5	14.21 13871 6	0.898 32747	18.47 92633 1	0.549 11515 1	0.318 13659 1
1954	Steelhead	0.7882 94942	0.6579 81144	0.5186 83208	0.3009 45807	112.7 8	120.3 7	127.6 7	137.3 4	21.09 85241 8	28.39 41111 8	11.21 68712 6	205.4 02148 7	0.858 98347	14.19 94122 4	11.86 03992 4	11.15 11825 1	9.846 81091 3	87.35 54565 4	0.761 35958 4	11.22 04500 2	7.251 24851 6	24.82 07467 1	11.58 49491 8	257.5 56704 2	0.869 82854 2	14.59 44273 5	264.8 38836 7	0.568 48034 2	0.431 51965 8	0.714 90430 4	0.858 29571 3	0.894 34304 3	5.388 36661 7	26.29 85022	11.80 05373	0.884 40115 5	16.30 95357 9	1.821 0418	21.92 69034 5	12.07 58482 6	0.893 6252	16.84 28061 8	1.412 21005 5	17.97 60290 1	12.30 31415 9	0.904 79195 1	18.16 76416 4	0.606 94134 5	0.415 41795
1955	Steelhead	0.7543 2654	0.6030 66812	0.4549 09302	0.4151 17633	121.7 4	127.5 9	134.3 5	136.2 9	19.49 23478 6	28.81 49158 6	12.37 28775 3	180.1 16585 9	0.870 70184 9	13.53 08866 5	10.35 26867 3	12.09 00512 2	10.88 97392 3	77.30 74615 5	0.785 74416 6	10.85 00145	7.175 56643 5	24.64 78224 4	12.91 03665 4	229.8 62286 9	0.876 85113 2	14.08 90431 4	242.8 71063 2	0.413 39452 2	0.586 60547 8	0.667 28559 1	0.835 13858 5	0.875 10464 5	5.366 23370 6	25.98 78094 6	13.11 36522 3	0.891 94704 3	15.71 17704 4	1.836 39040 6	21.74 34990 3	13.36 40718 5	0.896 28732 2	16.08 04869 3	1.424 03960 2	17.82 82032 8	13.55 36661 1	0.908 12170 5	17.16 85681 3	0.558 11522 4	0.332 39136 9
1956	Steelhead	0.7949 63964	0.6859 93897	0.5453 40427	0.4771 4423	126.0 9	123.2 1	128.0 6	140.6 6	14.72 69093 6	34.06 47557	11.77 19556 3	320.3 23787 1	0.827 17617 9	19.11 76227 8	7.222 83211 4	17.55 36592 7	10.64 82616 4	144.1 39428 7	0.686 45858 8	15.66 43161 8	5.529 13241 8	32.52 32671 5	11.98 75222 8	413.4 93133 5	0.858 02928 6	19.89 67065 8	429.0 84594 7	0.394 49909 8	0.605 50090 2	0.737 59642 2	0.871 78434 2	0.904 32170 9	4.151 39394 3	34.31 38619 2	12.18 71641 2	0.850 97893 5	21.97 69073 5	1.343 07780 1	29.68 89640 6	12.44 75278 9	0.908 60422 5	21.92 10815 4	1.039 03495 5	24.47 88712 9	12.69 35362 8	0.918 66216 1	22.91 71037 7	0.629 42821 7	0.448 12287
1957	Steelhead	0.7891 33397	0.6692 53891	0.5281 30597	0.4444 06001	117.3	120.4 8	126.9 1	142.0 3	17.80 81478 4	30.58 79523 6	11.55 95691 5	272.6 70687	0.838 42179 2	16.84 48996 9	9.236 51280 3	13.59 88596 2	10.31 16487 5	118.9 68829 3	0.714 50513 6	13.35 90845 1	6.596 72734 1	27.70 59698 3	11.82 95811	335.0 68308 5	0.860 89667 7	16.95 43391 1	343.5 99121 1	0.419 89086 2	0.580 10913 8	0.725 79394 1	0.865 71905 4	0.900 01037 3	4.873 20622 8	29.47 88664 7	12.02 03529 4	0.867 63570 3	18.86 87946 3	1.593 52524 6	24.98 83657 9	12.30 32093	0.899 18488 3	19.54 23450 5	1.232 61828 7	20.58 77511 3	12.57 35321	0.910 78996 7	21.10 18896 1	0.607 87497	0.441 03883
1958	Steelhead	0.7528 01623	0.6358 56424	0.4786 73748	0.5463 33776	125.6 4	128.5 1	133.9 6	138.6 2	17.38 43032 9	31.38 52888 6	12.35 85643 1	261.8 58227 3	0.833 76847	16.43 88076 2	9.139 23260 6	14.09 30399 5	11.05 75985	118.1 27896 1	0.706 23611 2	13.56 37825	6.284 04091 3	28.92 59161 1	12.75 59833 5	326.9 72742 7	0.856 92999 8	16.50 98104 5	339.1 41998 3	0.305 47692 4	0.694 52307 6	0.696 09721 6	0.852 81058 5	0.890 06065	4.673 63046 1	30.67 81274 9	12.94 06129 8	0.863 44286 2	18.31 86679 8	1.541 23154 3	25.86 59363 5	13.15 77920 9	0.893 38433 7	18.92 16588 3	1.193 41772 8	21.26 81172 6	13.33 90145 3	0.905 15580 8	20.32 35082 6	0.563 22240 3	0.377 31591
1959	Steelhead	0.7418 6261	0.6118 52133	0.4539 1022	0.2622 75555	116.7 4	121.7 9	126.8 5	139.7 1	20.46 92637	28.91 39485 7	12.33 84827 9	205.8 70139	0.863 15265 3	13.95 45677	11.52 49754	10.94 46286 8	10.71 31486 9	74.50 29083 7	0.781 01037 7	10.81 16306 3	6.970 50231	25.99 34460 3	12.85 11052 1	270.3 39673 4	0.863 18117 4	14.48 057	280.1 96044 9	0.586 78606 4	0.413 21393 6	0.676 39127 6	0.841 63288 4	0.880 65118 2	5.174 23408 5	27.57 64502 8	13.04 71437 5	0.875 80299 4	16.44 29105 8	1.737 12458 5	22.97 45091 1	13.33 77281 8	0.886 98842 1	16.95 07643 4	1.346 70766 4	18.84 39723 2	13.58 75425 3	0.895 44612 2	18.12 49380 1	0.543 25272	0.355 26167 3
1960	Steelhead	0.7687 46618	0.6312 21634	0.4852 49497	0.2913 86491	118.7 4	125.7 5	132.3 7	136.4 5	19.60 00928 8	28.79 75794 1	11.90 34437 5	194.4 93137 9	0.872 85826 9	13.97 86132 7	10.58 35179 2	11.40 11435 7	10.45 50104 1	77.10 76477 1	0.800 00089 4	11.50 36449 4	7.040 61459	25.37 63118 4	12.33 98226 1	251.6 35330 2	0.870 00226	14.23 72175 1	263.2 25952 1	0.565 00474 9	0.434 99525 1	0.691 49597 2	0.846 60175 3	0.884 52935 1	5.268 28180 3	26.78 70592 6	12.55 20401	0.884 41454 2	16.09 34120 2	1.787 04543 4	22.33 21499 9	12.83 90436 2	0.891 87300 2	16.54 57429 9	1.385 24420 6	18.32 29354	13.07 30671 9	0.902 48611 6	17.70 32537 5	0.584 75654 4	0.371 00653 4
1961	Steelhead	0.7256 30773	0.5871 8597	0.4260 80209	0.2793 12045	121.9 7	128.7 9	135.2 6	145.7 5	19.04 21803 1	29.83 97857 9	12.92 82487 5	216.8 84348 7	0.880 93868 3	14.67 36328 6	10.62 6552	11.24 26736	11.16 58567 4	68.54 52377 3	0.829 38214 5	11.50 18934 2	6.463 40727 8	27.54 83062 7	13.70 13444 9	286.3 68372 6	0.864 37201 5	14.97 71875 5	291.6 63330 1	0.553 56672 8	0.446 43322 2	0.654 11347 7	0.832 82837	0.873 53574	4.868 52097 5	28.98 57399 4	13.86 67905 8	0.876 96739 4	17.08 40475 1	1.647 41294 1	24.26 48329	14.05 00669 5	0.894 94313 8	17.67 25072 9	1.279 24753 7	19.83 55356 7	14.18 89915 5	0.905 95406 3	18.96 83675 8	0.516 66283 4	0.315 51761 2
1962	Steelhead	0.7348 39749	0.5852 83064	0.4300 8926	0.4632 78084	129.5 2	135.0 2	140.1 9	136.0 7	16.43 07147	31.23 53543 8	13.10 98732 3	207.3 15359 9	0.855 68647 7	14.09 44433 9	8.146 35913 1	14.59 51014	11.59 70529 6	88.55 34698 5	0.761 58570 1	11.53 52453 2	6.329 35445	28.05 70970 4	13.74 23489 9	271.8 65359	0.861 94731 8	14.54 81901 2	279.5 05493 2	0.356 09936 5	0.643 90063 5	0.650 09301 8	0.828 81316 2	0.870 13265 5	4.793 89731 6	29.43 86751 5	13.92 63597 5	0.875 94994 3	16.36 38740 5	1.637 28679 7	24.44 34698 8	14.11 40082 7	0.887 84476 1	16.81 52389 5	1.272 80823 9	19.93 59628 3	14.24 83682 6	0.897 47157 7	17.82 39603	0.548 03523 7	0.291 23299 7
1963	Steelhead	0.7056 96153	0.5589 66843	0.3944 60751	0.5744 22702	132.3	133.9 5	141.0 6	143.1 7	17.50 60121 3	30.23 44557 9	13.41 10369 7	196.3 80713 9	0.850 51916 3	13.93 21587 8	8.836 54361 2	13.74 51578 2	11.84 40494 5	89.20 18569 9	0.734 35064 6	11.16 79142	6.726 56934 7	26.22 70019 8	14.06 66971 2	247.3 83916 2	0.872 58617 1	14.41 65430 9	257.4 75036 6	0.245 19135 2	0.754 80864 8	0.629 33800 1	0.820 12490 4	0.863 27319 2	5.071 09909 5	27.54 92029 1	14.22 23768 2	0.885 31788 6	16.04 24068 5	1.739 81609 2	22.98 48576 9	14.39 48637 6	0.894 49785 2	16.45 24885 8	1.351 40632 8	18.77 87882 7	14.53 29318	0.907 06440 8	17.55 37147 5	0.512 00794 3	0.281 16851 1
1964	Steelhead	0.7413 83278	0.5957 35091	0.4416 68035	0.5159 97421	129.4 5	132.1 8	138.2 7	142.9	17.97 44366 7	29.76 73788	12.84 86787 3	206.7 95863	0.853 12585 7	14.41 67689 9	9.125 68179 5	13.21 52627 9	11.30 06111 1	92.22 69790 6	0.742 37183 3	11.62 55033 5	6.900 45028 2	25.66 97699 8	13.33 34954 6	258.0 7149	0.871 98419 4	14.78 18941 3	267.8 08685 3	0.313 89934 6	0.686 10065 4	0.660 43868 3	0.832 92096 1	0.873 29848 7	5.170 82303	27.04 87299 5	13.54 47832 1	0.884 53420 4	16.52 43858 3	1.762 87364 2	22.64 74851 8	13.83 08550 5	0.897 35273 5	17.02 16658 9	1.367 11519 2	18.56 42288 8	14.06 8923	0.910 03379 2	18.22 36485 5	0.551 48131 5	0.325 69429 5
1965	Steelhead	0.7813 83026	0.6528 48468	0.5101 24711	0.5444 25669	125.6 8	119.8 1	124.7 2	143.9 1	17.73 74538	31.76 41770 4	12.02 93128 8	258.2 67589 6	0.804 18461 8	15.93 47136	9.462 01577	14.86 18521 3	10.41 46320 3	129.7 00410 5	0.623 68254 1	13.25 76095 6	6.317 56027 8	29.11 68395 8	12.36 43304 5	326.0 46722 4	0.856 69594	16.15 21608 8	333.7 69226 1	0.317 16826 8	0.682 83173 2	0.710 29713	0.855 81185	0.892 04870 2	4.686 80235	30.95 75563 1	12.59 17867 7	0.858 49659 4	17.82 81709 7	1.545 42610 8	25.83 64547 4	12.98 70357 5	0.889 56530 9	18.26 35215 1	1.198 55416 6	21.17 62929 3	13.34 44032 7	0.902 36556 5	19.59 77735 5	0.589 34793 8	0.414 04850 3
1966	Steelhead	0.6541 5906	0.5310 5678	0.3473 95604	0.4022 92168	131.1 1	137.7	142.4 5	134.3 6	17.78 11584 9	29.54 85782 3	13.49 71001 5	170.9 35697 3	0.879 05380 6	13.22 57693 8	9.086 21360 4	12.86 32657 1	12.20 79189 3	67.68 00262 5	0.810 67510 8	10.78 49849 7	6.736 32577 1	25.62 50215 9	14.21 55938 1	224.0 18336	0.875 56321 4	13.71 53372 8	229.4 51919 6	0.367 79912 3	0.632 20087 7	0.599 48944 8	0.802 06576	0.848 78665 5	5.139 39705 5	26.68 30065 5	14.38 83691 8	0.892 69225 6	15.54 85420 2	1.808 03215 5	22.15 39489 9	14.43 88513 6	0.895 23069 1	15.90 90925 9	1.406 38530 3	18.04 98011 5	14.40 05703 9	0.906 66741 1	16.93 31941 6	0.472 55362 4	0.224 17538 2

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1967	Steelhead	0.718616554	0.622839236	0.447582586	0.444576874	128.93	131.21	137.71	147.57	20.799222666	28.56754468	12.40799386	220.0285748	0.865836752	15.15170424	11.86112093	10.11385283	11.10948963	81.41789093	0.779381657	12.05275517	6.992734522	25.40554028	12.71825727	277.0011012	0.87080134	15.28741058	280.3849487	0.38401148	0.61598852	0.685734132	0.847351366	0.885456744	5.212346882	26.83871243	12.89525661	0.880286491	17.27742729	1.767904043	22.59318417	13.14271927	0.902054807	17.81998316	1.371602684	18.50388403	13.37648249	0.916762531	19.25795937	0.520604573	0.359468266
1968	Steelhead	0.660876968	0.53514937	0.353667893	0.228505541	114.13	120.81	128.56	146.73	24.22918079	25.8134762	13.05808408	143.2769566	0.87409859	12.78472556	13.75805401	8.839907871	11.49295349	58.08045273	0.782827711	10.4526701	8.516794667	20.19181869	13.51089907	177.4926682	0.88720717	13.06750099	181.4013977	0.575653593	0.424346407	0.609723806	0.804988478	0.850483634	6.357621893	21.22220638	13.68183022	0.902953267	14.73175964	2.247359321	17.83056174	13.97211075	0.910622199	14.84789435	1.74486284	14.61152878	14.22648096	0.931443095	15.96960735	0.435817133	0.262055213
1969	Steelhead	0.734717095	0.5977224	0.439156866	0.659559352	130.75	129.9	135.01	139.31	14.39191289	33.79262423	13.36082854	279.9591915	0.822540815	16.96513486	6.773258127	17.38880565	11.76080112	123.7551147	0.67448746	13.91020432	5.667672247	31.62907774	14.05421416	356.4922028	0.857189397	17.06697488	361.2131042	0.199683017	0.800316983	0.661968716	0.838027137	0.877562099	4.283723325	33.26198887	14.22668056	0.85632813	19.05298576	1.419465899	28.15747808	14.40066147	0.895983676	19.59555117	1.101371884	23.06751319	14.5292182	0.906953663	21.1221447	0.553275743	0.305111466
1970	Steelhead	0.748293213	0.613562151	0.459124393	0.466376252	119.16	127.44	134.7	144.82	22.0250866	27.74407998	12.03167718	188.3070548	0.870159098	14.39817636	12.51520885	10.25574959	10.57153721	81.73014526	0.777579546	12.10971737	7.554736264	23.52951292	12.51338196	228.2668762	0.882388691	14.4138329	232.9473572	0.368102324	0.631897676	0.678105584	0.841173271	0.880303001	5.595103391	24.92115186	12.71556301	0.893673527	16.00208206	1.909379549	20.93890696	12.9621226	0.901214004	16.44031398	1.482083775	17.1385025	13.1550045	0.916308135	17.74596786	0.546667366	0.339884111
1971	Steelhead	0.743597792	0.642569332	0.477813137	0.643693304	139.63	138.57	140.43	145.4	14.78034249	34.26065071	12.82344668	313.8872931	0.819812856	18.70853363	7.332433812	17.34153716	11.59665985	143.8618378	0.669718063	15.46289024	5.502429463	32.66834034	13.15093613	399.3854065	0.854798575	18.99479373	403.6701355	0.225204823	0.774795177	0.70097189	0.857024859	0.89294111	4.133303382	34.45829627	13.31020107	0.848171353	21.00068626	1.351792552	29.5478751	13.5253032	0.904481928	21.27652423	1.047666259	24.27274044	13.73432541	0.91637668	22.58339787	0.581546752	0.374373422
1972	Steelhead	0.777015196	0.643112015	0.499707808	0.474853254	124.16	122.09	127.57	140.41	16.32925127	32.0215129	12.35128335	282.8195675	0.838150595	17.40366721	8.280672126	15.04325164	10.76081066	122.3123001	0.716054714	14.11517868	6.082891867	29.69600812	12.76935244	358.9469248	0.858972778	17.82595833	353.6027832	0.376928112	0.623071888	0.702338897	0.854840512	0.890762311	4.561721489	31.36564198	12.95593224	0.858420813	19.87093964	1.512777805	26.43742508	13.27379672	0.896941145	20.15617498	1.175003976	21.60426544	13.57883596	0.90547362	21.29734135	0.580348261	0.400946831
1973	Steelhead	0.679281812	0.520113036	0.353303326	0.244005822	116.62	127.42	134.96	147.14	24.22409531	26.42275126	13.06140307	128.9798581	0.898798823	12.68336466	14.26433489	8.893195079	11.08097343	51.06139145	0.841017866	10.80750999	8.016260132	21.38694045	13.93570964	164.8510768	0.896349519	12.95731052	172.8821259	0.552274931	0.447725069	0.592737037	0.795515628	0.842263139	6.018616542	22.41312796	14.12986488	0.910148239	14.54187756	2.126645908	18.8419482	14.33590698	0.910815338	14.65516822	1.652418301	15.40527778	14.48405123	0.930003107	15.57971144	0.452009593	0.257601438
1974	Steelhead	0.756037061	0.638031162	0.482375205	0.480224263	134.6	135.84	137	140.17	14.89825719	34.13264287	12.86156498	301.6744145	0.840370068	18.15968943	7.521165706	16.63131985	11.31744194	127.1333618	0.724239111	14.79393463	5.42420502	33.085694	13.31413015	393.9949849	0.857330918	18.65466833	401.0102539	0.365955697	0.634044303	0.696756452	0.853262351	0.88973253	4.097829893	34.80622408	13.48607693	0.849107373	20.57461853	1.342089429	29.75282095	13.76430607	0.903026243	20.73654683	1.039751276	24.4615816	14.0198431	0.916014016	22.08230019	0.587600155	0.373988695
1975	Steelhead	0.786980391	0.635468331	0.500101115	0.273824252	113.68	122.1	129.55	138.59	20.75064405	28.21963604	11.61542273	191.4453501	0.869804616	13.89484048	11.34003896	11.39117456	10.03985901	83.35051727	0.784699714	11.03722496	7.432441317	24.07199942	12.06712882	239.4127477	0.875627846	14.32026315	246.7445526	0.592845272	0.407154728	0.695869108	0.847583124	0.885133352	5.524494253	25.48235308	12.29270515	0.890411031	16.02823753	1.874776803	21.31536423	12.62269243	0.898115019	16.5025514	1.454755537	17.45604328	12.88679361	0.911649376	17.75468683	0.592701928	0.383888258
1976	Steelhead	0.809084065	0.689489153	0.557854686	0.486503813	117.3	118.12	124.67	137.76	17.5394673	30.76078407	11.04425458	252.0238936	0.809987752	15.81370786	8.844160013	14.72801183	9.925176048	125.6428238	0.634532028	13.14499226	6.707580961	27.37612141	11.16214434	309.316747	0.861194928	15.87962508	309.3200073	0.389105608	0.610894392	0.74140507	0.87061143	0.904036147	4.971592225	29.11011174	11.39370174	0.865823305	17.57487659	1.648670308	24.23683475	11.72213046	0.886291345	18.13036378	1.279739164	19.82791338	12.03107166	0.894109666	19.56137371	0.630188151	0.464256714
1977	Steelhead	0.615664474	0.495616139	0.30513325	0.160121183	122.38	129.22	135.85	134.3	22.24490682	26.5791097	13.66513477	113.6502438	0.912142911	12.62726559	12.35460485	9.672807065	12.15408344	38.59640274	0.87368511	11.21683292	7.936571866	21.27334869	14.33260727	152.7941844	0.90026319	12.67042271	158.859726	0.65328141	0.34671859	0.570994459	0.783318247	0.832184432	6.033582717	22.11510354	14.48054333	0.915379739	14.34455147	2.169812769	18.49948912	14.63935598	0.916889429	14.36315918	1.688280761	15.08662786	14.74111414	0.939087212	15.26049519	0.400496102	0.208822372
1978	Steelhead	0.727017994	0.598006488	0.434761478	0.500866363	134.77	137.42	141.83	142.93	16.45804115	31.15600187	12.9015492	209.1196959	0.84893319	14.14059976	8.144270666	14.852526	11.6139616	95.26701508	0.73650744	11.56513271	6.364219554	27.56671711	13.39115747	268.5338491	0.867088109	14.57216557	278.2644653	0.325218073	0.674781927	0.661835012	0.835101048	0.875874643	4.842418678	28.8122617	13.54174767	0.87837255	16.32780323	1.67242118	23.88398755	13.70322673	0.887276272	16.72178014	1.297716342	19.55330645	13.83687162	0.895942688	17.77860737	0.53168578	0.32561776
1979	Steelhead	0.762229505	0.635269516	0.484221169	0.415176629	119.28	125.44	131.73	136.2	20.53021596	28.70708993	11.75035449	194.680675	0.860786387	13.69014246	11.41320565	11.36369893	10.47960701	80.56386108	0.768533647	10.87233295	7.137701876	25.25109837	12.17476463	249.7607676	0.868057122	14.20895584	260.9950562	0.429720765	0.570279235	0.696659324	0.850729139	0.888206484	5.294297107	26.77808749	12.35776482	0.883003151	15.9159853	1.78742484	22.34430374	12.57013798	0.888940871	16.38864263	1.38656158	18.30565779	12.73860025	0.897937328	17.481462	0.576343459	0.374436457
1980	Steelhead	0.777998877	0.643020348	0.500269108	0.342282242	113.49	121.17	126.75	145.59	19.80419623	31.03333749	12.08866331	248.8732867	0.85676037	15.43620106	11.59647499	12.37737774	10.12044334	94.43970947	0.765088987	11.75740738	6.245063193	29.56083539	12.73029407	327.051	0.861533483	16.06158185	346.7476501	0.515468668	0.484531332	0.702001706	0.851751182	0.888522971	4.613153823	31.49316136	12.97135086	0.863930154	18.00864658	1.499395512	26.54209538	13.34363651	0.891113321	18.63777574	1.158842228	21.90860274	13.63282204	0.903195888	19.96024323	0.590964363	0.397789423
1981	Steelhead	0.613269048	0.535496206	0.328403248	0.47487472	137.22	136.44	141.13	150.36	16.77548075	31.00909853	14.37844249	211.2338399	0.853420266	14.53109772	8.398956254	14.29374683	13.08987541	89.56213074	0.746650684	11.61190166	6.455481395	27.20455584	14.80837329	269.6633301	0.86910519	14.90984305	276.3310242	0.294947163	0.705052837	0.609421637	0.811636971	0.856831089	4.880176172	28.52262154	14.94609737	0.878374684	16.69328251	1.681034908	23.76207763	15.14132722	0.893308063	17.10092608	1.304420933	19.45293124	15.31537199	0.906396896	18.31469107	0.419845501	0.238863763
1982	Steelhead	0.757995171	0.624661495	0.473490397	0.466734431	125.42	123.18	128.43	140.14	18.24538607	30.65757463	12.36754635	241.1728107	0.827139607	15.2522052	9.701120108	13.66667416	10.75203075	109.1117203	0.689766657	12.13887882	6.58000163	27.63690859	12.79766528	304.8291168	0.855187257	15.68965459	308.0129089	0.373514734	0.626485266	0.686679204	0.846745129	0.884823248	4.891640581	29.31751831	13.00006046	0.863261974	17.42682571	1.631265767	24.49685876	13.32148234	0.886348704	17.93118858	1.26629401	20.03865294	13.61760426	0.895703316	19.23534679	0.551201262	0.372877672
1983	Steelhead	0.770670468	0.613999136	0.473191001	0.437647012	120.96	122.25	128.29	147.34	18.64995969	30.10521453	12.43493843	226.2392382	0.845033475	14.80567064	9.965752639	12.84144368	10.64800491	100.0871155	0.731061697	11.82317543	6.73073557	26.85619462	13.02840042	284.7722829	0.862526804	15.13690448	290.7252808	0.400428241	0.599571759	0.678025153	0.841824554	0.88047619	5.009847432	28.45337068	13.22987633	0.874267864	16.92760353	1.678068131	23.80788893	13.54136213	0.889413575	17.49294027	1.302322686	19.48422486	13.80951166	0.897926688	18.82042503	0.554963961	0.368323934
1984	Steelhead	0.790958289	0.655723559	0.518649984	0.484892164	122.03	121.58	127.21	138.73	17.9083032	30.19491119	11.57789196	219.3720997	0.80662949	14.64854516	8.895327576	14.59652752	10.23521481	121.5491791	0.62788921	12.64760704	7.037634663	25.96428889	11.72826195	268.9071503	0.858894507	14.82023152	274.4838257	0.374599177	0.625400823	0.713804378	0.857550808	0.893629045	5.210937552	27.60169132	11.94493027	0.872991896	16.23516293	1.743588202	22.94590557	12.32958253	0.885727962	16.6553812	1.354937576	18.73008908	12.70130634	0.895175904	17.80942202	0.598952812	0.419673859

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1985	Steelhead	0.776531612	0.638011638	0.495436206	0.354927856	121.01	124.87	131.15	133.36	18.0819829	29.342263	11.6806823	192.270762	0.84666789	13.9245112	8.96740832	13.5327828	10.5172941	95.5019973	0.72456046	11.7607278	7.12839239	25.0370400	12.0300199	243.295079	0.87175883	14.2485450	251.630340	0.49672591	0.50327408	0.69724160	0.85035782	0.88787432	5.33678036	26.4193663	12.2339910	0.88661235	15.8343004	1.82363157	21.9363447	12.4535315	0.89367425	16.1829185	1.41673862	17.9191261	12.6253414	0.90477764	17.2489757	0.59418982	0.37585194
1986	Steelhead	0.763237571	0.605335835	0.462032236	0.423483214	122.54	121.46	126.85	143.13	17.6540732	30.0025568	12.4515361	206.746303	0.82657195	14.1587548	8.64985641	14.3723910	10.7520807	106.530874	0.67865359	11.6097204	7.04224000	25.4827322	12.9161404	256.756111	0.86312375	14.5294291	258.799346	0.40760734	0.59239265	0.66999378	0.83759736	0.8773482	5.25914190	26.9368879	13.1181238	0.87965096	16.0654140	1.78880195	22.3805921	13.4517405	0.89307717	16.4934053	1.39081637	18.2501068	13.7668600	0.90590003	17.6529145	0.54072880	0.36747053
1987	Steelhead	0.509889523	0.510526423	0.260312074	0.170519228	131.49	130.3	132.69	135.8	18.8350293	29.3563811	14.3066491	182.611975	0.88778546	13.7396225	10.1663037	11.5057505	13.2615013	54.4444123	0.84386941	11.2539564	6.71308729	26.2592891	14.6632216	250.579363	0.86827502	14.0898127	256.269989	0.60892814	0.39107185	0.58677542	0.80037937	0.8474952	5.06079278	27.5804070	14.7875473	0.88102480	16.0656011	1.74799332	22.9033640	14.9271326	0.89085193	16.4530617	1.35921315	18.6715046	15.0647306	0.90119272	17.5036478	0.34003535	0.18656047
1988	Steelhead	0.701670375	0.572765191	0.401892366	0.34016287	130.86	136.8	142.38	141.73	19.2355372	28.8089134	12.9369475	163.334339	0.88319241	13.0341435	10.3347799	11.3798411	11.5525955	62.9786384	0.82041099	10.6360647	6.95239701	24.9638787	13.5388836	215.993962	0.87710664	13.5058543	223.503921	0.46443216	0.53567683	0.63940130	0.82297982	0.8657333	5.27001562	26.0962100	13.7057022	0.89585218	15.2943264	1.84361633	21.7207107	13.8445959	0.89902291	15.6014932	1.43356809	17.7109866	13.9352159	0.91234639	16.5640114	0.49867940	0.29057472
1989	Steelhead	0.797217035	0.657928545	0.524511844	0.261437781	114.23	121	127.38	131.9	18.3037957	29.9182508	11.3866583	218.662584	0.84442458	14.4564503	9.56207111	12.9439627	9.98954238	96.2422958	0.72885453	11.8114849	6.74579756	27.0280563	11.7801620	282.654602	0.86294600	14.8144531	289.010894	0.61794058	0.38205941	0.71511971	0.85780892	0.8935906	5.03190533	28.6441994	11.9799562	0.87307466	16.6525461	1.68060019	23.7970559	12.2695490	0.88697463	17.1368449	1.30561208	19.4352016	12.5000488	0.89585679	18.2784624	0.61887956	0.39374312
1990	Steelhead	0.505494942	0.488009082	0.246727441	0.278291057	137.95	135.55	135.48	147.8	16.9803977	30.3994122	14.9767987	188.819301	0.87355391	13.6553580	8.45657227	13.5916492	13.8301418	68.8732070	0.80541101	10.8282432	6.59352017	26.5274483	15.2430687	250.183334	0.86711699	14.1374419	254.923080	0.43176757	0.56857823	0.56625702	0.79207154	0.8413183	5.00317610	27.7490796	15.3786338	0.88265854	16.0744934	1.74007110	23.0076251	15.5754035	0.89377309	16.4849230	1.35306908	18.7558353	15.7963347	0.90704035	17.6134929	0.33014608	0.16946540
1991	Steelhead	0.694269538	0.572430519	0.397421072	0.239506977	119.78	126.17	132.22	147.6	21.2059058	28.6071850	13.0040629	190.984127	0.88309081	13.9676711	12.3522647	9.89193444	11.1916006	63.5409347	0.82713815	11.0820976	6.90590553	25.7229931	13.6940536	253.275581	0.87126375	14.3176271	248.185913	0.58757099	0.41242900	0.64069891	0.82358432	0.8656716	5.18150692	27.1012120	13.8747812	0.88377952	16.2944774	1.78432317	22.4873494	14.1196454	0.89816772	16.7229617	1.39027404	18.2571775	14.3278670	0.91306889	17.9152054	0.47253946	0.30768455
1992	Steelhead	0.524692973	0.483215518	0.253539787	0.216411336	131.98	133.55	136.53	135.96	18.6133184	28.8240782	14.5301997	155.121913	0.89230731	12.9663262	9.64020508	11.7792276	13.4173873	50.2447258	0.84552146	10.7104475	7.02456041	24.6702523	14.9786968	210.567858	0.87744913	13.3277372	212.996765	0.52153872	0.47846127	0.56143299	0.78499886	0.8346607	5.33326634	25.7642018	15.0958286	0.89594337	15.2274461	1.87600828	21.3873826	15.2157805	0.90003486	15.5420634	1.46137752	17.3779815	15.3094749	0.91429758	16.5118045	0.34108186	0.17435134
1993	Steelhead	0.769211944	0.637268636	0.490194646	0.510601923	118.55	124.66	132.12	139.9	20.7214482	28.3836983	11.6480599	206.273654	0.85839545	14.6252007	11.3066335	11.3187485	10.3498689	90.9296310	0.75011733	11.7942459	7.44396352	24.3959424	11.9952130	250.891082	0.87782520	14.8076438	262.499511	0.33973652	0.66026348	0.70061547	0.85395893	0.8906077	5.46646058	25.9908172	12.1752456	0.88793113	16.4322748	1.81715089	21.9623659	12.4177236	0.89972909	16.9776773	1.40848651	18.0231145	12.6215248	0.91383326	18.4043946	0.57408606	0.37202005
1994	Steelhead	0.592453951	0.515297826	0.305290233	0.253329022	128.05	130.19	134.58	137.95	20.8098168	28.4458693	13.7402242	164.395310	0.88053080	13.0702043	11.8410807	10.5718571	12.1221111	60.4159912	0.81606971	10.5593088	7.01764260	24.8368097	14.3865764	219.485834	0.87451415	13.5871047	225.818893	0.51299428	0.48700571	0.58814991	0.79844425	0.8457518	5.30249773	26.0174711	14.5592086	0.89221892	15.4228555	1.85377077	21.6044401	14.7325077	0.89621381	15.7747974	1.44158862	17.6135646	14.8882789	0.90863642	16.7604761	0.40088061	0.20437083
1995	Steelhead	0.757093437	0.576159082	0.436200626	0.433645694	116.64	123.78	130.63	138.01	20.1476258	28.5903835	12.6229158	187.577940	0.86093088	13.6552895	10.8797683	11.6548018	10.6375864	83.6939086	0.75910573	10.9136158	7.30754908	24.4243195	13.4153191	232.709892	0.87625100	14.1652832	243.997802	0.38410367	0.61589633	0.64503984	0.82538179	0.8671880	5.43965801	25.8321391	13.6265655	0.89026203	15.7780618	1.84476363	21.6352746	13.9019886	0.89370552	16.1988331	1.42987921	17.7561681	14.1120929	0.90463832	17.3323321	0.53047157	0.32812350
1996	Steelhead	0.741153962	0.641566666	0.475499677	0.41034337	124.18	120.17	124.53	146.08	17.0030415	31.6368414	12.3543836	256.44841	0.82619114	15.9886372	8.75892332	14.6751677	11.0657245	117.687109	0.67967008	13.1791109	6.28469751	29.0014138	12.4900956	325.153376	0.86138795	16.0966591	335.006988	0.43021526	0.56978473	0.70115233	0.85345153	0.8906476	4.69799289	30.7084709	12.6993532	0.86185449	18.0013713	1.55824186	25.5894427	13.0576181	0.88973854	18.4367078	1.20691751	21.0285495	13.4065589	0.90207481	19.9017276	0.55280468	0.38037091
1997	Steelhead	0.780207275	0.659151214	0.514274572	0.580447767	134.62	128.94	130.81	142.57	13.5475129	35.913703	12.7697842	359.128302	0.82417285	21.3400583	6.49358417	19.5277143	11.2404130	168.058038	0.68376637	18.1441619	5.10291953	34.7964433	13.1508593	458.077341	0.85326498	21.9718808	459.878662	0.28808206	0.71191793	0.71423284	0.86236407	0.8963781	3.85554321	36.5490114	13.3373231	0.84120812	24.1569507	1.24752409	32.0210481	13.6433178	0.91559386	23.8701508	0.96585147	26.3818421	13.9380674	0.92626333	24.6979017	0.60175223	0.40684340
1998	Steelhead	0.74238164	0.604760174	0.448906285	0.692492925	126.48	125.62	130.89	136.6	15.9482643	32.7499709	13.1127456	267.283056	0.81397446	16.0848742	8.08528401	15.6128666	11.3592754	120.909176	0.65252832	12.8116809	5.90516877	30.7900716	13.8394115	343.462941	0.85550037	16.4981517	361.102081	0.18018797	0.81981202	0.66954506	0.84017931	0.8794063	4.40733540	32.6119962	14.0253583	0.85701549	18.4064331	1.44122423	27.6686852	14.2578729	0.89446554	18.9391409	1.11583851	22.7638833	14.4271063	0.90869507	20.2415294	0.56108962	0.32741589
1999	Steelhead	0.737006273	0.604658869	0.445603738	0.501766228	132.65	132.01	136.86	146.9	16.2887624	31.8400026	13.0357235	241.187103	0.84095369	15.4147141	8.15368305	15.0043526	11.4539554	105.530578	0.72042913	12.5626438	6.19196306	28.9276256	13.5164014	308.36468	0.86186780	15.6014041	319.253814	0.32948913	0.67051086	0.66955580	0.83936497	0.8781057	4.66877483	30.4492392	13.6875885	0.86735581	17.4707101	1.56600003	25.4972667	13.9636287	0.89230269	17.9319677	1.21457844	20.8950881	14.2213869	0.90479138	19.2872095	0.53981265	0.34086047
2000	Steelhead	0.635645115	0.562663149	0.357654082	0.366289801	130.71	129.64	132.85	141.81	18.0744161	30.2501522	13.3126457	197.001021	0.85232125	13.8716168	9.49353165	13.4673777	11.8912206	88.3888778	0.74816373	11.4686290	6.62852565	26.6551862	13.6497523	256.855382	0.86528025	14.3452042	266.984680	0.41830693	0.58169307	0.63097407	0.82046446	0.8645646	5.01124266	27.9703895	13.8258585	0.87964209	16.0527076	1.72294693	23.2040099	14.0866562	0.88843884	16.3815679	1.33800836	18.9659548	14.3621535	0.89818691	17.4328918	0.44480014	0.27666779
2001	Steelhead	0.664822293	0.500466718	0.332721775	0.322931789	130.29	134.81	140.7	140.8	19.7856724	28.0753791	13.7206996	136.491814	0.89446207	12.7740482	10.4846644	11.5037474	11.9563255	58.5733017	0.83318980	10.8030529	7.36134943	23.0024709	14.5749336	175.019503	0.89275390	13.0832326	182.667312	0.44178915	0.55826084	0.57323378	0.78723548	0.8359604	5.62000746	23.8730886	14.7375118	0.90862895	14.6194356	2.00712564	19.9647734	14.8556512	0.90987002	14.8143625	1.56066057	16.2899888	14.9291954	0.92856875	15.7653670	0.44043759	0.22873776
2002	Steelhead	0.739709432	0.608201778	0.449904429	0.291617543	122.89	128.38	134.08	142.81	19.2013796	29.3186318	12.4871797	198.603121	0.87259648	14.0591955	10.4933059	11.6466864	10.9152074	75.9621017	0.80004773	11.3663181	6.74737224	26.1369670	12.9857141	259.890708	0.86935226	14.4249892	266.895629	0.54909169	0.45090830	0.67044905	0.83700595	0.8767839	5.09536752	27.4329310	13.1850868	0.88298299	16.3286901	1.75209812	22.7978965	13.4621082	0.89260258	16.7544673	1.35943196	18.6685141	13.7033481	0.90303117	17.9465632	0.54292181	0.34110159

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
2003	Steelhead	0.7338 24369	0.5758 68311	0.4225 862	0.3462 29541	125.01	129.04	135.41	142.44	18.24 008342	29.59 352403	12.93 854625	197.1 987948	0.869 471235	13.96 985701	9.498 79387	12.62 786293	11.24 735565	78.20 1297	0.789 271677	11.05 706081	6.788 046829	25.83 642174	13.65 258328	251.3 356984	0.871 039748	14.31 564172	267.7 485046	0.470 336135	0.529 663865	0.643 447449	0.825 894566	0.868 096966	5.131 113522	27.08 397078	13.81 866341	0.885 534859	16.12 805214	1.759 750031	22.64 289796	14.01 481501	0.892 696559	16.64 570777	1.362 038903	18.63 299318	14.16 995192	0.903 622568	17.89 786291	0.521 100068	0.311 573643
2004	Steelhead	0.7073 8	0.5500 82426	0.3891 17306	0.4622 96621	130.01	133.9	139.95	142.8	17.72 293501	30.15 268369	13.53 579065	188.1 296409	0.863 693957	13.45 522567	9.207 679801	13.26 767867	11.76 975994	77.78 208923	0.776 410651	10.68 719139	6.574 962556	26.39 013012	14.31 357654	241.3 967717	0.868 277043	14.00 392056	261.4 805603	0.334 786302	0.665 213698	0.619 105129	0.813 999412	0.858 57245	5.008 518636	27.52 198792	14.48 338013	0.885 571945	15.70 485306	1.734 448105	22.96 52888	14.65 35848	0.886 221687	16.14 840635	1.342 046499	18.90 913338	14.78 048515	0.893 174082	17.23 299837	0.491 876871	0.271 533491
2005	Steelhead	0.6405 95376	0.5255 51618	0.3366 65937	0.4594 18128	127.18	129.35	135.24	142.02	17.70 420557	29.82 094121	14.14 361164	178.9 619653	0.865 252652	13.50 856212	8.954 570182	13.35 160446	12.70 979271	76.14 666748	0.769 895339	11.02 459126	6.812 415347	25.49 394501	14.65 714089	228.3 383814	0.877 343694	13.92 445827	236.3 350677	0.307 994189	0.692 005811	0.598 701422	0.803 398898	0.849 644774	5.172 80446	26.63 158686	14.81 969662	0.892 966199	15.61 443615	1.801 424101	22.19 339379	15.02 723598	0.896 273235	16.02 2343	1.398 759291	18.14 734703	15.19 393587	0.908 168465	17.08 255196	0.441 214244	0.225 977697
2006	Steelhead	0.8005 19673	0.6874 20419	0.5502 93569	0.4396 39311	117.24	115.29	121.16	136.62	16.77 976903	31.42 543833	11.09 892872	257.1 440446	0.810 043965	16.02 775901	8.218 230553	15.97 412273	10.04 967155	131.4 174667	0.632 808018	13.60 117245	6.565 112375	28.02 850929	11.20 543893	320.8 370819	0.862 763137	16.18 278646	327.5 342102	0.433 264758	0.566 735242	0.739 740202	0.870 323595	0.903 810168	4.864 46657	29.81 522663	11.42 527847	0.863 839662	17.81 809826	1.607 498266	24.83 060586	11.73 143355	0.889 716208	18.18 409252	1.246 426262	20.35 883382	12.02 664185	0.898 903459	19.47 931957	0.633 666749	0.441 812919
2007	Steelhead	0.6614 28875	0.5536 83536	0.3662 22278	0.2631 32702	118.31	124.37	130.37	136.76	18.79 804754	29.79 821001	13.55 854825	188.3 171567	0.886 030717	13.63 662951	10.26 018686	12.34 369073	12.00 524122	66.87 052765	0.835 176134	11.08 621807	6.581 047468	26.61 052964	14.20 472383	251.4 160156	0.871 425142	14.08 781258	259.0 453491	0.543 446486	0.456 553514	0.624 476986	0.817 225767	0.861 177396	4.992 978029	27.84 292775	14.34 796658	0.883 825888	15.98 239307	1.732 535861	23.07 679032	14.50 941086	0.887 746831	16.36 610349	1.345 505528	18.86 073557	14.63 179064	0.895 342141	17.38 348293	0.457 965443	0.254 077861
2008	Steelhead	0.7352 71981	0.6020 74697	0.4426 88655	0.4863 64332	125.76	127.58	134.66	145.35	19.03 773405	29.26 017474	12.74 892153	220.5 767436	0.860 770579	15.43 133603	10.02 682005	12.56 880677	11.19 604702	98.52 460022	0.757 204008	12.57 252655	7.065 752119	24.97 236208	13.16 685597	265.5 030034	0.877 461821	15.46 218181	274.7 186279	0.342 726114	0.657 273886	0.666 771868	0.836 219202	0.876 025733	5.278 714508	26.33 247338	13.37 517567	0.886 582243	17.08 977242	1.790 033072	22.25 160122	13.69 69099	0.903 366784	18.32 777722	1.384 876788	18.32	13.98 285151	0.918 404685	19.26 114607	0.535 438795	0.328 261475
SCN MO1-RESSIM																																																			
1929	Steelhead	0.6943 52172	0.5528 11743	0.3838 46035	0.3577 98101	128.47	134.2	141.15	144.5	21.48 090918	27.32 881498	12.88 278103	141.8 528366	0.922 727862	13.61 092044	11.78 44573	10.62 590872	11.39 534435	66.85 003357	0.864 760661	11.60 044231	7.748 623416	22.12 962955	13.48 350207	176.5 483856	0.932 397962	14.06 494403	188.5 388031	0.440 382099	0.559 617901	0.622 061597	0.812 689078	0.856 058179	5.835 112616	23.16 140688	13.66 481953	0.925 065975	15.56 11291	2.055 258825	19.47 285585	13.83 850543	0.924 143692	15.83 518473	1.595 783576	15.93 881923	13.95 540094	0.938 986659	16.88 751173	0.486 748348	0.273 397222
1930	Steelhead	0.5079 14706	0.4377 66549	0.2223 48068	0.3126 51501	141.29	139.71	141.34	147.61	18.42 130437	28.36 242719	14.85 987786	128.8 578589	0.915 948012	12.92 246529	8.953 914881	12.75 129261	13.36 337318	63.29 980774	0.853 671956	10.94 150009	7.546 876466	22.30 599685	15.37 953536	162.8 255692	0.925 818771	13.43 119121	168.1 236877	0.372 413853	0.627 586147	0.514 141662	0.757 375697	0.811 082074	5.765 061408	23.12 218267	15.54 379253	0.920 613982	14.94 333267	2.084 769636	19.25 645982	15.70 336628	0.922 813614	15.23 872789	1.623 132378	15.67 637544	15.88 751411	0.940 058416	16.22 873402	0.319 221291	0.149 217428
1931	Steelhead	0.5355 80962	0.4041 76132	0.2164 69042	0.2515 77517	139.73	144.94	148.47	140.65	17.48 031259	29.04 688822	15.14 859084	127.2 519798	0.946 662958	13.56 502461	8.449 633583	13.44 746223	13.45 459518	58.37 386932	0.911 225045	11.70 377083	7.104 440592	23.42 094159	16.11 867269	162.9 462566	0.949 526296	14.02 544347	167.4 572449	0.437 512287	0.562 487713	0.478 606097	0.734 228194	0.790 363444	5.489 966415	24.08 230919	16.28 075047	0.944 257522	15.75 336952	2.001 644842	20.06 923699	16.28 637727	0.942 119342	16.25 222429	1.560 040854	16.29 634885	16.23 959684	0.952 861816	17.40 490055	0.344 959204	0.123 387354
1932	Steelhead	0.7805 07736	0.6493 11386	0.5067 92559	0.4079 36149	118.33	124.06	130.29	136.46	18.38 145198	30.10 419406	11.87 319006	227.6 514822	0.885 404817	15.32 633584	9.773 733124	12.67 428442	10.36 358109	94.88 704071	0.809 032714	12.65 466576	6.631 790012	27.36 367744	12.28 162654	289.4 621735	0.891 750991	15.55 530723	300.6 024788	0.447 088511	0.552 911493	0.708 187211	0.854 314249	0.891 284773	4.947 103232	28.98 12512	12.48 598843	0.875 845122	17.50 929184	1.650 44644	24.14 600679	12.79 772504	0.887 909333	17.84 232585	1.277 744547	19.85 888226	13.07 888222	0.903 091818	18.95 868206	0.601 950659	0.373 157949
1933	Steelhead	0.7119 84551	0.5781 01242	0.4115 99153	0.2748 73607	127.39	130.97	136.6	147.18	18.97 195271	29.68 223443	13.17 755766	199.7 226388	0.906 752122	14.42 37161	10.35 732262	11.90 986357	11.46 293716	71.70 292664	0.860 948789	11.56 570873	6.668 075474	26.52 945776	13.81 147226	260.1 650823	0.898 297856	14.80 937044	272.6 832886	0.551 607597	0.448 392403	0.645 590621	0.825 746264	0.867 610499	5.017 739706	27.89 994414	13.99 549618	0.887 156212	16.73 207779	1.711 583667	23.32 068157	14.25 033824	0.896 414836	17.25 009855	1.327 135138	19.12 077177	14.45 376921	0.908 909041	18.44 034386	0.505 525393	0.309 042521
1934	Steelhead	0.4451 74943	0.4856 85405	0.2162 14973	0.1880 05675	140.76	138.81	137.91	142.84	15.62 711034	31.84 516172	15.14 064489	205.3 271705	0.903 119675	14.30 858214	7.735 295676	14.32 044202	14.24 163494	58.23 385086	0.882 627761	11.84 179363	5.953 258947	29.43 407242	15.44 369237	286.3 538717	0.871 756385	14.65 408206	292.6 188049	0.539 90304	0.460 09696	0.563 201159	0.790 953891	0.841 008377	4.567 390278	30.63 448324	15.52 040844	0.862 17047	16.67 382259	1.583 767638	25.26 722048	15.59 581979	0.875 47799	16.91 840712	1.231 040463	20.61 424087	15.71 701384	0.885 777891	17.82 757807	0.295 747569	0.144 357703
1935	Steelhead	0.7019 59154	0.5548 71625	0.3894 97217	0.2857 60219	125.95	132.02	138.71	137.66	18.58 207102	29.36 823169	13.32 263197	176.4 066413	0.911 549909	13.69 650691	9.814 537235	12.22 000413	11.61 332512	68.70 234985	0.863 802528	10.98 538818	6.817 500062	25.59 684963	14.29 242644	230.7 637024	0.907 114834	14.29 828928	242.4 699554	0.525 080547	0.474 919453	0.624 130234	0.815 815519	0.859 840403	5.163 07313	26.79 054604	14.23 661537	0.896 178555	16.17 407265	1.789 157666	22.32 881934	14.41 081651	0.898 786783	16.45 344575	1.388 271369	18.28 33053	14.53 965855	0.913 483548	19.47 934199	0.497 724509	0.270 111734
1936	Steelhead	0.6962 3104	0.6469 61081	0.4504 34386	0.3746 36595	118.49	118.49	124.54	141.22	18.16 170619	30.54 189053	11.89 270776	233.5 185476	0.843 397132	15.53 521756	9.419 006288	14.27 555139	10.78 219662	119.2 200607	0.706 974626	13.45 188179	6.765 529141	27.07 258081	11.94 593972	290.9 375102	0.878 781229	15.72 305075	301.6 559448	0.461 666257	0.538 333743	0.706 221906	0.855 647416	0.893 333088	5.000 088438	28.80 827615	12.17 391109	0.864 692783	17.20 870724	1.666 877687	23.92 717553	12.49 829515	0.878 860652	17.48 280811	1.291 496575	19.64 740744	12.84 137392	0.894 59154	18.46 232414	0.524 716956	0.363 172129
1937	Steelhead	0.7221 3926	0.5640 4463	0.4073 18772	0.2593 95532	119.88	129.49	136.51	132.62	23.46 38186	26.73 714717	12.48 50705	137.3 857209	0.921 50761	13.31 08997	13.59 81743	9.554 676399	10.80 232449	56.97 736359	0.865 777779	11.08 974915	7.896 881901	21.98 94702	13.19 173066	177.0 912348	0.928 703328	13.84 236217	189.9 126434	0.569 081603	0.430 918397	0.632 073651	0.815 397654	0.857 641325	5.899 723969	23.13 537304	13.39 436798	0.922 021675	15.40 757637	2.057 219438	19.43 671403	13.61 033885	0.921 798468	15.72 446251	1.595 900026	15.93 76496	13.76 004934	0.936 786324	16.75 308466	0.515 149175	0.284 502433
1938	Steelhead	0.7714 73852	0.6502 13527	0.5016 22734	0.3989 35601	119.43	120.2	125.16	139.43	16.24 452951	31.92 092202	12.05 804825	244.4 331033	0.847 394428	15.64 478544	8.005 341115	15.81 550527	10.80 834942	114.8 504822	0.731 260493	13.35 121269	6.262 491629	28.99 819257	12.31 340488	316.4 925944	0.867 870122	15.76 898662	328.3 497624	0.454 645648	0.545 354352	0.708 595694	0.854 497285	0.892 079768	4.694 964692	30.65 452749	12.48 978558	0.854 583168	17.49 387798	1.565 184414	25.49 526353	12.78 184096	0.880 937497	17.62 953027	1.213 226378	20.91 852884	13.06 857824	0.900 648803	18.63 003254	0.588 240144	0.388 242099
1939	Steelhead	0.5380 18177	0.4917 79105	0.2645 86097	0.3504 27081	139.76	142.57	142.96	138.83	17.43 166669	29.55 548751	13.72 189052	167.4 220281	0.910 216893	13.78 017405	8.587 423012	13.64 787497	12.91 771851	73.62 545013	0.848 715901	11.44 054298	6.883 743266	25.01 957589	14.24 715773	214.7 287242	0.916 576197	14.25 134087	218.6 174927	0.372 128915	0.627 871085	0.565 190985	0.789 083638	0.838 505013	5.242 701508	26.06 579774	14.33 624935	0.907 261264	16.07 096767	1.855 896987	21.60 044806	14.25 751114	0.910 264095	16.42 090257	1.444 536246	17.57 803737	14.19 339609	0.923 743367	17.48 182678	0.357 971018	0.181 864832
1940	Steelhead	0.6380 84136	0.5516 00252	0.3519 6737	0.3404 49584	124.88	125.5	130.95	144.3	18.60 782201	29.07 558665	13.32 63417	176.9 883766	0.895 771831	13.77 617761	9.467 10933	12.73 432091	11.68 693905	81.04 142914	0.814 46383	11.34 855728	7.191 044986	24.48 019843	13.78 195842	224.8 190969	0.911 414653	14.36 100086	231.8 405457	0.439 357312	0.560 642688	0.622 075997	0.815 229701	0.858 929331	5.400 791466	25.74 840556	13.97 541943	0.901 619422	16.11 147022	1.868 859917	21.39 247799	14.26 469549	0.904 376705	16.46 933206	1.450 823337	17.50 279247	14.55 479288	0.916 205555	17.48 289394	0.449 424028	0.258 785685

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas
1941	Steelhead	0.613307597	0.498673443	0.305840211	0.238132914	129.49	132.75	137.89	139.45	18.13828312	28.91402478	14.30181953	145.8682311	0.931876272	13.58910012
1942	Steelhead	0.773002592	0.621334286	0.480293014	0.292546695	116.73	122.17	129.39	145.12	20.04986906	27.92003567	11.71900286	167.9390689	0.90773734	13.9937268
1943	Steelhead	0.762473457	0.623035134	0.475047753	0.472598617	126.86	128.28	130.66	132.48	15.82428973	31.80863132	12.31370115	235.1472631	0.851224857	15.60968781
1944	Steelhead	0.698557451	0.51337091	0.358619074	0.234288339	121.04	129.96	137.46	139.72	22.5161894	26.80384053	13.19279637	124.8981402	0.935778486	13.06236649
1945	Steelhead	0.711599418	0.577459635	0.41091994	0.525475616	128.49	129.61	135.35	138.67	18.96704344	29.52257534	13.00866025	186.6507999	0.887909919	14.17715999
1946	Steelhead	0.787496116	0.665810769	0.524323394	0.388665438	119.7	120.75	126.22	133.72	16.60962199	31.9801491	11.68412658	258.7794304	0.847862342	15.99388463
1947	Steelhead	0.59677925	0.547156892	0.32653188	0.537057907	134.9	129.14	131.06	139.37	16.65244279	31.39873865	13.94658967	235.7311777	0.848262272	15.12752281
1948	Steelhead	0.749601501	0.631719547	0.47353792	0.543378872	133.1	135.37	140.46	140.99	14.33072692	34.36837144	13.23019396	339.16516	0.856240119	20.23673098
1949	Steelhead	0.783133216	0.633769097	0.496325631	0.4157159	117.86	120.46	126.24	135.58	16.7026844	31.65893263	12.23699161	257.3768256	0.83162408	16.00191658
1950	Steelhead	0.763270772	0.635063244	0.484725213	0.373568449	123.09	126.73	133.12	139.63	18.94484387	29.26338306	11.8606754	202.6527824	0.883839356	14.51295682
1951	Steelhead	0.756278544	0.621122868	0.469741898	0.408097745	120.78	122.91	128.46	134.46	16.70130624	31.4152266	12.56576729	242.7828969	0.853377312	15.27465388
1952	Steelhead	0.811051835	0.686873332	0.557089877	0.54610745	120.28	120.44	125.95	135.11	14.7120925	33.60829121	11.38877848	286.5953129	0.812787343	17.82384137
1953	Steelhead	0.75464519	0.586868444	0.442877449	0.414921092	122.58	126.27	133.04	144.39	17.81897163	30.4477619	12.85256679	211.8069616	0.87675075	14.66519918
1954	Steelhead	0.787468726	0.6516806	0.513178092	0.303593558	112.96	120.23	127.62	137.76	21.13857541	28.27099565	11.30618804	202.356375	0.901896758	14.87811562
1955	Steelhead	0.748527489	0.595038536	0.445402701	0.40122006	122.73	128.13	135.05	135.16	19.43693635	28.73225328	12.45866912	175.9891058	0.900618962	13.80994637
1956	Steelhead	0.790552988	0.679648552	0.537298194	0.471122103	126.35	123.42	128.27	140.42	14.73986463	33.9854034	11.9060515	315.0793141	0.841356099	18.74932092
1957	Steelhead	0.783484673	0.658639154	0.516033682	0.434518862	117.65	120.79	127.39	141.67	17.90958422	30.29816602	11.69755384	267.9858824	0.8566481	16.86808194
1958	Steelhead	0.752193109	0.633490764	0.476507387	0.537968453	125.8	128.57	134.1	138.77	17.31366251	31.40666515	12.4376376	260.6719894	0.866688532	16.77923366

Year	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv
1941	9.055692844	12.67479616	12.99317112	58.23269806	0.898243392	11.6031559	7.144687943	23.95358616	14.8571922	191.0788676	0.925841977	13.92958872	198.5404816	0.536790061	0.463209939	0.57384004	0.78882368
1942	10.3495893	11.97208037	10.30949268	83.54557648	0.831056118	11.7609848	7.728449933	22.78586246	12.1154364	207.6794383	0.925507218	14.47863197	211.7116241	0.560727435	0.439272565	0.682573627	0.841265157
1943	7.54133673	15.99303498	10.94889469	114.7602798	0.724762547	13.58187904	6.307964899	28.56005647	12.76046642	299.4459229	0.88222297	15.64825217	316.8927307	0.367935478	0.632064522	0.68386759	0.844245304
1944	12.65376849	9.880617155	11.18945827	55.07175674	0.905448437	11.51603508	7.91366183	21.54162277	14.11275164	158.8505402	0.928942889	13.30803156	167.9658661	0.571341991	0.428658009	0.585654401	0.792740003
1945	10.10701048	12.65550506	11.43306656	85.33507538	0.802247548	11.85205364	6.908196904	25.62421054	13.6075484	236.4322281	0.903250605	14.611485	252.232193	0.294616335	0.705383665	0.645033327	0.825181369
1946	8.468683816	15.201604	10.30455399	113.4378067	0.736638868	13.12131939	6.154862233	29.79968125	12.01588694	333.5621643	0.864480158	16.23901002	345.2068176	0.474989192	0.525010808	0.721239826	0.859574183
1947	8.333369434	14.81500293	12.52802677	109.0559769	0.733645368	12.48094883	6.374279417	28.08537484	14.3418506	296.7760925	0.867907961	15.28216108	304.4197998	0.248559	0.751441	0.618208425	0.816401785
1948	6.978618987	17.47945282	11.78452702	150.666098	0.766631973	16.99050293	5.406117789	32.81306973	13.7803189	434.8279419	0.859033962	21.28714053	455.1990356	0.307090461	0.692909539	0.691880939	0.850474908
1949	8.39677655	15.44518373	10.365769	124.8891815	0.682323366	13.38395691	6.333166063	28.6303249	12.80233908	318.9309082	0.871853292	15.99081254	328.5315552	0.434282714	0.565717286	0.692942128	0.84587141
1950	9.928440854	12.62026544	10.51938019	91.185289	0.793043184	11.97765903	7.043513767	25.3975425	12.22071759	255.3745193	0.90142256	14.91099135	266.7581177	0.473398038	0.526601962	0.695693474	0.849859594
1951	8.441451773	14.49223399	10.97842674	101.076889	0.745657396	12.38635769	6.287070602	28.85683467	13.06083536	313.408315	0.869833132	15.48329918	325.4518738	0.43070038	0.56929962	0.683251425	0.844024376
1952	6.650591336	19.2530529	10.19640865	162.5365112	0.64768402	16.75673447	6.07494881	30.23041327	11.60930729	350.6323954	0.856767307	17.13797919	359.5844421	0.333912911	0.666087089	0.738294792	0.867658189
1953	9.258369811	13.58954256	10.98610115	92.36903534	0.784478354	11.8313448	6.6142767	26.91208284	13.66952356	267.192426	0.892019918	15.07289116	280.5549316	0.410402268	0.589597732	0.653032981	0.829085978
1954	11.82673298	11.14681002	9.83184967	87.39797821	0.830037689	12.18843441	7.327476434	24.49651589	11.71901703	251.7747498	0.912727952	15.26822352	258.7251587	0.563719493	0.436280507	0.70967766	0.854839123
1955	10.24436037	12.19466462	10.93262939	77.84252472	0.83129108	11.1437233	7.229128525	24.35707694	13.0520401	223.5545349	0.908701946	14.39556925	237.4858551	0.425335834	0.574664166	0.659753641	0.830919301
1956	7.186264671	17.61721614	10.67143459	144.6024933	0.725018239	15.96464119	5.580484927	32.25522705	12.2008268	404.7263031	0.858982652	18.98809926	420.0516968	0.397695716	0.602304284	0.732419314	0.867601189
1957	9.149887808	13.7117058	10.35503769	120.1317169	0.743426418	13.76716423	6.787060663	26.89859354	12.0418876	325.7558543	0.8793238	16.80897498	337.1509094	0.425035149	0.574964851	0.717427111	0.860898264
1958	9.06460464	14.17846584	11.053479	119.1816376	0.770145929	14.32595673	6.290029682	28.87142594	12.87384701	325.1198578	0.880485564	16.73581918	338.1745911	0.312281478	0.687718522	0.694179048	0.85054133

Year	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1941	0.836688636	5.440318994	24.93366133	14.9921032	0.917083073	15.65985775	1.9281184	20.77879517	15.13498465	0.916884363	15.9488198	1.499496691	16.94247841	15.23573828	0.932047129	16.91285753	0.410043021	0.204337763
1942	0.879187939	5.766455524	24.03276048	12.34593258	0.915824342	16.11165047	2.004992925	19.9850093	12.6149133	0.916553756	16.49996312	1.558947437	16.30749562	12.8430438	0.928919286	17.57653236	0.575198774	0.360142704
1943	0.882973505	4.743253209	30.12130948	12.94677181	0.869424403	17.41380749	1.584182613	25.17053267	13.17077351	0.888819993	17.72074477	1.227077357	20.68114129	13.37552166	0.90276897	18.81002998	0.576056315	0.35863195
1944	0.839274668	5.97561311	22.49877254	14.30823402	0.924342406	14.87973442	2.12215703	18.8930336	14.4888773	0.922728956	15.0599165	1.649903767	15.42815206	14.61172676	0.937586725	16.11239052	0.464610754	0.251694577
1945	0.867421275	5.170065023	27.0124317	13.7936903	0.891986263	16.15725956	1.76590509	22.59277345	14.02110831	0.896171808	16.46396033	1.368517496	18.54532435	14.19802999	0.910818756	17.44461107	0.511627475	0.300846205
1946	0.896301039	4.599484511	31.58395013	12.21537323	0.849153364	18.06809959	1.515921034	26.29205218	12.51572037	0.877641181	18.31208611	1.173469104	21.63280557	12.78584814	0.89799732	19.43315697	0.604634459	0.408306729
1947	0.861862626	4.783784665	29.6189783	14.50742626	0.85743351	17.05965538	1.621039636	24.61452982	14.73163478	0.87809066	17.42985408	1.256506927	20.19503786	14.97954178	0.895765752	18.616539	0.4195472	0.240564567
1948	0.88710499	4.065646522	34.53056677	13.95228748	0.841657424	23.65221939	1.335684948	29.91639293	14.15106869	0.904024263	23.37341817	1.035454445	24.56536053	14.3068471	0.914560437	23.23404598	0.57038962	0.355065418
1949	0.883718735	4.743128955	30.27174307	13.0451458	0.861870551	17.77971363	1.573042125	25.34461905	13.42065334	0.884444714	18.36611271	1.218223691	20.83222388	13.72665644	0.893485814	19.89736176	0.591501221	0.390225269
1950	0.887345027	5.259420864	26.83669125	12.421492	0.889806175	16.69147778	1.785187684	22.36451715	12.6731383	0.895501435	17.08408705	1.384363078	18.33451105	12.89000368	0.905115664	18.23216343	0.576388485	0.37888039
1951	0.882988026	4.719940633	30.48384848	13.25501652	0.859071445	17.41998329	1.568389103	25.42963401	13.54065323	0.881160339	17.86551476	1.215077028	20.88647874	13.79077196	0.893285096	19.13424301	0.569508148	0.352003583
1952	0.902995311	4.535384797	32.05793798	11.83643093	0.840900707	18.5422596	1.486958601	26.82117302	12.12079112	0.878741503	18.71979777	1.151655741	22.04685646	12.38534117	0.9007622	19.9295454	0.638701302	0.441707947
1953	0.870534174	4.965797715	28.35466149	13.8634922	0.881007659	16.78286896	1.67833399	23.76755323	14.08773168	0.891267598	17.24360148	1.300569348	19.5104598	14.24262714	0.904383212	18.40984726	0.544247076	0.311830599
1954	0.890844209	5.438598566	25.95740724	11.94657288	0.900127578	17.10173893	1.843803816	21.65660503	12.23015976	0.905506055	17.54316807	1.429790638	17.75723621	12.461555	0.917006254	18.81025028	0.603066177	0.406411604
1955	0.871615061	5.411356971	25.65557911	13.25502586	0.898453951	16.01659184	1.857235238	21.49370964	13.48318704	0.902901729	16.32612642	1.439732119	17.63600288	13.65107679	0.918664873	17.34295511	0.549465104	0.324069596
1956	0.901655018	4.188900173	34.03911871	12.40617294	0.841871464	20.91503983	1.358700201	29.34309269	12.65629164	0.898972988	20.89589373	1.051104203	24.19172183	12.88610125	0.913035721	22.17215443	0.626285576	0.443380909
1957	0.896212485	4.987798378	28.66864396	12.2425602	0.868100166	18.59576607	1.631040424	24.39944376	12.51711782	0.898690224	19.22367223	1.26094535	20.1238045	12.77249765	0.912186831	20.79348469	0.598113507	0.428283415
1958	0.888411914	4.675201453	30.62377252	13.06960087	0.864113629	18.5326561	1.543074094	25.82878669	13.29536247	0.892570396	18.97727521	1.194559805	21.24762764	13.48211384	0.90740943	20.30007744	0.563343872	0.368601047

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1959	Steelhead	0.735995572	0.611798854	0.450281247	0.275296817	116.88	121.53	126.61	138.66	20.48667886	28.90824012	12.35799122	205.6181074	0.880303779	13.93236232	11.54787221	10.92554699	10.70846825	74.77101135	0.804240191	10.69130096	6.964563668	26.00347436	12.88288196	270.2880376	0.88384215	14.51692812	280.2844238	0.570391739	0.429608261	0.676429444	0.840781404	0.880340075	5.169194281	27.5866741	13.07915955	0.873888922	16.48034325	1.736125216	22.9848686	13.37039153	0.885431667	16.90465768	1.345770106	18.85703858	13.61948919	0.897402942	18.04477501	0.539397435	0.35218617
1960	Steelhead	0.766653571	0.628093372	0.481530026	0.287192058	119.02	125.81	132.48	137.3	19.6128783	28.78803848	11.9827479	194.1654592	0.90957754	14.44048882	10.58694862	11.3977954	10.4503973	77.03744354	0.85642755	11.91518936	7.052812867	25.31036957	12.44716295	250.5988007	0.908657968	14.8166275	261.9957581	0.569844003	0.430155997	0.688723221	0.844497961	0.882217923	5.271534853	26.72633101	12.67075806	0.896059275	16.82104168	1.790563039	22.28704713	12.96539561	0.900336663	17.23979473	1.387884311	18.28835042	13.20942402	0.910250127	18.3656826	0.581921449	0.361512386
1961	Steelhead	0.721236541	0.583995684	0.421199027	0.289174349	122.07	128.95	135.71	144.87	19.15278073	29.63769122	12.94508321	212.703719	0.904288901	14.74490544	10.63451405	11.26221115	11.16608086	69.09833679	0.864421272	11.62252407	6.565800011	27.06455193	13.7245938	279.8973236	0.889656633	15.06263963	286.9944763	0.540034095	0.459965905	0.65082597	0.829783363	0.871222431	4.937435925	28.48895627	13.90015545	0.877945697	17.13040543	1.671043724	23.9097853	14.0872879	0.896792412	17.60374006	1.29697004	19.56454709	14.22885895	0.912794858	18.83975697	0.51446787	0.312315795
1962	Steelhead	0.730838919	0.583629272	0.426538986	0.487190852	129.03	133.72	139.19	136.94	16.62217236	30.94396981	13.11833089	201.2005288	0.883834038	14.20134626	8.207667932	14.49729479	11.55658131	88.47792969	0.803076541	11.71219597	6.461524621	27.42493591	13.73591201	261.9174042	0.89304925	14.68863519	269.2401123	0.333815456	0.666184544	0.648278362	0.826849416	0.868513422	4.888901845	28.78004523	13.9340126	0.881339872	16.50777302	1.674348891	23.90293214	14.14353498	0.891176343	16.79755592	1.30164513	19.49435402	14.30353212	0.903270513	17.79921341	0.547990834	0.286992856
1963	Steelhead	0.703354653	0.560101199	0.393949785	0.567526379	133.25	135.13	142.21	143.64	17.43277156	30.28968129	13.41618586	196.6846717	0.880181317	14.28886414	8.773684904	13.84436841	11.84992695	89.94852905	0.787189496	11.62789536	6.716802306	26.26279067	14.06698322	247.5749842	0.897765656	14.76570066	258.4037476	0.252334766	0.747665234	0.629856035	0.819140699	0.862670631	5.058694907	27.59838902	14.22761135	0.88630631	16.38514175	1.735204227	23.03826211	14.40387058	0.894756198	16.76996803	1.347401299	18.83432986	14.54681253	0.911881924	17.74319458	0.511301745	0.280203052
1964	Steelhead	0.738891118	0.590664976	0.436437104	0.510331021	128.83	131.78	138.14	143.09	18.14640179	29.52138807	12.89211253	203.2031958	0.888354978	14.80648014	9.169161052	13.0988779	11.28395615	91.23221741	0.799368358	12.41915073	7.031174719	25.15511722	13.39708646	250.6468506	0.906688541	15.03675508	260.6533203	0.316841845	0.683158155	0.65610193	0.830292944	0.870328717	5.259756386	26.51973399	13.61693726	0.897335505	16.79480762	1.794624418	22.24849162	13.90849368	0.907008549	17.45765877	1.391745925	18.23802534	14.15291166	0.916047394	18.72619343	0.547231817	0.321133469
1965	Steelhead	0.777210152	0.651853794	0.506627386	0.54232386	125.76	119.89	124.83	143.71	17.7342319	31.72049683	12.05992379	255.9246396	0.822945774	15.88848141	9.434246838	14.92586021	10.4210638	130.4902786	0.664325404	13.47392082	6.342461534	28.95567851	12.41444174	322.3329061	0.866602689	16.03178501	330.0487061	0.31791124	0.68208876	0.709459059	0.853821241	0.890625967	4.707151838	30.77524845	12.64852409	0.855316746	17.65773926	1.555742703	25.66905548	13.04444218	0.883631726	18.0660464	1.20676624	21.03120142	13.39940643	0.897102892	19.30283165	0.585450156	0.410361196
1966	Steelhead	0.656063843	0.529018108	0.347069653	0.383028669	130.58	136.98	141.89	135.49	17.74629215	29.54975286	13.5727458	169.6363373	0.909853211	13.60269359	9.035206385	12.89719711	12.16898308	68.29048157	0.862574637	11.55763893	6.756862968	25.52628931	14.30474583	222.1399434	0.904178808	13.89272618	227.3656921	0.39081936	0.60918064	0.597325239	0.80117657	0.848082461	5.156007618	26.57450354	14.48411388	0.895542765	15.68922462	1.815986723	22.06225122	14.55183919	0.89874659	16.03748099	1.412864894	17.96780049	14.53900862	0.910755426	17.10862255	0.472431563	0.226405263
1967	Steelhead	0.714724124	0.619398193	0.442698831	0.429378496	129.73	131.8	138.24	147.49	20.6172965	28.64220681	12.46070903	218.270419	0.890846218	15.358831	11.70381719	10.28227458	11.16279049	83.10477448	0.824593079	12.55476589	6.967733011	25.44571967	12.80893135	275.676061	0.891480535	15.47579114	279.6327209	0.397420624	0.602579376	0.68280848	0.844900067	0.883844026	5.19656764	26.86793329	12.98056564	0.879394889	17.39022293	1.766750559	22.60665662	13.20582326	0.901246846	17.80728149	1.370635554	18.51685435	13.41386366	0.920420766	19.05176592	0.514831354	0.354483401
1968	Steelhead	0.661745767	0.535520111	0.354378167	0.241098767	113.7	120.34	128.14	147.91	24.41161642	25.62809004	13.01613712	139.8995773	0.903599335	12.87477684	13.78951087	8.737381016	11.42259502	57.31383896	0.824693632	10.47155342	8.669384316	19.81779758	13.44908985	170.9057897	0.921153992	13.30353419	173.4002991	0.559093568	0.440906432	0.610115151	0.80515303	0.849362314	6.462779596	20.83803882	13.62947731	0.919196486	15.03451729	2.291800991	17.51016901	13.93695958	0.921711564	15.38750966	1.781239882	14.32260866	14.21190786	0.933156282	16.69826412	0.438827147	0.261925249
1969	Steelhead	0.729819159	0.598333144	0.436674992	0.649401527	131.23	130.69	135.82	139.2	14.317966	33.87368049	13.39677095	279.3349326	0.836784921	16.97348874	6.714652315	17.56627672	11.78838768	124.9891663	0.705968404	14.23624954	5.652740598	31.6634532	14.09952052	355.8097178	0.864191294	16.9542861	360.755127	0.206918767	0.793081233	0.662269889	0.836453127	0.876645138	4.275420904	33.28065184	14.27758312	0.850273526	18.91070709	1.418713912	28.17489468	14.45011743	0.890008589	19.36750158	1.100879118	23.07800441	14.57655573	0.903484643	20.78035259	0.551586487	0.305122935
1970	Steelhead	0.748691775	0.604808138	0.452814878	0.463759549	119.21	127.32	134.79	144.54	21.97575813	27.55671042	12.11050892	181.5735479	0.907105927	14.6597569	12.36980151	10.27352263	10.55562725	82.14423065	0.839724982	12.74033566	7.652214356	23.05419606	12.6454711	218.0788549	0.916809758	14.63494913	220.6038055	0.367498178	0.632501822	0.669653469	0.836035653	0.875241386	5.684757061	24.36395218	12.85637779	0.908027637	16.25092926	1.958052106	20.44481835	13.10317834	0.912042797	16.78768667	1.521429546	16.702191	13.29613113	0.924504995	18.11686611	0.540796338	0.333732816
1971	Steelhead	0.738657167	0.637237161	0.470699796	0.62471299	139.56	139.94	141.75	145.38	14.64184388	34.3756949	12.95162766	313.6346098	0.832592653	18.61060252	7.218882434	17.55001235	11.65316391	144.7290741	0.70292871	15.73442917	5.478675574	32.74292669	13.35681852	398.8805084	0.856942713	18.65296268	403.4262695	0.238130772	0.761869228	0.697114605	0.853780818	0.890826866	4.119802207	34.51200854	13.50833397	0.840902185	20.63141861	1.349545091	29.60020894	13.70369148	0.897969822	20.88916969	1.046014547	24.31189029	13.88464928	0.912358642	22.21021748	0.572403543	0.360292568
1972	Steelhead	0.773400809	0.642307149	0.496760868	0.475764619	124.04	122.03	127.49	140.48	16.3543968	31.97319183	12.36489943	281.2147032	0.858295458	17.45436123	8.287436582	15.02178467	10.75968475	121.9381683	0.758720529	14.34619598	6.101485491	29.59765383	12.79617246	356.2947439	0.870422502	17.75603199	350.750824	0.375152093	0.624847907	0.701848848	0.85286441	0.889989133	4.573688984	31.26613416	12.98459301	0.853388262	19.75029793	1.518224508	26.33017063	13.29827277	0.892630994	19.88594755	1.178716242	21.53560481	13.59932041	0.909210801	20.97630692	0.577701098	0.398061831
1973	Steelhead	0.675827003	0.521125372	0.352190598	0.21152832	117.44	128.06	135.87	144.58	23.81179793	26.59213136	13.1156589	132.1351553	0.92824583	13.3204674	13.96191181	9.054913826	11.1428978	51.95390472	0.886585867	11.44148998	7.905471981	21.66285157	13.99734306	168.9019547	0.927085757	13.64201069	177.8549805	0.602760164	0.397239836	0.592818212	0.795450883	0.841610169	5.94253844	22.68673116	14.19396439	0.920911944	15.30355167	2.097261399	19.09015344	14.39264711	0.921449641	15.44725609	1.628595382	15.62500587	14.53342342	0.939396858	16.4024415	0.452836728	0.25577932
1974	Steelhead	0.750767581	0.640864382	0.481140202	0.506117301	134.43	133.14	133.96	140.21	15.00991321	33.99561966	12.82589851	299.2755487	0.845008624	17.86553744	7.570715033	16.62404897	11.28077393	128.1112946	0.736575317	14.69557228	5.486256525	32.77292062	13.26267815	390.1990712	0.857874284	18.23517148	397.9495544	0.342177825	0.657822175	0.699718125	0.852437763	0.889646838	4.13616924	34.51689726	13.43988819	0.841339588	20.197995	1.354069546	29.48216225	13.73051675	0.893558681	20.3409392	1.048878863	24.24409475	13.99671888	0.909968615	21.57774448	0.586290417	0.374119659
1975	Steelhead	0.780712301	0.634384953	0.495272136	0.291938847	113.53	121.9	129.18	137.63	20.78989694	28.25643023	11.6437617	190.9890496	0.885835111	13.80474087	11.41391205	11.34481031	10.02226448	83.65300903	0.803955662	10.86855583	7.397543237	24.20101082	12.12772894	239.8143794	0.896985541	14.2824951	247.0542908	0.56926276	0.43073724	0.694781567	0.846483373	0.884579261	5.497581646	25.62285967	12.35922585	0.887693214	15.9936245	1.865924343	21.41662146	12.68219789	0.896089713	16.43497372	1.44793959	17.53719916	12.94008827	0.912378877	17.63739252	0.587646861	0.378317936
1976	Steelhead	0.806520557	0.683656945	0.55138338	0.478458899	117.66	118.34	124.82	138.07	17.44843074	30.84982628	11.18623802	251.5015526	0.839983329	16.15126089	8.794846386	14.82167917	9.951525307	126.3492813	0.697417969	13.68621693	6.668254428	27.46715488	11.38321527	309.1289825	0.878779759	16.22183235	309.5315552	0.394767763	0.605232237	0.736670049	0.86731288	0.902417695	4.943789057	29.19435192	11.61967144	0.86372565	17.90420341	1.642822035	24.30855597	11.93780899	0.88465625	18.18530718	1.274455167	19.91017805	12.23313141	0.90330407	19.35983467	0.624455673	0.457563525

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas
1977	Steelhead	0.612330316	0.488495899	0.299120848	0.132196746	122.56	130.03	136.69	131.54	22.2971523	26.37650112	13.68326419	106.5170746	0.944524207	12.83627078
1978	Steelhead	0.721533046	0.597192078	0.430893819	0.53199576	134.35	136.11	140.52	143.09	16.55227594	31.09143644	12.92907906	209.2825672	0.871286294	14.32809155
1979	Steelhead	0.755261567	0.625300837	0.47226569	0.424528925	119.58	125.38	131.74	134.45	20.61181386	28.54163273	11.86914042	190.367485	0.885151769	13.81783274
1980	Steelhead	0.777828098	0.64349431	0.500527955	0.350858371	113.46	120.94	126.6	145.88	19.79384691	30.93550888	12.0770374	246.4547626	0.88220538	15.76613317
1981	Steelhead	0.60904769	0.531824676	0.32390659	0.465744239	137.21	137.31	142.23	150.88	16.77051277	30.97682492	14.41024787	209.953986	0.878457342	14.68459249
1982	Steelhead	0.754289541	0.624568623	0.47110558	0.48246999	125.06	122.71	127.9	140.52	18.43361019	30.46248874	12.34431887	237.9253987	0.856347386	15.50026369
1983	Steelhead	0.765306222	0.615089681	0.47073196	0.439950873	121.16	122.28	128.38	146.8	18.62737755	30.13874904	12.45021112	225.8189534	0.864133818	14.85744994
1984	Steelhead	0.787445046	0.64704679	0.509513789	0.464258702	122.62	122.18	127.82	138.66	17.8901825	30.08992858	11.69960601	215.6303651	0.850480361	15.11954056
1985	Steelhead	0.770638404	0.630757102	0.486085646	0.374327509	120.79	124.42	130.79	132.46	18.12421361	29.29302733	11.78268664	189.6062415	0.867546827	13.97804836
1986	Steelhead	0.760256094	0.603850216	0.459080806	0.417664077	122.88	121.6	127.23	143.6	17.60546859	30.01093306	12.47183813	205.9339349	0.868665657	14.7436457
1987	Steelhead	0.49919488	0.498957064	0.249076812	0.182504512	132.3	130.59	132.25	132.15	18.9807378	29.06014509	14.29605995	176.5970944	0.913727083	13.75259197
1988	Steelhead	0.69930628	0.56147847	0.39264542	0.331426422	130.51	136.14	141.97	142.66	19.44561004	28.43023183	13.00959682	150.7748751	0.918655838	13.24920487
1989	Steelhead	0.789538297	0.65514153	0.517259328	0.277209509	114.13	120.79	127.17	131.35	18.39691976	29.8442794	11.43161304	217.4467185	0.855753171	14.34487343
1990	Steelhead	0.50873546	0.487477096	0.247996885	0.279637464	137.39	134.51	135.29	148.99	17.10741913	30.19026574	14.9830562	185.0203073	0.9043596	13.98871289
1991	Steelhead	0.689879732	0.570876555	0.393836165	0.241187903	119.93	126.22	132.3	147.7	21.23727943	28.58763782	13.01916334	190.3171763	0.903357523	14.04725729
1992	Steelhead	0.528280579	0.481209052	0.254213397	0.19929306	131.56	133.1	136.59	139.09	18.67402312	28.63332752	14.54450008	148.8662725	0.927701805	13.34225948
1993	Steelhead	0.761858826	0.635359983	0.48405461	0.511173001	119.12	124.73	132.31	139.45	20.65032688	28.3423238	11.6694088	203.5741038	0.877370268	14.65553325
1994	Steelhead	0.594190947	0.507130383	0.301332282	0.242558742	127.9	130.08	134.85	139.3	20.89832632	28.08783194	13.75204195	152.6440877	0.919974033	13.37670044

Year	Species	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv
1977	Steelhead	12.26340096	9.728867191	12.18365955	38.56911011	0.915669465	11.31458015	8.079353064	20.76506723	14.36723804	141.9213613	0.940832416	13.11180091	147.5903015	0.698529507	0.301470493	0.563706758	0.778950616	0.826890671
1978	Steelhead	8.210728072	14.74489533	11.57648945	95.24504547	0.7726331	11.86386967	6.393037044	27.48827996	13.43543768	268.5353394	0.889140477	14.75431124	278.6912537	0.297280108	0.702719892	0.661510739	0.834574241	0.875631714
1979	Steelhead	11.39296716	11.37708564	10.50687103	80.81246033	0.803043485	11.02832069	7.240646854	24.83587948	12.35889912	242.4489034	0.89615199	14.36723979	254.3594513	0.416261934	0.583738066	0.687918066	0.845964326	0.884509029
1980	Steelhead	11.53190835	12.37555709	10.08753338	94.71443634	0.819269025	12.62881641	6.299833767	29.3249295	12.71897729	323.4853923	0.87575533	16.2708834	343.8816528	0.506416662	0.493583338	0.702657179	0.850185121	0.887867383
1981	Steelhead	8.37639042	14.3194635	13.11050606	89.14533691	0.793013358	11.99565296	6.473463103	27.10125861	14.86710389	267.3772278	0.888889561	14.95269688	274.5610352	0.30109163	0.69890837	0.606291437	0.80942819	0.855438388
1982	Steelhead	9.801532596	13.53944066	10.7129715	108.6042023	0.739745331	12.46090221	6.668343559	27.27896787	12.7671655	298.9252218	0.881689787	15.94529915	301.6203918	0.358156323	0.641843677	0.686922962	0.845526181	0.884422063
1983	Steelhead	9.959656209	12.8727163	10.65311127	101.0354034	0.76100421	11.97811203	6.71404136	26.91183426	13.05053457	284.9066213	0.882142127	15.157794	291.5927124	0.397689449	0.602310551	0.67862923	0.841014641	0.879951436
1984	Steelhead	8.809622876	14.70326934	10.29660778	121.8246017	0.709074044	13.28848324	7.106773749	25.60496301	11.9132417	261.7028681	0.893559337	15.3235747	267.1828308	0.391361864	0.608638136	0.706527594	0.853269079	0.890336608
1985	Steelhead	8.995385118	13.52253561	10.51362286	95.72311707	0.751010764	11.71840172	7.143393785	24.91864485	12.20105553	239.9455338	0.898434232	14.38173604	248.1570282	0.471544064	0.528455936	0.690597259	0.846390944	0.884736823
1986	Steelhead	8.63063518	14.39805533	10.77589798	106.7024078	0.750794137	12.28932018	7.013289846	25.47374137	12.94150114	255.7217967	0.901225001	15.21293473	257.2997131	0.413134282	0.586865718	0.668101666	0.835281439	0.875272617
1987	Steelhead	10.19152357	11.46466336	13.30896778	54.03349152	0.878219938	11.19423065	6.82808391	25.69348173	14.70413558	239.5805384	0.900180032	14.1732922	244.3466797	0.580946838	0.419053162	0.576027348	0.794754215	0.842751223
1988	Steelhead	10.34415862	11.32770673	11.53132172	62.67219849	0.873597562	11.3462431	7.156788372	24.06149019	13.62695169	197.0508677	0.915532887	13.52154104	202.8101044	0.470798976	0.529201024	0.628305041	0.816000876	0.859356287
1989	Steelhead	9.631331749	12.8621244	9.983421135	95.94711914	0.737604189	11.59191952	6.769770652	26.92187136	11.8597463	280.2781525	0.882087529	14.75488456	286.7373352	0.596267111	0.403732889	0.712731211	0.855991324	0.892262953
1990	Steelhead	8.485829093	13.49704007	13.76331158	68.45791626	0.851462781	11.29949245	6.694971226	26.05510581	15.23194742	243.1795654	0.900620172	14.45740279	247.0550232	0.434319824	0.565680176	0.565489864	0.790518221	0.839874414
1991	Steelhead	12.37912303	9.877621911	11.18757057	63.53336334	0.859302676	11.26301537	6.910835221	25.68234741	13.72548405	252.227656	0.891748975	14.34947681	247.0250092	0.584138766	0.415861234	0.639144489	0.821879328	0.864537653
1992	Steelhead	9.577363826	11.78777071	13.37553654	50.54035187	0.90086726	11.34507103	7.151587717	24.15946645	14.97805484	201.5504405	0.913915128	13.66189559	204.3813782	0.555131017	0.444868983	0.558900007	0.782995182	0.832634828
1993	Steelhead	11.20691286	11.40916758	10.38855133	92.32722321	0.78120985	12.01861515	7.471832618	24.23597797	12.02493445	247.3330892	0.896189491	14.7984875	258.5205688	0.338042012	0.661957988	0.698504511	0.851719038	0.889416529
1994	Steelhead	11.71519913	10.61075658	12.10499382	60.60063782	0.87547251	11.22787571	7.233958155	23.93674514	14.40218878	201.8943405	0.917045911	13.8379395	207.9421234	0.527744177	0.472255823	0.580127042	0.793534821	0.841111092

Year	Species	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1977	Steelhead	6.151027054	21.55000912	14.51258965	0.937522626	14.80164776	2.226381719	18.05148791	14.65645599	0.936628044	14.99213918	1.733609825	14.7034539	14.74629736	0.951239765	16.07217693	0.39511406	0.203105928
1978	Steelhead	4.855361782	28.76219629	13.58799324	0.878761768	16.53496323	1.674250253	23.850217	13.7555275	0.88730067	16.80989329	1.298727341	19.53810052	13.89585686	0.897785842	17.82881737	0.524329321	0.321053456
1979	Steelhead	5.359798566	26.34996453	12.55033245	0.886056149	16.00881748	1.812413558	22.02866832	12.75608667	0.891763826	16.3778464	1.405388549	18.06247337	12.91624212	0.90487659	17.4279027	0.56426474	0.36313303
1980	Steelhead	4.643335454	31.26915077	12.96938763	0.860324001	18.18941689	1.510331221	26.3412104	13.35232004	0.883317848	18.6471494	1.166947462	21.75486048	13.6496954	0.900172502	19.69606209	0.591600185	0.396942998
1981	Steelhead	4.893133327	28.41177317	14.99467773	0.877011609	16.7162735	1.686889663	23.67601643	15.17462063	0.890854597	17.08602333	1.308766857	19.3884435	15.33562088	0.907701105	18.18543196	0.412006803	0.235286958
1982	Steelhead	4.946796313	28.96214352	12.97603951	0.86663487	17.69446621	1.651848197	24.17803637	13.30737464	0.888343513	18.00378005	1.281579167	19.79943372	13.61375046	0.905516803	19.2335186	0.550234378	0.36976372
1983	Steelhead	4.99721051	28.51121923	13.2588171	0.871794581	16.93079472	1.673773132	23.86663256	13.57021109	0.888426622	17.40128994	1.298867337	19.53599644	13.83777475	0.899131387	18.74964905	0.552397158	0.370137828
1984	Steelhead	5.25938572	27.2103217	12.13393459	0.880459833	16.71949196	1.766797885	22.63646112	12.50317828	0.89046969	16.92424997	1.372452363	18.49248997	12.85669804	0.9054223	17.96982288	0.590946437	0.405487729
1985	Steelhead	5.350596219	26.27968929	12.41250839	0.888923264	16.0178318	1.834013075	21.81646266	12.62544632	0.895055215	16.32553069	1.425028354	17.81594633	12.78710842	0.908855021	17.32364178	0.585150956	0.365209014
1986	Steelhead	5.2481573	26.88902658	13.14760647	0.888199711	16.83042202	1.791944452	22.33946237	13.47485256	0.900081515	17.04518731	1.393138297	18.21993603	13.78569889	0.916883618	18.05212688	0.539533254	0.363926604
1987	Steelhead	5.149636306	26.96268582	14.8100771	0.891179264	16.20986118	1.787926383	22.39898428	14.89340242	0.89765499	16.58769131	1.390574701	18.25325385	14.98086357	0.90927738	17.61105347	0.328216814	0.174696847
1988	Steelhead	5.436936043	25.09745239	13.80376053	0.907981431	15.2474865	1.919833444	20.88704028	13.95865949	0.909171164	15.60376104	1.494350068	16.99991827	14.06808615	0.922737062	16.62818384	0.487030323	0.287206395
1989	Steelhead	5.047464401	28.53529026	12.06665497	0.872670496	16.6316885	1.686487004	23.71190357	12.35038948	0.885511001	17.07740974	1.310070559	19.36917412	12.57987881	0.895443469	18.20859432	0.61115744	0.38662283
1990	Steelhead	5.079033516	27.24694977	15.37302151	0.889751589	16.43545742	1.771657906	22.59803737	15.59627342	0.899051905	16.7322588	1.377587728	18.42405064	15.85210657	0.914827913	17.79965782	0.332519467	0.168890877
1991	Steelhead	5.186606243	27.0520666	13.90674477	0.882064807	16.33244209	1.787592158	22.44539605	14.14629491	0.896306058	16.72852198	1.392763689	18.22480544	14.3496213	0.914202541	17.83713198	0.471261268	0.304454223
1992	Steelhead	5.425901167	25.22779097	15.10416317	0.905792964	15.53218632	1.915101908	20.95941134	15.24352392	0.908847928	15.82929802	1.492066942	17.02553306	15.36377811	0.92406702	16.81565142	0.343401247	0.172951444
1993	Steelhead	5.490829811	25.8046623	12.21051426	0.885512447	16.34978065	1.831157818	21.79816315	12.44348113	0.898277978	16.8081061	1.419528916	17.88426641	12.63544273	0.916143298	18.13839006	0.568482313	0.365306065
1994	Steelhead	5.467709333	25.04695654	14.57883587	0.90834552	15.63916206	1.925779969	20.81218695	14.7535998	0.909814835	16.0025301	1.498245269	16.9563971	14.91702461	0.923172921	16.97029209	0.401308395	0.205111367

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1995	Steelhead	0.750920724	0.574724994	0.431572909	0.444885094	117.06	123.67	130.6	137.57	20.2283853	28.4957243	12.6397365	185.569036	0.88161086	13.7541481	10.9103078	11.6099916	10.6319984	83.8032287	0.78793883	10.9959127	7.35813420	24.2347284	13.4407650	229.618395	0.90047675	14.2587929	241.113433	0.37281433	0.62718566	0.64331084	0.82387173	0.86627599	5.47280205	25.6367957	13.6603818	0.89095329	15.8363468	1.85667403	21.4905889	13.9393418	0.89604153	16.2160905	1.43866764	17.6489055	14.1518721	0.91175356	17.3177828	0.52741690	0.32386638
1996	Steelhead	0.737483195	0.640785424	0.472568482	0.402024535	124.58	120.34	124.72	146.21	16.9277650	31.6516484	12.3794806	255.758276	0.84465915	16.0974131	8.68514253	14.7734312	11.0946975	118.576231	0.72354205	13.5516250	6.28296969	28.9579423	12.5304554	323.772064	0.86792001	16.1333831	333.451477	0.43828834	0.56171165	0.70051890	0.85148987	0.88992781	4.69736311	30.6534706	12.7388591	0.85426625	17.9921272	1.56179020	25.5247057	13.0865259	0.88031361	18.2647508	1.20936299	20.9857556	13.4261794	0.89928951	19.4879474	0.54945707	0.37957160
1997	Steelhead	0.777325139	0.656360203	0.510205286	0.536794506	135.15	134.59	136.24	141.8	13.3864217	36.0760976	12.8926380	358.450425	0.83848454	21.0438848	6.35934004	19.8243479	11.3382391	168.426577	0.72697894	18.3834060	5.07633405	34.9238017	13.3416296	457.595443	0.85064847	21.2140955	460.217590	0.32440192	0.67559807	0.71191548	0.85920251	0.89422610	3.83923822	36.6585727	13.5319812	0.83090022	23.2843494	1.24378523	32.1168269	13.8143453	0.90875593	23.0483506	0.96289265	26.4678319	14.0774130	0.92189723	24.1814699	0.59891081	0.40647707
1998	Steelhead	0.740842412	0.605116365	0.448330899	0.682336982	126.63	125.79	131.08	136.8	15.8120595	32.8657974	13.1410254	267.430075	0.84058679	16.3720453	7.98388973	15.7638641	11.3764484	122.029185	0.71692302	13.8355102	5.87076626	30.9277537	13.8830823	344.015701	0.86393350	16.4153944	358.880371	0.18742512	0.81257487	0.66958317	0.83817223	0.87834162	4.38991484	32.7274896	14.0710865	0.84813777	18.2729763	1.44231153	27.6623399	14.2972364	0.88599330	18.6866639	1.11727625	22.7341613	14.4599471	0.90419977	19.9386873	0.56028744	0.32730173
1999	Steelhead	0.732438958	0.603188785	0.441798965	0.49306821	133.54	134.22	139.54	146.77	16.2795759	31.8030118	13.0726681	239.287410	0.86280842	15.5084476	8.10512806	15.1479068	11.4853628	106.779931	0.75933125	12.7969495	6.23118633	28.7240988	13.5734020	304.312739	0.88044378	15.6670885	316.118072	0.33674020	0.66325974	0.66777048	0.83740141	0.87748389	4.69139200	30.2509917	13.7486835	0.86746642	17.5129961	1.57442854	25.3542190	14.0188512	0.88989782	20.7875801	1.22082503	20.7845015	14.2660102	0.90422600	19.2363586	0.53407367	0.33766941
2000	Steelhead	0.634602714	0.566843097	0.359720168	0.377011452	130.24	129.12	132.52	143.1	18.1294123	30.2802019	13.2989606	198.849443	0.87761537	14.1210390	9.56583134	13.3951892	11.8538269	88.3067947	0.79167474	11.6642576	6.61286006	26.7580345	13.6201036	259.432683	0.88804046	14.6548426	269.677734	0.41064148	0.58935851	0.63450592	0.82202033	0.86567518	4.99308811	28.0999782	13.8028060	0.87774040	16.4114988	1.71448437	23.3091050	14.0763556	0.88604935	16.6020793	1.33092986	19.0664390	14.3709206	0.89976526	17.5523228	0.44651879	0.27811338
2001	Steelhead	0.662393326	0.494881457	0.327761869	0.263476052	131.89	137.34	143.02	138.7	19.6122183	28.0350621	13.7873371	130.834572	0.93575581	13.3972790	10.2799633	11.6728313	12.0210229	58.8080848	0.89462251	11.4680776	7.39228712	22.7727733	14.6644875	166.998995	0.93791169	13.8326607	174.212005	0.51463749	0.48536250	0.56606574	0.78257762	0.83059931	5.65420483	23.5906004	14.8269798	0.93142703	15.4639698	2.03164314	19.7380342	14.9380331	0.92993168	15.7907495	1.58059292	16.0887119	15.0018296	0.94420978	16.8187332	0.43545409	0.22396450
2002	Steelhead	0.737306238	0.604179653	0.445465427	0.300475812	122.82	128.02	133.88	143.6	19.4046484	29.0552207	12.5175375	193.315719	0.90647263	14.4011462	10.5702238	11.5269727	10.8846777	75.1249939	0.85273860	11.9096324	6.87620829	25.5808322	13.0184874	250.410196	0.90448767	14.7393790	256.859130	0.53713316	0.46286683	0.66668431	0.83402238	0.87409605	5.18710696	26.8519126	13.2310352	0.89268041	16.7298006	1.78925158	22.3243703	13.5249261	0.89910952	17.0294440	1.38814636	18.2849335	13.7851328	0.91162639	18.1617460	0.53926113	0.33583148
2003	Steelhead	0.730274949	0.577419479	0.421674981	0.337354578	125.68	129.67	136.22	141.97	18.1629155	29.6737776	12.9606093	198.441816	0.89689119	14.2487295	9.44458909	12.7267289	11.2612468	79.2625717	0.83012026	11.2371913	6.76534374	25.9369306	13.6759365	252.502540	0.90097950	14.6711240	270.075286	0.48219599	0.51780401	0.64434258	0.82569750	0.86777889	5.10870011	27.2038960	13.8501634	0.89086293	16.5501741	1.74910916	22.7693447	14.0482724	0.89818400	17.0799878	1.35315467	18.7546463	14.2057032	0.91086766	18.3074569	0.52134117	0.31008337
2004	Steelhead	0.705230363	0.547550781	0.386149436	0.442714743	129.49	133.13	139.37	144.8	17.7834128	29.9002630	13.5398659	180.991201	0.90297681	13.8481146	9.13189731	13.2785786	11.7766237	77.6017547	0.84111778	11.5983371	6.71369564	25.7501550	14.2983791	230.420074	0.90601460	14.2010245	249.950042	0.35347946	0.64652053	0.61611718	0.81210564	0.85691688	5.11336648	26.8418085	14.4771991	0.89526757	15.9137023	1.77715516	22.4139171	14.6565710	0.89487252	16.2671950	1.37501907	18.4582226	14.7962269	0.90426328	17.3506088	0.49020834	0.26811969
2005	Steelhead	0.633273207	0.518746468	0.328508824	0.426857014	129.49	130.43	136.14	141.4	17.5236750	29.7885853	14.2099527	174.640148	0.89942024	13.9247878	8.74310760	13.5786608	12.7946620	77.2731292	0.82673006	11.5996568	6.84221847	25.2484367	14.7550670	221.258102	0.90970587	14.3249289	228.406433	0.33767691	0.66232308	0.59146652	0.79859044	0.84559921	5.20236702	26.3375580	14.9131761	0.89990049	15.9962574	1.82172916	21.9506190	15.0943613	0.90233892	16.2922719	1.41473390	17.9443047	15.2346468	0.91780629	17.2812218	0.43394506	0.21893175
2006	Steelhead	0.797791195	0.681106319	0.543380624	0.4349158	117.55	115.42	121.37	136.8	16.7718098	31.3669892	11.2340049	255.548720	0.83245285	16.2123355	8.17797511	16.0181739	10.0553146	131.916893	0.68330541	13.8758106	6.60020679	27.8106082	11.4138887	317.053578	0.87296922	16.3718115	323.800262	0.43567779	0.56432221	0.73461779	0.86656990	0.90185193	4.88629180	29.5833121	11.6421964	0.85839613	17.9297208	1.61890782	24.6446757	11.9456030	0.88123410	18.1242367	1.25473804	20.2235868	12.2327146	0.89865848	19.1886005	0.62559184	0.43802638
2007	Steelhead	0.654504784	0.548706631	0.359131115	0.251497663	118.69	124.7	130.84	132.21	18.7961918	29.6224133	13.5813834	182.456726	0.91147249	13.7784881	10.2079292	12.3516132	12.0516614	66.4941001	0.87491958	11.4163763	6.62881599	26.2337653	14.2558169	243.031356	0.89766974	14.1464521	248.908981	0.55761003	0.44238996	0.61890357	0.81352372	0.85834920	5.04689334	27.3749194	14.3958936	0.88854789	16.0435485	1.76342372	22.6770725	14.5329246	0.89300123	16.3052954	1.36968357	18.5296339	14.6310734	0.90556487	17.3032994	0.45251591	0.24542584
2008	Steelhead	0.736401344	0.596701215	0.439411577	0.470078329	125.56	127.69	134.86	146.25	19.0263534	29.1281179	12.8000551	217.852396	0.89929765	15.9204130	9.92506961	12.5977601	11.1828903	98.2724578	0.82203626	13.3963504	7.15825189	24.6041517	13.2482741	259.369450	0.91333125	15.8553922	268.396453	0.35676027	0.64323972	0.66307077	0.83324193	0.87269950	5.34130026	25.9504565	13.4640598	0.90227788	17.536833	1.81524945	21.9484395	13.7859268	0.91524155	18.3140897	1.40467707	18.0715629	14.0775875	0.92712783	19.9908399	0.53104760	0.32541924
SCN MO2-RESSIM																																																	
1929	Steelhead	0.679578601	0.539159824	0.366401479	0.482784413	125.87	131.41	138.8	144.13	22.7309794	26.6609018	12.6457939	139.748603	0.82392234	10.8114835	12.7194639	9.82030085	11.1619623	63.2147186	0.74399610	8.06266479	21.2596479	13.1523575	171.892707	0.80248873	9.88526360	183.852417	0.30722882	0.69277117	0.62425340	0.81125203	0.86246872	6.05124907	22.2826378	13.3530977	0.82492656	10.7497785	2.13370793	18.7304553	13.5782111	0.82315599	11.6078027	1.65314617	15.3940318	13.7514200	0.87633034	12.9724320	0.44685606	0.27278821
1930	Steelhead	0.490262669	0.426347239	0.209022135	0.405267942	141.48	139.71	140.51	146.46	18.6330906	28.2524367	14.7588624	131.745018	0.80990383	10.5569020	9.13063484	12.6272800	13.3326709	64.7320526	0.71611375	9.30034065	7.57950295	22.1947386	15.2166927	166.63679	0.79301440	9.71362837	171.954498	0.27401593	0.72598406	0.51777077	0.75682186	0.81825774	5.78363694	23.0171916	15.3826725	0.82486807	10.6030057	2.09653474	19.1145539	15.5682547	0.82577147	11.4518340	1.62947802	15.6167784	15.7713670	0.88453188	12.7329288	0.29511219	0.13751516
1931	Steelhead	0.508284787	0.389079935	0.197763412	0.437475588	140.02	145.05	147.41	140.94	17.7321686	28.8039244	15.0017326	130.751817	0.82599522	10.7304804	8.64097204	13.1462409	13.4338016	58.2180290	0.76108481	9.67984581	7.15923864	23.2029064	15.9531876	167.131098	0.79308505	9.72747802	170.838531	0.23427663	0.76572336	0.47791284	0.73229567	0.79780472	5.53248126	23.8510423	16.0923519	0.82389246	10.6267602	2.02360839	19.8185124	16.0710379	0.82441622	11.4624067	1.57456410	16.1490411	16.0010976	0.88336352	12.7486543	0.31208523	0.10960451
1932	Steelhead	0.769494455	0.632111589	0.486406363	0.471932661	117.01	122.54	128.81	135.29	18.2960363	30.2123228	11.6966445	230.956798	0.79605078	12.9584935	9.69229832	12.9829778	10.2530159	98.0851272	0.64358757	10.2834157	6.62264698	27.4325752	12.0580873	293.556732	0.82112906	12.3523147	303.616149	0.37190028	0.62809972	0.70379667	0.85294677	0.89161309	4.94634217	29.0446517	12.2530433	0.83285168	13.7469638	1.65211838	24.1397643	12.5722150	0.84040083	14.3530362	1.27999985	19.8238730	12.8654141	0.85663688	16.7178850	0.57108297	0.38038847

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas
1933	Steelhead	0.701167656	0.56044802	0.392968025	0.386091511	125.71	127	132.59	145.17	19.42409757	29.46295934	13.01089348	198.7037114	0.822680137	12.13696282
1934	Steelhead	0.430931689	0.476479912	0.205330293	0.258581063	141.31	138.64	136.41	141.19	15.70400543	31.77554223	15.03626088	206.7520978	0.862764197	12.78163069
1935	Steelhead	0.683441267	0.533205372	0.364414555	0.422641057	124.78	130.13	136.81	139.13	19.34888641	28.99134691	13.22242451	175.7417976	0.827057715	11.28515737
1936	Steelhead	0.680424262	0.622082989	0.423280359	0.419404814	117.64	118.46	124.68	139.72	18.8533057	30.29113096	11.86746836	233.1871218	0.762853952	13.42494856
1937	Steelhead	0.711199655	0.545562242	0.388003678	0.360662544	119.07	128.28	135.36	134.12	24.05928361	26.39134447	12.31479291	138.7263402	0.820104263	10.64443323
1938	Steelhead	0.765331649	0.641620329	0.491052345	0.458147838	117.73	119.19	124.18	138.69	16.33494695	32.17961012	11.88456399	253.7402818	0.786439268	13.88381318
1939	Steelhead	0.497759178	0.476642015	0.237252938	0.530808586	140.57	140.89	133.4	139.49	18.04380021	29.15352387	13.55262538	169.0982661	0.801130035	11.15802182
1940	Steelhead	0.613526215	0.534679981	0.328040185	0.457594909	123.38	123.39	129.13	142.11	19.15227702	28.75690617	13.19849573	176.5849413	0.785781068	11.03230599
1941	Steelhead	0.605874213	0.483309662	0.292824861	0.375469399	126.97	129.02	135.26	141.79	18.69047148	28.48592643	14.1265974	145.8201261	0.822756767	10.7216068
1942	Steelhead	0.752550306	0.59559787	0.448217359	0.366854116	115.29	121.21	128.56	142.93	20.70015286	27.68780526	11.60882684	169.0675245	0.778876564	10.96216624
1943	Steelhead	0.757899846	0.609231406	0.461736389	0.537699113	125.18	125.03	128.96	134.14	16.09615906	31.55390081	12.11819799	232.5238097	0.795391896	13.92911805
1944	Steelhead	0.683225681	0.495341731	0.338430191	0.334535856	120	128.96	136.4	138.16	22.91690865	26.64494796	13.12280158	126.8969816	0.839635955	10.62623521
1945	Steelhead	0.689568462	0.565905871	0.390230841	0.658539863	123.15	126.5	132.9	138.04	20.12074357	28.96928217	12.7261779	189.4756998	0.798694261	11.64357475
1946	Steelhead	0.7796445	0.652325217	0.508581768	0.418161776	118.98	119.85	125.27	133.29	16.40387006	32.25133933	11.53406313	265.0100179	0.792880303	14.26242314
1947	Steelhead	0.588271409	0.535552208	0.315050052	0.589081235	135.33	125.88	129.3	139.58	16.87785599	31.30005781	13.84536362	237.3835275	0.787468587	13.32765419
1948	Steelhead	0.733280368	0.614212697	0.450390112	0.631936071	131.27	132.98	138.51	140.64	15.22258139	33.48901962	13.05303437	329.0343203	0.813099929	18.21040719
1949	Steelhead	0.771728844	0.614555155	0.474269939	0.461678897	116.18	120.06	125.9	135.38	17.10099805	31.3945696	12.15702077	256.7154258	0.770802664	14.1278427
1950	Steelhead	0.743726485	0.613516499	0.456288469	0.460786078	121.67	124.72	131.5	138.79	19.81300421	28.78701591	11.72372389	200.4300553	0.7974339	11.99884207

Year	Species	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv
1933	Steelhead	10.7201812	11.68569126	11.31868744	72.99806213	0.723541844	9.786742592	6.755598605	26.23421978	13.59115156	258.8974991	0.816635877	11.52660974	270.0967712	0.413021961	0.586978039	0.644159045	0.825021795	0.868622249
1934	Steelhead	7.787712455	14.26376484	14.25243092	58.40385971	0.823853028	11.2784111	5.975200661	29.36156059	15.26198864	288.5368398	0.82657222	11.95201532	294.9330444	0.417564217	0.582435783	0.561471306	0.790888416	0.842186453
1935	Steelhead	10.48962669	11.51148772	11.52995644	65.10539322	0.737198472	9.290724754	6.907957427	25.32915377	13.93333356	230.5425797	0.815469772	10.64099193	241.3036346	0.361367011	0.638632989	0.622005013	0.815958478	0.861055743
1936	Steelhead	10.10558289	13.59038707	10.6670908	115.4945953	0.568456393	12.03981571	6.772996195	27.01871829	11.94823631	292.2342631	0.806279182	12.21655575	303.0463562	0.400413597	0.599586403	0.693350727	0.849448182	0.891321095
1937	Steelhead	14.0314428	9.125620463	10.64109688	55.80671692	0.74778651	9.300889206	8.057196453	21.5710071	12.96248595	178.707016	0.790421496	9.721005122	191.5120697	0.438643248	0.561356752	0.632974364	0.813977383	0.864532794
1938	Steelhead	8.208263718	15.93129245	10.59264297	120.7910629	0.601490277	11.98743763	6.149699092	29.50996261	12.10801744	331.0119629	0.833783438	13.12220112	344.280426	0.387127437	0.612872563	0.708367796	0.856555425	0.894396829
1939	Steelhead	9.016018324	13.17257777	12.93019009	72.80284882	0.681730783	9.38039341	7.066362962	24.49289057	13.89395936	216.5304286	0.801194559	10.46374631	221.4703369	0.200722819	0.799277181	0.568464179	0.791957343	0.845028314
1940	Steelhead	9.861374475	12.36306188	11.64339218	79.71598816	0.637201869	8.863278198	7.340260491	24.06218297	13.53202057	224.4861069	0.802487592	10.56789732	231.3656769	0.311297045	0.688702955	0.624203272	0.815289566	0.861770677
1941	Steelhead	9.430779107	12.1293939	12.8056879	56.75728149	0.769484949	9.503834534	7.322540581	23.39638827	14.60323954	190.9400177	0.778528412	9.644471327	198.7478638	0.363784994	0.636215006	0.57646985	0.7876698	0.843981232
1942	Steelhead	10.95989852	11.46245445	10.15720654	81.79238892	0.637994826	9.011222458	7.768302016	22.67065844	11.99209213	210.3305842	0.785716633	10.19918903	214.3784637	0.459206487	0.540793513	0.678955333	0.838360138	0.884273873
1943	Steelhead	7.722902685	15.80792564	10.70794353	117.1258835	0.63298378	13.25876617	6.39874886	28.11204293	12.50204245	297.1278483	0.82842803	12.58309817	313.8751831	0.302669079	0.697330921	0.681927859	0.844669397	0.884715275
1944	Steelhead	13.02494593	9.614420453	11.12079868	54.3045784	0.791281581	9.606639099	7.939485684	21.45498234	14.03337145	162.3997904	0.799749325	9.605936845	172.0783691	0.435250942	0.564749058	0.58385672	0.789507595	0.844705897
1945	Steelhead	11.10976858	11.54135495	11.17735558	81.07827301	0.670695436	9.807741165	7.055477366	25.32278724	13.23698362	242.0062815	0.804707249	10.89146336	259.7524414	0.184372341	0.815627659	0.649097391	0.826435323	0.871248735
1946	Steelhead	8.319878615	15.70343228	10.14767742	121.0662155	0.615014535	12.19826965	6.096142031	30.04291559	11.84612465	340.4746043	0.837542345	13.22839554	352.0669861	0.435824567	0.564175433	0.715408822	0.860045058	0.897147859
1947	Steelhead	8.515045233	14.64339199	12.43337078	108.5947388	0.626156735	11.32720184	6.419706494	27.96973654	14.15646283	298.7521922	0.815629711	12.27266065	307.1643677	0.202901405	0.797098595	0.616600653	0.81606522	0.863048552
1948	Steelhead	7.715966225	16.095164	11.61464939	144.7255524	0.669401705	15.37294884	5.559420712	31.93502075	13.54359182	418.5317637	0.839398712	18.34712776	435.4868164	0.223179554	0.776820446	0.682750377	0.848195096	0.886785844
1949	Steelhead	8.726248607	15.08933189	10.24028988	124.3249023	0.56130749	11.47364388	6.402858697	28.29609347	12.7078673	316.3762156	0.830783774	13.41758839	325.0409851	0.375006236	0.624993764	0.684577631	0.84265595	0.882672582
1950	Steelhead	10.65955392	11.88938082	10.38125038	89.21872711	0.638109541	9.481425285	7.179241106	24.91663172	12.0455068	252.7795944	0.828921368	11.58154146	263.4962158	0.370286717	0.629713283	0.69168816	0.849493943	0.888285094

Year	Species	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1933	Steelhead	5.079075873	27.60712879	13.78020916	0.843459141	12.85553303	1.737846434	22.99511072	14.06918144	0.844691316	14.00592868	1.348987967	18.8122823	14.30546808	0.857158035	16.16689539	0.485242225	0.296586285
1934	Steelhead	4.579848059	30.5793216	15.32952747	0.832076836	13.17609196	1.588512264	25.19310331	15.41559442	0.841026684	13.53803698	1.234799944	20.55121104	15.54903412	0.85598278	15.70937872	0.269757183	0.140123441
1935	Steelhead	5.227240197	26.5307176	14.10762157	0.853742576	11.87643318	1.81321346	22.06530465	14.30024179	0.848150571	13.23495642	1.408862315	18.0183657	14.44673395	0.853745162	15.31618118	0.474168817	0.26237293
1936	Steelhead	5.003946312	28.7511466	12.18173771	0.812105393	13.13171425	1.671386354	23.84981145	12.523441	0.825721443	13.68224462	1.294297837	19.6049063	12.88795185	0.859372526	15.91445923	0.491201046	0.354710574
1937	Steelhead	6.004326656	22.72147159	13.16964226	0.81967423	10.69995193	2.095312551	19.05513356	13.42052492	0.820224504	11.61349678	1.622741446	15.67998594	13.60568523	0.875758559	12.98259974	0.485802576	0.286489688
1938	Steelhead	4.60586226	31.20507273	12.28363323	0.83578912	14.38323822	1.533268943	26.0382742	12.60558001	0.853494724	14.83778191	1.188950226	21.34867319	12.92807865	0.872965872	16.96715403	0.585122622	0.393708455
1939	Steelhead	5.353400573	25.59994352	13.95483913	0.834958279	11.57300529	1.892832294	21.17847021	13.89636389	0.831986487	12.62059498	1.473064259	17.24194469	13.89130735	0.856482744	14.45752811	0.323346193	0.16132958
1940	Steelhead	5.499858364	25.34564082	13.7333519	0.83788681	11.67684422	1.903723732	21.01664273	14.07669004	0.833550135	12.84602833	1.478774503	17.17630881	14.41712141	0.849053741	14.77199984	0.4089839	0.24591306
1941	Steelhead	5.560973585	24.38875534	14.74995518	0.80997963	10.72821827	1.970112801	20.29807454	14.94652716	0.812337001	11.62315941	1.52915889	16.61924941	15.10476065	0.873219907	12.93037033	0.394910714	0.203566896
1942	Steelhead	5.794847183	23.91373939	12.22964325	0.819346917	11.20806541	2.016898416	19.83763674	12.52037716	0.821725488	12.23975245	1.565902166	16.2364979	12.77412796	0.870812625	13.84831333	0.535241087	0.343132562
1943	Steelhead	4.809999213	29.64649467	12.69562168	0.840576649	13.63344269	1.614143312	24.72709334	12.97075049	0.853453398	14.30923239	1.251522899	20.2756738	13.23287058	0.870660454	16.50757742	0.564225771	0.354055984
1944	Steelhead	5.991561785	22.41179312	14.23215294	0.825843811	10.56143589	2.129981592	18.78155622	14.42825222	0.825766663	11.39050039	1.652374849	15.40565948	14.55751133	0.884971023	12.63517809	0.438619761	0.230339101
1945	Steelhead	5.239214763	26.81146311	13.43038387	0.826669562	11.92719917	1.77814512	22.42724725	13.69858074	0.826155563	12.88762029	1.377361909	18.42703498	13.92595959	0.848407328	14.77702332	0.480360663	0.285630923
1946	Steelhead	4.55830238	31.82821055	12.04385872	0.835945415	14.38967171	1.503670417	26.51501724	12.35704581	0.857802769	15.0339915	1.164321356	21.80444904	12.6438899	0.87790823	17.75298786	0.595221651	0.396177331
1947	Steelhead	4.802714258	29.54712776	14.33463402	0.825399446	13.51645775	1.625983253	24.5348871	14.61501726	0.838834325	14.38306586	1.260099605	20.13733338	14.91843653	0.861882865	16.68822336	0.39124921	0.229489692
1948	Steelhead	4.169857629	33.64808093	13.72631512	0.841867507	20.25149498	1.381242253	28.91205976	13.95976734	0.871528625	20.34160042	1.070530929	23.74392558	14.15376282	0.889045745	21.11009979	0.540804425	0.342137842
1949	Steelhead	4.791867577	29.92379398	12.95655117	0.837005389	14.74763851	1.594026826	25.00995031	13.36389478	0.848440111	15.53226566	1.234468393	20.55676392	13.69669914	0.864493638	18.02299404	0.566739829	0.373688384
1950	Steelhead	5.356499955	26.33678619	12.2544838	0.855499256	12.83891182	1.824655876	21.91376477	12.52711614	0.854716758	13.90975889	1.416893944	17.9171914	12.76826715	0.860535204	16.24357271	0.544423784	0.348680612

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1951	Steelhead	0.753361713	0.606588814	0.456980788	0.444675594	119.74	121.58	127.07	134.48	16.5024062	31.54843962	12.45412179	246.003861	0.804127353	13.70001973	8.226150498	14.9536083	10.89237423	106.7103531	0.653540587	11.64686775	6.302707709	28.79566407	12.88952843	315.6484884	0.831680546	12.74689364	327.4259338	0.385034746	0.614965254	0.678556807	0.843270973	0.883518232	4.729259767	30.42708486	13.08434563	0.837117565	14.09776764	1.573857285	25.3441475	13.39768473	0.850672901	14.75171407	1.219463415	20.81092928	13.67637014	0.866802663	17.25861406	0.554585618	0.356834108
1952	Steelhead	0.804004466	0.675780551	0.543330581	0.612044523	118.65	119.61	125.1	134.99	15.1403207	33.32433907	11.14963995	287.0499834	0.763702961	16.52911847	7.019305296	18.75820001	9.873932457	164.0852478	0.536039466	16.22723923	6.134131283	29.98559833	11.33588028	350.6810506	0.835274071	14.81471682	358.9090271	0.269382336	0.730617664	0.734458643	0.868446984	0.904494678	4.566669911	31.83924109	11.57870026	0.831898606	15.65233574	1.500506043	26.58241542	11.90882238	0.855170647	16.14215183	1.162360013	21.84162085	12.22669983	0.880273312	18.4567275	0.623069009	0.441697916
1953	Steelhead	0.744801282	0.563796934	0.419916679	0.472182737	119.92	124.94	131.64	144.26	17.96436268	30.33651302	12.79035452	212.9343376	0.803149555	12.62538559	9.354965299	13.46384511	10.94557514	91.92216949	0.66796329	10.46947098	6.662220985	26.7715779	13.5784591	267.9598389	0.817379773	11.87824925	279.7966003	0.339948296	0.660051704	0.646663477	0.826113946	0.868871734	5.00011614	28.21835419	13.7722168	0.843696177	13.09387608	1.694468573	23.5698846	14.01576328	0.842155973	14.40318267	1.314627811	19.302179	14.18494749	0.848247498	16.57587481	0.516065264	0.326874684
1954	Steelhead	0.770237022	0.628808166	0.484331329	0.354637238	111.71	119.36	126.72	136.6	21.44875301	28.22812879	11.21137292	203.8073425	0.79333514	12.06194043	12.118369	11.11096854	9.742738914	89.01227417	0.638301945	9.478227425	7.344904058	24.44434359	11.59575303	253.553772	0.819197218	11.45817796	259.5649414	0.490451521	0.509548479	0.705268508	0.85355697	0.892412665	5.457255594	25.89256108	11.8293478	0.845796967	12.66720352	1.856104009	21.53743193	12.12680308	0.844771624	13.98554579	1.440851115	17.6224453	12.37574673	0.858540744	16.23191833	0.581000814	0.380053172
1955	Steelhead	0.729537538	0.566909329	0.413581636	0.527261556	120.64	127.13	134.21	136.47	21.15071641	27.85401963	12.29653726	170.8403816	0.806133781	11.31408562	11.67942724	10.81754678	10.64428196	72.480867	0.7113819	9.580735016	7.508499816	23.44454987	12.8925581	215.3775711	0.788160811	10.4615825	229.1055145	0.291495931	0.708504069	0.651373717	0.824339435	0.872253113	5.599081233	24.73203699	13.11437416	0.815270913	11.45432777	1.923855856	20.72299464	13.39145629	0.816820721	12.48383331	1.489127055	17.05862116	13.60377693	0.864013016	14.09728146	0.508597914	0.313687026
1956	Steelhead	0.786069708	0.670958223	0.527419934	0.567389767	123.62	120.39	125.25	139.14	15.08525644	33.68963563	11.65430614	313.9540362	0.806238928	17.71349055	7.475684144	17.23203896	10.38508472	145.9204346	0.630935657	14.96338768	5.635028906	31.90941817	11.88436524	403.3097382	0.855444938	17.77646367	418.1915894	0.302700962	0.697299038	0.72977904	0.868695705	0.903278182	4.213278241	33.72317312	12.10282841	0.852571332	19.40126266	1.375594087	28.98641543	12.39791139	0.877350569	19.58865166	1.064462252	23.88198216	12.68293047	0.893721282	21.06684589	0.617690444	0.434132827
1957	Steelhead	0.768786514	0.636839432	0.489593567	0.489974784	115.58	118.48	125.76	141.87	18.09963918	30.15837811	11.58210468	265.3689003	0.774920249	14.75776986	9.20264937	13.86985973	10.30833607	118.1632797	0.57979117	11.25694523	6.924699776	26.43499047	11.81335576	318.7064463	0.824988196	14.18121322	329.0740662	0.356807741	0.643192259	0.713725688	0.860280197	0.897404742	5.071776263	28.21685737	12.02365227	0.850824714	15.60368004	1.664993726	23.90339879	12.34144274	0.858449837	17.05671978	1.287291311	19.71156889	12.6486578	0.874989122	19.2350049	0.564412359	0.405276332
1958	Steelhead	0.733740103	0.608591352	0.446547881	0.605239179	124.72	127.89	133.55	137.86	18.2130042	30.93017892	12.36266368	257.1362059	0.800838824	14.61209941	9.911739089	13.19593225	10.96558437	113.5329575	0.656209719	12.30792656	6.340363257	28.60945771	12.81124385	321.5799561	0.821783215	13.67212145	333.8982849	0.242507931	0.757492069	0.682971624	0.846597214	0.887131667	4.706493132	30.35628422	13.00799637	0.836001933	14.97577209	1.561112277	25.53166591	13.23111153	0.850369414	15.95206006	1.208640598	20.99837852	13.41578817	0.871667624	18.23687887	0.539748324	0.355579924
1959	Steelhead	0.72674395	0.593691606	0.431461783	0.357181176	114.64	119.28	124.88	138.95	20.86866673	28.86557967	12.23797206	208.1096655	0.798561194	11.80324207	11.8645286	10.94768049	10.60462551	76.82619476	0.658905184	8.896666145	7.03111358	25.86549376	12.68218915	272.3340276	0.814222296	11.43323835	282.2879944	0.462441823	0.537558177	0.674322748	0.839884201	0.881050312	5.204306439	27.48335131	12.89069023	0.83717345	12.88616829	1.747027233	22.85035157	13.22865709	0.839748283	13.89724159	1.354716405	18.73313198	13.52498102	0.853342086	16.06797743	0.513071701	0.339781428
1960	Steelhead	0.750385707	0.606658987	0.455228233	0.406881088	117.55	124.59	131.3	135.77	20.55966777	28.5763685	11.78212466	193.488303	0.810195693	11.58411203	11.52034781	10.83359403	10.2070713	75.69188232	0.69078064	9.284072113	7.062609576	25.34528459	12.25653203	251.319163	0.814806213	10.96289047	262.8232727	0.423407498	0.576592502	0.686923693	0.844755076	0.884231833	5.282552026	26.76572914	12.4778511	0.847137165	12.29486027	1.795621924	22.25128052	12.77997526	0.844272176	13.59810289	1.393439256	18.21602381	13.0329113	0.850451201	15.80088568	0.556790055	0.34477835
1961	Steelhead	0.716426172	0.560640474	0.401657509	0.375434001	120.66	127.02	133.83	142.55	19.20456781	29.53809619	12.88520731	210.0330565	0.835845713	12.72304201	10.60326845	11.44743405	11.14461651	70.00917511	0.756059146	10.06052322	6.646384194	26.71864055	13.62150224	275.4191208	0.820257545	12.18635734	281.0655823	0.429307083	0.570692917	0.645020396	0.827295193	0.870028855	4.997968987	28.12237831	13.80021591	0.850026774	13.72360554	1.702340126	23.50452923	14.01090844	0.851391196	15.07614994	1.323093534	19.17899613	14.16877413	0.860168308	17.08086824	0.487792009	0.310859166
1962	Steelhead	0.714628671	0.563459246	0.402664133	0.623094224	128.74	133.24	138.4	135.5	17.01884209	30.77465565	12.95062671	202.5115144	0.798101519	11.80710275	8.594753034	14.09808065	11.41477814	89.00850372	0.656360924	9.676533699	6.465042748	27.46355852	13.58159765	265.5312602	0.815269987	11.31786998	273.7792969	0.212327223	0.787672777	0.643773008	0.825863092	0.868974837	4.887854017	28.83834833	13.76976852	0.83907491	12.54766102	1.676214479	23.9015802	13.96118259	0.842029015	13.40955289	1.304398589	19.45325944	14.10408401	0.85082683	15.54869938	0.509791965	0.280630188
1963	Steelhead	0.675798544	0.534639835	0.361308822	0.686196665	131.03	130.07	136.93	142.4	18.20372538	29.51778674	13.27846166	190.2781699	0.791001086	11.69840183	9.268585943	12.98435583	11.75144787	86.46892395	0.638527894	9.724462509	6.989207171	25.24001274	13.88968786	236.8452581	0.813563069	10.89949711	245.2272339	0.155337393	0.844662607	0.622749854	0.816831574	0.862879956	5.25193157	26.54955261	14.05667763	0.845541942	11.95877686	1.808371566	22.12461067	14.25207965	0.846491456	13.19848887	1.40513169	18.06576762	14.41104174	0.86484611	15.26668549	0.464735489	0.252956752
1964	Steelhead	0.722033576	0.573117199	0.41380986	0.622135637	128	130.85	137.27	141.71	19.0175811	29.16078867	12.70358167	202.3157894	0.803904989	12.38064674	10.00345476	12.29506467	11.08827076	89.69496155	0.659406519	10.1309864	7.063458003	25.06080609	13.21056016	251.4566727	0.826273491	11.7297558	261.5673828	0.216755663	0.783244337	0.655733169	0.831565473	0.873752189	5.28165523	26.42792864	13.42907143	0.856218874	12.94542694	1.807667859	22.10477638	13.72302723	0.858031412	14.29922295	1.402853079	18.09484396	13.97021484	0.870613575	16.45952845	0.51103238	0.31559544
1965	Steelhead	0.763495879	0.636534571	0.485991522	0.587318444	122.54	118.7	123.86	143.58	18.22874003	31.59886538	11.93792554	258.5192751	0.767069659	14.47532606	9.910308048	14.61576288	10.29079361	131.0814423	0.557030785	12.82201557	6.361559577	28.91943667	12.23302158	325.7964986	0.825637162	13.50008615	333.7662964	0.269948935	0.730051065	0.703704536	0.852366937	0.891389736	4.709934779	30.77099022	12.47656746	0.82851119	14.59471741	1.557487898	25.63572025	12.91334343	0.847099861	15.28761895	1.207913123	21.01110327	13.30709171	0.871216953	17.50346041	0.558295094	0.401257092
1966	Steelhead	0.629703439	0.500233401	0.314998693	0.554673353	131.17	138.61	142.44	134.09	18.01122599	29.4536787	13.48312167	175.2257363	0.80799288	11.21794224	9.314738087	12.62267929	12.14612865	69.32323608	0.712315416	9.488957214	6.733931601	25.66938415	14.28819338	228.4107539	0.791720966	10.44155343	235.1871185	0.224145289	0.775854711	0.585076001	0.793224206	0.846087102	5.12843889	26.75793585	14.45941982	0.819157696	11.648946	1.802411079	22.20001276	14.48239708	0.819551567	12.53258928	1.4006567	18.12295994	14.40984964	0.853597164	14.26328993	0.429181541	0.187732376
1967	Steelhead	0.698161349	0.601331315	0.419826282	0.525279421	126.56	128.89	135.67	146.68	21.69631389	27.86191578	12.25924199	209.2201473	0.824119849	13.06683561	12.41734873	9.644815114	11.05023365	77.74415283	0.709246671	10.57960281	7.331852123	24.1792796	12.47063017	259.2283681	0.831907709	12.23195473	260.9085388	0.29704544	0.70295456	0.682125321	0.845885952	0.885929317	5.449341461	25.56509397	12.65388908	0.857691562	13.69027996	1.865717724	21.43961574	12.92701276	0.859502117	15.08694744	1.449120298	17.52311139	13.19294739	0.873569727	17.25477743	0.501763182	0.339519297
1968	Steelhead	0.640153915	0.518355381	0.331827226	0.30129823	111.48	119.46	127.65	146.69	25.63355304	25.186788	12.96945088	137.2172454	0.820004357	10.70837528	14.81270701	8.105672978	11.3879879	54.06876678	0.689389014	8.646183395	8.870415032	19.27609351	13.3444163	165.9549459	0.838852843	10.08723346	167.0797424	0.467006017	0.532993983	0.607046572	0.802409158	0.851483795	6.613925278	20.25306293	13.53164902	0.862402737	11.27104969	2.359752804	17.00421555	13.87377898	0.859237731	12.277469	1.832918257	13.93257587	14.18416452	0.890140653	14.03884029	0.413344839	0.243713266

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1969	Steelhead	0.722150247	0.581850694	0.420183622	0.741086346	129.92	127.39	132.92	138.9	14.7941462 5	33.1903220 3	13.2071242 3	271.7367761	0.793991219	15.3962026 3	6.995946065	16.8627279 2	11.5663871 8	122.0796417	0.617753333	12.9118030 5	5.845447354	30.6917246 8	13.8721952 4	342.810557	0.837851355	14.7804479 6	346.602050 8	0.137390853	0.862609147	0.655126382	0.833617805	0.875381228	4.405141525	32.32079112	14.0602472 3	0.842631304	16.3758459 1	1.470390611	27.1840104 1	14.2747119 3	0.856672108	16.9515883 1	1.141261391	22.2500092 7	14.4388780 6	0.872255534	18.9335131 6	0.524148832	0.300259027
1970	Steelhead	0.719324805	0.582346298	0.418896137	0.542459235	117.79	126.87	134.32	143.57	23.6243993 1	26.9195663 9	12.0461049 1	177.9527517	0.835700614	12.2193823 9	13.8352978 2	9.0811804 7	10.4993856 4	73.8108322 1	0.731105471	10.4195974 3	7.834728196 6	22.5716977	12.5519830 4	214.241358 4	0.840713511	11.2328504 7	217.551803 6	0.281533336	0.718466664	0.666189155	0.836848041	0.878140141	5.801085427	23.89238883	12.7666269 3	0.870511234	12.3483387	1.996660843	20.0576468 4	13.028608	0.866892556	13.8437067 7	1.551745042	16.3817423 6	13.2371635 4	0.878474712	16.0695176 1	0.509092327	0.316897535
1971	Steelhead	0.727028819	0.630306558	0.458251032	0.697125921	139.64	135.56	135.88	145	15.3007508 7	33.7721371	12.7303921 8	311.4281398	0.806252569	17.6700269 8	7.758016817	16.6304998 6	11.4641504 3	142.2212769	0.631757224	14.5448268 9	5.597641796	32.1144325 9	13.0232296	394.744344 1	0.854791959	17.6114252 4	399.240417 5	0.178780053	0.821219947	0.696511724	0.855392899	0.892658826	4.179183096	33.95858869	13.1934434 9	0.854398882	19.3308166 5	1.376345471	29.0172763 6	13.4395017 6	0.875916183	19.8849331 1	1.066782191 1	23.8289723 9	13.6819367 4	0.890162144	21.4497547 1	0.552928455	0.352395775
1972	Steelhead	0.761186671	0.627360237	0.477553825	0.511814872	121.95	120.81	126.36	140.13	16.6930214 8	31.5564723 8	12.2658361 7	277.1201973	0.818755286	15.7480268 5	8.524901211	14.4838957 3	10.7415741	116.9757797	0.683462465	12.9409709 9	6.203099139	29.0660266 8	12.5878243 4	351.542495 7	0.840877116	15.331213	345.285919 2	0.331364505	0.668635495	0.696681738	0.852253267	0.889976718	4.643526204	30.71479709	12.7797517 8	0.845521724	16.8958179 5	1.551029094	25.7983692 6	13.1318721 8	0.861122767	17.4391549 4	1.205422558	21.0548030 5	13.4754447 9	0.873082727	19.4997782 7	0.555040175	0.385590453
1973	Steelhead	0.663312602	0.503185916	0.333769559	0.311968709	116.19	126.03	133.56	146.67	24.0188236 3	26.2029231 5	13.0026108 9	131.884109	0.838404354	10.6807385 5	13.8876005 8	8.836916412	11.1287000 7	49.7402175 9	0.781072327	9.444771767	8.186231762	20.9398601 5	13.7813137	167.282351 2	0.805380354	9.687364499	175.334762 6	0.457774506	0.542225494	0.591150967	0.792364957	0.846176581	6.130896956	21.96788959	13.9839023 6	0.828623497	10.7411472 3	2.167907357	18.4506728	14.2172190 3	0.827071786	11.6082086 6	1.681177222 9	15.1486359 3	14.3894515	0.881182253	12.9632682 8	0.411986282	0.236024654
1974	Steelhead	0.742820333	0.632926216	0.470150463	0.563507228	133.57	128.88	129.52	141.66	15.5002317 7	33.5545252 4	12.6473712 9	294.5635082	0.820619464	16.5698849 1	7.987158895	15.8802298 3	11.0991161 3	123.8067841	0.670196414	13.3384323 1	5.560478829	32.3576774 2	13.0121526 7	384.802500 4	0.856282125	16.7189463	393.702423 1	0.285378966	0.714621034	0.697574165	0.853348105	0.890724125	4.173527 74	34.14646666	13.2019491 2	0.853544998	18.3275590 9	1.373715572	29.0564828 9	13.5404313 4	0.874681254	18.7787148 2	1.064121567	23.8897370 4	13.8547000 7	0.890265375	20.42 11359	0.561 39924	0.369707213
1975	Steelhead	0.774186475	0.609323855	0.471730287	0.322984759	112.8	122.03	129.31	137.23	21.3302069 5	28.1235910 9	11.5525536 5	193.470744	0.810633783	11.8861114 6	11.9678888 8	10.8642917 9	9.85915260 3	81.7920059 2	0.692137575	9.603 86467	7.384762265	24.2770405 2	12.0503562 3	243.264279 7	0.814697832	11.1882309 9	250.975921 6	0.519100347	0.480899653	0.691464993	0.846460048	0.886224415	5.486382939	25.71124618 8	12.2853017 8	0.850639188	12.3962406 2	1.863675423	21.4547737 1	12.6249640 8	0.849506438	13.8252296 4	1.447005596 5	17.5483786	12.9019198 4	0.863669962	16.0355587	0.574 41409	0.357256742
1976	Steelhead	0.790933445	0.664622617	0.525672256	0.549863847	114.99	116.78	123.42	136.99	18.2705872 1	30.3887109 2	11.0087060 2	249.7179489	0.764725406	13.9568218 8	9.488120295	14.1000284	9.72782955 2	124.8404083	0.542788982	11.5233318 3	6.796249369	27.0069080 9	11.1755917 9	304.861185 7	0.832034588	13.2787816 5	304.069427 5	0.316221607	0.683778393	0.730124964	0.865706525	0.901382949	5.031076163	28.72891138	11.4205116 3	0.840684688	14.5405679 7	1.676769018	23.8438299 8	11.7699362 4	0.846984474	15.2024567 9	1.302239099	19.4854705 6	12.1034636 5	0.857105821	17.5884060 9	0.599 49875	0.433572401
1977	Steelhead	0.610373529	0.475173981	0.290033362	0.163645011	122.05	129.38	135.99	133.83	22.0650313 8	26.3707649 6	13.6174771 4	110.0567891	0.860 7704	10.5241955 9	12.0161327 1	9.77463104 4	12.1639738 1	38.4635932 9	0.840 04809	9.882955742	8.093 59833 6	20.7285774 8	14.2557096 5	147.213406 9	0.808 42470 1	9.323 95533 7	153.037780 8	0.636 18281 5	0.363 81718 5	0.565 85548 9	0.778 32277	0.834 62170 9	6.157 6415	21.51 94971	14.3996608 7	0.835 45872	10.4390968 3	2.231 76503 2	17.9730143 7	14.5611995 1	0.834 37448 7	11.19 41611	1.734 586	14.6954283 2	14.6678299 9	0.891 27200 8	12.3726162 9	0.376 94587 5	0.202 68406 5
1978	Steelhead	0.710258595	0.580405697	0.412238135	0.585159014	133.15	134.17	138.67	142.38	16.8776976 4	30.8213766 8	12.8158264 2	209.4464171	0.804407196	12.3536484 6	8.454904483	14.3593918 7	11.4964201	94.3810714 7	0.671 00449 8	10.6630573 3	6.473 50454 3	27.1924020 8	13.2609624 3	268.054321 3	0.817 78001 8	11.5602920 9	278.158111 6	0.243 14502 9	0.756 85497 1	0.657 31392 1	0.832 45325 7	0.875 71297	4.910 92121 6	28.47 44705	13.4233013 2	0.832 76047 7	12.8424404 1	1.693 68414 6	23.5808067 4	13.6184234 6	0.834 95801 7	13.39 7487	1.314 02029 1	19.3110823 9	13.7878370 3	0.848 91668	15.48 84305	0.511 20257 2	0.320 15943
1979	Steelhead	0.742957523	0.603420004	0.448315431	0.481235641	118.31	124.67	131.07	134.81	21.0633772 5	28.4096990 8	11.7896883 8	192.7206623	0.813121476	11.9815543 4	11.8269083 4	11.027596	10.4770641 3	79.8279159 5	0.702 46204 1	10.2901351 9	7.257 16370 3	24.8372708 3	12.2237965 3	246.418459 6	0.811 89833 1	11.09 7145	258.583679 2	0.348 34873 4	0.651 65126 6	0.683 67947 1	0.844 32859 2	0.885 11728	5.367 92153 1	26.36 69762	12.4170633 3	0.837 04897 2	12.2027624 1	1.815 78737 5	21.99 70841	12.6403640 1	0.836 00908 5	13.25 6121	1.408 57511 8	18.02 19855 8	12.8207998 3	0.850 16682 7	15.35 16540 5	0.544 61459 1	0.354 91626 6
1980	Steelhead	0.752239903	0.622462712	0.468244129	0.405418896	112.85	120.89	126.58	143.29	20.4535222 6	30.8182974 4	12.0856370 9	249.5685234	0.812522194	13.6835827 8	12.2315538	11.8737069	10.0949504 9	92.3379531 9	0.685 30825 4	10.3219081 9	6.259 86020 3	29.4697173 4	12.7179584 5	328.546763 1	0.824 79507 7	13.49 37383 3	350.206726 1	0.432 90640 5	0.567 09359 5	0.692 98172	0.847 18507 5	0.887 19134 3	4.608 89141 3	31.42 97645 2	12.9673507 7	0.832 46508 8	15.0153839 1	1.499 63988 4	26.51 20549 9	13.3616037 4	0.849 51945 1	15.91 64155 3	1.157 87242 4	21.9271505 2	13.6678481 1	0.876 27902 6	17.90 14878 3	0.546 45389	0.370 83320 5
1981	Steelhead	0.588864226	0.518879545	0.305549602	0.553453281	136.58	134.86	138.86	148.84	17.1756175 8	30.5152268 6	14.2599725 7	206.501392 9	0.804576644	12.4199756 6	8.616377778	13.8301213 7	13.0459833 1	87.3124237 1	0.669 45045	10.2613580 7	6.636 09509 9	26.4747840 7	14.6114687 9	262.625735	0.819 47042 5	11.59 95385 6	270.060882 6	0.221 99312 9	0.778 00687 1	0.606 50942 7	0.810 05158 6	0.857 54470 6	4.998 41123 1	27.80 39327 6	14.7512052 5	0.841 08675 7	12.7695402 1	1.726 53605 8	23.1384823 9	14.9658807 1	0.844 99323 4	13.82 09899 3	1.339 82165 9	18.9404027 4	15.1642918 6	0.862 59502 2	16.01 47399 9	0.393 15240 7	0.221 65476 9
1982	Steelhead	0.741311948	0.611314 68	0.453174876	0.549227334	121.57	120.78	126.14	139.01	18.9374055 1	30.3651917 2	12.1669868 7	239.246348 8	0.767407117	13.1642914 2	10.2603637 3	13.3607296	10.4932580 9	111.1407837	0.560 84682 3	10.1589439 4	6.704 36700 4	27.2052218 5	12.5270547 9	300.644755	0.823 24459 2	12.92 08587 8	303.063201 9	0.288 11962 8	0.711 88037 2	0.685 70300 9	0.844 79317 9	0.884 58533 4	4.966 20031 4	28.90 97200 9	12.7547750 5	0.836 50538 9	14.2324934	1.661 76816 1	24.0588993 2	13.1456263 9	0.843 44687 1	14.99 90135 8	1.290 58524 2	19.6612730 2	13.5063309	0.856 13331 2	17.20 99204 1	0.535 22022 1	0.360 35266 6
1983	Steelhead	0.749504587	0.591360292	0.443227252	0.502079802	117.59	120.92	127.07	146.31	19.2430902 6	29.6910934 7	12.3607345 3	221.621722 6	0.789404737	12.6457767 1	10.4122782 3	12.3025228 3	10.6128007 9	95.8015838 6	0.639 10930 2	10.0695585 3	6.877 99620 6	26.3280217 1	12.8781126 3	279.162236 5	0.809 35367 9	12.02 07227 9	284.885437	0.323 08193 3	0.676 91806 7	0.670 81624 1	0.836 58669 5	0.878 75165 4	5.105 49771 8	27.92 94536 8	13.0910352 7	0.828 11414	13.3469753 3	1.714 51264 6	23.3025257	13.4425191 9	0.832 24205 2	14.28 18441 4	1.330 60926 2	19.0710163 5	13.7490668 3	0.851 90719 4	16.45 03006 9	0.522 27862 2	0.358 32545 2
1984	Steelhead	0.768699476	0.632413976	0.486136292	0.589026485	119.61	119.34	125.53	137.4	19.2908397 5	29.3806165 3	11.3540116	212.256542 2	0.737214233 4	12.0272971 6	10.0137772	13.4481897 9	9.91035289 8	117.3313461	0.502 92195 1	9.988 55037 7	7.301 70013	25.0340523	11.4724408 8	258.924171 4	0.801 06087 5	11.43 78167 8	263.648407	0.268 18010 4	0.731 81989 6	0.709 11788 8	0.853 66957 7	0.893 19469 7	5.384 55165 9	26.65 31543 5	11.7103637 7	0.823 69341 9	12.3960962 3	1.810 50474 9	22.1132165 8	12.1446917 9	0.824 95796 7	13.17 19649 6	1.407 67003 6	18.0334679 6	12.5699353 2	0.844 55975 9	15.21 69094 1	0.572 76445 7	0.401 27119 2
1985	Steelhead	0.760458095	0.609715022	0.463662724	0.475705187	119.09	121.88	128.5	132.13	18.5650701 3	29.1603431 3	11.5926941 5	189.385564	0.775 01928 2	11.4597083 2	9.380 31069 2	13.3448083 1	10.2956670 8	96.5743789 7	0.596 98435 7	9.495 69568 6	7.196 80953	24.7977446 7	11.9932316 1	240.628590 9	0.810 89092 3	10.91 97882 8	248.775512 7	0.358 11204 9	0.641 88795 1	0.688 94444 1	0.846 12321 6	0.886 43456	5.384 91535 2	26.17 27906 6	12.2120466 2	0.840 43979 6	11.9886514 7	1.848 95539 3	21.6652709 4	12.4469906 5	0.838 55116 4	12.98 93229 8	1.438 15299 9	17.6551253 3	12.6363835 3	0.851 45115 9	14.95 10335 9	0.561 31295 9	0.343 40352 9
1986	Steelhead	0.738598656	0.588952327	0.434999397	0.517602829	119.67	118.85	124.73	143.05	18.1664326	29.6295925 3	12.2797055 2	203.756717 1	0.761 05247 9	12.0619359	9.009 92669 9	13.9623192 6	10.6432237 6	105.428466 8	0.553 27482 8	9.575 29964 4	7.195 13811 2	24.9440409 2	12.6042628 3	252.193631 5	0.814 72698 8	11.73 71074 4	252.553726 2	0.306 90003 4	0.693 09996 6	0.670 53776 9	0.836 22619 7	0.877 88053 9	5.372 13231 6	26.37 01944 9	12.8195598 6	0.840 62629 9	12.8931282	1.836 61414 7	21.82 65217	13.2157446 5	0.839 08617 5	13.74 34984 8	1.429 56967 7	17.7599696 7	13.5995378 5	0.852 07822 9	15.75 49362 2	0.518 72657 2	0.341 61032 5

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas
1987	Steelhead	0.49597824	0.48909762	0.242581777	0.234920944	132.17	129.48	131.32	132.61	18.99056509	29.00487348	14.20251281	179.8676949	0.843053196	11.80374387
1988	Steelhead	0.682834008	0.534573638	0.36502506	0.443234908	130.32	135.56	141.39	141.61	19.79764487	28.138158	12.90937117	149.2174189	0.8121437	10.67773243
1989	Steelhead	0.785532555	0.638336749	0.501434297	0.335311017	113.56	119.31	125.88	131.14	18.26426032	29.9149034	11.19999327	220.8148629	0.766905446	12.35734054
1990	Steelhead	0.487560926	0.466906143	0.227645191	0.346826081	137.69	134.6	134.22	147.4	17.47989141	29.99981379	14.92759235	185.0332898	0.812585222	11.46987496
1991	Steelhead	0.670993203	0.548619763	0.368120132	0.288243086	118.86	125.36	131.64	146.7	21.5586425	28.34083918	13.01296609	188.7365804	0.835525611	12.08370835
1992	Steelhead	0.511743271	0.460109896	0.235458143	0.308989501	132.04	132.75	135.14	135.17	18.88749114	28.46761113	14.40885592	152.9345267	0.822594498	10.791387
1993	Steelhead	0.750315359	0.614633988	0.461169321	0.577562146	117.27	123.46	131.14	138.95	21.43313554	27.79212212	11.52258893	196.7057746	0.818147463	12.62114215
1994	Steelhead	0.573670144	0.489647215	0.280895989	0.339793654	127.31	128.73	133.44	137.31	21.29613537	28.05099006	13.67943798	160.1886106	0.813884492	10.87603756
1995	Steelhead	0.737235197	0.551589898	0.406651487	0.506915569	115.15	122.44	129.46	137.1	20.64075288	28.11111942	12.55571651	182.7348938	0.806015385	11.65913524
1996	Steelhead	0.732893276	0.63680444	0.466709692	0.475915943	121.75	118.64	123.22	144.27	17.24348206	31.87431431	12.18519599	264.5742983	0.787800093	14.38802733
1997	Steelhead	0.77167632	0.648622209	0.500526399	0.618951149	133.72	125.17	128.59	142.32	13.83785839	35.52747959	12.66918353	356.22052	0.820936822	20.3243678
1998	Steelhead	0.721289002	0.590539297	0.4259495	0.748371149	124.53	124.5	129.96	136.07	16.39571454	32.40688873	13.00146988	265.1371209	0.781701925	14.32818842
1999	Steelhead	0.720190162	0.588667673	0.423952667	0.594844198	131.66	126.14	131.2	145.79	16.85991472	31.25139122	12.86260264	234.7890385	0.797809209	13.27453763
2000	Steelhead	0.618746057	0.548745599	0.339534175	0.434876079	130.81	127.82	130.87	140.24	18.41629376	30.29715103	13.25086825	202.2546169	0.803718503	11.93484456
2001	Steelhead	0.647506694	0.47449855	0.307240987	0.404622925	129.7	133.48	139.62	140.62	19.98710737	27.66548388	13.67471484	130.3941386	0.828933388	10.64922915
2002	Steelhead	0.724895095	0.587683895	0.426009173	0.407106669	121.43	126.53	132.31	142.01	19.8518852	28.95806032	12.32162946	195.7878407	0.812962983	11.8461631
2003	Steelhead	0.712392933	0.551326778	0.392761301	0.44241919	124	127.24	133.61	140.89	18.59505382	29.27755601	12.88290725	193.383164	0.806250994	11.8150036
2004	Steelhead	0.680178386	0.523629996	0.356161805	0.589924329	129.44	131.96	138.09	142.29	18.36270544	29.56157835	13.43168981	181.462592	0.792804143	11.16609372

Year	Species	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1987	Steelhead	10.1550748	11.43740645	13.25742798	55.09633026	0.78494395	10.29015732	6.875255771	25.57243963	14.52246014	243.7948608	0.813004434	10.81623356	249.0643158
1988	Steelhead	10.59013665	11.09443279	11.48564091	62.52862778	0.736651337	9.293404579	7.258318968	23.6505029	13.50680399	195.0077413	0.781126231	9.727763732	200.9882202
1989	Steelhead	9.423254214	13.42864678	9.723135757	106.6475098	0.567067665	10.22073402	6.843755551	26.63750771	11.58246485	280.410258	0.816889544	11.75254122	286.0270081
1990	Steelhead	8.841698594	13.08450485	13.76578255	67.07363434	0.727703822	9.482338715	6.709303007	25.99329374	15.16071177	244.6555608	0.789612462	10.59641687	249.6903229
1991	Steelhead	12.61295586	9.568418888	11.28300495	60.57371979	0.757357097	10.0392374	6.998583913	25.36049363	13.64424038	250.1364466	0.818428924	11.18309482	244.5673828
1992	Steelhead	9.749119364	11.62387975	13.34912357	51.71162415	0.770194852	9.352728271	7.186505921	24.02336885	14.83235312	205.3304469	0.77755784	9.809432308	207.9067841
1993	Steelhead	11.74560683	10.78007141	10.28249359	86.1184845	0.690990067	10.49101734	7.714610018	23.49836548	11.80176926	238.0878805	0.833186001	11.758576	248.7206116
1994	Steelhead	12.15103758	10.28389941	12.06165829	60.21376038	0.730580688	9.242833138	7.193733327	24.15989737	14.292267	212.6018372	0.790246556	10.04506008	219.6065826
1995	Steelhead	11.13549982	11.25356284	10.6044281	80.22773132	0.673067248	9.730360031	7.544187412	23.6529851	13.2802852	224.9323247	0.819813371	10.9424355	235.7066193
1996	Steelhead	9.090586275	14.70044751	10.8623539	121.6220001	0.601552814	11.95264549	6.193055607	29.54131178	12.26277812	338.3696086	0.836906453	13.62201436	350.7251282
1997	Steelhead	6.712503873	19.06580193	11.09867668	167.3378174	0.658869022	17.42843704	5.174785189	34.27279803	13.03242922	451.0796458	0.866462022	20.49783134	451.7920837
1998	Steelhead	8.470819674	14.99812463	11.25509109	116.9353424	0.59756189	11.41329613	5.965772144	30.52360976	13.6893541	341.0352681	0.826003075	13.91886504	358.3944092
1999	Steelhead	8.500438705	14.53122055	11.32230244	104.351593	0.641153252	10.74890079	6.414768443	27.97530972	13.26381524	297.8392487	0.827260802	12.6957806	307.7036133
2000	Steelhead	9.888923541	13.2448647	11.8091217	90.25231323	0.667817044	9.992883682	6.574987061	26.95061845	13.55971018	265.222758	0.818829119	11.42375708	275.5880737
2001	Steelhead	10.46290282	11.39896291	11.95200253	57.93218307	0.765741539	9.594996452	7.582404852	22.16956286	14.50720882	165.3428396	0.796060214	9.606944323	172.6250305
2002	Steelhead	11.0009737	11.29202419	10.68558025	76.56694031	0.694562149	9.43501339	6.889297247	25.6062698	12.79515235	254.2724406	0.818112234	11.33916974	260.1223145
2003	Steelhead	9.720958844	12.37060178	11.21644821	77.39218597	0.692976141	9.50330658	6.919768766	25.33163316	13.54623779	246.1243464	0.803772132	11.06719923	262.0448608
2004	Steelhead	9.643621892	12.67296683	11.68985806	75.3704834	0.686196101	9.363776779	6.777122855	25.53463008	14.15652943	232.1304779	0.77804636	10.26846306	252.4963989

Year	Species	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1987	Steelhead	0.489697705	0.510302295	0.579318105	0.79646782	0.847215547	5.1742943	26.86865176	14.63289108	0.835783315	12.181703	1.795423813	22.29606889	14.76235549	0.839702229	13.06213729	1.395825662	18.18514887	14.89552212	0.862572223	15.06861973	0.319267887	0.16977185
1988	Steelhead	0.341010629	0.658989371	0.622140024	0.810663591	0.862300809	5.513068505	24.65922358	13.68098068	0.815263927	10.81752605	1.954877563	20.48397438	13.83439382	0.81690983	11.75507959	1.519403853	16.72408303	13.94044304	0.870904148	13.14144754	0.465283595	0.272799915
1989	Steelhead	0.520162249	0.479837751	0.71026391	0.855046234	0.893248573	5.101641245	28.23693011	11.79642982	0.832002676	12.96388378	1.71020887	23.40004232	12.11913872	0.837560276	13.6295379	1.329397626	19.08832513	12.38942003	0.851684093	15.88712263	0.590859227	0.380742012
1990	Steelhead	0.342229027	0.657770973	0.559573201	0.786167548	0.840713589	5.089245781	27.18299533	15.29478168	0.814843118	11.89059868	1.778807864	22.49759857	15.51283677	0.81911242	12.92474842	1.382566258	18.35818541	15.76115179	0.854751319	14.763762	0.302341476	0.155544859
1991	Steelhead	0.509517349	0.490482651	0.634477005	0.82120867	0.865871047	5.245488882	26.7278645	13.8268837	0.847458935	12.58136692	1.814026654	22.13455292	14.08155219	0.851029476	13.83672269	1.414223015	17.95071755	14.29916573	0.868782103	15.96468544	0.446386909	0.275404837
1992	Steelhead	0.391739287	0.608260713	0.554763479	0.778824637	0.836426263	5.450302728	25.08727079	14.93640633	0.807383668	11.04388809	1.926570214	20.80034077	15.05215899	0.810940325	11.8792003	1.498631544	16.95209093	15.14745474	0.866141111	13.31289244	0.325882558	0.165266426
1993	Steelhead	0.269963082	0.730036918	0.697619869	0.853532977	0.892183151	5.654498972	25.04542211	11.98740807	0.862614882	12.88391762	1.893464513	21.109431	12.24910037	0.861085157	14.41605663	1.469454534	17.28370664	12.4758687	0.873670965	16.62471485	0.547573754	0.351623934
1994	Steelhead	0.395917249	0.604082751	0.579772743	0.792131767	0.845727463	5.426272504	25.31726074	14.47113323	0.822200704	11.24038448	1.905155323	21.00673935	14.66624006	0.823485633	12.17844645	1.480274133	17.15915599	14.84448814	0.864181787	13.75371981	0.365794711	0.191989279
1995	Steelhead	0.301437914	0.698562086	0.639441499	0.822013074	0.86590361	5.604174003	25.03580114	13.50412006	0.853564644	11.99087143	1.905760005	20.95858082	13.82085546	0.84765329	13.35335128	1.477923468	17.18604964	14.06647587	0.857834727	15.48997021	0.495449234	0.310142792
1996	Steelhead	0.360414713	0.639585287	0.703238783	0.855040785	0.893453877	4.613496877	31.33783085	12.48906059	0.837282896	14.98363075	1.52469831	26.14269602	12.88820394	0.856757859	15.59913826	1.180389337	21.50480469	13.28095102	0.876872927	18.06907749	0.546932029	0.387772057
1997	Steelhead	0.249883061	0.750116939	0.708693297	0.859965412	0.895461343	3.890468173	36.07039746	13.23299599	0.860200262	22.37217369	1.273290478	31.36501008	13.57017454	0.889162322	22.42236265	0.985871695	25.83300039	13.8929615	0.903607339	23.50983143	0.587134849	0.393027364
1998	Steelhead	0.135566624	0.864433376	0.664777165	0.837158537	0.87912118	4.435313813	32.38467484	13.88475609	0.832557929	15.39220123	1.456705146	27.36023613	14.15203889	0.854133248	16.31211758	1.12731915	22.52879003	14.3489399	0.881061733	18.06676769	0.52623498	0.331571363
1999	Steelhead	0.241329169	0.758670831	0.666039023	0.837262772	0.878309854	4.815241918	29.5099576	13.44977131	0.843217039	14.04416389	1.622187436	24.63278873	13.77047284	0.851230542	14.95874341	1.259182423	20.1520321	14.06983089	0.863617659	17.19246054	0.520118592	0.312873002
2000	Steelhead	0.338258159	0.661741841	0.62893378	0.818916072	0.864274149	4.96499861	28.3067132	13.74632168	0.835371935	12.65728741	1.707452498	23.4288954	14.03980954	0.837299148	13.32888317	1.326776288	19.12592503	14.34241533	0.848653048	15.45357895	0.42790577	0.249444343
2001	Steelhead	0.342635542	0.657364458	0.563263975	0.778578707	0.83557394	5.79016304	22.97966755	14.66854267	0.825064135	10.57148952	2.084991634	19.20151245	14.7957023	0.824614485	11.38424047	1.619105518	15.71441353	14.87560701	0.882549524	12.63653374	0.402802087	0.20893648
2002	Steelhead	0.409808237	0.590191763	0.66705623	0.834972841	0.876820712	5.195831418	26.89234746	13.00719681	0.844145823	12.7253952	1.794020683	22.28903246	13.31725947	0.842965583	13.7474219	1.393279999	18.21809825	13.59707403	0.853991181	15.83271313	0.516993275	0.332798078
2003	Steelhead	0.356493935	0.643506065	0.637229701	0.821289207	0.867175887	5.22329326	26.5695874	13.72431545	0.835364246	12.33143482	1.798216507	22.16394756	13.95105139	0.834703783	13.47408104	1.392035767	18.23425435	14.13391018	0.856596917	15.44191551	0.483741536	0.291242541
2004	Steelhead	0.218354893	0.781645107	0.609833828	0.804919243	0.85623305	5.154494882	26.63895038	14.34016552	0.80608809	11.33305283	1.79154098	22.2121813	14.54454486	0.804365138	12.36922105	1.384736508	18.32962158	14.7015934	0.842997253	14.02274227	0.450575468	0.252841085

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
2005	Steelhead	0.620794024	0.503038364	0.31228321	0.559821432	126.11	127.59	133.92	141.58	18.39194626	29.06513795	13.97450631	171.1011489	0.796461271	11.20597509	9.355238803	12.59341655	12.55624523	71.73017731	0.68886174	9.633879662	7.097959511	24.38816164	14.42633708	216.8785706	0.784357945	10.208781	224.9502869	0.218180071	0.781819929	0.592653655	0.796658062	0.849832659	5.375145547	25.4959499	14.60105019	0.812781608	11.3113596	1.880154006	21.24217649	14.84213511	0.813467324	12.24818007	1.458083622	17.41674058	15.04670906	0.859900117	13.84901953	0.397360048	0.226000525
2006	Steelhead	0.780515883	0.662328474	0.516957894	0.496739286	114.26	114.83	121.05	135.93	17.71905693	30.81411733	11.0877176	250.8979432	0.757297233	13.60450026	9.008012503	14.98694894	9.826822472	127.0940872	0.520137399	11.17008686	6.718658261	27.35990439	11.25553306	310.7403412	0.833579193	13.0662113	315.6636353	0.361010468	0.638989532	0.726963034	0.864562497	0.900772854	4.967754178	29.12252159	11.49384403	0.839018798	14.26285191	1.651604943	24.17463623	11.83027331	0.849153042	14.78383128	1.281030081	19.80792406	12.15551233	0.863377124	17.06381607	0.596073956	0.426905594
2007	Steelhead	0.644104922	0.535177481	0.344710449	0.365803161	117.35	123.46	129.73	136.4	19.33758182	29.3780521	13.45223652	187.2842718	0.837065365	11.71112755	10.65026132	11.78789621	11.91595554	63.35505829	0.767777789	9.846943092	6.729387492	26.11192802	14.0499959	248.9310989	0.813338081	10.93863185	258.8134155	0.411124226	0.588875774	0.619980855	0.814218879	0.860864363	5.081214041	27.39374536	14.20516205	0.835769403	12.2301878	1.757610142	22.73608855	14.3890206	0.833425681	13.15212282	1.364258736	18.60285354	14.53776503	0.84757036	15.16537333	0.444537909	0.239307019
2008	Steelhead	0.717108404	0.579489793	0.415557001	0.561990346	123.66	126.74	133.98	143.53	19.80723871	28.63009344	12.64720903	213.8966708	0.823999886	13.78274144	10.56548286	11.91625164	11.07677803	96.06969604	0.69381187	11.36696568	7.294430621	24.08235599	13.06854534	255.5558599	0.84449026	13.0919265	263.3865356	0.265307717	0.734692283	0.661856312	0.834824163	0.875875394	5.438998707	25.39843467	13.2811264	0.873127079	14.27336597	1.86144767	21.43200672	13.60642338	0.87228022	15.73857657	1.44211302	17.60723698	13.89722586	0.882246047	17.9886179	0.515503988	0.319251066
1929	Steelhead	0.713935307	0.560586262	0.400222325	0.046930781	130.35	138.08	143.52	138.76	19.5011618	28.88540581	13.11269052	162.0356505	0.978938712	16.11667279	10.59958964	11.67474568	11.58248463	71.311409	0.974630153	14.17520733	6.957873039	24.81819775	13.7947189	208.5421778	0.971998801	16.49243402	218.7356262	0.901456243	0.098543757	0.628534719	0.81682792	0.856502358	5.27222877	25.9288654	13.95752125	0.96886363	18.64677143	1.848404281	21.64037019	14.09684722	0.966055473	19.69474475	1.435750388	17.68437094	14.17847395	0.969600409	20.95804691	0.503143213	0.282187805
1930	Steelhead	0.517218311	0.430858498	0.222847905	0.044629186	142.21	143.66	144.92	145.98	17.43369381	29.15560934	15.00364488	138.032017	0.977239426	14.96183085	8.41231899	13.42486476	13.5802002	63.36408615	0.976245916	13.91794338	7.092608631	23.73785611	15.67377361	177.4670537	0.966687342	14.87973873	182.7993774	0.853025672	0.146974328	0.506436057	0.753812517	0.80570643	5.439876139	24.55572906	15.82184696	0.963156927	16.9241188	1.965103835	20.4229859	15.88494174	0.958933075	17.83574327	1.530482471	16.60514088	15.94485569	0.963547438	19.25581837	0.325275027	0.147429982
1931	Steelhead	0.560615917	0.429678703	0.24088472	0.053968333	139.35	144.11	147.44	144.71	16.96886492	29.7520613	15.14278139	140.8752501	0.977199286	14.99851717	8.287923589	13.59221944	13.36479778	58.73664703	0.974701929	13.4031086	6.76501815	24.76745613	15.99521653	185.7251002	0.967880478	15.22458172	188.7052002	0.833732446	0.166267554	0.502847177	0.748702387	0.801090509	5.233147189	25.48120382	16.17217827	0.964028239	17.46345329	1.897725061	21.16643679	16.25471624	0.959941606	18.34476503	1.4795966	17.16693582	16.30020905	0.964196086	19.69054127	0.374588	0.147505462
1932	Steelhead	0.799441645	0.634371441	0.507142948	0.065683591	121.17	129.3	134.77	138.29	16.80210713	31.37522902	12.29008245	236.0285792	0.974717587	19.18272475	8.611361265	14.32307312	10.70632992	103.0095139	0.973722589	17.20484619	6.218332209	28.89814942	12.91893848	303.3031108	0.962905685	19.69557397	315.5992737	0.886912488	0.113087512	0.695383597	0.85071561	0.883970085	4.659811415	30.51053301	13.09982491	0.956699717	22.2772213	1.569032125	25.41721228	13.31026109	0.955440124	22.82827568	1.215481572	20.87948705	13.47408485	0.952472657	23.33359432	0.604193775	0.36808132
1933	Steelhead	0.728480519	0.574260827	0.418337825	0.063675647	128.2	134.98	140.83	146.8	18.08214819	30.32524074	13.3335792	206.8618006	0.973591008	17.3519438	9.727513336	12.56513353	11.5973175	75.41379242	0.969692016	14.33237972	6.409251548	27.46421217	14.07216279	271.6687826	0.963635961	18.24977056	285.9343872	0.872952211	0.127047789	0.642668227	0.826199148	0.864357299	4.828985788	28.84715097	14.23821774	0.958397293	20.82676773	1.652918153	24.14508642	14.42414347	0.956920445	21.72564697	1.281510465	19.80049504	14.55475235	0.95649147	22.56328297	0.51433199	0.31603212
1934	Steelhead	0.463372854	0.489216405	0.226689602	0.052114454	140.62	139.37	139.65	147.66	15.39156362	31.97355086	15.12541505	204.1973305	0.978664126	17.58937321	7.568260394	14.46898613	14.23307533	57.84837494	0.975125885	13.47845345	5.881685078	29.66216332	15.49101384	284.5768738	0.970944941	19.32219354	290.2307739	0.836287314	0.163712686	0.56585433	0.793215984	0.838154334	4.505684197	30.87458448	15.57489929	0.96601212	22.280439	1.570804268	25.47227863	15.6219492	0.963782509	22.65676689	1.220779687	20.78835567	15.69610023	0.96101588	23.10511971	0.307906007	0.154583772
1935	Steelhead	0.718460384	0.555539749	0.399133301	0.041607443	126.79	134.21	140.78	133.59	17.85705314	29.8720696	13.40337215	179.9035372	0.9809458	16.82652998	9.285110414	12.73642226	11.71880283	69.7640625	0.979275382	14.52424088	6.625273384	26.28573647	14.18585984	236.4421921	0.972810825	17.35520474	248.103363	0.911672165	0.088327835	0.625090316	0.817581183	0.857098668	5.022370256	27.49102318	14.34128437	0.968909442	19.89305916	1.74384702	22.9092178	14.47428004	0.966039479	20.87728691	1.353246249	18.75338644	14.56039381	0.966902524	21.9014864	0.509917479	0.276729044
1936	Steelhead	0.704858326	0.615558371	0.433881443	0.052832756	123.62	125.12	128.81	139.57	16.6900173	31.42929222	12.30726535	234.7057762	0.973356622	19.62806273	8.323297426	15.5748794	11.32149181	118.8863297	0.964290786	18.04461136	6.378346592	28.24185875	12.68506018	294.5987142	0.967590143	20.09826835	305.0700684	0.896984922	0.103015078	0.679223579	0.846137222	0.88070694	4.754997522	29.88940276	12.84258823	0.962306428	22.31460533	1.609649509	24.79699253	12.95318731	0.959975938	22.82665634	1.248075992	20.33183671	13.05267239	0.956198066	23.31248283	0.512598053	0.340584273
1937	Steelhead	0.738894775	0.578220107	0.427243816	0.035643643	121.01	131.39	137.44	130.8	21.7598521	28.08498416	12.65107788	162.3746294	0.978399605	15.78256982	12.65937825	10.1571633	10.90029907	58.8263092	0.972319043	12.79782238	7.137960404	24.52939904	13.40862195	215.7958399	0.97266677	16.65288734	226.9016571	0.928555048	0.071444952	0.644797086	0.823594544	0.861379385	5.351659507	25.79941883	13.59964905	0.969775212	19.08555107	1.853585541	21.55618431	13.79631615	0.967233121	20.14357313	1.438229591	17.65421713	13.9332509	0.970617384	21.3742342	0.533740961	0.304153614
1938	Steelhead	0.790376185	0.623779144	0.49302018	0.051853015	122.89	127.42	131.54	146.01	15.49087352	32.24351095	12.47368649	240.8648126	0.972693873	19.52411192	7.405490912	16.42792929	11.12325497	113.5918243	0.970744526	17.94477615	6.108443886	29.24472908	13.01489449	308.0708415	0.960665584	19.89893413	318.606781	0.907531423	0.092468577	0.685705176	0.84667809	0.880909163	4.600375682	30.78701292	13.17224598	0.954066825	22.34522858	1.558263704	25.61994909	13.34535599	0.953689575	22.70139949	1.208376989	21.00299735	13.48889732	0.950985104	23.25785637	0.5826672	0.371525655
1939	Steelhead	0.589077942	0.520473493	0.306599454	0.039795808	138.6	140.98	143.7	146.27	16.77369852	30.25586458	13.80696692	174.482442	0.982145905	17.08983118	8.201324135	14.03081855	12.69990978	75.41317902	0.980308783	15.35778713	6.626409687	26.09199347	14.26484013	227.7511622	0.974750012	17.41191395	233.411087	0.896826039	0.103173961	0.590430713	0.799818521	0.843042026	5.038944282	27.2191282	14.42118416	0.971159565	19.87256622	1.775460757	22.55146522	14.49578794	0.968815168	20.79096667	1.380640276	18.38359679	14.56326199	0.97148487	21.82513428	0.405986854	0.221171887
1940	Steelhead	0.64665872	0.530968177	0.343355202	0.026897382	130.16	131.36	135.3	140.09	17.22463575	29.94926799	13.60521855	180.4162609	0.983346181	17.51954784	8.474848278	13.89235657	12.09919052	82.78103027	0.983232987	16.15813923	6.789947413	25.72377471	14.26426474	231.8424505	0.97511366	17.61658581	239.2621765	0.934554577	0.065445423	0.602060998	0.805771132	0.847450524	5.127906106	26.96084097	14.42472229	0.971558309	20.0196228	1.787044875	22.37320119	14.5555652	0.969398419	20.99205462	1.387715958	18.29055947	14.66267347	0.971969694	22.00327587	0.439454297	0.245394507
1941	Steelhead	0.629485077	0.512595769	0.322671387	0.037095203	130.47	135.17	139.65	139.84	17.38390853	29.82245124	14.32012027	161.6444084	0.979141372	15.89451204	8.755116031	13.05691898	13.02106476	59.40743179	0.973877776	13.201964	6.692726292	25.72364238	14.8961703	215.9223557	0.973098636	16.66541529	222.7122345	0.90738851	0.09261149	0.586537251	0.796958094	0.840146034	5.101136483	26.78770889	15.02644901	0.96984539	19.16662102	1.798179723	22.26663959	15.14465586	0.967197398	20.17545128	1.398240276	18.15402645	15.22412252	0.9703269	21.33228493	0.425945835	0.21129024
1942	Steelhead	0.784173728	0.623025321	0.488560088	0.031277192	120.66	128.75	134.26	142.28	18.37403207	29.33288406	11.97852094	186.0037825	0.981898163	17.54052983	9.415811382	12.92325828	10.63942947	86.05147247	0.981838131	16.08948212	6.982418083	25.35497061	12.5278635	238.3290202	0.97289753	17.71528729	246.0165253	0.942982853	0.057017147	0.684658021	0.844513371	0.87868633	5.225097202	26.73014568	12.71155014	0.968904138	20.05298538	1.801457606	22.19776889	12.87021891	0.966353198	20.99715551	1.399076097	18.14324828	12.97949886	0.967388719	21.98291874	0.583573516	0.367898843

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1943	Steelhead	0.784065531	0.603530449	0.473207422	0.056102273	127.37	132.93	137.58	139.44	15.31497857	31.97125194	12.75285012	228.5142179	0.971546207	19.0544282	7.140326999	16.32526913	11.22059708	111.840036	0.964447379	17.72042236	6.209225364	28.50594636	13.38669109	288.8290507	0.96323507	19.2603991	300.8528442	0.896459144	0.103540856	0.666577216	0.837079745	0.872969455	4.697297879	29.91146666	13.56902294	0.957161188	21.65391273	1.601985686	24.92387903	13.7532781	0.95547688	22.13753637	1.242527746	20.42291601	13.89759588	0.953064919	22.83389759	0.579612492	0.350800567
1944	Steelhead	0.709634719	0.541690279	0.384402229	0.039168489	122.85	132.69	138.98	133.66	20.95689173	28.2430167	13.24136714	152.5212462	0.977215733	15.37221851	11.94739536	10.41180152	11.31884747	56.92349396	0.971736133	12.80831604	7.061100997	24.45081896	14.13949776	202.6391805	0.970390439	16.08456604	210.4670868	0.914588041	0.085411959	0.611217084	0.807848832	0.848960166	5.342804827	25.5612269	14.32156067	0.967627883	18.40869217	1.877707668	21.32066469	14.47519938	0.964519242	19.40364838	1.459542938	17.3995425	14.5744462	0.968224972	20.6631918	0.490408626	0.275394654
1945	Steelhead	0.741725874	0.563054826	0.417632333	0.037970398	131.28	136.51	141.23	139.15	17.08821917	30.85719393	13.42209475	194.0108577	0.981522096	17.98193124	8.672222532	14.50136002	11.70281906	91.3909668	0.97942338	16.21284332	6.475093812	27.01615143	14.17084058	246.4049276	0.974032621	18.33822878	258.1566772	0.920838617	0.079161383	0.631073489	0.818921491	0.857750784	4.900520891	28.29461879	14.34359608	0.970517337	20.55705757	1.693741843	23.57653922	14.52081045	0.968336682	21.53787168	1.313876763	19.31318861	14.64381266	0.96935454	22.43157291	0.527127018	0.302122863
1946	Steelhead	0.806474868	0.648119904	0.522692414	0.030636692	123.11	128.14	132.06	132.74	15.60760257	32.65361429	12.12887907	258.6338272	0.973403692	19.9854797	7.730968334	15.90907592	10.66221008	111.258725	0.979937005	18.20269279	5.893761568	30.72994577	12.70687755	336.0312093	0.954661369	20.5060757	347.855835	0.9465061	0.0534939	0.706883607	0.856825608	0.889438176	4.419451289	32.47066142	12.88522224	0.946661949	23.11430969	1.477694608	26.99829533	13.08163706	0.946512242	23.26158333	1.144815601	22.18012687	13.22894907	0.941301495	23.64058113	0.607617347	0.403084374
1947	Steelhead	0.627628134	0.536031304	0.336428327	0.102729741	136.45	137.03	137.93	131.94	14.91062327	32.93418119	14.22630739	242.8564459	0.971521101	19.54482552	7.072772011	16.9390525	12.8807478	113.3858536	0.966795158	17.93374748	5.88493792	30.0344518	14.8641715	309.9003092	0.961219986	19.92963338	316.4244385	0.772362446	0.227637554	0.607198632	0.812938309	0.854384187	4.453511156	31.50409291	15.00538197	0.954659259	22.44925575	1.5299839	26.11814123	15.08047803	0.953754584	22.81630007	1.187460445	21.37565724	15.13890266	0.949929625	23.31833458	0.430400534	0.243493962
1948	Steelhead	0.777639892	0.625463624	0.486385465	0.205962472	132.97	136.87	141.97	149.51	13.84422494	35.01402509	13.44840547	346.8086897	0.944734003	22.47040878	6.63251669	18.19326613	11.82439137	145.8340637	0.928271329	19.43375702	5.277433574	33.52645586	14.07588116	433.0882772	0.930820028	23.33564583	448.8515625	0.674093275	0.325906725	0.687541996	0.849684086	0.884184295	3.966280878	35.2782889	14.25693798	0.922225356	26.11963768	1.307341382	30.54412668	14.46680133	0.938989242	26.31357511	1.01250042	25.13571888	14.63438368	0.93779099	26.17141533	0.588627297	0.361297202
1949	Steelhead	0.80619503	0.625605098	0.504359721	0.113903629	120.59	124.85	130.47	138.45	15.49381411	32.63700808	12.50692116	265.030977	0.964084838	20.15329538	7.511850446	16.69003047	10.75887871	126.9873215	0.957649374	18.7202816	6.00782302	29.89809379	13.20803626	332.1781057	0.951490144	20.4198939	345.7086182	0.809511839	0.190488161	0.687157008	0.84705479	0.881333137	4.503151089	31.56132978	13.40637665	0.94408989	22.76642265	1.502738088	26.52870774	13.63547484	0.94323347	23.11710231	1.163474172	21.82047533	13.79906988	0.937368333	23.61547184	0.603240608	0.391734723
1950	Steelhead	0.777849409	0.622235716	0.484005684	0.038950729	125.17	133	138.41	138.24	17.44812895	30.35935113	12.24808911	211.9655549	0.979346952	18.42579402	8.888806313	13.74170293	10.91272469	93.89082184	0.981148648	16.84871292	6.587238468	27.00723034	12.79952081	271.26179	0.967519313	18.65006248	286.083374	0.928641616	0.071358384	0.685070191	0.846963793	0.881253032	4.936941542	28.47317856	12.96251621	0.962548912	21.12642288	1.67937877	23.75545616	13.10750612	0.959911108	21.88711675	1.301524006	19.49616396	13.20259476	0.958140701	22.65551472	0.576940259	0.372944019
1951	Steelhead	0.778820257	0.61558283	0.479428378	0.037595731	123.34	129.57	134.56	135.89	15.55702487	32.43575479	12.80899838	249.4486596	0.974713658	19.58573876	7.653290763	15.64328622	11.30745621	103.1178253	0.98167789	17.68133926	5.93057175	30.28514987	13.46201181	325.400472	0.956267128	20.07214999	338.9208984	0.930195096	0.069804904	0.67924776	0.845818358	0.880624127	4.462992027	31.91670305	13.62113113	0.948853707	22.79708138	1.497817561	26.63919081	13.77374554	0.94817698	23.09259987	1.160659507	21.87394463	13.88479233	0.943246007	23.51507378	0.58291211	0.361422448
1952	Steelhead	0.828141527	0.667941763	0.553150311	0.172553848	124.12	127.61	132.09	135.57	13.79134097	34.54098381	11.90254627	288.9533517	0.946656725	20.94565392	6.080307849	20.24190874	10.69156971	159.1961304	0.917695236	19.79884987	5.726250604	31.55414958	12.37256829	356.9617615	0.944120258	21.28865306	368.0228271	0.740335566	0.259664434	0.723720524	0.865090866	0.896591908	4.298272684	33.31677192	12.54895878	0.934931266	23.34730988	1.430505067	27.90830389	12.70345942	0.936546624	23.3864816	1.10875544	22.91154035	12.81544256	0.930343568	23.70989037	0.641878059	0.432630071
1953	Steelhead	0.779061627	0.597480229	0.46547392	0.054936882	127.12	132.44	140.29	158.5	16.59532707	31.48419907	12.96263892	222.8708725	0.97566442	18.57972472	8.437466741	14.53747346	11.18328819	95.13761902	0.975429595	16.4947731	6.216914229	28.44972987	13.75695276	285.1935374	0.963692745	19.02785714	299.0349426	0.89773966	0.10226034	0.662565774	0.835364787	0.871558215	4.686267309	29.89654183	13.93157368	0.958311355	21.49631767	1.591979466	25.06165634	14.1153628	0.957144956	22.30476634	1.23383569	20.56733874	14.24310732	0.956070244	23.02878284	0.569677977	0.330671012
1954	Steelhead	0.80100964	0.647003322	0.518255898	0.045313271	116.42	126.17	132.44	140.87	19.2625974	29.45600175	11.61119904	213.8913231	0.975962818	18.16826197	10.47044396	12.36105126	10.2192749	92.8664505	0.977365541	16.41032639	6.806506351	26.27050088	12.16003052	274.1253153	0.962775439	18.4979589	286.2509155	0.922037913	0.077962087	0.706262465	0.855385093	0.888036626	5.070374206	27.78367613	12.34722977	0.957107913	20.85012207	1.719340727	23.21315187	12.52298832	0.954928398	21.57397397	1.333008662	19.03680282	12.6393981	0.953404367	22.44852352	0.609468363	0.409419998
1955	Steelhead	0.770950769	0.595099527	0.458792438	0.035090394	125.26	132.64	138.79	140.52	17.96919201	29.96146374	12.72799233	191.1209706	0.980096481	17.47057431	9.310109079	13.15779243	11.11749039	81.01792908	0.979339278	15.46051598	6.705949888	26.25129579	13.40732543	245.5547536	0.97077624	17.8416702	259.2750854	0.932967642	0.067032358	0.660059101	0.832568592	0.868814699	5.041179404	27.60027242	13.59260292	0.966908526	20.23391342	1.728320792	23.08887436	13.78965028	0.964693487	21.24199486	1.339746848	18.94144623	13.93230581	0.965822995	22.24092579	0.565727186	0.335792718
1956	Steelhead	0.806442204	0.668534988	0.539134829	0.150564372	128.15	132.23	136.94	147.67	14.1503292	34.51030035	12.2594971	320.7999246	0.942298736	21.29339279	6.782795146	18.04051798	10.97191086	140.4077881	0.928773785	19.02763138	5.399875894	33.037711	12.69604476	409.2612	0.924719205	21.67435471	425.8200684	0.767736788	0.232263212	0.724401253	0.86571613	0.897718994	4.054040447	34.81944777	12.87584572	0.917097247	24.1437252	1.327799439	30.02899753	13.06291167	0.929965576	24.32078044	1.027007967	24.77214367	13.21608496	0.928682327	24.82870865	0.630910884	0.441034729
1957	Steelhead	0.805201967	0.658650867	0.530346974	0.176586553	120.63	126.21	131.45	144.72	16.32541562	31.78467222	11.9448467	283.2730282	0.950232872	20.0573428	8.141823843	15.33173598	10.61629333	127.2147293	0.938656771	18.25971603	6.210444383	29.02540679	12.41651297	354.096583	0.934996376	20.14325142	368.1734924	0.728179845	0.271820155	0.717489707	0.86148443	0.89378	4.589696221	30.82324005	12.59065113	0.927885699	22.35448303	1.511657082	26.35028266	12.78488255	0.934399148	23.00391388	1.169436656	21.70810643	12.94437504	0.932954699	23.74646854	0.617143719	0.443525494
1958	Steelhead	0.774838602	0.627693219	0.486360936	0.160495386	128.36	132.63	137.77	145.4	15.64193049	32.94618181	12.79886995	271.334641	0.958718743	20.01575749	7.840159267	16.17370813	11.42180061	124.7692459	0.94787972	18.14374084	5.847935379	30.71441362	13.34305032	341.0656281	0.947110703	20.41466411	354.7636719	0.735916431	0.264083569	0.689893079	0.850804412	0.885191706	4.376312196	32.44397908	13.50903339	0.939418137	22.72567177	1.459666356	27.33222618	13.66147836	0.94130518	23.24088987	1.130772993	22.45904759	13.76976252	0.937234998	23.7391901	0.578265704	0.373720219
1959	Steelhead	0.751902049	0.604238745	0.45432835	0.026752302	119.81	126.67	131.5	139.37	19.10342026	29.61556116	12.54301303	208.4007792	0.978994897	17.88022842	10.48377576	11.75612324	10.96509895	76.91465302	0.979932475	15.22744331	6.641824283	27.02026002	13.20904239	275.9836044	0.967711031	18.62957088	287.2496643	0.947972528	0.052027472	0.670098649	0.839828011	0.875125566	4.949060954	28.58754412	13.37247639	0.962759566	21.415308	1.675487109	23.81716776	13.54891936	0.96093301	22.18350283	1.298860945	19.53609041	13.67603159	0.959177285	22.86328697	0.546344238	0.352986673
1960	Steelhead	0.780268411	0.615745903	0.480447077	0.033814716	121	130.15	135.67	133.69	18.44563363	29.57825908	12.26899522	197.2839781	0.980083615	17.65376966	9.762058817	12.27513339	10.68476658	80.35516357	0.980808854	15.66036091	6.711786762	26.40154915	12.91296466	257.7793401	0.969521224	18.05861688	269.3298645	0.937649698	0.062350302	0.678008938	0.840925509	0.875704266	5.040280595	27.79629749	13.10725861	0.964806783	20.65949249	1.724152729	23.15057357	13.31348515	0.962554375	21.45777067	1.336856589	18.98222295	13.46173811	0.96233505	22.32384014	0.584184137	0.35731727

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas
1961	Steelhead	0.742033208	0.594640003	0.441242629	0.046043318	124.15	132.84	140.15	140.9	18.04605901	30.59335032	13.00465107	224.6426828	0.970678436	17.76762693
1962	Steelhead	0.753638726	0.569902567	0.429500644	0.033967557	130.48	136.91	142.7	136.39	15.83746234	31.62922605	13.47299433	204.9791113	0.981841215	18.2995347
1963	Steelhead	0.737276549	0.567540787	0.418434513	0.056073012	134.31	140.85	146.45	146.16	15.67369605	32.16458182	13.6712983	214.9932387	0.978679027	18.54879407
1964	Steelhead	0.764387827	0.579512829	0.442972552	0.083179626	132.08	138.67	143.92	145.19	16.29271767	31.38965719	13.36022942	222.4768911	0.971502249	18.39721741
1965	Steelhead	0.798210951	0.633241406	0.505460224	0.114145046	130.94	134.99	139.52	152.04	15.66004682	33.01760366	12.54722078	261.5801713	0.964315244	20.16177627
1966	Steelhead	0.676125177	0.538428221	0.364044876	0.046726444	131.15	137.06	142.31	138.23	16.98553368	30.30246476	13.75447375	176.2307183	0.98200824	16.88385047
1967	Steelhead	0.741145937	0.612583161	0.454013521	0.100304005	133.94	140.68	145.23	147.77	18.27405532	30.52003964	12.85862214	236.6676641	0.962890727	18.17791554
1968	Steelhead	0.667465779	0.538622647	0.359512185	0.022963916	120.76	126.52	132.32	141.62	22.30300793	26.96629297	13.24023615	156.5194095	0.972903584	15.45583776
1969	Steelhead	0.772323208	0.607542494	0.469219168	0.149397258	132.73	136.59	141.51	140.36	13.27059562	35.39191727	13.56157276	293.8931285	0.953143912	20.52650281
1970	Steelhead	0.769941779	0.618711763	0.476372036	0.102064304	124.14	133.02	139.85	150.03	18.99701134	29.97491745	12.4154924	212.2127331	0.968712956	17.84049504
1971	Steelhead	0.773536607	0.628915873	0.486489451	0.236501614	140.18	144.65	147.95	149.15	13.34946743	35.83899814	13.29924413	322.4809134	0.935772789	21.28386409
1972	Steelhead	0.793714101	0.63727296	0.505812534	0.113351161	127.78	131	135.94	148.47	14.85488509	33.59624281	12.71776036	299.6328392	0.954175391	20.84887484
1973	Steelhead	0.69163276	0.544780908	0.376788323	0.031579168	118.74	130.32	137.05	141.85	22.18239393	27.77774385	13.1436273	150.4222995	0.975415336	15.21675478
1974	Steelhead	0.775131282	0.625964475	0.485204646	0.116206777	134.73	139.67	143.51	137.12	14.01635045	34.85200255	13.18918187	302.9268079	0.950856728	20.82410247
1975	Steelhead	0.80066799	0.627601243	0.502500226	0.048459132	115.7	125.33	132.21	143.13	19.2803041	29.20764603	11.92628316	201.0195977	0.976303071	17.62154048
1976	Steelhead	0.825776291	0.668814136	0.552290856	0.118091008	122.53	127.49	132.56	138.86	15.6498766	32.45395707	11.69672394	263.8564933	0.963104129	20.22533812
1977	Steelhead	0.624902333	0.514047302	0.321229358	0.057121496	122.92	130.4	136.47	135.18	21.50357617	27.20301519	13.63599723	126.691776	0.970898624	13.63432011
1978	Steelhead	0.744475922	0.580772392	0.432371062	0.037167348	136.26	141.49	145.79	144.2	15.5245185	31.88474668	13.32703836	209.7030531	0.982061497	18.70191465

Year	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1961	9.898335129	12.10714633	11.27799301	73.88793335	0.974589968	14.67274704	6.197009116	28.5610653	13.80514256	301.5140483	0.952758511	18.69500963	312.2522278
1962	7.662555814	15.21083733	11.74697418	89.02812653	0.984902513	16.68743553	6.233822256	28.22942721	14.2287968	266.1032562	0.970210969	18.58745646	272.9195557
1963	7.66027014	15.74415222	12.0686718	97.02918549	0.978801322	16.72814484	6.080235861	28.89995273	14.40859826	276.4297155	0.967916816	18.98443858	284.8128967
1964	8.029481143	14.98976317	11.60313053	100.4326126	0.969696963	16.78874321	6.325049527	27.80569771	14.11520354	281.4987106	0.958758265	18.62328291	294.0235901
1965	7.816901051	16.68538807	11.04880238	130.0321518	0.955181777	18.6990921	5.885106303	30.5245547	13.13661098	330.1996409	0.954084188	20.54170863	337.8169556
1966	8.558658063	13.40310566	12.24948273	69.30612183	0.979247999	14.53819389	6.485508941	26.64480539	14.41534917	233.8540115	0.975312769	17.50510748	239.2645569
1967	10.08711334	12.15812118	11.43385239	94.5437088	0.959573019	15.62713623	6.243593089	28.22389374	13.45185264	308.3923442	0.947100878	18.89292741	316.7858582
1968	12.61632817	9.62183804	11.78109531	62.05497818	0.971321082	13.52468662	7.722336449	22.39645623	13.87422355	203.6764832	0.960674365	15.84111253	213.6751099
1969	6.063869685	19.35261687	12.00777702	131.3948578	0.952301455	18.86039467	5.26326523	33.59781975	14.29050477	379.6414642	0.930418015	20.9587121	385.7804565
1970	10.45365781	12.40070713	10.93540668	95.13202057	0.959254336	15.6112606	6.593116254	26.86539229	13.03401788	269.2847875	0.960951606	18.4577829	276.6607971
1971	6.310333997	19.38730663	11.88768616	147.6029236	0.92059716	19.33307762	5.099071927	34.55502981	13.89489762	415.0561371	0.916305572	21.74399551	420.3525696
1972	7.335438758	16.62328386	11.15898437	125.2051163	0.955209804	18.66348495	5.554667011	32.03897559	13.3514336	389.4624888	0.930401256	21.36216942	389.4176331
1973	13.03435823	9.598386929	11.23832531	54.04240265	0.968935299	12.55642319	7.202422492	23.99661219	14.01661873	199.9495316	0.968523592	15.98592154	207.8065796
1974	6.844068438	17.70320016	11.61931534	127.721228	0.950558746	18.57928314	5.221395284	33.83775372	13.84808652	396.2433421	0.92653357	21.56484652	401.6264954
1975	10.34185083	12.26554902	10.27268867	87.81808167	0.975468802	15.95916595	6.962337859	25.61541186	12.55672725	256.8431193	0.965149999	17.82053693	266.1262817
1976	7.596193396	16.659364	10.45650597	131.569165	0.954018033	18.83123436	6.068123385	29.68258793	12.1585741	332.1865641	0.952228189	20.57853349	334.975708
1977	12.02154575	9.787913964	12.14210091	38.61992569	0.96144948	10.82733974	7.529902846	22.60644636	14.29724296	173.4745814	0.964222233	14.44458449	179.8299255
1978	7.454509676	15.77152366	11.88002453	96.39107666	0.983864641	17.23191757	6.129638143	28.34671449	13.97635746	268.8924357	0.971589704	18.92738024	278.0987244

Year	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate
1961	0.910463314	0.089536686	0.660809164	0.836039456	0.872654589	4.662367016	30.04119063	13.96542473	0.946409047	21.42736931	1.578778684	25.30874548
1962	0.930694495	0.069305505	0.636169904	0.822013648	0.860248384	4.729774505	29.55713858	14.42009296	0.965410352	21.17816505	1.629209846	24.56141468
1963	0.886381233	0.113618767	0.63623181	0.824390235	0.862842388	4.616823457	30.24186418	14.54944592	0.962754166	21.41228561	1.591799863	25.12509471
1964	0.843004236	0.156995764	0.646475104	0.828182485	0.866071131	4.765853889	29.2013946	14.29592991	0.952979696	20.9142437	1.630556412	24.48041426
1965	0.809737212	0.190262788	0.694216305	0.851374958	0.885016255	4.41485808	32.21202109	13.3024004	0.946702635	22.83440742	1.485354371	26.90167089
1966	0.894113982	0.105886018	0.60617367	0.805692164	0.847384792	4.952657722	27.73673426	14.6004076	0.971737313	20.16025963	1.740511559	23.00157001
1967	0.818517107	0.181482893	0.676543035	0.843775371	0.87957249	4.687062852	29.69609694	13.60499306	0.940547967	21.34341888	1.598434083	24.99760576
1968	0.945544014	0.054455986	0.612970067	0.810128763	0.851863546	5.771862067	23.54592163	14.00534573	0.957982934	18.09890671	2.028216995	19.72040663
1969	0.744154254	0.255845746	0.671066684	0.842448184	0.878623634	3.991239168	35.21156064	14.44848404	0.920614707	23.46908684	1.336365961	29.94472953
1970	0.822046722	0.177953278	0.681970828	0.844034812	0.878833954	4.933214873	28.32574432	13.20429916	0.956065094	20.68000183	1.686301515	23.70489394
1971	0.631231357	0.368768643	0.690337619	0.851069673	0.886283089	3.857873268	36.23340041	14.03138504	0.90791924	24.06906662	1.282436348	31.19590624
1972	0.811279931	0.188720069	0.698318466	0.853883241	0.887724371	4.177117482	33.73206545	13.50323505	0.92325412	23.93781853	1.391018748	28.75564572
1973	0.930068114	0.069931886	0.614221946	0.808249582	0.849173467	5.427329652	25.13711755	14.19948292	0.966233301	18.33156128	1.905202441	21.00781451
1974	0.80115491	0.19884509	0.687594733	0.849393694	0.884500985	3.957943588	35.46483093	13.99174366	0.91787194	23.95246391	1.322737604	30.23105566
1975	0.914868736	0.085131264	0.689331573	0.845580583	0.879536143	5.185367234	27.08354355	12.76266727	0.960237491	20.16119576	1.763983048	22.64642018
1976	0.815874462	0.184125538	0.724771511	0.864290867	0.895325262	4.534153268	31.38516385	12.33644924	0.945358992	22.89421654	1.522468507	26.25560455
1977	0.861329139	0.138670861	0.587774663	0.794502885	0.838410614	5.71451357	23.5501338	14.44554882	0.96165328	16.68204041	2.040489167	19.65752822
1978	0.924860761	0.075139239	0.646494567	0.827881571	0.86573275	4.682583399	29.52780978	14.11798782	0.967019832	21.50665817	1.630685203	24.49066673

Year	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1961	14.10725848	0.94820859	22.16437976	1.225362986	20.71020603	14.20480108	0.947612494	22.81708717	0.534579186	0.329141799
1962	14.60044003	0.96386385	21.96752993	1.266366035	20.03750855	14.72618818	0.963709801	22.6497879	0.555625804	0.283973014
1963	14.67408593	0.961015681	22.14207395	1.236606933	20.52105599	14.75727177	0.95965609	22.79277992	0.541190973	0.303194503
1964	14.48289553	0.952024857	21.67990494	1.264377125	20.0690788	14.61565781	0.950598598	22.42483997	0.561995685	0.317175237
1965	13.48690637	0.947659473	23.13662593	1.152593501	22.02868722	13.63009214	0.943699837	23.53152752	0.588746144	0.404730142
1966	14.72325548	0.969673991	21.0852286	1.353397839	18.75129871	14.78195906	0.972195059	22.050704	0.491166131	0.233912671
1967	13.74168746	0.943536739	21.8839035	1.240656964	20.45381513	13.83770227	0.943066597	22.5503149	0.533072661	0.361174391
1968	14.15034803	0.954556664	18.69175084	1.574095048	16.15370989	14.24939013	0.959115028	19.77821064	0.444407565	0.26055558
1969	14.5679636	0.925327937	23.55085627	1.0374844	24.51620377	14.64705372	0.919283986	23.71663094	0.589030203	0.3272659
1970	13.37613519	0.955067217	21.43866094	1.309415117	19.37885838	13.49623442	0.955096871	22.22792721	0.570283396	0.350809391
1971	14.16327286	0.921345472	24.12178103	0.99481345	25.59439985	14.25817442	0.919011027	24.34958267	0.590488314	0.375338506
1972	13.6764005	0.93611596	24.0648791	1.079921335	23.53365919	13.82078123	0.936053932	24.34260082	0.590594864	0.403935414
1973	14.36935139	0.962991238	19.21874237	1.480417155	17.15752872	14.48456526	0.966980428	20.41676617	0.47452499	0.272837073
1974	14.14936988	0.926336726	23.92955208	1.026028723	24.79630552	14.2694397	0.922111243	24.1663599	0.592097146	0.371930961
1975	13.00742022	0.95848008	21.07640012	1.368748732	18.54219965	13.18382883	0.958738238	22.08823109	0.598154596	0.381165089
1976	12.50682863	0.946698109	23.16247559	1.181975007	21.47572285	12.63499594	0.942777961	23.51855755	0.628989599	0.453200384
1977	14.58886528	0.95737795	17.52144623	1.587783992	16.01737185	14.68313217	0.962601066	18.92149067	0.416790503	0.228142473
1978	14.236667	0.96495378	22.12174352	1.265093468	20.05769634	14.3124299	0.964529932	22.8291111	0.530973205	0.315841872

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas
1979	Steelhead	0.778527583	0.620256325	0.482886657	0.035108822	122.86	130.46	136.54	140.09	18.69729701	29.70660135	12.20040062	196.840798	0.980192993	17.82790082
1980	Steelhead	0.79194571	0.634059873	0.502140996	0.030528025	116.91	125.53	129.96	146.06	18.12147598	31.71036987	12.37610926	247.1260937	0.973760745	19.18938409
1981	Steelhead	0.638859387	0.53092634	0.339187276	0.054149765	139.56	143.39	147.82	152.38	15.25639565	32.48531977	14.6603008	218.7267402	0.975925842	18.47853109
1982	Steelhead	0.776619711	0.613651991	0.476574232	0.066140221	128.16	132.3	137.67	147.46	16.28073734	32.05507643	12.75811386	251.6741371	0.970121822	19.71467682
1983	Steelhead	0.785010201	0.609095816	0.478146429	0.099613225	127.41	130.2	136.02	152.7	16.89379216	31.37489099	12.72347212	236.1546702	0.969620049	19.05001538
1984	Steelhead	0.807853755	0.620388733	0.501183368	0.108960489	125.4	130.79	135.94	144.91	16.33184494	31.29500436	12.25756087	223.1663208	0.97250382	19.43166699
1985	Steelhead	0.788624505	0.617727879	0.487155342	0.025344631	123.75	130.5	136.53	135.83	17.19127736	29.92471463	12.13679266	193.215732	0.98072591	17.9377313
1986	Steelhead	0.77582288	0.592915758	0.45999761	0.071845482	127.61	130.61	135.67	153.13	16.25512802	31.1139432	12.8119077	217.7646326	0.974947321	18.81971206
1987	Steelhead	0.52461044	0.516434694	0.270927032	0.043786532	131.57	131.09	134.09	145.1	18.37833513	29.61871138	14.30113704	181.8175092	0.978101688	16.55196307
1988	Steelhead	0.713286669	0.563974289	0.402275342	0.046486464	132.65	139.73	145.1	136.54	18.276612	29.46424223	13.21234499	164.1358128	0.980914018	16.23175137
1989	Steelhead	0.810808627	0.639870182	0.518812263	0.023474949	115.84	124.26	129.9	133.14	17.47283923	30.28531407	11.74611037	213.3369304	0.980534494	18.73807297
1990	Steelhead	0.511792289	0.477710255	0.244488425	0.040079333	138.89	138.89	139.94	142.89	16.15818315	31.02142158	15.08812073	190.6870183	0.979931235	17.14350476
1991	Steelhead	0.704415791	0.571348359	0.402466806	0.031283004	124.51	131.57	137.16	141.64	19.82523508	29.44372453	13.17746483	194.0708716	0.976373749	16.96076662
1992	Steelhead	0.54065041	0.4909329	0.265423074	0.051310774	132.03	134.63	138.6	140.67	18.09553391	29.29627925	14.59117351	159.9859298	0.978078617	15.6286982
1993	Steelhead	0.788552256	0.635276876	0.500949014	0.109142707	124.7	131.51	137.06	141.16	17.84278496	30.62953008	12.063497	229.9273376	0.967064879	18.56719272
1994	Steelhead	0.606963645	0.514008452	0.311984444	0.041662026	129.92	133.04	137.58	141.36	19.7469165	28.89939162	13.84384802	164.3867217	0.979982836	16.11062486
1995	Steelhead	0.774080462	0.583843244	0.451941648	0.037157129	121.99	129.62	136.12	141.13	17.86576127	30.21735269	12.87014389	200.1347945	0.980346854	18.08537929
1996	Steelhead	0.755072432	0.628624897	0.47465733	0.119583233	128.18	129.8	132.69	145.1	15.54467705	32.70084911	12.70417118	262.1011581	0.963790728	19.96164724

Year	Species	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime
1979	Steelhead	9.950377569	12.76404753	10.80759926	85.86602631	0.978849006	15.77277031	6.776893303	26.26478761	12.78556077	253.332962	0.971409897	18.31493266	264.5161438	0.935601213	0.064398787	0.683276744	0.844819702	0.879090803	5.060559556
1980	Steelhead	10.16913799	13.53260846	10.51163177	97.12567596	0.97979666	16.57596054	5.986470528	30.23086569	13.13068183	323.751002	0.955611666	20.07713739	337.9854431	0.94508704	0.05491296	0.694723555	0.849948234	0.883600759	4.457152434
1981	Steelhead	7.368038237	16.01870649	13.36587887	94.8865387	0.976197338	16.46253624	5.96838142	29.19326519	15.25066042	284.4865468	0.963662773	19.01788855	290.6830139	0.870092555	0.129907445	0.604450551	0.810283374	0.851953408	4.545203701
1982	Steelhead	8.245922469	15.31967413	11.2107172	112.0903793	0.973450232	18.08857956	6.071100391	29.51131354	13.40855662	323.9661407	0.952409188	20.05496176	329.9237671	0.879627423	0.120372577	0.677910943	0.844232172	0.879265045	4.539805092
1983	Steelhead	8.673623063	14.49864095	11.04649315	106.8268082	0.963513052	17.16971359	6.266306072	28.44443008	13.44162909	299.7299093	0.959519347	19.4301095	306.6013794	0.825492123	0.174507877	0.67345988	0.840709355	0.875903037	4.692613989
1984	Steelhead	7.725674018	16.1991482	10.74897346	125.2277191	0.958685064	18.58280602	6.635680467	27.11656067	12.79232248	272.2793147	0.970271379	19.46272993	279.8034058	0.816263262	0.183736738	0.68346502	0.844715742	0.878705675	4.942690045
1985	Steelhead	8.330809861	14.18444265	10.7947897	94.58073425	0.980473018	16.948703	6.882891543	25.71361718	12.67622423	244.1692581	0.971299708	17.88949958	253.2319489	0.953388163	0.046611837	0.679945156	0.842624042	0.87728659	5.167502888
1986	Steelhead	7.755775191	15.52917023	11.17622032	107.8517624	0.971512794	17.79072838	6.536109403	27.13329865	13.47398885	272.9738668	0.965283146	18.84364184	276.2826538	0.866997872	0.133002128	0.658546498	0.832913636	0.869361854	4.910796598
1987	Steelhead	9.82877814	11.75775627	13.25353909	54.71821289	0.972733319	13.04232559	6.593726777	26.66454937	14.69435581	250.5988642	0.97162653	17.81447335	256.0716248	0.87777464	0.12222536	0.591728922	0.803302505	0.845761563	4.964762829
1988	Steelhead	9.65312165	12.03404903	11.70560665	64.33492661	0.97787143	14.08029881	6.683618024	25.80474893	13.89276743	217.9588598	0.973906944	16.72735373	223.3024292	0.902770228	0.097229772	0.630120146	0.817142188	0.856416447	5.092949942
1989	Steelhead	8.859496906	13.64458358	10.22291679	97.03410339	0.98174125	17.21551666	6.62147335	27.23581535	12.31821203	276.1764832	0.969796787	19.02924291	281.4852295	0.959002898	0.040997102	0.699727294	0.850675689	0.883312428	4.944364466
1990	Steelhead	7.901301883	14.30804921	14.04731331	70.06410217	0.979176319	14.46077652	6.315726608	27.56654212	15.55714289	256.2602615	0.97052596	17.95873308	260.8067017	0.875791897	0.124208103	0.555757698	0.787075209	0.833043792	4.802046508
1991	Steelhead	11.34571815	10.72087091	11.40414486	67.35961609	0.97658726	14.10813122	6.526704021	27.06935766	13.97645124	263.9131877	0.964383056	17.97569283	262.3751831	0.933390374	0.066609626	0.639730492	0.824105884	0.862352163	4.911271401
1992	Steelhead	9.344688065	12.04930458	13.41215706	50.7405777	0.970766211	12.3877697	6.806431532	25.47745129	15.07301426	219.2028503	0.973212043	16.73795696	222.0729828	0.855328336	0.144671664	0.567537065	0.788297672	0.833208602	5.161010146
1993	Steelhead	9.399577051	13.58304559	10.75777321	103.8527161	0.959256327	16.60527115	6.475548081	27.69683759	12.60154565	290.3964742	0.957104574	18.99652823	299.4246216	0.816943079	0.183056921	0.696808452	0.852009229	0.885509958	4.816470794
1994	Steelhead	10.9646515	11.17957105	12.2607563	61.24996262	0.975585294	13.53166656	6.831085198	25.39000708	14.54522292	219.994868	0.973638574	16.84816615	225.1981964	0.894389441	0.105610559	0.585901311	0.797044371	0.84040533	5.172583692
1995	Steelhead	9.258448318	13.49620011	11.06904144	91.8108902	0.979297948	16.4068779	6.649581589	26.64325109	13.68854872	254.5380096	0.971394618	18.36332313	265.7830505	0.927031796	0.072968204	0.651048869	0.830078625	0.867043363	4.989786305
1996	Steelhead	7.665261276	16.20302925	11.54687443	122.4427521	0.954600072	18.17663727	5.913366877	30.32055138	13.07567851	333.8313599	0.953345329	20.43348583	344.4588318	0.793584679	0.206415321	0.691499424	0.851071881	0.885132872	4.443019591

Year	Species	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1979	Steelhead	27.73366758	12.95655746	0.967485702	20.72821388	1.726565257	23.1300019	13.11090851	0.965144575	21.58242607	1.339389399	18.94647444	13.21340752	0.965504348	22.38325787	0.577147107	0.36882846
1980	Steelhead	32.03021796	13.3336298	0.948363054	22.67024765	1.48571647	26.83797806	13.57576879	0.947260062	23.12325859	1.150446661	22.07027136	13.74124956	0.942411393	23.5203619	0.595386994	0.394464124
1981	Steelhead	30.46837011	15.36015739	0.958064318	21.49759636	1.579413056	25.31056081	15.45685482	0.957921545	22.04306984	1.226420462	20.69224937	15.52373028	0.957470298	22.70696068	0.431676909	0.234021831
1982	Steelhead	31.17223886	13.56419964	0.945882082	22.49355354	1.527745076	26.15998934	13.72578494	0.948358774	22.96192296	1.18587286	21.4045188	13.84842682	0.94630751	23.3945179	0.564756035	0.37277257
1983	Steelhead	30.00624443	13.6105257	0.953790283	21.86929779	1.588420823	25.15665164	13.79084365	0.954211473	22.54400317	1.232938275	20.58237736	13.92669058	0.952843994	23.15298367	0.563060104	0.369544922
1984	Steelhead	28.70361955	12.97609596	0.965596962	21.39628754	1.672776505	23.89838378	13.20427863	0.963896116	22.20083555	1.299016878	19.5337484	13.39457273	0.962904751	22.90332317	0.587360485	0.39310963
1985	Steelhead	27.07017823	12.86478348	0.966958344	20.16878815	1.776418544	22.50919869	13.03006554	0.964259704	21.04382133	1.379624225	18.39702058	13.13799238	0.964621156	22.0197525	0.58690005	0.360279465
1986	Steelhead	28.56396451	13.64759102	0.960106039	21.12466164	1.682672948	23.78322078	13.8389883	0.959281007	21.88738187	1.30803448	19.39927347	13.99473476	0.959358513	22.63794327	0.53988116	0.35735074
1987	Steelhead	28.01042195	14.82076397	0.967669022	20.67028008	1.722939514	23.23293515	14.93344275	0.965240737	21.39261754	1.339591049	18.94363928	15.03991747	0.965088457	22.15831375	0.352865682	0.193184947
1988	Steelhead	26.88267218	14.06172009	0.97039187	19.24021492	1.794259086	22.3285998	14.19228204	0.967676719	20.25729497	1.395989463	18.18304518	14.27134609	0.970415384	21.39223862	0.50153336	0.288374747
1989	Steelhead	28.81039742	12.514814	0.964804113	21.64220963	1.672499307	23.91856294	12.74421819	0.96352909	22.27744166	1.299648114	19.52426927	12.91010094	0.962512285	22.87586308	0.615601741	0.382233711
1990	Steelhead	28.7891553	15.66102619	0.965914559	20.71530647	1.680792496	23.81970501	15.71432145	0.964789887	21.53200976	1.307088837	19.41328696	15.76813078	0.965814739	22.33987713	0.33582381	0.159876712
1991	Steelhead	28.46279534	14.13491402	0.958753502	20.67021027	1.700663216	23.59484942	14.29315662	0.958313624	21.29112498	1.325333901	19.14667394	14.40526772	0.958659232	21.9804821	0.480229131	0.307230459
1992	Steelhead	26.62578244	15.20028439	0.97010541	19.41478882	1.815335095	22.08931517	15.31643963	0.967455745	20.36645699	1.413505942	17.95973777	15.40498543	0.97012952	21.35628033	0.355760474	0.181813899
1993	Steelhead	29.32153515	12.76387272	0.951577616	21.31221008	1.620538913	24.65225238	12.90255102	0.951124946	22.02825419	1.257623814	20.17706602	12.99718428	0.949636638	22.73172665	0.590693271	0.380971586
1994	Steelhead	26.55197949	14.71135883	0.97017113	19.40337257	1.818289809	22.02481377	14.83441289	0.967606882	20.39470927	1.414073698	17.95259182	14.93120432	0.970573545	21.48426533	0.413691414	0.212349556
1995	Steelhead	28.05892478	13.86339302	0.967304921	20.71447639	1.706633247	23.39572913	14.02965132	0.964987218	21.62111028	1.323712863	19.17004862	14.14353323	0.965048552	22.42577267	0.550399565	0.339775158
1996	Steelhead	31.96751472	13.22069817	0.946278632	22.95212288	1.496584974	26.66058832	13.39596081	0.946481645	23.18697357	1.159675531	21.89269578	13.54716587	0.941749066	23.63734245	0.557633435	0.376247855

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	ProportionTransported	MedDayLGR	MedDayConfl	MedDayBONinriv	MedDayBONtrans	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	propBONinriv	propBONtrans	JDAInRivSurv	DeschInRivSurv	BONInRivSurv	JDATTime	JDAMigRate	JDATemp	JDAFSpill	JDAGas	DESTTime	DESMigRate	DESTemp	DESFSpill	DESGas	BONTTime	BONMigRate	BONTemp	BONFSpill	BONGas	monte_q975	monte_q025
1997	Steelhead	0.7939 3359	0.6476 15514	0.5141 63709	0.2666 67673	134.5 2	135.2 2	138.7 1	143.4 2	12.65 385982	36.97 187373	13.12 709325	366.6 269041	0.918 992566	22.55 512292	5.874 498226	20.78 384606	11.61 037751	166.0 417511	0.893 975806	20.05 732422	4.829 385027	36.20 165171	13.73 180151	471.9 149781	0.899 336537	23.20 701408	476.6 847839	0.605 015251	0.394 984749	0.705 508151	0.857 428788	0.891 763352	3.654 675111	37.91 317888	13.89 338455	0.890 791192	25.48 850517	1.198 090374	33.37 332746	14.06 387838	0.916 714271	25.27 16465	0.927 775651	27.50 313626	14.20 609283	0.919 031918	25.41 215706	0.605 885694	0.406 643979
1998	Steelhead	0.7805 05285	0.6058 35434	0.4728 57758	0.1468 30473	129.8 8	133.7 8	138.7 3	136.6 1	14.18 223472	34.48 350126	13.40 525334	275.1 11733	0.960 292863	20.20 967865	6.721 901432	18.47 979249	11.74 365044	130.2 778122	0.954 642916	18.51 234322	5.510 329425	32.31 547186	14.16 345342	351.5 113118	0.945 147932	20.69 627539	360.3 44574	0.749 924978	0.250 075022	0.670 38297	0.841 901763	0.877 914693	4.167 94163	33.94 03667	14.31 894166	0.936 193752	23.09 957008	1.402 460396	28.50 64938	14.46 483835	0.938 012362	23.30 220159	1.088 344574	23.34 827025	14.56 243372	0.933 031768	23.60 799503	0.595 496246	0.343 198373
1999	Steelhead	0.7553 83416	0.5916 07129	0.4468 90213	0.1103 84	134.4 2	140.2 6	145.8 2	150.5 2	15.12 965158	32.86 281609	13.39 8361	247.7 322535	0.966 263353	19.27 479066	7.296 2211	16.55 295789	11.78 990879	111.9 387924	0.961 651337	17.45 822334	5.893 584803	29.96 84761	14.07 107623	316.1 639404	0.953 236381	19.68 697397	326.7 410889	0.799 77551	0.200 22449	0.657 911196	0.834 952075	0.871 888797	4.458 969191	31.43 500743	14.21 838436	0.946 127141	22.10 430107	1.514 796287	26.37 304938	14.38 301531	0.946 131945	22.62 982178	1.175 315619	21.59 846297	14.50 988913	0.942 757457	23.19 9646	0.545 561113	0.334 081626
2000	Steelhead	0.6448 05252	0.5396 48884	0.3479 68435	0.0278 27265	132.1 3	134.0 8	137.8 4	140.0 5	16.93 532622	30.70 241901	13.56 895079	195.3 637788	0.982 922729	18.05 642976	8.514 458795	14.41 436545	12.24 505386	87.82 248077	0.983 941042	16.41 046219	6.460 961185	27.04 724287	14.14 888668	252.5 815074	0.973 535736	18.36 325145	261.4 147644	0.933 396424	0.066 603576	0.609 436461	0.810 749752	0.851 815223	4.899 679147	28.29 681524	14.29 470901	0.969 400585	20.85 422821	1.702 369325	23.48 109836	14.39 203358	0.966 963629	21.58 530299	1.321 873181	19.19 664941	14.47 486591	0.967 2243	22.46 934128	0.437 298112	0.261 809827
2001	Steelhead	0.6820 3293	0.5153 27132	0.3514 70074	0.0468 69272	132.3 3	138.0 8	143.2 2	143.5 9	18.73 417831	28.90 464687	13.77 923427	146.4 035437	0.976 679683	15.23 178639	9.844 962962	12.01 499247	12.01 282749	59.82 145386	0.973 541641	13.38 955402	6.956 762552	24.38 896964	14.61 394662	192.3 728841	0.967 634807	15.57 482274	199.1 487427	0.890 801226	0.109 198774	0.585 747721	0.794 238631	0.838 170556	5.325 891495	25.28 438864	14.77 740993	0.964 387131	17.78 305454	1.902 123839	21.07 561412	14.90 074507	0.960 717678	18.71 588707	1.480 281323	17.15 909338	14.98 404646	0.965 275943	19.98 252296	0.461 376374	0.243 698126
2002	Steelhead	0.7506 37282	0.5895 30862	0.4425 23844	0.0385 25794	125.2 1	132.9 8	138.5 4	137.4 4	18.26 853951	29.76 370881	12.81 149544	197.3 468361	0.977 291886	17.34 157283	9.711 361423	12.42 711752	11.14 096241	78.51 215363	0.978 241289	15.23 534908	6.598 838441	26.48 601476	13.51 117627	258.9 229914	0.965 14684	17.83 180873	269.0 195618	0.924 318957	0.075 681043	0.653 879195	0.829 461547	0.866 668802	4.987 980835	27.75 136537	13.69 991779	0.960 102534	20.35 223083	1.726 196669	23.13 164927	13.89 356391	0.958 049059	21.09 184901	1.338 918202	18.95 311807	14.03 736687	0.957 84387	22.02 959633	0.538 733909	0.327 040159
2003	Steelhead	0.7504 83912	0.5854 52694	0.4393 72828	0.0653 2111	126.9 7	133.7 3	140.4 4	149.0 6	17.15 621537	30.60 532511	13.04 122898	210.2 401079	0.975 441446	17.83 105499	8.805 342138	13.52 470122	11.39 965153	83.10 513611	0.973 819757	15.50 328979	6.400 391579	27.40 379185	13.79 2202	271.0 10348	0.964 513997	18.28 368704	289.8 631287	0.875 046014	0.124 953956	0.651 931145	0.831 043724	0.868 422324	4.836 073399	28.73 27478	13.95 053616	0.959 245658	20.83 419762	1.654 786393	24.06 049905	14.09 402339	0.957 053363	21.74 353155	1.279 919192	19.82 512175	14.19 606781	0.956 401378	22.69 683838	0.542 168865	0.327 118488
2004	Steelhead	0.7246 14176	0.5441 4291	0.3942 93666	0.0369 84625	131.9 8	138.5 2	144.1 5	140.0 6	16.68 199499	30.79 994657	13.72 598437	185.8 379833	0.982 956618	17.50 798764	8.340 166107	14.36 162221	11.99 655895	80.90 696106	0.981 920934	15.51 871204	6.409 057379	26.86 115938	14.54 619312	237.6 275075	0.975 298305	17.75 890923	257.2 844849	0.919 7267	0.080 2733	0.612 709575	0.811 154347	0.852 106337	4.898 269057	27.93 448326	14.70 885888	0.971 678472	20.16 565361	1.707 560569	23.31 918403	14.83 019574	0.969 486137	21.22 179031	1.320 842952	19.21 158644	14.90 844107	0.972 061962	22.42 420101	0.500 715816	0.273 693783
2005	Steelhead	0.6606 57111	0.5226 0951	0.3452 65689	0.0415 0243	131.9 7	136.2 6	140.6 1	142.4 9	16.14 863661	31.13 40728	14.37 626845	185.7 461134	0.980 906363	17.37 955924	7.833 708928	15.11 402651	13.01 112442	84.02 145386	0.978 331161	15.44 582596	6.381 118171	27.03 130383	14.98 241949	239.4 404856	0.973 505755	17.85 173734	245.6 020966	0.900 54247	0.099 45753	0.595 181641	0.802 038148	0.844 308556	4.877 70962	28.11 755458	15.11 482239	0.969 624007	20.23 218002	1.713 998281	23.34 079072	15.23 769124	0.966 973543	21.05 18411	1.331 928156	19.05 220469	15.32 058144	0.967 939764	22.02 10638	0.453 962634	0.229 452917
2006	Steelhead	0.8165 63543	0.6638 75474	0.5420 96509	0.1095 63114	122.2 3	125.1 3	129.8 5	142.1	15.50 951718	32.40 443138	11.69 239603	265.1 429029	0.964 550934	20.39 636632	7.314 890601	17.27 407768	10.49 837608	132.9 519409	0.955 839431	19.02 487679	6.201 270826	29.18 047354	12.11 645635	329.9 758809	0.954 086224	20.67 410103	339.5 34668	0.827 259303	0.172 740697	0.721 191326	0.863 504127	0.894 782756	4.614 574678	30.92 332078	12.29 569035	0.947 699571	22.86 807404	1.540 416487	25.90 103298	12.46 658262	0.948 334674	23.26 117706	1.193 767346	21.26 18621	12.60 117149	0.944 40493	23.70 859241	0.629 991832	0.430 157749
2007	Steelhead	0.6742 45785	0.5490 18895	0.3701 73676	0.0264 21712	120.4 6	126.6 8	132.7 1	147.1 6	18.16 213478	29.95 632295	13.64 820262	183.2 608419	0.980 713619	16.87 515082	9.627 3681	12.93 964508	12.12 797947	68.40 067596	0.977 361941	13.97 747669	6.580 881424	26.43 404142	14.32 049068	242.5 782674	0.973 863999	17.77 550427	251.2 594604	0.939 854023	0.060 145977	0.619 612662	0.814 698733	0.854 771221	4.994 898625	27.62 576116	14.46 425724	0.969 920671	20.36 19442	1.740 441807	22.94 919833	14.59 515826	0.967 309376	21.19 902992	1.350 334384	18.79 361555	14.68 685818	0.968 364418	22.16 052914	0.464 603434	0.250 930069
2008	Steelhead	0.7537 27217	0.5866 10556	0.4421 44342	0.1230 34442	130.0 7	134.4 4	140.2 2	145.8 6	17.03 933626	30.97 403927	13.25 819445	239.3 464753	0.959 418689	18.40 018238	8.677 764133	14.49 165081	11.54 168377	108.3 036758	0.952 656198	16.63 945923	6.421 756782	27.27 872995	13.95 22508	297.4 585317	0.944 76371	18.59 601514	312.0 987244	0.777 563511	0.222 436489	0.653 135583	0.831 07097	0.868 946318	4.818 473496	28.68 357611	14.13 482723	0.938 54109	20.56 200409	1.637 478031	24.32 604799	14.34 257507	0.938 649754	21.27 002017	1.267 114438	20.02 565573	14.50 003767	0.936 701328	22.26 277447	0.538 671666	0.322 68661

5517 **Table 4-6. Snake River MO3 Steelhead Raw Data**

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
SCN MO3-RESSIM-GRNIMN																									
1929	Steelhead	0.909564749	0.542766236	0.493681035	132.73	136.93	143.31	0.01855251	9150.437077	10.22482531	9.137801051	10.4682683	11.67113132	69.35019684	0.98776015	0.861444092	7.507311143	22.76190546	13.75526714	180.2208761	0.948329101	15.11096573	191.8394775	0.62420504	0.360657245
1930	Steelhead	0.926676095	0.369231732	0.342158219	144.19	147.75	148.99	0.016167148	5526.983348	10.07119199	7.281026013	12.38910056	14.40856266	62.97882919	0.990560615	0.970558167	6.977151908	23.71119485	16.70770009	162.7431056	0.955918968	14.83666197	167.3792725	0.582626394	0.199376832
1931	Steelhead	0.934027342	0.403512819	0.376892006	140.21	143.72	147.18	0.017240195	6491.69309	10.09913608	6.3390949	13.86728934	13.30142288	58.34773483	0.991528475	0.990086746	7.087652311	23.404866	16.11866395	160.1384786	0.958140651	14.9367458	164.866394	0.603851964	0.226105864
1932	Steelhead	0.907325014	0.62050481	0.562999536	127.15	131.5	136.56	0.020881222	11746.6019	12.21347083	9.308955155	10.65597423	11.10763969	103.9789078	0.987256587	1.159049511	6.020127103	29.86121749	13.27374919	312.2877045	0.8980124	17.93769423	325.9284668	0.689461951	0.431677076
1933	Steelhead	0.905172103	0.563129923	0.509729497	131.87	136.55	143.17	0.018662695	9503.381236	11.87865141	9.616449326	10.02617395	11.85776367	74.49445496	0.992156088	1.116535759	6.391892962	27.43120428	14.26893934	266.3291245	0.926443358	17.56554635	280.4266357	0.632306122	0.366821075
1934	Steelhead	0.925517113	0.403561165	0.373502765	142.72	146.23	146.51	0.017155703	6401.425912	11.79347556	7.369450241	12.14710745	15.385602	54.3878891	0.990684056	1.243886185	5.715486638	29.94229174	17.07281367	269.2361857	0.918352534	17.60106182	274.084198	0.62340569	0.221065867

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1935	Steelhead	0.917671655	0.548197375	0.503065193	129.7	133.76	140.56	0.019518732	9809.848575	11.32932983	8.116183974	11.48267223	11.92925167	68.32539825	0.994471729	1.078274727	6.624377757	26.25661041	14.28988934	234.8296916	0.939024707	16.8893067	246.7285767	0.642577978	0.355267715
1936	Steelhead	0.901571739	0.535652089	0.482928785	130.27	134.84	135.41	0.02006703	9681.298907	11.9545908	10.21486856	9.685783702	12.39217873	113.0710236	0.985799038	1.194895935	6.068328641	29.14099994	14.09718895	291.7525126	0.904025167	17.68399779	303.2958984	0.614777393	0.368422778
1937	Steelhead	0.889539613	0.563624014	0.501365888	125.46	130.4	137.35	0.020823101	10430.31412	10.44886596	11.44434023	8.519565841	10.9604845	57.98252029	0.987440443	0.867823219	7.681829527	22.62700797	13.36412843	183.8172709	0.953231235	15.48380136	196.7193604	0.637522003	0.352415475
1938	Steelhead	0.909194076	0.597049777	0.542834121	127.9	132.46	137.28	0.020125539	10914.39707	12.02330674	9.136208996	10.61466108	11.34512253	110.6820206	0.985078371	1.154846096	6.073015779	29.09505825	13.66076581	295.1972453	0.906953752	17.74946451	303.9030762	0.663582276	0.405069363
1939	Steelhead	0.928260073	0.450334851	0.418027861	140.54	143.97	144.67	0.01788771	7470.793131	11.07573601	7.096021861	12.66786773	13.36241493	73.80453644	0.993551672	1.142361355	6.607821934	25.6511904	15.11769994	206.3823217	0.947502464	16.56767114	212.351532	0.584634991	0.291686601
1940	Steelhead	0.912230139	0.459409573	0.419087259	134.51	138.45	139.69	0.019045426	7972.590089	11.38372547	8.890903927	10.68177518	13.23808231	79.98398132	0.994157362	1.162361431	6.45670259	26.56537414	15.5065678	227.5396779	0.941748679	17.05405315	234.8130646	0.589450759	0.292327886
1941	Steelhead	0.918779706	0.485349001	0.445928812	133.45	137.14	142.05	0.018224632	8120.005961	10.71765014	7.900640331	11.72467994	13.44554119	59.88870697	0.993696249	0.943393707	6.919246592	24.59416539	15.23832782	192.953949	0.955375801	16.00019725	199.8234558	0.610707347	0.294407937
1942	Steelhead	0.890360111	0.598059933	0.532488709	128.14	133.39	140.01	0.01923253	10231.37495	10.97140912	11.36375075	8.878060812	10.95773525	84.05287323	0.992204976	0.988109207	7.067908011	24.67632579	13.01371876	221.7825216	0.93910561	16.26482773	231.3687744	0.654078924	0.409443564
1943	Steelhead	0.921696955	0.587172841	0.541195419	129.71	133.32	138.87	0.020196901	10920.5354	11.77734453	7.764792755	11.98501629	11.25463886	107.7869141	0.989335716	1.143270588	6.297411367	27.8459172	13.7430253	272.4194336	0.918300201	17.45914793	282.0322571	0.675610924	0.380454257
1944	Steelhead	0.897414665	0.50971598	0.457426595	127.82	132.61	139.87	0.019718874	9012.051896	9.952669655	10.42211574	9.454885397	11.42744942	56.55797882	0.986839271	0.864962769	7.745246753	21.89262635	14.19998503	158.9702861	0.955857317	14.6916705	167.1107635	0.597693788	0.323081923
1945	Steelhead	0.920434965	0.560816802	0.516195394	132.95	136.43	141.14	0.019132029	9865.864112	11.34450272	7.854712427	12.07933657	11.82983036	89.82672729	0.993010008	1.039020729	6.565493338	26.66914563	14.11833302	243.3911387	0.933451374	16.88381879	256.2494202	0.646875384	0.377524257
1946	Steelhead	0.906391875	0.620943033	0.56281772	127.8	131.66	136.11	0.021139708	11887.42706	12.49517352	9.511859827	10.39788838	11.06581211	109.8943268	0.97717663	1.153513145	5.685735427	31.71038577	13.41253519	342.9023081	0.87824587	18.18872833	354.7502747	0.691400827	0.437147292
1947	Steelhead	0.927936674	0.48108188	0.44641352	137.93	141.34	142.04	0.018427712	8217.798375	12.06330603	7.283183686	12.67068549	13.64562244	115.3757095	0.979874718	1.203177547	5.603525288	31.22844397	15.81276989	310.6450958	0.889811993	17.78660695	317.7140198	0.630534175	0.300097125
1948	Steelhead	0.940150798	0.620736771	0.583586171	136.04	139.16	143.96	0.018065131	10533.29782	15.85914353	5.832487233	15.46851019	12.07530155	152.4988129	0.981677401	1.452693558	5.004723579	36.48440233	14.33501911	459.9104716	0.862883012	23.60676384	481.7173157	0.712099936	0.444880636
1949	Steelhead	0.908730179	0.592151898	0.5381063	126.88	131.14	136.27	0.020860653	11213.67762	12.82011584	9.242641166	10.80269242	11.41090069	130.9932587	0.980542314	1.188987923	5.679472022	31.72942436	14.03853814	347.9525299	0.881387949	18.48584811	366.4682922	0.66199674	0.40354398
1950	Steelhead	0.907047571	0.604985922	0.548751011	129.48	133.77	139.48	0.019795396	10850.88224	11.75214314	9.528647177	10.09230541	11.36313629	91.95399628	0.990817404	1.084252644	6.464893386	27.45144895	13.30808846	274.5722427	0.917227934	17.33497985	292.0809021	0.679523519	0.417665131
1951	Steelhead	0.909803746	0.587610205	0.534609966	127.76	131.55	136.96	0.020680349	11044.0101	12.44457023	9.11501196	10.59220732	11.56968536	102.1277481	0.984214318	1.192652225	5.776962183	31.09899868	14.09695625	328.9064433	0.888326536	18.12170998	344.8418274	0.662110146	0.390356321
1952	Steelhead	0.925172405	0.642459101	0.594385431	128.64	131.93	136.51	0.020791977	12345.53421	12.65889798	7.436487384	12.79171634	11.08562412	158.3066315	0.971980381	1.107407856	5.579759479	32.44952333	12.94071563	358.4302928	0.868903389	18.28395335	369.9718628	0.697857916	0.464629256
1953	Steelhead	0.918768576	0.591443761	0.543399942	132.17	136.57	143.8	0.018031213	9789.802732	11.93057735	7.987603411	11.92864483	11.48774452	94.86805573	0.99095943	1.09791851	6.149263494	28.7975048	13.85478465	285.9973246	0.91432934	17.53193188	300.5162354	0.679871267	0.421508509
1954	Steelhead	0.880378181	0.629004993	0.553762271	126.3	131.73	137.34	0.01996615	11046.39209	11.90219	12.69331469	8.103576326	10.79465351	94.54316254	0.986383641	1.073181725	6.416526198	27.9009632	12.82372395	291.3820496	0.90657109	17.41735427	307.3956909	0.657552956	0.431030416
1955	Steelhead	0.9127521	0.589288506	0.537874321	128.61	132.6	139.21	0.019751672	10615.27206	11.28663138	8.653966658	11.12947399	11.0517458	81.17820892	0.993672144	1.005566788	6.876228049	25.51349171	13.42983278	233.7086258	0.939941516	16.74063857	248.094696	0.658111514	0.388321069
1956	Steelhead	0.922771981	0.643611762	0.593906901	132.71	136.21	141.06	0.019292907	11447.43232	14.12822396	7.767821379	12.19402662	11.28767624	141.734967	0.978933573	1.31863842	5.258324586	34.59121006	13.34108988	408.3592682	0.86525628	20.45940129	426.9901428	0.703703561	0.472130233
1957	Steelhead	0.901575991	0.637239752	0.574520061	130.4	134.94	137.97	0.018786796	10784.3399	13.74947415	10.23492891	9.872158817	11.38114834	136.4914032	0.977861249	1.199919987	5.412052155	33.8038193	13.19495217	397.4228668	0.864144911	19.68926938	415.3557739	0.678721816	0.456148518
1958	Steelhead	0.926251822	0.611752677	0.566637032	132.09	135.35	139.85	0.019029622	10772.53603	12.894007	7.367227897	12.69417062	11.64530163	127.6874191	0.981419861	1.178004074	5.629998669	32.22129125	13.70618296	355.6419169	0.87670509	18.64684995	372.5683899	0.686162752	0.434291714
1959	Steelhead	0.880755175	0.578445761	0.509469098	127.1	132.54	138.06	0.019466051	9907.026111	11.96837412	12.7262331	7.822013813	11.6015028	78.98971405	0.988623285	1.168867874	6.199783549	28.67592838	14.03494851	289.0211945	0.909507513	17.72262224	299.4566956	0.618596915	0.388662735
1960	Steelhead	0.898656712	0.605890001	0.544487116	126.52	131.26	136.85	0.020714639	11268.44663	11.65533372	10.26003181	9.65014023	10.90004253	78.57050171	0.992915821	1.10636673	6.567001767	27.03232724	13.24464099	263.2879206	0.92404906	17.27898614	277.8250427	0.671548311	0.391728618
1961	Steelhead	0.904263435	0.582660266	0.526878373	129.28	134.34	141.57	0.019216429	10115.2822	12.31022702	9.675436512	10.01386192	11.56381054	72.4572998	0.988783157	1.134455585	6.120086849	29.18747646	13.96619908	302.8013407	0.907509824	18.01183097	314.9577026	0.645598986	0.391194878
1962	Steelhead	0.932130121	0.574304312	0.535326348	131.5	134.75	140.67	0.019657926	10513.94126	11.69269535	6.54360719	13.75461315	11.48308735	88.26972198	0.994952333	1.176874924	6.346613623	27.71815196	14.07480494	260.0873871	0.926965793	17.45015367	265.8014526	0.696613673	0.375942668
1963	Steelhead	0.931590915	0.557095463	0.518985072	135.51	138.9	145.14	0.018250867	9461.858462	11.40242406	6.679887362	13.64576556	12.07456779	93.83895874	0.990484047	1.01924324	6.341201194	27.6719407	14.32001368	260.0899455	0.92065087	16.85448027	271.5150146	0.680833184	0.368770204
1964	Steelhead	0.927445598	0.576357427	0.534540159	134.81	138.22	143.57	0.018490918	9874.882474	11.84383968	7.138092063	12.92101967	11.68520718	99.52077789	0.988610947	1.06229353	6.302202985	28.05573996	14.16505003	283.6048228	0.91143625	17.34620269	298.5183105	0.679760061	0.397650974
1965	Steelhead	0.9131358	0.604098809	0.551624249	135.43	138.99	144.69	0.017633401	9717.695436	12.34980444	9.024948016	10.72518078	11.54698887	131.7182327	0.981067681	1.14915781	5.694014601	31.34509682	13.82818826	329.9228923	0.884787808	18.05310901	336.6486816	0.661681497	0.413070407
1966	Steelhead	0.930952496	0.537037319	0.499956232	132.1	135.47	140.77	0.019871125	9924.038768	11.27326042	6.617931575	13.50669155	12.07499752	69.59375458	0.995726776	1.117983341	6.678673737	25.77984732	14.2903018	222.554245	0.946751386	16.91088947	227.2043457	0.66682882	0.335844217
1967	Steelhead	0.909321857	0.602674131	0.548024761	137.88	141.71	145.81	0.017322138	9483.659097	12.47011226	9.317650825	10.30597708	11.84300957	95.66698303	0.981084824	1.115602684	6.04207246	29.4611658	13.68485753	320.5768687	0.89375939	18.20783758	330.281189	0.673105448	0.439912101
1968	Steelhead	0.871189543	0.505430768	0.440326	129.71	136.19	141.57	0.018007028	7920.196585	10.39839598	13.85457425	7.073554364	12.89947948	65.25844727	0.976982963	0.873376179	7.282833278	23.4725594	14.71765868	210.8840663	0.925603181	15.28580077	221.3681641	0.55874226	0.319689657
1969	Steelhead	0.943213059	0.599184094	0.565158262	134.91	137.53	142.52	0.019149395	10812.95752	13.28892367	5.392560631	16.49439456	11.87931957	132.2134827	0.974225521	1.228898048	5.200910002	34.82333841	14.34571139	385.9727275	0.85852322	19.0854551	393.5870667	0.689006669	0.398152182
1970	Steelhead	0.905280131	0.605718316	0.548344757	130.88	135.75	142.42	0.018497785	10134.23969	11.3289219	9.587484166	10.34687055	11.10630627	96.89950562	0.984046042	0.93798914	6.70399005	26.36588468	13.09351858	261.1885554	0.915444841	16.60910257	270.5882874	0.669471934	0.417103422
1971	Steelhead	0.937883796	0.612646559	0.574591281	141.84	144.96	148.65	0.01686249	9680.233158	13.94046235	6.19247926	14.66976545	12.38963394	150.3049561	0.971393442	1.265035534	4.914009281	36.85282197	14.27292109	421.5839132	0.846448898	19.9772377	427.2285767	0.722159078	0.430104551
1972	Steelhead	0.90878962	0.611580339	0.555797864	132.8	136.66	141.44	0.018762828	10417.9466	14.2762288	9.507763393	10.26148482	11.83739548	130.325174	0.980248344	1.327824306	5.177183263	35.12035584	14.16968711	413.2886759	0.863509377	20.87230666	416.5545349	0.662233882	0.421986349
1973	Steelhead	0.881066996	0.510685652	0.449948274	125.68	132.47	139.63	0.017971	8078.681209	10.21743965	12.49724953	8.009870689	11.74178448	54.33480377	0.983804858	0.91040535	7.489356898	22.7506052	14.25766357	177.234375	0.944931865	15.12173414	186.0165558	0.571131649	0.311730806
1974	Steelhead	0.926626001	0.604296856	0.559957179	136.53	139.92	144.92	0.018189604	10175.70198	13.55237981	7.417159654	12.54608408	12.05620613	128.5455734	0.973461711	1.255072021	5.129993282	34.9741039	14.33009656	392.744161	0.860433469	19.68873008	397.7309265	0.690162161	0.428897524
1975	Steelhead	0.889471383	0.61462471	0.546691091	124.26	129.86	136.14	0.020542571	11220.87259	11.7522066	11.37417798	8.980382163	10.79571152	90.9950882	0.991677737	1.06117115	6.593648911	27.05916054	13.08997901	273.2013143	0.919395208	17.3078289	285.8279114	0.665846721	0.415675889
1976	Steelhead	0.903765857	0.648537395	0.586125955	129.78	133.58	137.8	0.019752844	11565.14926	12.6791062	9.975753106	10.04443377	10.94559307	133.8158661	0.978173816	1.180313969	5.683006637	31.82768177	12.84753672	350.0135447	0.875651757	18.43249798	355.0894165	0.69478524	0.4549177
1977	Steelhead	0.89097557	0.476531332	0.424577775	127.39	132.58	139.27	0.019758141	8381.223006	9.443733181	11.16173524	8.648894787	12.61714611	38.2109169	0.985274088	0.831840134	7.928907514	21.0704393	14.64550559	141.9376577	0.953691314	13.89202062	147.5838623	0.583141652	0.29430403
1978	Steelhead	0.931335378	0.579563529	0.539768018	138.14	141.31	145.84	0.017652509	9519.773951	11.80684825	6.735465042	13.51835248	12.07408333	96.38840485	0.992229116	1.173317909	6.067861855	28.58586103	14.04621633	270.384023	0.922708561	17.59965086	278.7295532	0.683242628	0.404704301
1979	Steelhead	0.89812514	0.613613263	0.551101497	127.18	131.56	137.43	0.020526315	11301.29175	11.45280429	10.54181162	9.361446084	11.07487011	86.51013031	0.992375612	1.049907112	6.661470465	26.62299067	12.92699798	255.2938436	0.927438766	17.01793559	265.9825134	0.67279472	0.428280397
1980	Steelhead	0.887204185	0.609465312	0.540720175	126.73	132.8	136.7	0.019092335	10314.51817	12.29553403	11.85238449	8.806936593	11.13522339	99.43604584	0.980768859	1.122780895	5.770475291	31.11132123	13.66830826	328.5845388	0.884886603	17.96583668	338.7140503	0.658682535	0.412815305
1981	Steelhead	0.929088083	0.508916154	0.472827934	142.05	145.23	149.76	0.015508583	7326.375955	11.61122571	7.049047187	13.06307717	14.10737076	95.27616882	0.981692278	1.05086832	5.874397665	29.51895922	15.66071908	283.8055827	0.904081553	17.08435154	290.0054321	0.648788589	0.319465344
1982	Steelhead	0.907953446	0.588631634	0.534450121	132.38	136.35	141.79	0.018800175	10037.01726	12.66017982	9.64948836	10.01817506	11.81349812	114.1905121	0.982602131	1.197982788	5.733217627	31.34568634	14.13271109	336.8872528	0.885832379	18.47540506	344.0282593	0.654841876	0.398472143
1983	Steelhead	0.903546655	0.59491641	0.537534732	133.81	138.36	144.94	0.017785476	9551.69358	12.20584045	10.01635277	9.910422394	11.55235996	111.9743027	0.986831677	1.146789169	5.94923687	29.91642133	13.89800596	308.3604279	0.900073111	17.8581055	317.0205994	0.645775089	0.421848807
1984	Steelhead	0.910406903	0.59443584	0.541178492	130.17	134.12	139.44	0.019723274	10662.28889	11.74619613	9.276265629	10.42328092	11.31083908	126.4463181	0.990579176	1.112491035	6.352896884	28.0179283	13.60567109	275.816747	0.916138142	17.43282477	284.1950378	0.66453201	0.413239382
1985	Steelhead	0.905770835	0.600841747	0.544224931	128.09	132.12	138.49	0.020777927	11296.95052	11.40578488	9.502558902	10.30842723	11.06982136	90.77202148	0.994858515	1.057550812	6.814943865	25.84106863	13.10861874	239.8265737	0.937192559	17.03514099	250.7898865	0.677275301	0.409865621

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1986	Steelhead	0.904048104	0.559345052	0.505674834	132.56	136.85	142.97	0.018456246	9322.652388	11.82232577	9.987126932	9.744572859	11.69566956	108.5246719	0.989734924	1.111314201	6.283696316	27.96229923	14.30096245	272.3168411	0.918467611	17.46716468	277.5614624	0.619127012	0.376890179
1987	Steelhead	0.905665684	0.42323813	0.383312251	134.63	138.82	138.48	0.019227819	7362.299962	11.21562995	9.731433555	9.603790884	14.43050327	52.35490494	0.989934695	1.114935207	6.396369249	26.78175613	16.11029132	230.9827652	0.933398892	16.70613988	235.5072174	0.576453786	0.240237558
1988	Steelhead	0.92122308	0.55656433	0.512719906	134.09	137.75	143.44	0.018414763	9431.133945	10.76107294	7.715888873	11.8111583	11.57831993	62.73820343	0.994098532	0.98125124	7.102435336	24.1400813	13.75205437	192.7078985	0.956274807	16.06876516	198.7187805	0.650759849	0.370433209
1989	Steelhead	0.896064445	0.613016781	0.549302542	123.3	128.46	133.59	0.022009491	12078.66196	11.8602531	10.47670518	9.560909763	10.86094227	93.96195068	0.993406832	1.158818531	6.364226773	28.19843768	13.12369394	282.5874074	0.913659285	17.62292353	289.0899353	0.683585792	0.405460239
1990	Steelhead	0.922560821	0.416372413	0.384128875	141.15	144.89	147.14	0.017223228	6610.41062	11.50735893	7.774322502	11.78817988	14.94555817	70.34169464	0.986305881	1.127603626	6.044709906	28.38622095	16.87754345	259.2722321	0.918871224	17.08730523	262.5505981	0.639432225	0.228128483
1991	Steelhead	0.886147128	0.551216991	0.488459354	132.39	138.44	142.81	0.017537789	8557.147549	11.54785449	12.02621078	8.282938661	12.13352776	68.43561554	0.98329879	1.082971573	6.234157905	28.26663801	14.5012668	273.9857585	0.908764899	17.07459625	273.2573242	0.608642299	0.366945181
1992	Steelhead	0.915756278	0.426835355	0.390877156	134.52	138.46	141.22	0.019157729	7481.089617	10.87409033	8.375935495	10.89748675	14.26045799	50.10090332	0.992548215	1.037850189	6.764475204	25.12735493	16.01404444	198.1802444	0.952689976	16.30038802	199.5639343	0.579843449	0.239852514
1993	Steelhead	0.907400378	0.619245816	0.561903887	130.08	134.27	139.03	0.020024105	11241.42007	11.77443286	9.358392142	10.64266233	10.96669292	107.5979172	0.983264768	0.986349678	6.423411027	27.94141803	12.84444555	288.6217143	0.90532585	17.1998407	299.6308899	0.685791019	0.425070912
1994	Steelhead	0.905060624	0.447215681	0.404757304	133.05	137.17	139.51	0.019360976	7828.204952	10.8266465	9.793310784	9.66681766	12.95371265	59.55548096	0.991505349	1.059957218	6.900047347	24.662653	15.35882616	196.690094	0.950432857	16.14534998	202.4002075	0.573324729	0.276330936
1995	Steelhead	0.903884782	0.572429413	0.517410235	128.25	132.55	139.26	0.019584422	10124.75335	11.4703738	9.752284072	10.24077629	11.48763981	93.94382324	0.99206053	1.050737095	6.478395797	27.28253302	13.97645966	259.7134043	0.924408515	16.98139906	272.2706299	0.646283143	0.389437935
1996	Steelhead	0.907474213	0.580971247	0.527216425	134.84	138.47	143.07	0.01771414	9329.510598	12.48205873	9.680202328	10.10519379	12.60196209	125.1081558	0.977878773	1.139690208	5.592656553	31.66971637	14.35034704	335.6924388	0.884078165	18.15841166	346.5257874	0.65441472	0.398232698
1997	Steelhead	0.934927135	0.623786958	0.583195353	138.48	141.07	144.81	0.017819135	10382.85147	15.89503983	6.52722194	14.14145924	11.97265377	169.6637024	0.971486628	1.502549744	4.563989989	39.92341745	14.45801306	484.1472931	0.840475887	23.20323149	489.4086304	0.705678593	0.436261873
1998	Steelhead	0.936698059	0.591519784	0.554075433	132.11	134.97	140.48	0.019869755	10998.49087	12.4581118	6.103095636	14.98278967	11.96026249	131.4403137	0.976730919	1.134665012	5.532217167	32.38630938	14.26392301	344.7746429	0.875751088	18.11008358	352.1695557	0.683044853	0.396112211
1999	Steelhead	0.925906172	0.573600697	0.531100426	137.33	141.03	146.65	0.017590061	9333.921849	12.29988173	7.407806218	12.55343148	12.19056129	110.8438919	0.98545593	1.131844139	5.823649652	30.35254546	14.40454594	311.6775106	0.899670025	17.95027733	323.964447	0.666240008	0.390945323
2000	Steelhead	0.914877999	0.481237056	0.440273195	134.84	138.88	141.72	0.018694118	8220.956141	11.5890099	8.745212197	10.77738576	13.04804955	85.66663361	0.991971397	1.211767769	6.269889683	27.46012235	15.29232232	245.7944616	0.932058513	17.33489068	254.5999146	0.591896072	0.296855457
2001	Steelhead	0.915933641	0.497625075	0.455791547	134.29	138.02	144.02	0.017889299	8146.152328	10.17166407	8.335078597	11.18723868	12.02075272	59.74881668	0.989842343	0.908218861	7.316596247	23.02713942	14.63610284	169.2177022	0.954553584	15.0739948	177.3386841	0.611718072	0.326029567
2002	Steelhead	0.902224447	0.579670681	0.522993059	129.4	134.32	140.01	0.019556006	10217.58334	11.7690708	9.951279931	9.785462228	11.30199795	76.16759949	0.991121149	1.147953701	6.453806035	27.08290655	13.84608332	262.6516164	0.925335844	17.47450082	272.9683228	0.645881562	0.389939179
2003	Steelhead	0.914639262	0.567545313	0.519099226	130.29	134.52	141.77	0.019194182	9953.836422	11.69417586	8.492436647	11.15811237	11.63504429	81.82277832	0.99148823	1.083253479	6.515399456	26.70989856	13.96659485	254.9020386	0.930055837	17.21970336	274.6119995	0.645722541	0.383731139
2004	Steelhead	0.927357323	0.541102519	0.501795384	133.4	137.15	143.66	0.018259661	9153.897941	11.3791666	7.053150982	13.02060213	11.96562195	79.27626953	0.996190333	1.108075333	6.556841038	26.19982477	14.50953738	229.363416	0.943596035	16.96340688	249.3887634	0.644791211	0.348721781
2005	Steelhead	0.926950674	0.503890982	0.467082086	134.39	137.72	141.92	0.018382735	8578.950127	11.21445077	7.136997737	12.96161554	13.37923183	84.75066223	0.994252837	1.051383972	6.445758343	26.60841124	15.27640343	230.1927694	0.939822396	16.74060996	236.7787933	0.619948173	0.305757366
2006	Steelhead	0.895485537	0.631268899	0.565292169	129.23	133.53	138.47	0.02029532	11461.00094	12.84420708	11.03633439	9.211195556	11.02763309	136.787146	0.982354367	1.197616386	5.762199946	31.20979944	13.09519609	346.2032267	0.885413875	18.70550712	357.2106628	0.674874319	0.442355804
2007	Steelhead	0.89992833	0.528234281	0.475372994	126.62	132.15	136.2	0.019507337	9264.298732	11.52442384	10.11478405	9.830265026	12.7965107	68.11459885	0.994151473	1.14369154	6.3553138	27.17870241	14.85756906	247.5346909	0.933105499	17.23771922	254.7496796	0.622188652	0.316571399
2008	Steelhead	0.917796035	0.578542226	0.530983761	134.79	138.7	143.03	0.018117978	9611.822089	12.28164148	8.233011588	11.76331624	12.02190857	112.1785431	0.981550181	1.060881424	6.124804817	28.84980148	14.21084007	311.6900991	0.8976671	17.7098333	328.5264282	0.649373051	0.398263109
SCN MO3-RESSIM-SAL																									
1929	Steelhead	0.896404826	0.57219035	0.512914191	128.47	130.27	137.12	0.020370096	10438.26138	9.81203304	4.393150523	19.64609822	11.05545006	63.82778244	0.982632887	0.793209839	8.328929938	20.77013038	12.70908244	165.2178116	0.946995318	14.46935479	176.1290894	0.635994963	0.395027466
1930	Steelhead	0.754506966	0.446434311	0.336837797	140.16	140.21	143.9	0.01857351	6250.748091	9.894645521	3.86003042	22.08241311	13.21075382	62.70593262	0.985576141	0.905415058	7.678334981	22.01112095	15.08399041	159.0707677	0.951663693	14.5319651	164.8411407	0.502351442	0.240046535
1931	Steelhead	0.819409272	0.458975423	0.376088718	138.02	139.24	144.36	0.018814931	7069.412837	10.09336659	3.587064728	23.73527577	12.62741623	58.86043243	0.990219724	0.958304501	7.43275062	22.60556987	15.13726981	161.9846242	0.957180421	14.92655834	167.0583496	0.536485475	0.250273738
1932	Steelhead	0.91996341	0.649212346	0.597251603	121.13	123.49	129.16	0.022118218	13199.0931	11.94124079	4.242455661	20.46083254	10.53812847	99.57953033	0.988763583	1.09147625	6.5642519	27.65612496	12.20318778	292.7756602	0.910047382	17.64748637	304.4317932	0.717040501	0.464734673
1933	Steelhead	0.891480232	0.585149624	0.521649323	127.65	129.55	135.13	0.020345437	10602.48455	11.464896	4.456168808	19.43170886	11.33985081	68.18749084	0.989073682	1.023069382	7.004742913	25.46742892	13.36325423	247.8490067	0.931248983	16.95366081	263.3229675	0.638590025	0.41803955
1934	Steelhead	0.708992631	0.487274981	0.345474371	138.63	138.2	139.61	0.01938923	6691.829648	11.80909978	3.76440233	22.63763276	14.37220631	59.37915726	0.986854625	1.198201275	5.974547252	29.33341021	15.45164076	285.1780446	0.905493965	17.56161229	290.4157715	0.502606531	0.252600751
1935	Steelhead	0.892439992	0.568780313	0.507602298	125.94	127.93	134.38	0.021162373	10731.75636	11.1316123	4.002016	21.47374829	11.40548744	67.98436737	0.993132329	1.019650269	7.16366668	24.52938334	13.51748625	221.4864477	0.944690824	16.59884659	232.6940002	0.632765953	0.379483616
1936	Steelhead	0.850459035	0.615519331	0.523473976	122.36	122.51	126.33	0.021291917	11134.72124	11.6533511	4.524609543	19.16133342	11.11823978	115.172731	0.978297222	1.08417511	6.847507112	26.79613432	12.33980719	285.7381541	0.89881588	17.2086331	297.7406616	0.614812654	0.416851566
1937	Steelhead	0.909755063	0.583936217	0.53123893	119.71	122.47	130.25	0.02220311	11784.22681	9.796817899	5.189643942	16.7677542	10.47388992	50.86909637	0.975555384	0.73988719	8.805743955	20.0964587	12.27655935	163.9306361	0.941904436	14.36937634	177.5213165	0.656662977	0.395091012
1938	Steelhead	0.913491572	0.630050305	0.575545644	123.24	124.98	129.12	0.021196357	12187.74332	12.06171533	4.058421768	21.31636419	10.93256416	111.5926208	0.980600774	1.078533663	6.265449606	28.88492154	12.6768961	309.0633392	0.897590826	17.66275565	321.1536865	0.690139304	0.448150204
1939	Steelhead	0.802366318	0.541705575	0.434646307	136.79	137.22	140.63	0.019655171	8535.258722	11.15670722	3.784023359	22.54554946	12.28020897	77.29988403	0.990398324	1.119676781	7.0004149	24.85591609	13.55895726	217.2592646	0.941746821	16.69557858	222.8695526	0.55901917	0.33225473
1940	Steelhead	0.82349798	0.546992593	0.450447295	128	127.86	130.79	0.020756141	9338.771948	11.17178924	4.235048972	20.33053601	11.9209219	83.53600616	0.988514972	1.053679466	7.144379333	24.67277149	13.68392642	225.1434631	0.937396894	16.70084667	232.7225494	0.554697113	0.345230135
1941	Steelhead	0.832127208	0.504266707	0.419614047	129.36	130.73	135.77	0.019968608	8371.864249	10.3923283	3.899196826	21.98794612	13.08317108	55.46320648	0.991073382	0.87036314	7.520124942	22.83302499	14.51827113	181.8326035	0.954566091	15.45406675	189.7847443	0.551939979	0.288343674
1942	Steelhead	0.917552221	0.628229877	0.576433719	120.49	122.66	128.8	0.020904694	12038.42062	10.90007697	4.779930487	18.22255614	10.32886944	83.53708801	0.987992167	0.931820011	7.64486187	23.29221131	11.92450428	215.9066315	0.943158627	16.20077324	224.6229248	0.685450254	0.443419254
1943	Steelhead	0.920615211	0.614598601	0.565808821	127.41	129.18	133.97	0.021215761	11992.92894	11.82587269	3.660147779	23.40638228	10.95284805	113.5797653	0.986106718	1.110214424	6.38473323	27.8385642	12.94294373	284.1959178	0.910037011	17.47139057	293.8853149	0.687115113	0.426675698
1944	Steelhead	0.903470054	0.542602786	0.490225368	121.5	123.8	131.1	0.021683356	10620.42319	9.407698785	4.845276706	17.91073999	10.64998608	51.74303818	0.979177606	0.768539858	8.816180743	19.54381663	12.97972536	143.5545247	0.949272662	13.87258673	151.6450348	0.619918796	0.347872411
1945	Steelhead	0.89414054	0.577464351	0.516334286	130.17	131.62	136.48	0.020467342	10557.16731	10.95486832	3.835825458	22.43425551	11.48583412	82.97876587	0.98991282	0.945573616	7.2543758	24.3381576	13.37719472	223.1079356	0.937719891	16.2422967	237.8478851	0.638278256	0.393691244
1946	Steelhead	0.922775542	0.656694446	0.605981574	123.41	125.26	129.45	0.02211895	13391.89092	12.3037483	4.164284848	20.83603337	10.51072006	111.1220093	0.978738654	1.084479046	6.11627008	30.02581722	12.14476029	333.7866007	0.88352409	17.95499404	346.4668579	0.729689476	0.469275654
1947	Steelhead	0.797575669	0.541477883	0.431869584	134.55	134.31	137.01	0.019922893	8595.153528	11.88387629	3.663355961	23.34518438	12.81149673	113.1097534	0.976684475	1.142481327	6.093876682	29.28562637	14.53567791	304.3712311	0.887621462	17.51115513	312.6004944	0.553927564	0.317657177
1948	Steelhead	0.903118334	0.631508482	0.570326888	134.03	135.54	140.69	0.019268862	10979.54743	15.01084099	3.209396958	26.63107371	11.7688179	145.9042328	0.981186414	1.365327549	5.400612846	33.96383038	13.74026092	426.7423147	0.869012952	22.2957557	447.7825623	0.681039441	0.438819051
1949	Steelhead	0.917591166	0.634941196	0.582616433	121.81	123.51	128.26	0.021848807	12716.1333	12.43995963	4.032340311	21.49701404	10.71792965	126.4264862	0.981630754	1.116067791	6.16496218	29.67362489	12.67351087	331.7122192	0.886970262	18.09997145	347.686554	0.697088265	0.469823995
1950	Steelhead	0.912985126	0.635848622	0.580520334	124.46	126.38	132.84	0.021259121	12327.72175	11.463924	4.443659849	19.464192	10.67598476	91.72471313	0.987944984	1.039714432	7.047333196	25.44040628	12.09106127	255.8590088	0.923167417	16.98757807	269.9475403	0.702310099	0.450698362
1951	Steelhead	0.907930829	0.616968696	0.560164899	122.66	124.58	129.85	0.021740878	12165.22373	12.16442629	4.211160481	20.53115501	11.02642021	101.0824066	0.984333587	1.128641605	6.20365715	29.27401681	13.07548253	315.8403269	0.89308845	17.80695756	329.6502686	0.676759742	0.438115394
1952	Steelhead	0.930403833	0.665599477	0.619276304	124.93	126.49	131.21	0.0217365	13446.46596	12.59245723	3.523328915	24.39091469	10.622118	157.7349426	0.971730149	1.086239433	5.840829216	31.48488805	12.13607788	357.28125	0.867849191	18.16727495	369.9491882	0.732174399	0.482229524
1953	Steelhead	0.91486358	0.605341868	0.553805229	127.19	129.18	136.26	0.019595689	10842.64858	11.50666056	3.912724376	22.08310465	11.01538754	88.15855408	0.988940966	0.969183064	6.837144502	26.24403497	13.15240224	261.2819468	0.923655113	16.92334445	278.2255554	0.665670714	0.438956999
1954	Steelhead	0.920909794	0.661644135	0.609314564	117.12	119.93	126.32	0.021339287	12990.26901	11.44969	5.48339463	16.06096309	9.953236961	88.78773804	0.979803216	0.964610481	7.297733769	24.99782339	11.35567649	263.4781723	0.917634259	16.85397768	276.7589722	0.723441781	0.469584186
1955	Steelhead	0.921401486	0.602808879	0.555428997	124.58	126.71	133.4	0.021303808	11822.91216	10.82895906	4.100961283	21.03157386	10.66366043	75.5759552	0.991218686	0.91504631	7.644723326	23.15299778	12.63486481	210.1589533	0.945569684	16.02073574	224.2655182	0.666780732	0.418928344

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1956	Steelhead	0.923707759	0.665863282	0.615063081	129.3	130.96	135.47	0.020385955	12526.61927	13.95670332	3.705699094	23.23676113	10.84546814	140.7667145	0.975665498	1.260844994	5.468505844	33.69276815	12.50887648	406.4331207	0.861614853	20.13580306	425.0817261	0.718689536	0.482012951
1957	Steelhead	0.912058643	0.655641868	0.597983833	123.68	125.44	130.57	0.019927961	11906.70036	12.8775786	4.441955186	19.57622505	10.6985424	129.0360443	0.974527824	1.077175713	6.391599946	28.72532428	12.24531603	343.9087067	0.885906845	18.62470357	359.8193359	0.692491335	0.464518845
1958	Steelhead	0.914431104	0.634604223	0.58030184	128.65	130.25	135.07	0.020257347	11744.08313	12.49406518	3.725073703	23.05621371	11.13103008	121.8859909	0.980503166	1.110761166	6.24333062	29.38095123	12.81690645	329.7268728	0.887094229	18.15130695	346.9906006	0.683843497	0.465045155
1959	Steelhead	0.89208689	0.613460243	0.54725984	119.53	121.69	126.24	0.02072507	11330.2162	11.40239075	5.627502717	15.54205756	10.72065678	74.9362381	0.975803876	1.015288353	7.13815093	25.50587703	12.56462987	263.1998316	0.909591645	16.87416252	274.5951538	0.665244553	0.439899415
1960	Steelhead	0.922308219	0.638167018	0.588586686	120.6	122.97	129.39	0.022111045	13001.97795	11.4711878	4.520997494	19.15787331	10.28928757	78.78773651	0.992888153	1.079260635	7.179466464	24.88390571	12.01974773	244.9225006	0.934343924	17.10478131	255.4190216	0.716399578	0.431868076
1961	Steelhead	0.902179407	0.60371928	0.544663102	123.79	125.95	132.53	0.020702897	11265.4485	11.77524076	4.385648131	19.70446374	11.00650787	69.32971191	0.987746227	1.029169464	6.825082563	26.32627311	13.10548846	271.1297379	0.920370559	17.31652832	282.6332703	0.662015289	0.421937837
1962	Steelhead	0.914574859	0.59429912	0.543531033	129.55	131.39	136.98	0.020878863	11337.6012	11.62428505	3.489296585	24.46415093	11.24126205	88.10972443	0.994562316	1.155988216	6.594088994	26.88694682	13.44529915	255.4711482	0.929607123	17.3652571	261.3048706	0.682464363	0.396034598
1963	Steelhead	0.892552256	0.565790702	0.504997768	133.49	135.4	142.46	0.019521707	9847.860954	11.19440246	3.54872144	24.1229229	11.79104404	88.84111328	0.989487457	0.971642017	6.773732163	26.08661714	13.88234043	244.9379476	0.926648239	16.53789616	257.5479431	0.638980145	0.367248218
1964	Steelhead	0.910044643	0.590657588	0.537524774	131.58	133.47	139.4	0.020085386	10786.03637	11.30993891	3.701803245	23.1592305	11.25650406	93.43356323	0.98772887	1.001938248	6.942563869	25.48777044	13.37106673	251.6714223	0.922464301	16.61736727	263.9472656	0.663831449	0.412042734
1965	Steelhead	0.913610686	0.630493035	0.576025174	131.74	133.53	138.43	0.018960945	10911.50625	12.11523747	4.191693738	20.67736427	11.00301476	126.7678345	0.97758975	1.075537586	6.155276738	29.63252103	12.82973512	322.467687	0.882045647	17.689768	332.0551147	0.680446272	0.462168687
1966	Steelhead	0.882724024	0.57459971	0.507212968	130.04	131.7	137.16	0.021209336	10745.9371	11.1269502	3.621065386	23.54895478	11.65660858	68.36349335	0.994591486	1.049771309	7.033034168	24.80028466	13.42401044	219.2739003	0.94637388	16.63656537	226.5662384	0.658326665	0.361696335
1967	Steelhead	0.891776763	0.619869732	0.552785423	133.7	135.23	140.8	0.018989459	10486.68061	11.65166044	4.346973307	19.85887816	11.26246243	88.02864838	0.977092147	1.000310135	6.910654821	25.83280788	12.71362289	280.2549947	0.902856876	16.9868083	289.3380432	0.665178631	0.438761601
1968	Steelhead	0.833762784	0.538012412	0.448574726	120.06	121.04	126.31	0.019372285	8680.331971	9.453710624	6.023260608	14.49283743	11.95480881	60.48068314	0.949843776	0.730220032	8.685131043	20.06627703	13.15001059	180.5535177	0.904026449	13.75874488	188.7473755	0.567501239	0.348369581
1969	Steelhead	0.911440591	0.608828437	0.55491095	133.28	134.98	140.07	0.020155677	11174.558	13.06876223	3.040269211	28.01316254	11.6565588	130.6308746	0.976312828	1.213567162	5.435539432	33.39408176	13.97409185	371.5631866	0.866227289	18.85858011	378.5861206	0.693738183	0.420336623
1970	Steelhead	0.916631182	0.615224101	0.563933595	124.14	126.61	134.23	0.020185853	11373.29909	10.58624056	4.484038122	19.35404671	10.59582996	84.63358154	0.981658483	0.838075256	7.778035529	22.75969266	12.27600447	223.7584712	0.923213452	15.51108917	233.4108124	0.67916912	0.43482883
1971	Steelhead	0.89302811	0.631374077	0.563834799	139.89	141.17	145.18	0.01805293	10169.42527	13.61407546	3.31407994	25.79185861	11.97907238	146.3385956	0.970946169	1.223018837	5.224903345	34.96538724	13.57395347	406.21993	0.84994333	19.54330603	412.9869995	0.671413056	0.430797126
1972	Steelhead	0.902140297	0.637185459	0.574830679	128.84	130.39	135.19	0.01979283	11366.06383	13.57007538	4.229539245	20.46731952	11.2472826	124.4462631	0.980565143	1.229454613	5.651298977	32.33838828	13.12061024	383.3737233	0.872650981	19.86900043	385.5175781	0.679108414	0.469003459
1973	Steelhead	0.884094208	0.550659624	0.486834984	117.72	120.58	129.09	0.019771673	9616.92096	9.49808274	5.420190036	16.08074657	10.77659855	50.5571907	0.970337832	0.782455254	8.780433103	19.67366429	12.92595021	155.2285716	0.934637219	14.05164997	161.3557739	0.606970037	0.369026977
1974	Steelhead	0.899441774	0.625077685	0.562220982	134.42	135.93	140.43	0.019284658	10831.82166	13.23502118	3.663339466	23.43826014	11.63127136	126.604895	0.97342732	1.203693771	5.41818957	33.46835929	13.51336686	380.5458934	0.86195448	19.20689106	386.7110291	0.675611635	0.434314725
1975	Steelhead	0.923859465	0.648018005	0.598677567	116.08	118.91	125.67	0.022015318	13168.68026	11.16915842	5.084749795	17.24105092	9.985352707	83.58813782	0.9897874	0.907075596	7.656961821	23.68241752	11.55098232	235.9888535	0.937657426	16.5305961	247.2622681	0.719684797	0.457385912
1976	Steelhead	0.927083727	0.668911762	0.620137209	124.16	125.96	131.04	0.02090303	12948.64875	12.30253278	4.339301363	20.02067125	10.3811409	131.3689972	0.975753379	1.117785358	6.230949216	29.3560437	11.90744702	328.9560852	0.882868926	17.99498018	333.1289978	0.724328737	0.498617897
1977	Steelhead	0.854830545	0.507916062	0.434182164	121.4	123.31	130.15	0.021808296	9460.135521	9.171996815	5.134325884	16.92021407	11.73026485	36.76270905	0.971774149	0.759212065	8.925983585	19.11760693	13.56092087	134.0347252	0.943731358	13.44835385	141.4520569	0.562492852	0.315867929
1978	Steelhead	0.896432857	0.604916457	0.542266987	135.22	136.82	141.78	0.019270309	10440.12626	11.70229449	3.572484337	23.95701216	11.62664471	94.80915222	0.992163098	1.138587379	6.384977207	27.45971185	13.284434	264.6935883	0.924999595	17.45861832	273.6483154	0.66325162	0.40498694
1979	Steelhead	0.914074822	0.628674519	0.574655549	122.38	124.56	130.71	0.021668461	12439.95452	10.9957742	4.639955707	18.70907814	10.59845524	79.38390961	0.984645069	0.919882011	7.518155225	24.01438388	12.09575748	232.9874395	0.930137356	16.23743725	247.1830444	0.711156709	0.449857714
1980	Steelhead	0.915560722	0.64622455	0.591657815	117.37	119.98	124.99	0.020641876	12201.98635	11.57835443	5.150686406	17.09334119	10.20369568	87.52772064	0.976709783	0.924421883	7.029357277	26.49639245	12.01251539	287.3805974	0.902963152	16.91244427	306.3229675	0.69153917	0.462253495
1981	Steelhead	0.813910324	0.526165034	0.428251153	138.32	139.03	143.97	0.017565093	7515.535563	11.34899364	3.643664837	23.52584149	13.57654171	89.95480957	0.97933166	0.988533783	6.491647698	26.99447945	14.90098111	264.7968216	0.91081051	16.69239219	273.5896606	0.552763216	0.308463138
1982	Steelhead	0.89943063	0.616141411	0.554176457	128.49	130.06	135.33	0.020027471	11086.85628	12.20161833	4.399626836	19.67876374	11.18741302	110.3999908	0.97991153	1.117410278	6.333283961	28.78731367	13.02074289	314.4502411	0.890233765	17.85340754	322.8909607	0.661396827	0.438200375
1983	Steelhead	0.909481507	0.620331505	0.564180032	127.95	129.68	134.55	0.01936454	10915.12463	11.83005479	4.556219198	19.11260473	10.90520668	102.5412827	0.982633114	1.036968708	6.596256636	27.50247394	12.86991978	290.219752	0.904457996	17.31657489	301.9002991	0.662619152	0.444448087
1984	Steelhead	0.917008205	0.626049254	0.574092302	126.31	128.16	133.36	0.020902387	11986.85803	11.50791904	4.227654658	20.47733254	10.76446934	123.5200653	0.985661614	1.047274971	6.830230214	26.49914548	12.43791199	266.8156153	0.914784978	17.07453903	275.0581055	0.688786915	0.45148162
1985	Steelhead	0.922143076	0.634497566	0.585097537	122.99	124.9	131.05	0.022142346	12942.53651	11.33645817	4.212798946	20.49175795	10.4731781	95.66685638	0.993110919	1.034306049	7.230438568	24.6442372	12.02175824	235.3912811	0.939843973	16.97562011	242.7809753	0.709160187	0.461108762
1986	Steelhead	0.902688245	0.594979116	0.537080654	128.25	129.89	134.55	0.019566616	10497.43454	11.57930143	4.393635534	19.71052003	11.12368107	106.907579	0.988083303	1.054391479	6.722778492	26.497897	13.2116313	263.4075368	0.918498337	17.1319046	268.0259705	0.645456471	0.431588746
1987	Steelhead	0.746476783	0.506059933	0.377761991	129.38	128.85	131.3	0.021065326	7949.153769	10.95123863	4.569509588	18.76929503	13.29232025	53.87142487	0.980275393	1.024452209	7.223487042	24.49196435	14.34355847	228.9732768	0.923014661	16.22441196	235.3372498	0.504362548	0.276041043
1988	Steelhead	0.902621686	0.579881895	0.523413974	131.7	133.72	139.36	0.019843705	10374.83583	10.65812244	3.902253382	21.89821221	11.27122421	62.38008804	0.99237119	0.945582294	7.460412778	23.21123038	13.06718365	190.0762431	0.955778013	15.8938454	195.8269806	0.649266146	0.389531616
1989	Steelhead	0.926397269	0.6650208	0.616073453	115.62	118.23	124.41	0.022997449	14154.76277	11.65478325	4.655301481	18.70846247	10.01159401	98.01724091	0.993217671	1.056023026	6.976107083	26.29237139	11.40716076	273.5014165	0.920243482	17.33704662	281.1698608	0.729673791	0.466829841
1990	Steelhead	0.745597087	0.474864484	0.354057576	136.93	136.62	138.52	0.0194664	6886.498732	11.20508756	3.96621979	21.54801205	13.97490025	67.22151794	0.984207523	1.066629696	6.733239718	25.93604192	15.26287778	238.7786382	0.924222618	16.64313968	244.7165985	0.502565578	0.257815648
1991	Steelhead	0.877002869	0.597313044	0.523845254	122.91	124.29	128.8	0.019595301	10253.7404	11.21093382	5.363547124	16.28073083	11.08968525	65.26640167	0.97376889	0.961120796	7.12695536	25.38820966	12.9226621	256.1004512	0.910779456	16.57790073	256.1395264	0.622701801	0.418842909
1992	Steelhead	0.77424172	0.490696872	0.37991799	130.56	131.26	135.29	0.0209313	7944.419519	10.61635426	4.13420777	20.70583975	13.44504623	50.56856384	0.985313332	0.95418129	7.432457373	23.37077823	14.62282928	195.4266052	0.944981923	15.84318209	197.9950409	0.505057022	0.283503405
1993	Steelhead	0.920211266	0.633943738	0.58336217	125.22	127.24	134.07	0.021292511	12409.70362	11.14843999	4.2174256	20.55351174	10.50654125	98.73529968	0.981555343	0.870842648	7.389689006	24.41386211	11.98845784	253.91996	0.916448762	16.25932868	264.7316895	0.698906455	0.444052405
1994	Steelhead	0.827803541	0.531643004	0.440095961	127.31	128.07	131.98	0.021080887	9267.817844	10.64164707	4.7330103	18.21650736	11.68439541	60.06785583	0.983887458	0.9752985	7.769652776	22.62711231	13.56304995	194.1081619	0.944515824	15.84584697	200.0101624	0.559372941	0.335729916
1995	Steelhead	0.908746887	0.592635337	0.538555518	121.8	123.93	130.47	0.021180739	11397.5202	10.97297134	4.426675737	19.62098932	10.81963711	87.48014526	0.989782321	0.947387218	7.407452643	23.97555011	12.96274233	228.0972239	0.93589897	16.22116502	239.1461639	0.653703473	0.405524276
1996	Steelhead	0.877078161	0.616550471	0.540762953	129.45	130.63	133.75	0.019298086	10424.84419	12.25257632	4.436069004	19.56990464	11.83000622	121.2668213	0.973672843	1.074608707	6.026314557	30.05009111	13.01077096	330.6763814	0.879690925	17.81742827	343.4128113	0.642904358	0.440931688
1997	Steelhead	0.912725992	0.643923376	0.587725602	135.72	137.14	140.92	0.019025751	11171.90304	15.42379975	3.386271462	25.34920596	11.54818172	168.031073	0.970996034	1.42218523	4.844352908	37.99200177	13.65971041	468.9469503	0.841754397	22.44833422	475.1591492	0.692605785	0.46719943
1998	Steelhead	0.906900917	0.602587508	0.546487163	129.15	130.78	135.79	0.021155913	11549.59631	12.18130844	3.337499209	25.65949105	11.59333324	121.8556549	0.979257667	1.062734127	6.006689675	30.23161477	13.7414314	324.8388163	0.886165162	17.73034509	336.7099609	0.687306628	0.41846539
1999	Steelhead	0.893815669	0.595030232	0.531847345	134.06	135.92	142.04	0.019088529	10143.08239	12.09727475	3.757216603	22.89420596	11.72446156	105.5274368	0.98576175	1.089112186	6.143010169	29.10077516	13.64578549	302.4578044	0.902340849	17.69154565	315.5550842	0.664015013	0.412017188
2000	Steelhead	0.824931131	0.557161531	0.459619892	130.36	130.8	134.16	0.020373756	9353.39944	11.4997672	4.224003628	20.3734445	12.00434418	87.68536072	0.984187686	1.138268375	6.684954569	26.50044161	13.60553296	256.4916178	0.919210911	17.12368774	265.757782	0.577725442	0.359450427
2001	Steelhead	0.887249814	0.523773786	0.464718194	130.47	132.4	138.82	0.019589371	9094.944328	9.966211012	4.152715206	20.73571502	11.52562504	57.93331604	0.985485792	0.843837357	7.896692567	21.62671677	13.89762529	163.7508443	0.952697535	14.73141964	172.219162	0.597719821	0.353800444
2002	Steelhead	0.910358766	0.616942096	0.561638646	124.63	126.59	131.4	0.021043797	11807.31273	11.58115731	4.436862983	19.50474867	10.76114769	76.34583435	0.988982272	1.076717091	6.938207559	25.62714146	12.57362286	253.9883092	0.92872416	17.23500061	264.1842346	0.670026908	0.442031061
2003	Steelhead	0.904135963	0.588270552	0.531876562	126.39	128.41	134.65	0.020695526	10996.50724	11.45710284	4.038047165	21.3457172	11.20576553	79.72070923	0.990386903	1.011466408	6.964268513	25.33419635	13.27935632	243.8407974	0.934437195	16.92016856	262.9431763	0.657872429	0.413764427
2004	Steelhead	0.897717118	0.560253103	0.502948801	131.04	132.94	138.95	0.019599386	9848.025284	11.28688761	3.646626271	23.49613398	11.65357285	76.13249359	0.995143247	1.055051708	6.862370744	25.30407886	13.95194117	226.0559362	0.944763601	16.80724573	247.2705688	0.647893563	0.382017541
2005	Steelhead	0.847636736	0.52316738	0.443455891	130.84	132.07	137.09	0.020003879	8863.312129	10.95966492	3.679081395	23.34269015	12.91405163	79.7695343	0.992021084	1.001525784	6.988527745	24.75461613	14.57389657	217.2708486	0.942850262	16.31297414	224.1720581	0.607037163	0.320992881
2006	Steelhead	0.919592042	0.661156729	0.607994466	123.39	125.04	129.75	0.021148802	12845.14665	12.36102584	4.640461057	18.8351272	10.41577911	131.9135956	0.977856886	1.103369999	6.311378852	29.06700254	11.98360809	327.2440948	0.888694108	18.05902004	338.9646301	0.711538666	0.483634659

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
2007	Steelhead	0.856724783	0.565605943	0.484568629	119.84	121.62	126.88	0.021084432	10206.89314	11.38517424	4.516054206	19.25804403	11.9668602	62.26437759	0.993400764	1.07820425	6.971380718	25.22022076	13.69916789	236.2321192	0.940188219	17.0453976	244.1781616	0.600561271	0.363532554
2008	Steelhead	0.893723276	0.598397532	0.534801802	130.37	131.68	137.64	0.019793206	10575.94719	11.6931432	3.928961128	21.99711958	11.46669712	104.263472	0.980663323	0.972412586	6.90284624	25.67813058	13.25769726	279.2753042	0.908605347	16.87077363	294.5507202	0.641787377	0.427433185
SCN MO3-RESSIM-SNK																									
1929	Steelhead	0.944407521	0.578017024	0.545883624	127.92	128.76	135.55	0.020535357	11199.33597	9.677137681	2.055807069	41.28143458	10.92869759	62.42379227	0.977927637	0.766868496	8.623500131	20.19861589	12.41083988	161.9134979	0.943303446	14.23600451	173.075592	0.693197174	0.411221852
1930	Steelhead	0.821700286	0.461956696	0.379589949	138.85	138.42	142.66	0.018773126	7119.820834	9.758234365	1.919481657	44.14930445	12.87877502	62.21346817	0.981247473	0.879280853	7.982344516	21.39574361	14.67419926	157.5306854	0.944959293	14.29807806	163.3903198	0.510195519	0.272653702
1931	Steelhead	0.881013927	0.477384655	0.42058253	136.63	137.19	142.7	0.019373717	8140.556916	10.05936595	1.969978489	43.06802783	12.36698494	58.84364548	0.988747418	0.936647224	7.603114791	22.24354929	14.75657352	162.7002538	0.955072979	14.87135379	167.9967499	0.5736282	0.289367307
1932	Steelhead	0.966533656	0.657668892	0.635659118	119.3	120.31	126.06	0.022024199	13988.26231	11.80969858	1.737669356	48.92129708	10.26670856	98.57740021	0.981174004	1.030682373	6.793946154	27.018795	11.8026673	288.9082438	0.908701797	17.43848435	301.9046021	0.750556001	0.469612858
1933	Steelhead	0.94659711	0.590514111	0.558978951	126.1	126.98	131.99	0.020520471	11458.95694	11.17244104	2.022724532	42.00650616	11.12950554	65.22486343	0.981199062	0.972707272	7.434524968	24.16743102	12.9463013	235.6095606	0.928727686	16.47657998	250.6846008	0.684491736	0.427202396
1934	Steelhead	0.767172725	0.497529193	0.381690827	138.24	137.23	138.81	0.019317961	7366.186801	11.70987201	1.8942426	44.8192908	14.22887383	59.7496994	0.98449738	1.179457378	6.093769982	28.94061587	15.17217573	285.2144623	0.899663299	17.37480974	290.5718384	0.5239388	0.274215635
1935	Steelhead	0.944188301	0.579471335	0.547130055	124.39	125.41	131.63	0.021525349	11765.8483	11.00830487	1.936995253	43.84849949	11.16278019	67.30825806	0.989745474	0.982171059	7.462159127	23.73535812	13.06860876	216.1095403	0.944284747	16.39626487	227.2841187	0.676649595	0.408085187
1936	Steelhead	0.903505467	0.619910938	0.560092922	120.72	119.71	123.55	0.020888541	11687.82551	11.3503902	1.723034956	49.34239114	10.85079174	110.1766068	0.968249393	1.003802204	7.411155485	25.39064318	11.9977808	277.4890671	0.8898727	16.66187223	292.4010925	0.652473477	0.442490162
1937	Steelhead	0.96229482	0.589378441	0.567155821	117.86	119.2	127.46	0.022191437	12574.32377	9.465528318	2.243339218	37.89022461	10.22553787	48.80555038	0.968232882	0.697959328	9.403710566	19.08277667	11.83895143	157.0655848	0.929955631	13.80268248	170.1932526	0.703449776	0.410650413
1938	Steelhead	0.96237532	0.638254544	0.614240421	121.62	122.28	126.18	0.021127506	12964.92154	11.9015412	1.670599088	50.90113167	10.72307091	109.0496124	0.974249625	1.024262714	6.555801541	28.00008178	12.27295939	304.5385946	0.894396077	17.35947482	319.382843	0.734551768	0.489600261
1939	Steelhead	0.848467743	0.551578014	0.467996152	136.33	136.04	139.76	0.019706661	9214.238943	11.04715633	1.814730242	46.77268937	12.14235706	77.3489212	0.986960304	1.098605156	7.200677797	24.39639516	13.29609664	216.9308879	0.935671479	16.49588585	222.745163	0.580591157	0.3586832
1940	Steelhead	0.882583046	0.56264404	0.49658009	126.54	125.66	128.5	0.020567499	10201.67242	10.95990559	1.780642189	47.68881812	11.57603931	83.48213806	0.981424654	1.005593014	7.481772631	23.88932363	13.17182859	222.6467336	0.927517543	16.32078123	230.4407959	0.607438883	0.38477695
1941	Steelhead	0.900708592	0.51277171	0.461857885	127.85	128.31	133.37	0.020400553	9414.017861	10.21933178	2.051184095	41.40782622	12.91723213	54.05540543	0.98906821	0.838633347	7.798830628	22.08829192	14.17749008	177.2918523	0.953024815	15.17223159	184.7454071	0.610899315	0.330660283
1942	Steelhead	0.964663201	0.631653709	0.609333089	118.49	119.15	124.78	0.020743259	12627.23456	10.71428067	1.860756606	45.66254264	10.16017609	80.64489746	0.974910128	0.859461975	8.010463096	22.60298249	11.59986766	212.1547343	0.935747176	15.84205929	223.0956879	0.721656569	0.450989927
1943	Steelhead	0.963880921	0.626858972	0.604217404	125.91	126.78	131.49	0.021439083	12941.8605	11.78985531	1.632063851	52.04033296	10.77762203	116.0526001	0.983289921	1.085265827	6.481952451	27.6632999	12.55505006	288.2841899	0.904228916	17.35842514	298.2898865	0.734186711	0.457284076
1944	Steelhead	0.954717341	0.559176481	0.533855483	119.59	120.55	127.78	0.021906868	11684.77986	9.159626518	2.182073653	38.86941248	10.36599998	50.50281601	0.971699202	0.721602726	9.335228994	18.6371543	12.31190507	138.8908234	0.943197985	13.46718327	146.7219543	0.675470963	0.398721603
1945	Steelhead	0.945288535	0.582573231	0.550699797	128.69	129.32	134.38	0.020876377	11484.89561	10.72410182	1.889786869	44.97173626	11.26701946	80.34062805	0.98669548	0.913335228	7.620852932	23.22050381	13.04504013	213.0422897	0.937636008	15.87103192	226.9079895	0.700398734	0.416059082
1946	Steelhead	0.967504904	0.667670349	0.645974337	121.77	122.53	126.82	0.022014582	14208.32284	12.11323745	1.658422314	51.24838168	10.24416332	109.4587265	0.973102129	1.025263214	6.449030392	28.83932536	11.60024389	324.6413371	0.884797176	17.67604812	339.0128174	0.760545555	0.489235722
1947	Steelhead	0.860517128	0.552695237	0.475603718	133.26	132.47	135.21	0.019916247	9462.398387	11.70011544	1.618363157	52.50736431	12.52007866	111.9126175	0.972857785	1.111180401	6.360966444	28.35971743	14.16969554	299.7569784	0.881533931	17.20551777	308.4036865	0.597843055	0.350778183
1948	Steelhead	0.950052388	0.635548615	0.60380448	132.61	133.37	138.63	0.019760905	11920.85271	14.53126206	1.559862696	54.55858579	11.58298359	140.9909027	0.979750681	1.317539406	5.662003867	32.54953113	13.43436797	408.495341	0.870076219	21.54741796	429.1503296	0.730559905	0.453130325
1949	Steelhead	0.963052924	0.647948184	0.624008393	120.13	120.7	124.8	0.021741534	13552.49305	12.22815061	1.610098407	52.83108207	10.46311512	122.4954971	0.978264964	1.06553545	6.4868076	28.55958544	12.04618041	323.002065	0.886618823	17.79162137	340.5340576	0.730663898	0.493250438
1950	Steelhead	0.960866987	0.645192818	0.619944479	122.87	123.74	130.08	0.021147585	13095.86159	11.27143727	1.768322408	48.0090431	10.42506371	91.33742371	0.98101052	0.997033024	7.31827905	24.7536792	11.61870686	251.933342	0.915474405	16.65654977	266.1247864	0.742174896	0.462968044
1951	Steelhead	0.957546	0.626157863	0.599574958	122.03	122.86	127.85	0.021487978	12869.66076	12.04405986	1.687210992	50.36665546	10.89800758	100.8697357	0.982089508	1.095694637	6.348158799	28.83628181	12.68831062	314.9921265	0.888429463	17.57722346	329.2552185	0.726225488	0.4682845
1952	Steelhead	0.96916989	0.671675414	0.650967587	123.44	124.11	128.86	0.021804429	14178.78154	12.46011591	1.471653342	57.83011603	10.4472887	155.7930542	0.96999557	1.058277893	6.060200334	30.67327156	11.81897465	352.258194	0.866459539	17.94711542	366.5858459	0.771236232	0.50749422
1953	Steelhead	0.961233135	0.60941238	0.585787373	125.51	126.3	132.44	0.020065488	11743.77128	11.23858932	1.873108193	45.39534502	10.80365467	82.50395203	0.98514694	0.923733997	7.277809143	24.79707517	12.7768542	247.2917862	0.925742557	16.5031023	265.0632629	0.714400935	0.446609315
1954	Steelhead	0.970655268	0.668042726	0.648439192	114.51	115.2	120.93	0.020849241	13506.90221	11.0985727	1.879582129	45.19236617	9.656412125	84.42534027	0.957962775	0.861542225	7.829491936	23.87127874	10.78434388	255.8834432	0.902608633	16.2073849	272.7609558	0.761802149	0.494546107
1955	Steelhead	0.96554114	0.608052835	0.587100027	122.95	124.01	130.84	0.021664944	12708.89459	10.57743096	1.915205367	44.34376084	10.46811771	73.23875427	0.987916338	0.872291279	8.046966806	22.08257	12.2636474	199.8270874	0.945882668	15.61128553	213.2886047	0.722059452	0.447075065
1956	Steelhead	0.965467469	0.670888677	0.647721192	127.81	128.64	133.24	0.020482374	13254.14568	13.67505642	1.551852532	54.83151105	10.67522488	137.585611	0.973331535	1.211978054	5.68771752	32.69349835	12.17797105	397.1357015	0.85936298	19.65728283	417.4082031	0.756843507	0.514160777
1957	Steelhead	0.960931875	0.656856693	0.631194534	121.88	122.45	128.38	0.019688815	12417.09548	12.50920623	1.615598537	52.61827136	10.49365788	128.227446	0.960550463	1.00800457	6.735840358	27.44919691	11.94897827	332.2135468	0.87916552	18.04895226	347.0903931	0.745625914	0.502586294
1958	Steelhead	0.957589596	0.638408806	0.61133363	128.13	128.84	133.79	0.020333008	12418.3536	12.31725339	1.644752704	51.66759737	11.01730385	120.5212967	0.977377844	1.084255219	6.501210682	28.4216196	12.55856403	322.0119781	0.885534644	17.88785108	339.3289795	0.731249085	0.484212078
1959	Steelhead	0.953699908	0.623236892	0.594380966	117.49	118.14	122.83	0.020031126	11893.73268	10.9285406	1.905898288	44.52984151	10.40641403	74.14539948	0.957441521	0.937294865	7.655592375	24.20564315	11.90840228	255.0901845	0.887689302	16.04250733	265.931427	0.707590451	0.470034886
1960	Steelhead	0.967768764	0.6495753	0.628638685	118.84	119.96	126.1	0.021950898	13786.16399	11.39273334	1.861240409	45.60509401	10.07997112	79.84299316	0.988298285	1.037152004	7.324692123	24.61110123	11.59307082	246.6417211	0.929730703	16.95736392	257.0776978	0.757553965	0.472486077
1961	Steelhead	0.953355217	0.611297423	0.582783588	122.02	122.9	129.02	0.02087936	12156.68136	11.50811052	1.954515092	43.41495927	10.78060341	67.99992218	0.982386518	0.985304642	7.156249858	25.17941319	12.67371782	258.2490946	0.921032975	16.93967835	269.1837158	0.719407253	0.446053898
1962	Steelhead	0.956596277	0.600729627	0.574655725	129.04	130.01	135.55	0.02117965	12159.54219	11.57518765	1.750958085	48.51006236	11.16742096	87.946698	0.993292177	1.142143917	6.705788039	26.54678684	13.21981319	253.7211049	0.929290146	17.28696283	259.790863	0.723613448	0.432211808
1963	Steelhead	0.940045419	0.56682596	0.532842147	133.02	134.06	141.23	0.019822822	10551.10647	11.08087131	1.774776623	47.89581717	11.71741905	87.39080658	0.987717295	0.954159737	6.971213736	25.42165678	13.72476355	238.0975647	0.927494893	16.35874224	250.9115448	0.687140582	0.381663529
1964	Steelhead	0.954713025	0.594277647	0.56736461	131.09	132.12	138.23	0.020308226	11511.09498	11.16584158	1.767453752	48.07518816	11.16447258	92.36756592	0.985051131	0.979333878	7.145626843	24.87375653	13.14703321	245.2334061	0.921521763	16.39781841	257.2776184	0.707256748	0.421734313
1965	Steelhead	0.960659113	0.634874133	0.609897622	130.19	131.04	135.71	0.019003504	11579.06351	11.81527809	1.614158757	52.66911513	10.78950081	122.6556915	0.971423435	1.031163883	6.550540023	28.15473247	12.4080596	310.9990641	0.875356068	17.22422822	321.4949341	0.730846227	0.498242267
1966	Steelhead	0.931910729	0.589198163	0.549080089	128.58	129.4	135.08	0.021752021	11930.61334	11.03280061	1.930785999	43.97410862	11.45978165	67.58778687	0.993025124	1.010489845	7.225859039	24.31523141	13.02250353	217.8582713	0.944711645	16.45810095	226.4705811	0.702711249	0.391685747
1967	Steelhead	0.94569582	0.623841643	0.589964435	132.19	132.8	138.87	0.019115515	11266.28687	11.34990784	1.903804488	44.58970735	11.03178177	85.07948761	0.969861364	0.956646442	7.234276548	24.85101766	12.39318641	270.0919062	0.896948934	16.49697574	279.2383118	0.706121537	0.463291742
1968	Steelhead	0.920281991	0.548207146	0.504505164	116.69	115.21	119.85	0.018561877	9354.22755	8.871425322	2.058756873	41.1774431	11.42614956	59.42380295	0.923367012	0.69296217	9.386174224	19.02711699	12.45335277	176.400533	0.853645186	12.70158513	183.9228363	0.621081104	0.394806576
1969	Steelhead	0.954228869	0.6128329	0.584782845	131.86	132.77	137.86	0.02076903	12134.55644	12.9280276	1.545578219	55.03705048	11.53237495	128.9617142	0.977442753	1.202875996	5.582850501	32.60193644	13.75244761	363.2995097	0.869966994	18.69194889	370.5930786	0.73298226	0.43156769
1970	Steelhead	0.962376669	0.616304355	0.593116933	123.17	124.25	132.08	0.020283932	12020.03295	10.36481857	1.934363991	43.87758865	10.46935272	83.19284973	0.977431846	0.810835266	8.081178941	21.93674276	12.06493886	215.6630325	0.922755917	15.17093372	224.5950317	0.728677698	0.457827418
1971	Steelhead	0.944538472	0.639244081	0.603790628	138.52	139.13	143.03	0.018452358	11131.0281	13.42994758	1.496338725	56.83216869	11.74780426	144.6745361	0.969060218	1.199868584	5.408673652	33.99833206	13.24061664	399.5814158	0.847997437	19.27533197	406.5090637	0.732452785	0.471279865
1972	Steelhead	0.954670428	0.645652991	0.616385817	127.34	128	132.47	0.019489082	12000.68829	13.35958287	1.590839274	53.45388271	11.03336239	123.0222336	0.978827906	1.183892345	5.79014422	31.80425974	12.7124699	379.9134572	0.8695514	19.4925305	382.6547546	0.729013074	0.488239059
1973	Steelhead	0.944136256	0.565134407	0.533563883	115.41	116.51	125.52	0.019727003	10516.19784	9.231839657	2.252189279	37.61788815	10.45921364	49.76065216	0.958834744	0.7393363	9.306792319	18.77533358	12.35046132	152.1306051	0.921217988	13.59664448	157.5777588	0.657191328	0.400461526
1974	Steelhead	0.949582219	0.631816699	0.599961903	132.99	133.7	137.82	0.019504306	11690.61641	13.04104607	1.577614196	53.90206832	11.43180943	126.1545288	0.972027493	1.18069706	5.595457315	32.61049949	13.16605473	374.3622894	0.859123548	18.91160615	380.4128418	0.729471733	0.481120508
1975	Steelhead	0.972466961	0.657479778	0.639377362	113.64	114.57	121.6	0.021761694	13901.91641	10.83821392	1.886988424	44.96797364	9.665036774	80.52624969	0.97526257	0.817986679	8.240451366	22.31640381	10.92049472	223.6025721	0.936215709	15.95104281	235.9442444	0.765079102	0.472530817
1976	Steelhead	0.970529816	0.673113483	0.653276705	122.49	123.24	128.56	0.020653608	13477.8516	12.07079816	1.584121987	53.72092746	10.20570812	130.1738617	0.966728115	1.055689144	6.47940246	28.61415929	11.58071613	326.0912882	0.872868419	17.58670489	331.9050293	0.763866575	0.521238505

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SAR	TotalReturn	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1977	Steelhead	0.923275467	0.519244174	0.479405408	119.65	120.34	127.22	0.021914222	10496.23279	8.927125301	2.392723761	35.44330584	11.3860405	36.02304153	0.962040806	0.712500811	9.465697177	18.17019995	13.05276934	128.9196943	0.933557669	13.04303018	136.4020386	0.619157765	0.350381813
1978	Steelhead	0.943765594	0.609444624	0.575172868	134.78	135.62	140.58	0.019445619	11174.39892	11.63171881	1.703874521	49.87182442	11.54311409	94.61353912	0.99053067	1.122973347	6.495955624	27.09161496	13.10257896	263.0589854	0.922792931	17.33636888	271.9752502	0.70342463	0.437363788
1979	Steelhead	0.962127392	0.629312339	0.605478639	120.58	121.51	128.32	0.021661207	13102.81126	10.67064479	1.906010292	44.5370023	10.40276165	76.74631653	0.97412107	0.862904835	7.995775141	22.75420426	11.77653567	221.7910461	0.922290037	15.66671848	235.8960266	0.740470929	0.444273737
1980	Steelhead	0.965198067	0.648659579	0.626084972	114.7	115.29	121.59	0.020509609	12829.25216	11.05479578	1.942470141	43.71076688	9.906707382	81.56938477	0.958000255	0.831768417	7.934712388	23.74138117	11.37985086	261.4382655	0.901164313	16.05413938	280.9003601	0.731906847	0.464157407
1981	Steelhead	0.880719004	0.529268594	0.466136909	137.98	138.07	143.07	0.017675346	8231.748354	11.19799188	1.75436601	48.40467927	13.46868839	88.77433319	0.975557709	0.965102291	6.718850255	26.16315852	14.69026756	259.556516	0.907541682	16.43760204	268.3829346	0.598981489	0.348111744
1982	Steelhead	0.951692094	0.62373794	0.593606466	126.97	127.62	132.29	0.019827137	11756.90589	11.89145599	1.6542776	51.37652955	10.94748554	108.76707	0.975004411	1.075795364	6.635788329	27.70673527	12.54840024	305.6701508	0.882509937	17.35148319	314.3806152	0.719375716	0.458914146
1983	Steelhead	0.961122484	0.624092917	0.599829735	126.29	126.88	131.08	0.019262398	11543.62544	11.49791057	1.749238312	48.58794343	10.68498955	99.55403595	0.974321973	0.982891273	6.988309413	26.1350537	12.46339115	277.8696416	0.897498449	16.77179782	290.2330627	0.712220695	0.459773612
1984	Steelhead	0.963434597	0.634970416	0.611752467	124.73	125.59	130.59	0.020789309	12704.05952	11.26178006	1.611928694	52.71886071	10.52229958	121.1428986	0.977781332	0.99959259	7.138589516	25.65877799	11.96137985	261.9307073	0.903994739	16.63731575	270.7822876	0.735830094	0.480836069
1985	Steelhead	0.965217876	0.641486421	0.619174161	122.36	123.26	129.29	0.022013616	13616.7287	11.27416924	1.730986394	49.04827076	10.36995163	96.26601868	0.987771332	0.993084335	7.326652519	24.56984055	11.75861136	239.054095	0.934472541	16.82617601	247.821701	0.755439846	0.469681508
1986	Steelhead	0.954930274	0.604907366	0.577644357	126.69	127.3	131.32	0.019321995	11149.04485	11.3454565	1.667900518	50.92995488	10.91304684	106.0566391	0.984047556	1.012547207	6.924727567	25.9522592	12.76732747	261.2251536	0.908594002	16.70139917	265.8638	0.71233226	0.45878962
1987	Steelhead	0.814088643	0.517999905	0.42169784	127.96	126.72	129.4	0.020845558	8781.069556	10.64853839	2.032799661	41.67236941	12.95933743	53.74814529	0.970947134	0.979227829	7.686961524	23.31839996	13.87350384	222.7730357	0.90976884	15.70330318	229.0942535	0.54161676	0.326771885
1988	Steelhead	0.949123638	0.588547154	0.558604016	130.2	131.33	137.31	0.020389314	11376.87412	10.58042489	1.988356173	42.61176579	11.11414509	61.68101578	0.989496875	0.918593884	7.674675003	22.73789995	12.75811545	189.0765025	0.953096807	15.75203101	195.2707672	0.697162661	0.420368169
1989	Steelhead	0.972816589	0.679928233	0.661445465	113.43	114.27	120.35	0.022597551	14932.93957	11.48165464	1.736478418	48.87498421	9.681834221	97.62979889	0.984986591	0.966850281	7.31601657	25.54891172	10.74417098	270.9819921	0.917677909	17.00156832	282.3641357	0.773913735	0.49826322
1990	Steelhead	0.812698475	0.482561286	0.392176821	136.61	135.76	137.48	0.019311032	7567.035835	11.02217245	1.862332456	45.53372873	13.82674789	66.51201019	0.979477668	1.040451813	6.963348128	25.27916253	14.92963568	235.0402807	0.916493634	16.33179998	241.2984009	0.533922766	0.281401324
1991	Steelhead	0.93947621	0.60486785	0.568258956	120.91	120.54	124.54	0.019239262	10920.98048	10.91002945	2.047503017	41.43791359	10.80307693	63.55664673	0.956734502	0.891715145	7.607952267	24.22258067	12.42140547	249.8678665	0.89401258	16.02296273	251.8464966	0.682396783	0.441234256
1992	Steelhead	0.845971548	0.504472411	0.426769307	129.12	129.14	133.42	0.021050771	8975.090585	10.42528554	2.050770506	41.36928948	13.1704525	50.35667267	0.978773212	0.919053268	7.752750389	22.63893857	14.20603418	193.2508799	0.935411255	15.50035365	196.1519623	0.564069824	0.315154004
1993	Steelhead	0.965305994	0.636746113	0.61465484	123.52	124.42	131.76	0.021447426	13170.61314	10.8706583	1.799720436	47.17075189	10.26640911	96.25097046	0.97806865	0.828869629	7.804560974	23.20569458	11.68006404	243.0054626	0.917404821	15.78692079	254.2701874	0.733740132	0.453289255
1994	Steelhead	0.878074557	0.543415883	0.477159661	126.68	126.46	130.33	0.020939346	9980.859032	10.43439225	2.024039857	41.90067971	11.48439083	59.42835617	0.976613057	0.937110329	8.210085824	21.75120104	13.10595163	190.9553706	0.934398293	15.48018662	197.2277985	0.617766876	0.364609178
1995	Steelhead	0.95957962	0.602775597	0.578411178	119.92	120.71	127.19	0.021206546	12255.8925	10.78511024	1.80952014	46.94051576	10.56839867	86.83223877	0.981830561	0.905512524	7.724846423	23.09801684	12.48196538	221.3573761	0.933475941	15.91495148	230.7607727	0.699885736	0.445857118
1996	Steelhead	0.935746296	0.623748349	0.583670207	127.95	128.28	130.44	0.019045444	11104.69479	11.91145359	1.620499134	52.44656604	11.57348881	118.2889282	0.96769129	1.02497654	6.340410128	28.85455108	12.50204404	321.8462524	0.870035281	17.26289876	335.1849365	0.6986559	0.472222982
1997	Steelhead	0.957793993	0.650343454	0.622895054	134.31	135.04	138.9	0.019287072	12003.05514	15.15501635	1.433926716	59.39017768	11.36882763	166.3526733	0.970166624	1.379742432	5.029007681	36.84473357	13.30293417	459.9169769	0.841392587	22.01428763	467.0167236	0.736504334	0.498026136
1998	Steelhead	0.951880035	0.604796749	0.575693951	128.71	129.5	134.35	0.021403967	12309.5055	12.03706336	1.620850109	52.4850686	11.50982513	119.8513214	0.97843256	1.038471508	6.225543283	29.27078495	13.55119626	315.9241384	0.888792853	17.53958909	327.8252258	0.716871981	0.427984006
1999	Steelhead	0.943672651	0.598545309	0.564830838	133.58	134.57	140.69	0.019119568	10789.64221	11.97367447	1.693359554	50.2372584	11.62525749	103.892363	0.984822154	1.0723279	6.29392416	28.49592538	13.41983366	296.7595774	0.902330309	17.50766929	309.9812012	0.696680393	0.427320881
2000	Steelhead	0.87434887	0.565890951	0.494786114	129.88	129.51	132.69	0.020169424	9968.054542	11.30115461	1.754343174	48.47743341	11.84303131	87.15810547	0.97773031	1.103100777	6.947648011	25.82150561	13.23482275	254.9361064	0.909311523	16.76185767	264.9900208	0.614635966	0.390455089
2001	Steelhead	0.938428627	0.531082513	0.498383034	129.92	130.87	137.32	0.019846198	9881.663687	9.859524659	2.059752785	41.23555607	11.4028532	57.20214157	0.981994724	0.820332813	8.134386301	21.10760854	13.62295389	161.6595281	0.949301024	14.55026364	170.4470825	0.633903344	0.376110006
2002	Steelhead	0.95929431	0.629079124	0.603472024	122.97	123.83	128.33	0.02106842	12701.59204	11.41591116	1.891854785	44.91972394	10.50216637	76.55457001	0.981510866	1.019870472	7.219336852	24.96964233	12.03053077	251.7400335	0.922583252	16.9373757	262.9814148	0.732475424	0.469114872
2003	Steelhead	0.953264578	0.594336337	0.566559777	124.83	125.83	131.38	0.021003143	11887.836	11.26385638	1.853579476	45.84043019	11.0127985	78.11331329	0.986066186	0.97500391	7.259435318	24.45593767	12.92866405	235.6211751	0.933331182	16.62785784	253.9583893	0.711380355	0.424088392
2004	Steelhead	0.94740645	0.569537298	0.53958331	129.55	130.5	136.11	0.020158257	10866.63425	11.20234796	1.863877922	45.61493797	11.46764755	74.43114014	0.993126082	1.025600815	7.061843805	24.73498058	13.61977577	223.0925852	0.94431448	16.66425212	244.2779846	0.68816174	0.401145385
2005	Steelhead	0.912388706	0.531855827	0.48525925	129.42	129.91	135.03	0.020447131	9913.763238	10.81394087	1.857743293	45.77060705	12.68434429	77.80341492	0.98908062	0.972150993	7.260197699	23.95438729	14.23052899	212.6719462	0.941160262	16.06243722	219.6639252	0.626240662	0.347560682
2006	Steelhead	0.966255826	0.662942907	0.640572446	121.7	122.25	126.93	0.020690319	13240.12438	11.93747909	1.589484356	53.59509807	10.23211327	128.5206375	0.963087511	1.018362236	6.694364384	27.8461689	11.63457282	316.1989339	0.878096441	17.32920106	329.8375549	0.764633766	0.503961604
2007	Steelhead	0.924261519	0.582171511	0.538078725	117.89	118.28	123.64	0.021038393	11309.27894	11.28836261	2.012084536	42.2500475	11.57402973	60.92116776	0.98881433	1.032085896	7.264398783	24.36821315	13.11751223	231.7659022	0.940458337	16.90203714	239.1182404	0.666668547	0.404135307
2008	Steelhead	0.94700877	0.604011974	0.572004636	128.88	129.36	135.35	0.020036565	11450.73928	11.46029588	1.783272207	47.71782087	11.20399323	101.2273209	0.976207781	0.933631516	7.220810056	24.6821329	12.91767104	269.6495921	0.908269316	16.50716321	284.7478027	0.677317746	0.454996371

5518 **Table 4-7. Snake River MO3_Chinook_SAL_W_Wildfish Raw Data**

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	MedDayLGR	MedDayConfl	MedDayBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas
1929	Chinook_1	0.928357245	0.660388861	0.613076784	124.99	127.68	135.31	15.61414757	25.39925313	12.249997	116.4245761	0.913621298	9.445647052	4.620796092	18.69584258	11.09575596	54.09363785	0.898328197	0.75318675	8.32892593	19.66939881	12.66242043	143.7363892	0.883176486	13.83508452
1930	Chinook_1	0.905715686	0.667377405	0.604454184	103.93	109.4	117.67	20.84318539	18.6661567	11.02845594	119.3109662	0.921401339	9.321961948	7.829573594	11.69708146	9.682554626	59.33450851	0.908602405	0.663420486	9.104318202	17.41190759	11.44944302	148.4239655	0.892768006	13.48886887
1931	Chinook_1	0.897166759	0.67031142	0.601381124	106.55	111.67	120	21.5591597	18.41557936	11.10570138	104.4473452	0.907451957	8.917138253	8.50026194	10.74549776	9.566019058	42.97081604	0.891246021	0.655017328	9.243554853	17.21636423	11.56169287	133.8507538	0.874683022	12.98325332
1932	Chinook_1	0.929680119	0.737970911	0.686076884	117.64	120.5	127.95	16.22781984	23.56081621	11.40538113	210.8462219	0.923208679	11.6433943	4.995455891	17.43620728	10.32642632	82.57201233	0.960838521	1.024285984	7.979636677	20.75241093	11.69129944	272.749911	0.853455196	17.2168088
1933	Chinook_1	0.927657514	0.617036848	0.572398868	131.16	133.78	140.86	14.22815643	27.68639439	13.04152441	163.1537566	0.942810446	11.26976153	4.46476157	19.48336896	11.63727741	56.05530777	0.96332314	1.101433849	7.250796698	22.91051072	13.71642288	217.2336884	0.897121797	16.87941408
1934	Chinook_1	0.921984172	0.634071161	0.584603574	114.54	117.26	123.07	16.62890626	22.66440404	12.37452568	227.4601075	0.909600449	11.9346512	5.161730133	16.98495696	11.14434586	78.89875641	0.953875625	1.109517002	7.935626559	20.59129958	12.7882568	307.5053304	0.827504883	17.69172303
1935	Chinook_1	0.928366336	0.588027961	0.545905364	125.64	128.12	135.26	14.34832015	27.11159217	13.26330921	165.5472161	0.940769945	11.14373895	4.243967913	20.44746447	11.80034485	62.74397888	0.959525144	1.038751221	7.448547184	22.12645172	13.95136674	216.6394374	0.895525744	16.63037157
1936	Chinook_1	0.94292368	0.725616399	0.684200886	116.42	118.93	126.33	15.22456141	25.09445139	11.10381896	235.7620168	0.923186983	11.86958299	4.132692635	20.95292767	10.02758312	127.4037766	0.967074478	1.1084198	7.8848138	21.1173631	11.44130691	291.1449331	0.848207633	17.60522461
1937	Chinook_1	0.919801304	0.668925496	0.615278543	124.7	127.36	134.46	16.82828362	23.77596712	12.18555219	134.1540105	0.925462646	10.08149457	5.835220024	15.54447275	10.68247204	54.94858475	0.921893406	0.810753727	8.132963262	20.14746941	12.70344369	171.6011963	0.891169012	14.82595269

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas
1938	Chinook_1	0.9428013	0.629320011	0.593323724	129.62	131.99	136.62	13.12980019	29.43547309	12.9312597	230.0714395	0.918362443	12.00424184	3.458891086	24.76891889	11.4953577	108.5496277	0.960557067	1.14256773	6.989955246	24.18111903	13.50489426	294.9294128	0.842381616	17.72536898
1939	Chinook_1	0.932663434	0.730297054	0.681121359	116.26	119.3	126.63	16.09688574	23.73185555	11.05243015	179.6031669	0.941351069	11.1677865	4.777873665	18.23326605	10.25021286	84.20984497	0.965126467	0.95206461	8.127569884	20.10714516	11.33248631	227.765007	0.89221408	16.67483012
1940	Chinook_1	0.897181013	0.741841107	0.665565756	95.01	101.29	110.58	23.14981412	16.80789933	9.979395594	159.7398491	0.870330636	9.803946665	9.067651533	10.05293569	8.90916481	83.4686203	0.855995822	0.572818279	9.50826332	16.82794299	10.31166538	196.356753	0.817441692	14.14873425
1941	Chinook_1	0.918098565	0.491367568	0.451123859	132.94	135.1	136.18	14.34438361	26.83996943	14.30083254	139.9344474	0.93625385	10.41355865	4.073638529	21.2303918	13.41648827	57.05632095	0.941843772	0.89277029	7.540341422	21.50623326	14.66612307	182.7448807	0.899722715	15.4876922
1942	Chinook_1	0.935438284	0.670121098	0.62685693	135.78	137.98	144.4	14.07071905	28.20495423	12.51990162	185.4200352	0.92574163	11.05964201	4.391121432	20.29452976	11.2254137	82.89598694	0.948317802	0.956099224	7.151454926	23.6046947	13.06309144	235.7948583	0.869799376	16.31995535
1943	Chinook_1	0.935659055	0.711049889	0.665300267	122.41	124.62	130.89	16.04456062	23.97664466	11.5868003	227.2685285	0.914344783	11.7258968	4.952138975	18.10939747	10.18534355	122.8862	0.951875997	1.063215733	7.859501831	21.05050102	12.05805842	286.6865387	0.840241869	17.32282909
1944	Chinook_1	0.931310454	0.589108693	0.548643084	130.65	133.04	140.54	14.26953673	27.78881458	13.11945779	130.5085733	0.93191106	10.07825814	4.167114973	20.84824354	11.71320038	62.59826965	0.926839221	0.863035774	7.637243986	21.52553226	13.79637162	165.9525757	0.90209341	14.91286413
1945	Chinook_1	0.924807161	0.68801211	0.636278526	118.92	122.12	129.37	16.29735523	23.89111577	11.94898605	161.1848962	0.92267225	10.53424805	5.181002282	17.04313545	10.72434158	67.20752563	0.927726293	0.799880028	8.103697516	20.28813519	12.32439089	203.4799296	0.879796724	15.51340143
1946	Chinook_1	0.935184073	0.771318153	0.721324452	110.64	113.62	121.69	17.25354118	22.05161905	10.39500557	251.0249525	0.909397164	12.05411656	5.259769082	16.71379025	9.310554695	114.8619568	0.95593766	0.97758646	8.359643765	19.88627815	10.59841601	320.7272746	0.825312018	17.6318388
1947	Chinook_1	0.927380933	0.689266364	0.639212484	110.45	113.93	121.75	17.2759674	21.89473134	11.5767389	204.6822602	0.931122414	11.50056989	5.478531554	16.12173416	9.992050362	86.89625397	0.962491655	0.955011559	8.238034755	19.6479517	12.04440371	259.0696106	0.870543182	17.0072217
1948	Chinook_1	0.945119325	0.631212744	0.596571363	132.96	134.96	138.9	11.8433664	32.73970281	13.25773478	313.9151862	0.911958673	14.37064889	3.100323163	27.59181269	12.01188374	133.5401215	0.967187107	1.3467103	6.224513762	28.00791802	13.75130812	402.9443919	0.821914375	21.22877169
1949	Chinook_1	0.941611146	0.574706819	0.541150347	126.06	128.17	134.13	12.59286495	30.782015	13.63211877	263.9463283	0.911411801	12.70895403	3.166792646	26.95728627	12.16335049	118.1861816	0.962479687	1.203732204	6.777512379	25.19968191	14.31540887	330.8536174	0.824561338	18.30514701
1950	Chinook_1	0.94036978	0.687408497	0.646418178	132.28	134.4	140.49	13.33911378	29.26868728	12.44174596	208.9338139	0.928749778	11.58676846	3.772573136	22.84777049	11.26592464	89.06238098	0.965813947	1.076886272	7.015434071	24.18215191	12.89964469	267.1746852	0.862238169	17.15840705
1951	Chinook_1	0.940750052	0.646447492	0.608145512	130.78	132.73	139.02	13.08679114	29.5947293	12.93380063	261.100514	0.903174537	12.55835734	3.752009198	23.14820785	11.39031487	105.1453979	0.955452979	1.160851383	6.672856867	25.73017306	13.61551523	341.1260376	0.811197539	18.19406907
1952	Chinook_1	0.948563121	0.725084227	0.687788157	125.29	127.26	133.35	13.51345792	28.65859	11.7980002	288.9339458	0.893868289	12.60081226	3.539834403	24.41712368	10.65001907	157.7332123	0.94629916	1.073069286	7.090015888	24.32481543	12.19655816	355.4608307	0.797111829	18.17847077
1953	Chinook_1	0.932248763	0.669975253	0.6245836	132.34	134.84	141.57	14.5384144	26.94388853	12.46399437	199.0854972	0.920639162	11.33709363	4.667881675	18.88274721	11.04626389	82.66471863	0.950010598	1.003823853	7.169836618	23.44053174	13.06891155	255.7379532	0.856482973	16.66896693
1954	Chinook_1	0.942225263	0.69061057	0.650710726	139.47	141.18	145.82	12.98163103	30.11547434	12.4458174	238.6945724	0.909547099	12.09502762	3.857077681	22.60513913	11.16204472	101.815036	0.952953672	1.094530773	6.61133185	25.98620794	12.98049911	310.9767456	0.828148872	17.71284389
1955	Chinook_1	0.939907352	0.648403469	0.609439188	135.09	137.18	143.18	13.33498262	29.47321137	12.78401143	185.8551423	0.932727316	11.22092761	3.834919341	22.61800312	11.27868443	84.46255035	0.95787344	1.015513134	7.038611092	23.94228091	13.46064043	237.0767568	0.878135989	16.64743392
1956	Chinook_1	0.942830813	0.731503672	0.689684202	117.66	119.99	126.58	14.85357446	25.69955246	11.27465568	302.6483721	0.897261828	13.54893126	4.175037801	20.7840104	10.15770817	138.2622681	0.956456435	1.195939445	7.445017643	22.83812743	11.65659555	391.3129832	0.796564112	19.64556964
1957	Chinook_1	0.93420003	0.712974366	0.666060674	117.2	120.63	126.56	15.64924931	24.26768902	11.50165367	254.7900124	0.91012222	12.48391996	4.874808751	18.01972988	10.44516907	121.3573898	0.949143672	1.010146332	7.500547677	22.04596233	11.88011662	319.1820882	0.832665871	18.07788976
1958	Chinook_1	0.945098289	0.677667818	0.640462696	127.42	129.53	134.78	12.67661649	30.70322459	12.53825276	265.0110964	0.910099298	12.62663443	3.369606204	25.3395453	11.3269207	118.6450653	0.961831141	1.12254343	6.725796096	25.74195715	12.97789256	334.7067719	0.822059167	18.29989735
1959	Chinook_1	0.937574189	0.618094196	0.579509165	136.17	138.11	143.76	12.90572157	30.07717962	13.26790633	216.0809065	0.925344642	11.94332153	3.689203463	23.2951907	11.81298332	81.67079468	0.968663418	1.168298054	6.700755835	25.34666963	13.89464839	285.3157247	0.851918221	17.72595628
1960	Chinook_1	0.939273595	0.642865181	0.603826289	134.4	136.23	141.48	13.4435164	29.01829826	12.83479146	202.0211225	0.928103643	11.64252291	3.949062288	21.99997941	11.22958927	87.2541687	0.962797773	1.129856777	6.945016883	24.29223141	13.52760204	263.2388763	0.863244593	17.33662446
1961	Chinook_1	0.919747768	0.65404419	0.601555683	118.75	121.99	128.42	16.72839127	23.18204857	12.32017013	178.2271808	0.93108362	11.24308021	5.695669383	15.6826935	10.75580101	61.61362991	0.955645823	0.983410835	7.875345595	20.74029479	12.91482051	236.8989131	0.876157304	16.64345519
1962	Chinook_1	0.936064364	0.701709363	0.656845128	119.62	122.22	129.47	15.28701611	25.12688982	11.84704542	192.7912619	0.937266205	11.51029338	4.443298809	19.54585256	10.53264713	89.14200134	0.971485114	1.115723515	7.819613539	21.16719134	12.25541528	248.4374568	0.877383858	17.22079865
1963	Chinook_1	0.922118709	0.632716658	0.583439868	118.22	121.31	127.83	16.80927831	22.87640296	12.38530724	155.2652032	0.930187894	10.52444322	5.453058347	16.24292243	10.84863815	68.49351196	0.936803067	0.851952267	8.149402574	19.87273529	12.96026754	198.6662725	0.889769624	15.53909707
1964	Chinook_1	0.942494274	0.625559549	0.589586293	133.63	135.81	142.03	12.58996022	31.23691135	13.23946272	214.7156176	0.921702453	11.59369547	3.510752045	24.59205289	11.49808865	92.38935547	0.956769037	1.038137913	6.688321568	25.65391146	13.98641904	273.7887929	0.853331635	17.08172274
1965	Chinook_1	0.941251681	0.53172566	0.500487671	144.43	145.95	145.8	11.5413539	33.98329551	14.02750955	261.5578799	0.899217712	12.33797417	2.765829861	30.83941682	13.28970165	135.6426117	0.950970209	1.166245174	6.350620344	27.22420967	14.34511995	328.2438914	0.805699408	18.00134134
1966	Chinook_1	0.91776341	0.70931603	0.650984298	111.14	115.02	123.18	18.3648573	20.876761	11.05357674	145.3671611	0.936785919	10.34624887	6.198017053	14.27082342	10.03481083	60.78222275	0.945206892	0.850830936	8.658792965	18.55111284	11.40186898	187.0498098	0.898161858	15.28496393
1967	Chinook_1	0.927480631	0.72076884	0.668499139	125.08	128.22	135.3	15.42005945	25.49679496	11.61102343	171.7115816	0.926491231	10.92439246	5.019380093	17.31911221	10.62183495	56.82792053	0.941828096	0.904004383	7.644236095	21.84263557	11.98564021	225.2710597	0.876956294	16.06693236
1968	Chinook_1	0.921347794	0.432473416	0.398458428	139.77	141.64	143.21	12.71497348	30.52794186	15.08551659	169.6152485	0.919785261	10.7282705	3.302830435	25.87403081	14.55237217	69.4795929	0.937691772	0.969315243	6.955081396	23.64994323	15.31961234	219.468928	0.864755889	15.82570632
1969	Chinook_1	0.937039861	0.679528951	0.636745714	117.41	119.97	126.74	15.46070144	24.61449907	12.05850513	246.300348	0.91200327	12.24280749	4.547307834	19.23751374	10.33544292	112.4046646	0.961330724	1.145501614	7.66193717	21.70353055	12.68593597	315.6274719	0.826899171	17.97530365
1970	Chinook_1	0.933650678	0.69065435	0.644829902	127.1	129.39	135.97	14.80566791	26.38582776	12.04041215	179.9658661	0.914855961	10.68964471	4.516891666	19.27573168	10.89266911	86.61368408	0.929344296	0.861142731	7.557863615	22.07096482	12.48099995	225.1454442	0.860210627	15.69011251
1971	Chinook_1	0.950421234	0.636456445	0.60490172	138.89	140.6	144.3	10.77596619	36.49665958	13.47600072	325.1509432	0.884797924	13.86473915	2.661568828	31.93759469	12.33267479	152.385495	0.957174885	1.256460953	5.784659103	31.10767442	13.95049334	419.1665192	0.766882931	19.87914181
1972	Chinook_1	0.942491373	0.649117034	0.611787204	125.5	127.69	133.18	13.03607337	29.3573705	12.96499518	280.9304395	0.912703148	13.41989613	3.54624708	24.20599601	11.46660709	119.6628113	0.97017132	1.250487137	6.711715788	25.29125163	13.54101864	365.9802806	0.821164727	19.73440361
1973	Chinook_1	0.913193272	0.611634707	0.558540699	121.06	124.33	130.03	17.34924465	22.76162748	12.49716234	122.4352643	0.908939417	9.590033531	6.078401223	14.72326771	11.07201538	50.61755295	0.902614748	0.808424759	8.245299086	19.68059114	13.04298321	158.3396784	0.868679911	14.16824961
1974	Chinook_1	0.945961269	0.604379063	0.571719185	135.51	137.44	142.07	11.51614597	33.81150239	13.72167982	304.6633977	0.893124142	13.60874588	2.917803772	29.21484027	12.35430679	135.994458	0.956823778	1.263627911	6.125857674	28.68114484	14.3077693	396.9584961	0.786602904	19.77946806
1975	Chinook_1	0.94676303	0.609644962	0.577189311	145.26	147.18	151.03	11.29261836	34.80044401	13.55729328	257.3763172	0.907076223	12.47009509	2.866186619	29.72577534	12.36120605	125.9185928	0.960694695	1.197625542	6.155119143	28.29045785	14.07452027	326.6459045	0.815932463	18.15838575
1976	Chinook_1	0.94451281	0.743425442	0.702174853	121.33	123.77	130.84	14.29871897	26.92945574	11.43038845	257.1501312	0.914548814	12.45945161	3.954241969	21.83101861	10.26920013	120.8968262	0.96657778	1.160975838	7.381582856	23.03168937	11.80424134	323.7626343	0.828465879	18.18076038
1977	Chinook_1	0.909786448	0.526476252	0.478980959	129.65	132.32	137.55	15.80582208	24.92664553	13.81714719	104.3206471	0.91868071	9.315673419	5.047585279	17.38200224	12.73987713	37.89460449	0.907703424	0.80447979	8.054873206	20.0123951	14.26644484	138.8616689	0.887168994	13.6734217
1978	Chinook_1	0.923525729	0.747228532	0.690084775	109.73	113.34	121.64	18.34812308	20.86712834	10.68697786	192.4246189	0.929825672	11.25661155	6.247914135	14.36029351	9.533019066	87.91951752	0.95799787	0.940094376	8.454946823	19.14117334	11.07270447	243.161555	0.871262779	16.72959963
1979	Chinook_1	0.916696722	0.744508453	0.682488458	112.4	115.78	124.2	18.71572306	20.87689447	10.75218507	160.2203603	0.919000485	10.47224006	6.556150682	13.72775406	9.737675476	61.28513336	0.922333229	0.732594442	8.694164589	18.77789584	11.05236419	201.1289876	0.875723879	15.32460459
1980	Chinook_1	0.94623682	0.642720276	0.608165591	136.29	138.34	144.09	12.02897976	32.55487704	13.18410907	252.7318202	0.90324226	12.32364699	3.151192054	27.12809575	11.69546432	110.1160034	0.952361441	1.145692348	6.452726185	26.97968409	13.82061466	330.4660034	0.813931356	18.07436895
1981	Chinook_1	0.916968267	0.550056384	0.50438425	128.43	130.94	130.42	15.67624462	24.43885151	13.58913864	181.7198993	0.913013918	10.83764631	5.086183272	17.48265757	12.68612442	78.56468964	0.931120825	0.917032146	7.509309687	21.68622288	13.93286371	234.2440898	0.854432225	15.90608851
1982	Chinook_1	0.942309848	0.547608554	0.516016934	142.91	144.55	146.04	11.35462605	34.30107996	14.25369358	273.2094776	0.903875249	12.8977684	2.856555156	29.84335955	13.15684605	125.3093582	0.962913072	1.232223797	6.108978271	28.40835315	14.73411783	352.0756276	0.806614707	18.77580198
1983	Chinook_1	0.934794136	0.640478448	0.598715497	123.11	125.5	130.43	14.51615298	26.35001812	12.73253148	217.8641859	0.919320575	11.69385413	4.240389757	20.52435274	11.36320229	101.2793457	0.95906353	1.057750702	7.328883894	22.65651841	13.23821799	278.999349	0.845861981	17.22938426
1984	Chinook_1	0.94400516	0.6107048	0.576508483	129.19	131.42	136.54	12.57447059	31.03025625	13.26034886	219.4318216	0.927732246	11.73177161	3.102400057	27.42957441	12.14361057	123.3448364	0.967642426	1.134802437	6.935248218	24.33579357	13.65525277	269.9874725	0.858339926	17.45892
1985	Chinook_1	0.929962644	0.75177095	0.6991189	109.72	112.84	121.27	18.11582492	21.00901367	10.45505326	189.7880189	0.933354672	11.24312976	5.816444643	15.33226732	9.259793091	107.2824631	0.957647622	1.007415676	8.638843872	18.73299949	10.83036725	237.2470093	0.879788329	16.85447963
1986	Chinook_1	0.930119178	0.611158673	0.568450403	122.65	125.02	127.59	15.66390194	24.13363297	12.49084336	201.3202199	0.924847352	11.4492165	4.704209402	18.72195743	11.27041702	104.3336731	0.957410884	1.040338707	7.694690824	21.10517285	12.96448421	254.3580043	0.860135019	17.01057053
1987	Chinook_1	0.916999568	0.556915952	0.510691687	117.95	120.58	126.6	15.50325859	24.52491067	13.3676719	186.6519863	0.927787112	11.38061721	4.629806578	18.81898763	12.31899204	57.82825012	0.955830932	1.033363342	7.741961546	21.09032682	13.76416	250.6776148	0.868311405	16.86145226

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas
1988	Chinook_1	0.907851691	0.733173252	0.665612577	109.15	112.86	121.25	20.48248313	19.37168307	10.49605928	140.0291195	0.933873377	10.27026531	7.910552666	11.72246198	9.335994148	59.47561111	0.933925879	0.779426765	8.886822343	18.03544632	10.89973752	183.347702	0.900767098	15.20299387
1989	Chinook_1	0.940908683	0.568672679	0.535069062	141.85	143.9	148.52	12.65472893	30.90013625	13.53968722	185.3334454	0.938927868	11.56930849	3.409482844	24.97608008	11.81730518	78.12469025	0.969640326	1.162176704	6.840721935	24.70346833	14.29802497	242.5163371	0.882798155	17.32834816
1990	Chinook_1	0.923189594	0.434070986	0.400729817	131.6	133.82	138.25	13.07381677	29.62345846	14.92803274	157.9730331	0.944407059	11.13117405	3.431225017	24.8303309	13.88313637	62.96385422	0.96513468	1.137556171	7.134627737	22.93533546	15.34020456	212.437439	0.899337659	16.71860949
1991	Chinook_1	0.92111316	0.640586694	0.590052834	123.59	126.65	131.83	15.96501416	24.35283784	12.54200969	184.3834122	0.925236097	11.3217377	5.417795964	16.39552016	11.0617485	60.4889595	0.952485096	1.000993538	7.54182338	21.85990735	13.12295262	250.767156	0.865146806	16.7612319
1992	Chinook_1	0.910810052	0.544127735	0.495597011	121.11	123.73	128.39	15.89444603	23.88094742	13.50608451	143.9428079	0.933919792	10.49935906	4.775075763	18.23057276	12.79803829	49.30284119	0.939830983	0.874329376	7.977134332	20.15477689	13.73491716	192.6713613	0.895954231	15.60594257
1993	Chinook_1	0.933821883	0.728200206	0.680009288	120.74	123.53	131.11	15.52881972	24.98698997	11.35056087	181.449598	0.921542896	10.83734051	4.602341816	18.79821446	10.44984303	78.15470886	0.929125226	0.757965136	7.986709952	20.85676949	11.64633528	222.5053584	0.875995984	15.81847413
1994	Chinook_1	0.924724046	0.478607948	0.442580278	128.68	130.92	136.2	13.47905357	28.81354085	14.07383565	159.7593907	0.941056209	11.13523851	3.671446666	23.33482813	12.9633976	60.64072266	0.958910322	1.078376007	7.258037418	22.69643285	14.63310623	213.3847427	0.896706412	16.663836
1995	Chinook_1	0.931189519	0.648575576	0.603946778	127.36	129.61	135.26	15.14827235	25.44026998	12.49478258	191.1623753	0.921734312	11.06263689	4.729979694	18.64473668	11.09065399	92.08553772	0.945824325	0.969075108	7.474182501	22.08428898	13.07465458	241.1202189	0.862526973	16.31427908
1996	Chinook_1	0.936483339	0.536659398	0.502572585	140.7	142.07	143.92	11.70786005	33.25943092	14.41256693	259.6054459	0.900391557	12.41698228	2.894296721	29.45435112	13.74603443	122.2700714	0.951605511	1.168589115	6.356456138	27.03757343	14.66434844	331.6889496	0.80790927	18.04236031
1997	Chinook_1	0.946430549	0.56759401	0.537188311	134.64	136.19	138.76	11.04769084	35.2216239	13.94577312	359.0536575	0.891592064	15.3644899	2.685642488	31.7096264	12.71912651	161.8798187	0.961983311	1.42484169	5.845867239	30.33914993	14.50276311	462.907252	0.778728803	22.30342436
1998	Chinook_1	0.926089561	0.673411068	0.62363896	116.01	118.99	125.84	16.50233982	23.28649212	12.15619176	221.6330828	0.909726718	11.57903406	5.388713598	16.47037562	10.52623863	89.67572021	0.940230286	0.901768494	7.827654161	21.11601171	12.72366683	281.9791361	0.839171072	16.77839613
1999	Chinook_1	0.933498789	0.6440518	0.601221575	121.06	123.27	129.55	15.34908157	24.84555804	12.51363856	208.5366336	0.926728249	11.65984389	4.460633345	19.59851642	10.97312603	99.10372162	0.96206826	1.083430195	7.75849174	21.18066698	13.11939955	269.2292633	0.860644897	17.36858368
2000	Chinook_1	0.934128531	0.491964452	0.459558031	131.06	133.15	136.33	12.89917924	30.00482797	13.99807903	192.2661029	0.938069833	11.68468107	3.307569943	25.86380102	12.75286827	87.11137543	0.971442997	1.214183807	7.015308201	23.6310689	14.55499999	248.8124034	0.87929367	17.53622659
2001	Chinook_1	0.901998114	0.668820721	0.603275029	110.85	115.27	123.55	20.30370936	19.65049962	11.61719356	106.9310028	0.902305322	9.162345988	7.732205547	11.81471181	9.812289238	40.84489517	0.877699685	0.642381001	9.065834157	17.72747057	12.18252468	138.8234444	0.87396268	13.34401735
2002	Chinook_1	0.930664983	0.692019062	0.644037909	119.9	122.82	129.7	15.680272	24.53646591	11.87192815	177.3372116	0.940441281	11.39164284	4.828399539	18.02926746	10.54598541	70.11482849	0.967599273	1.07222271	7.846530214	20.92437974	12.28840812	234.8616511	0.888030926	17.06499465
2003	Chinook_1	0.933996581	0.625510205	0.584224393	130.58	133.05	140.1	13.88954074	27.98336534	12.94375944	189.1425182	0.933400933	11.46981124	4.058642268	21.32613473	11.54360847	76.90997314	0.95915066	1.04174099	7.218223877	23.03570869	13.57815647	240.9558792	0.878643284	16.90962474
2004	Chinook_1	0.911677585	0.720735875	0.657078742	107.4	111.8	120.19	20.04435213	19.42595846	10.84661627	156.8628693	0.934568724	10.65870864	7.491854139	12.13189929	9.239259338	60.71099243	0.944861388	0.831694698	8.787384219	18.19309401	11.32144101	202.0887909	0.893276095	15.75589188
2005	Chinook_1	0.920659327	0.577970625	0.532114046	122.67	125.34	131.08	15.45239247	24.87703169	13.42231921	160.7789759	0.934611333	10.75613764	4.737477459	18.55627983	12.15538731	67.1325058	0.947854865	0.95613308	7.759533256	20.92396858	13.89541594	206.7044169	0.890881052	15.93471718
2006	Chinook_1	0.944676789	0.727941282	0.687669233	121.51	123.64	130.82	14.39976376	26.76108028	11.59064014	235.8189278	0.921862606	11.9877989	3.853836223	22.4557847	10.42948494	127.8444931	0.962502337	1.132489204	7.580875888	22.13471165	11.95247412	291.8727773	0.848927726	17.79081662
2007	Chinook_1	0.920351544	0.605417304	0.55719675	120.87	123.23	129.47	15.70214823	24.37049418	13.15608788	184.3533156	0.936246174	11.46169359	4.957941048	17.81328382	11.89204922	68.44199371	0.965548635	1.094354916	7.662223019	21.24761167	13.6193374	243.8244171	0.879951119	17.13318952
2008	Chinook_1	0.902274752	0.731506469	0.660019817	107.41	112.13	120.36	20.81229638	18.99225373	10.70697124	141.630179	0.911723226	9.860057541	8.151316971	11.1369262	9.57006855	60.82829208	0.902300012	0.678269243	8.886300884	18.05682375	11.04602242	181.1583989	0.875437617	14.2479349

5519 **Table 4-8. Snake River_MO3_Chinook_SAL_W_Wildfish Raw_Data**

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
SCN MO3-RESSIM-SAL-W																										
1929	Chinook_1	0.928357245	0.660388861	0.613076784	124.99	127.68	135.31	15.61414757	25.39925313	12.249997	116.4245761	0.913621298	9.445647052	4.620796092	18.69584258	11.09575596	54.09363785	0.898328197	0.75318675	8.32892593	19.66939881	12.66242043	143.7363892	0.883176486	13.83508452	155.6888428
1930	Chinook_1	0.905715686	0.667377405	0.604454184	103.93	109.4	117.67	20.84318539	18.6661567	11.02845594	119.3109662	0.921401339	9.321961948	7.829573594	11.69708146	9.682554626	59.33450851	0.908602405	0.663420486	9.104318202	17.41190759	11.44944302	148.4239655	0.892768006	13.48886887	156.8544769
1931	Chinook_1	0.897166759	0.67031142	0.601381124	106.55	111.67	120	21.5591597	18.41557936	11.10570138	104.4473452	0.907451957	8.917138253	8.50026194	10.74549776	9.566019058	42.97081604	0.891246021	0.655017328	9.243554853	17.21636423	11.56169287	133.8507538	0.874683022	12.98325332	142.3947296
1932	Chinook_1	0.929680119	0.737970911	0.686076884	117.64	120.5	127.95	16.22781984	23.56081621	11.40538113	210.8462219	0.923208679	11.6433943	4.995455891	17.43620728	10.32642632	82.57201233	0.960838521	1.024285984	7.979636677	20.75241093	11.69129944	272.749911	0.853455196	17.2168088	288.116394
1933	Chinook_1	0.927657514	0.617036848	0.572398868	131.16	133.78	140.86	14.22815643	27.68639439	13.04152441	163.1537566	0.942810446	11.26976153	4.46476157	19.48336896	11.63727741	56.05530777	0.96332314	1.101433849	7.250796698	22.91051072	13.71642288	217.2336884	0.897121797	16.87941408	226.2290649
1934	Chinook_1	0.921984172	0.634071161	0.584603574	114.54	117.26	123.07	16.62890626	22.66440404	12.37452568	227.4601075	0.909600449	11.9346512	5.161730133	16.98495696	11.14434586	78.89875641	0.953875625	1.109517002	7.935626559	20.59129958	12.7882568	307.5053304	0.827504883	17.69172303	314.8951111
1935	Chinook_1	0.928366336	0.588027961	0.545905364	125.64	128.12	135.26	14.34832015	27.11159217	13.26330921	165.5472161	0.940769945	11.14373895	4.243967913	20.44746447	11.80034485	62.74397888	0.959525144	1.038751221	7.448547184	22.12645172	13.95136674	216.6394374	0.895525744	16.63037157	228.8704224
1936	Chinook_1	0.94292368	0.725616399	0.684200886	116.42	118.93	126.33	15.22456141	25.09445139	11.10381896	235.7620168	0.923186983	11.86958299	4.132692635	20.95292767	10.02758312	127.4037766	0.967074478	1.1084198	7.8848138	21.1173631	11.44130691	291.1449331	0.848207633	17.60522461	302.5773315
1937	Chinook_1	0.919801304	0.668925496	0.615278543	124.7	127.36	134.46	16.82828362	23.77596712	12.18555219	134.1540105	0.925462646	10.08149457	5.835220024	15.54447275	10.68247204	54.94858475	0.921893406	0.810753727	8.132963262	20.14746941	12.70344369	171.6011963	0.891169012	14.82595269	185.3708344
1938	Chinook_1	0.9428013	0.629320011	0.593323724	129.62	131.99	136.62	13.12980019	29.43547309	12.9312597	230.0714395	0.918362443	12.00424184	3.458891086	24.76891889	11.4953577	108.5496277	0.960557067	1.14256773	6.989955246	24.18111903	13.50489426	294.9294128	0.842381616	17.72536898	304.2151794
1939	Chinook_1	0.932663434	0.730297054	0.681121359	116.26	119.3	126.63	16.09688574	23.73185555	11.05243015	179.6031669	0.941351069	11.1677865	4.777873665	18.23326605	10.25021286	84.20984497	0.965126467	0.95206461	8.127569884	20.10714516	11.33248631	227.765007	0.89221408	16.67483012	237.5539093
1940	Chinook_1	0.897181013	0.741841107	0.665565756	95.01	101.29	110.58	23.14981412	16.80789933	9.979395594	159.7398491	0.870330636	9.803946665	9.067651533	10.05293569	8.90916481	83.4686203	0.855995822	0.572818279	9.50826332	16.82794299	10.31166538	196.356753	0.817441692	14.14873425	207.4420776
1941	Chinook_1	0.918098565	0.491367568	0.451123859	132.94	135.1	136.18	14.34438361	26.83996943	14.30083254	139.9344474	0.93625385	10.41355865	4.073638529	21.2303918	13.41648827	57.05632095	0.941843772	0.89277029	7.540341422	21.50623326	14.66612307	182.7448807	0.899722715	15.4876922	189.7191925
1942	Chinook_1	0.935438284	0.670121098	0.62685693	135.78	137.98	144.4	14.07071905	28.20495423	12.51990162	185.4200352	0.92574163	11.05964201	4.391121432	20.29452976	11.2254137	82.89598694	0.948317802	0.956099224	7.151454926	23.6046947	13.06309144	235.7948583	0.869799376	16.31995535	249.0049591
1943	Chinook_1	0.935659055	0.711049889	0.665300267	122.41	124.62	130.89	16.04456062	23.97664466	11.5868003	227.2685285	0.914344783	11.7258968	4.952138975	18.10939747	10.18534355	122.8862	0.951875997	1.063215733	7.859501831	21.05050102	12.05805842	286.6865387	0.840241869	17.32282909	291.9403381
1944	Chinook_1	0.931310454	0.589108693	0.548643084	130.65	133.04	140.54	14.26953673	27.78881458	13.11945779	130.5085733	0.93191106	10.07825814	4.167114973	20.84824354	11.71320038	62.59826965	0.926839221	0.863035774	7.637243986	21.52553226	13.79637162	165.9525757	0.90209341	14.91286413	173.5774841
1945	Chinook_1	0.924807161	0.68801211	0.636278526	118.92	122.12	129.37	16.29735523	23.89111577	11.94898605	161.1848962	0.92267225	10.53424805	5.181002282	17.04313545	10.72434158	67.20752563	0.927726293	0.799880028	8.103697516	20.28813519	12.32439089	203.4799296	0.879796724	15.51340143	221.3555756

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	MedDayLGR	MedDayConfl	MedDayBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1946	Chinook_1	0.935184073	0.771318153	0.721324452	110.64	113.62	121.69	17.25354118	22.05161905	10.39500557	251.0249525	0.909397164	12.05411656	5.259769082	16.71379025	9.310554695	114.8619568	0.95593766	0.97758646	8.359643765	19.88627815	10.59841601	320.7272746	0.825312018	17.6318388	335.7413025
1947	Chinook_1	0.927380933	0.689266364	0.639212484	110.45	113.93	121.75	17.2759674	21.89473134	11.5767389	204.6822602	0.931122414	11.50056989	5.478531554	16.12173416	9.992050362	86.89625397	0.962491655	0.955011559	8.238034755	19.6479517	12.04440371	259.0696106	0.870543182	17.0072217	274.3099976
1948	Chinook_1	0.945119325	0.631212744	0.596571363	132.96	134.96	138.9	11.8433664	32.73970281	13.25773478	313.9151862	0.911958673	14.37064889	3.100323163	27.59181269	12.01188374	133.5401215	0.967187107	1.3467103	6.224513762	28.00791802	13.75130812	402.9443919	0.821914375	21.22877169	422.6490479
1949	Chinook_1	0.941611146	0.574706819	0.541150347	126.06	128.17	134.13	12.59286495	30.782015	13.63211877	263.9463283	0.911411801	12.70895403	3.166792646	26.95728627	12.16335049	118.1861816	0.962479687	1.203732204	6.777512379	25.19968191	14.31540887	330.8536174	0.824561338	18.30514701	355.4908752
1950	Chinook_1	0.94036978	0.687408497	0.646418178	132.28	134.4	140.49	13.33911378	29.26868728	12.44174596	208.9338139	0.928749778	11.58676846	3.772573136	22.84777049	11.26592464	89.06238098	0.965813947	1.076886272	7.015434071	24.18215191	12.89964469	267.1746852	0.862238169	17.15840705	284.1130066
1951	Chinook_1	0.940750052	0.646447492	0.608145512	130.78	132.73	139.02	13.08679114	29.5947293	12.93380063	261.100514	0.903174537	12.55835734	3.752009198	23.14820785	11.39031487	105.1453979	0.955452979	1.160851383	6.672856867	25.73017306	13.61551523	341.1260376	0.811197539	18.19406907	356.9513245
1952	Chinook_1	0.948563121	0.725084227	0.687788157	125.29	127.26	133.35	13.51345792	28.65859	11.7980002	288.9339458	0.893868289	12.60081226	3.539834403	24.41712368	10.65001907	157.7332123	0.94629916	1.073069286	7.090015888	24.32481543	12.19655816	355.4608307	0.797111829	18.17847077	369.7636108
1953	Chinook_1	0.932248763	0.669975253	0.6245836	132.34	134.84	141.57	14.5384144	26.94388853	12.46399437	199.0854972	0.920639162	11.33709363	4.667881675	18.88274721	11.04626389	82.66471863	0.950010598	1.003823853	7.169836618	23.44053174	13.06891155	255.7379532	0.856482973	16.66896693	270.6851196
1954	Chinook_1	0.942225263	0.69061057	0.650710726	139.47	141.18	145.82	12.98163103	30.11547434	12.4458174	238.6945724	0.909547099	12.09502762	3.857077681	22.60513913	11.16204472	101.815036	0.952953672	1.094530773	6.61133185	25.98620794	12.98049911	310.9767456	0.828148872	17.71284389	321.0226135
1955	Chinook_1	0.939907352	0.648403469	0.609439188	135.09	137.18	143.18	13.33498262	29.47321137	12.78401143	185.8551423	0.932727316	11.22092761	3.834919341	22.61800312	11.27868443	84.46255035	0.95787344	1.015513134	7.038611092	23.94228091	13.46064043	237.0767568	0.878135989	16.64743392	249.609375
1956	Chinook_1	0.942830813	0.731503672	0.689684202	117.66	119.99	126.58	14.85357446	25.69955246	11.27465568	302.6483721	0.897261828	13.54893126	4.175037801	20.7840104	10.15770817	138.2622681	0.956456435	1.195939445	7.445017643	22.83812743	11.65659555	391.3129832	0.796564112	19.64556964	407.2499695
1957	Chinook_1	0.93420003	0.712974366	0.666060674	117.2	120.63	126.56	15.64924931	24.26768902	11.50165367	254.7900124	0.91012222	12.48391996	4.874808751	18.01972988	10.44516907	121.3573898	0.949143672	1.010146332	7.500547677	22.04596233	11.88011662	319.1820882	0.832665871	18.07788976	335.2315063
1958	Chinook_1	0.945098289	0.677667818	0.640462696	127.42	129.53	134.78	12.67661649	30.70322459	12.53825276	265.0110964	0.910099298	12.62663443	3.369606204	25.3395453	11.3269207	118.6450653	0.961831141	1.12254343	6.725796096	25.74195715	12.97789256	334.7067719	0.822039167	18.29989735	355.9057922
1959	Chinook_1	0.937574189	0.618094196	0.579509165	136.17	138.11	143.76	12.90572157	30.07717962	13.26790633	216.0809065	0.925344642	11.94332153	3.689203463	23.2951907	11.81298332	81.67079468	0.968663418	1.168298054	6.700755835	25.34666963	13.89464839	285.3157247	0.851918221	17.72595628	295.8647461
1960	Chinook_1	0.939273595	0.642865181	0.603826289	134.4	136.23	141.48	13.4435164	29.01829826	12.83479146	202.0211225	0.928103643	11.64252291	3.949062288	21.99997941	11.22958927	87.2541687	0.962797773	1.129856777	6.945016883	24.29223141	13.52760204	263.2388763	0.863244593	17.33662446	272.1536255
1961	Chinook_1	0.919747768	0.65404419	0.601555683	118.75	121.99	128.42	16.72839127	23.18204857	12.32017013	178.2271808	0.93108362	11.24308021	5.695669383	15.6826935	10.75580101	61.61362991	0.955645823	0.983410835	7.875345595	20.74029479	12.91482051	236.8989131	0.876157304	16.64345519	246.2315369
1962	Chinook_1	0.936064364	0.701709363	0.656845128	119.62	122.22	129.47	15.28701611	25.12688982	11.84704542	192.7912619	0.937266205	11.51029338	4.443298809	19.54585256	10.53264713	89.14200134	0.971485114	1.115723515	7.819613539	21.16719134	12.25541528	248.4374568	0.877383858	17.22079865	254.2403564
1963	Chinook_1	0.922118709	0.632716658	0.583439868	118.22	121.31	127.83	16.80927831	22.87640296	12.38530724	155.2652032	0.930187894	10.52444322	5.453058347	16.24292243	10.84863815	68.49351196	0.936803067	0.851952267	8.149402574	19.87273529	12.96026754	198.6662725	0.889769624	15.53909707	208.2541809
1964	Chinook_1	0.942494274	0.625559549	0.589586293	133.63	135.81	142.03	12.58996022	31.23691135	13.23946272	214.7156176	0.921702453	11.59369547	3.510752045	24.59205289	11.49808865	92.38935547	0.956769037	1.038137913	6.688321568	25.65391146	13.98641904	273.7887929	0.853331635	17.08172274	288.8950806
1965	Chinook_1	0.941251681	0.53172566	0.500487671	144.43	145.95	145.8	11.5413539	33.98329551	14.02750955	261.5578799	0.899217712	12.33797417	2.765829861	30.83941682	13.28970165	135.6426117	0.950970209	1.166245174	6.350620344	27.22420967	14.34511995	328.2438914	0.805699408	18.00134134	335.8592224
1966	Chinook_1	0.91776341	0.70931603	0.650984298	111.14	115.02	123.18	18.3648573	20.876761	11.05357674	145.3671611	0.936785919	10.34624887	6.198017053	14.27082342	10.03481083	60.78222275	0.945206892	0.850830936	8.658792965	18.55111284	11.40186898	187.0498098	0.898161858	15.28496393	197.3336334
1967	Chinook_1	0.927480631	0.72076884	0.668499139	125.08	128.22	135.3	15.42005945	25.49679496	11.61102343	171.7115816	0.926491231	10.92439246	5.019380093	17.31911221	10.62183495	56.82792053	0.941828096	0.904004383	7.644236095	21.84263557	11.98564021	225.2710597	0.876956294	16.06693236	238.6222229
1968	Chinook_1	0.921347794	0.432473416	0.398458428	139.77	141.64	143.21	12.71497348	30.52794186	15.08551659	169.6152485	0.919785261	10.7282705	3.302830435	25.87403081	14.55237217	69.4795929	0.937691772	0.969315243	6.955081396	23.64994323	15.31961234	219.468928	0.864755889	15.82570632	229.3779144
1969	Chinook_1	0.937039861	0.679528951	0.636745714	117.41	119.97	126.74	15.46070144	24.61449907	12.05850513	246.300348	0.91200327	12.24280749	4.547307834	19.23751374	10.33544292	112.4046646	0.961330724	1.145501614	7.66193717	21.70353055	12.68593597	315.6274719	0.826899171	17.97530365	322.8534546
1970	Chinook_1	0.933650678	0.69065435	0.644829902	127.1	129.39	135.97	14.80566791	26.38582776	12.04041215	179.9658661	0.914855961	10.68964471	4.516891666	19.27573168	10.89266911	86.61368408	0.929344296	0.861142731	7.557863615	22.07096482	12.48099995	225.1454442	0.860210627	15.69011251	234.0076141
1971	Chinook_1	0.950421234	0.636456445	0.60490172	138.89	140.6	144.3	10.77596619	36.49665958	13.47600072	325.1509432	0.884797924	13.86473915	2.661568828	31.93759469	12.33267479	152.385495	0.957174885	1.256460953	5.784659103	31.10767442	13.95049334	419.1665192	0.766882931	19.87914181	424.7606201
1972	Chinook_1	0.942491373	0.649117034	0.611787204	125.5	127.69	133.18	13.03607337	29.3573705	12.96499518	280.9304395	0.912703148	13.41989613	3.54624708	24.20599601	11.46660709	119.6628113	0.97017132	1.250487137	6.711715788	25.29125163	13.54101864	365.9802806	0.821164727	19.73440361	368.1121521
1973	Chinook_1	0.913193272	0.611634707	0.558540699	121.06	124.33	130.03	17.34924465	22.76162748	12.49716234	122.4352643	0.908939417	9.590033531	6.078401223	14.72326771	11.07201538	50.61755295	0.902614748	0.808424759	8.245299086	19.68059114	13.04298321	158.3396784	0.868679911	14.16824961	165.3374481
1974	Chinook_1	0.945961269	0.604379063	0.571719185	135.51	137.44	142.07	11.51614597	33.81150239	13.72167982	304.6633977	0.893124142	13.60874588	2.917803772	29.21484027	12.35430679	135.994458	0.956823778	1.263627911	6.125857674	28.68114484	14.3077693	396.9584961	0.786602904	19.77946806	401.2987976
1975	Chinook_1	0.94676303	0.609644962	0.577189311	145.26	147.18	151.03	11.29261836	34.80044401	13.55729328	257.3763172	0.907076223	12.47009509	2.866186619	29.72577534	12.36120605	125.9185928	0.960694695	1.197625542	6.155119143	28.29045785	14.07452027	326.6459045	0.815932463	18.15838575	333.7466431
1976	Chinook_1	0.94451281	0.743425442	0.702174853	121.33	123.77	130.84	14.29871897	26.92945574	11.43038845	257.1501312	0.914548814	12.45945161	3.954241969	21.83101861	10.26920013	120.8968262	0.96657778	1.160975838	7.381582856	23.03168937	11.80424134	323.7626343	0.828465879	18.18076038	334.5292053
1977	Chinook_1	0.909786448	0.526476252	0.478980959	129.65	132.32	137.55	15.80582208	24.92664553	13.81714719	104.3206471	0.91868071	9.315673419	5.047585279	17.38200224	12.73987713	37.89460449	0.907703424	0.80447979	8.054873206	20.0123951	14.26644484	138.8616689	0.887168994	13.6734217	144.9742737
1978	Chinook_1	0.923525729	0.747228532	0.690084775	109.73	113.34	121.64	18.34812308	20.86712834	10.68697786	192.4246189	0.929825672	11.25661155	6.247914135	14.36029351	9.533019066	87.91951752	0.95799787	0.940094376	8.454946823	19.14117334	11.07270447	243.161555	0.871262779	16.72959963	256.4623718
1979	Chinook_1	0.916696722	0.744508453	0.682488458	112.4	115.78	124.2	18.71572306	20.87689447	10.75218507	160.2203603	0.919000485	10.47224006	6.556150682	13.72775406	9.737675476	61.28513336	0.922333229	0.732594442	8.694164589	18.77789584	11.05236419	201.1289876	0.875723879	15.32460459	224.0758667
1980	Chinook_1	0.94623682	0.642720276	0.608165591	136.29	138.34	144.09	12.02897976	32.55487704	13.18410907	252.7318202	0.90324226	12.32364699	3.151192054	27.12809575	11.69546432	110.1160034	0.952361441	1.145692348	6.452726185	26.97968409	13.82061466	330.4660034	0.813931356	18.07436895	336.9369812
1981	Chinook_1	0.916968267	0.550056384	0.50438425	128.43	130.94	130.42	15.67624462	24.43885151	13.58913864	181.7198993	0.913013918	10.83764631	5.086183272	17.48265757	12.68612442	78.56468964	0.931120825	0.917032146	7.509309687	21.68622288	13.93286371	234.2440898	0.854432225	15.90608851	243.5005341
1982	Chinook_1	0.942309848	0.547608554	0.516016934	142.91	144.55	146.04	11.35462605	34.30107996	14.25369358	273.2094776	0.903875249	12.8977684	2.856555156	29.84335955	13.15684605	125.3093582	0.962913072	1.232223797	6.108978271	28.40835315	14.73411783	352.0756276	0.806614707	18.77580198	356.8670349
1983	Chinook_1	0.934794136	0.640478448	0.598715497	123.11	125.5	130.43	14.51615298	26.35001812	12.73253148	217.8641859	0.919320575	11.69385413	4.240389757	20.52435274	11.36320229	101.2793457	0.95906353	1.057750702	7.328883894	22.65651841	13.23821799	278.999349	0.845861981	17.22938426	287.1174316
1984	Chinook_1	0.94400516	0.6107048	0.576508483	129.19	131.42	136.54	12.57447059	31.03025625	13.26034886	219.4318216	0.927732246	11.73177161	3.102400057	27.42957441	12.14361057	123.3448364	0.967642426	1.134802437	6.935248218	24.33579357	13.65525277	269.9874725	0.858339926	17.45892	275.1799316
1985	Chinook_1	0.929962644	0.75177095	0.6991189	109.72	112.84	121.27	18.11582492	21.00901367	10.45505326	189.7880189	0.933354672	11.24312976	5.816444643	15.33226732	9.259793091	107.2824631	0.957647622	1.007415676	8.638843872	18.73299949	10.83036725	237.2470093	0.879788329	16.85447963	239.7513123
1986	Chinook_1	0.930119178	0.611158673	0.568450403	122.65	125.02	127.59	15.66390194	24.13363297	12.49084336	201.3202199	0.924847352	11.4492165	4.704209402	18.72195743	11.27041702	104.3336731	0.957410884	1.040338707	7.694690824	21.10517285	12.96448421	254.3580043	0.860135019	17.01057053	256.9103088
1987	Chinook_1	0.916999568	0.556915952	0.510691687	117.95	120.58	126.6	15.50325859	24.52491067	13.3676719	186.6519863	0.927787112	11.38061721	4.629806578	18.81898763	12.31899204	57.82825012	0.955830932	1.033363342	7.741961546	21.09032682	13.76416	250.6776148	0.868311405	16.86145226	265.0837097
1988	Chinook_1	0.907851691	0.733173252	0.665612577	109.15	112.86	121.25	20.48248313	19.37168307	10.49605928	140.0291195	0.933873377	10.27026531	7.910552666	11.72246198	9.335994148	59.47561111	0.933925879	0.779426765	8.886822343	18.03544632	10.89973752	183.347702	0.900767098	15.20299387	190.3101501
1989	Chinook_1	0.940908683	0.568672679	0.535069062	141.85	143.9	148.52	12.65472893	30.90013625	13.53968722	185.3334454	0.938927868	11.56930849	3.409482844	24.97608008	11.81730518	78.12469025	0.969640326	1.162176704	6.840721935	24.70346833	14.29802497	242.5163371	0.882798155	17.32834816	246.6417389
1990	Chinook_1	0.923189594	0.434070986	0.400729817	131.6	133.82	138.25	13.07381677	29.62345846	14.92803274	157.9730331	0.944407059	11.13117405	3.431225017	24.8303309	13.88313637	62.96385422	0.96513468	1.137556171	7.134627737	22.93533546	15.34020456	212.437439	0.899337659	16.71860949	211.2398376
1991	Chinook_1	0.92111316	0.640586694	0.590052834	123.59	126.65	131.83	15.96501416	24.35283784	12.54200969	184.3834122	0.925236097	11.3217377	5.417795964	16.39552016	11.0617485	60.4889595	0.952485096	1.000993538	7.54182338	21.85990735	13.12295262	250.767156	0.865146806	16.7612319	252.3577881
1992	Chinook_1	0.910810052	0.544127735	0.495597011	121.11	123.73	128.39	15.89444603	23.88094742	13.50608451	143.9428079	0.933919792	10.49935906	4.775075763	18.23057276	12.79803829	49.30284119	0.939830983	0.874329376	7.977134332	20.15477689	13.73491716	192.6713613	0.895954231	15.60594257	198.5697021
1993	Chinook_1	0.933821883	0.728200206	0.680009288	120.74	123.53	131.11	15.52881972	24.98698997	11.35056087	181.449598	0.921542896	10.83734051	4.602341816	18.79821446	10.44984303	78.15470886	0.929125226	0.757965136	7.986709952	20.85676949	11.64633528	222.5053584	0.875995984	15.81847413	241.0409851
1994	Chinook_1	0.924724046	0.478607948	0.442580278	128.68	130.92	136.2	13.47905357	28.81354085	14.07383565	159.7593907	0.941056209	11.13523851	3.671446666	23.33482813	12.9633976	60.64072266	0.958910322	1.078376007	7.258037418	22.69643285	14.63310623	213.3847427	0.896706412	16.663836	221.3806305
1995	Chinook_1	0.931189519	0.648575576	0.603946778	127.36	129.61	135.26	15.14827235	25.44026998	12.49478258	191.1623753	0.921734312	11.06263689	4.729979694	18.64473668	11.09065399	92.08553772	0.945824325	0.969075108	7.474182501	22.08428898	13.07465458	241.1202189	0.862526973	16.31427908	251.1134033

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	MedDayLGR	MedDayConfl	MedDayBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1996	Chinook_1	0.936483339	0.536659398	0.502572585	140.7	142.07	143.92	11.70786005	33.25943092	14.41256693	259.6054459	0.900391557	12.41698228	2.894296721	29.45435112	13.74603443	122.2700714	0.951605511	1.168589115	6.356456138	27.03757343	14.66434844	331.6889496	0.80790927	18.04236031	342.5517273
1997	Chinook_1	0.946430549	0.56759401	0.537188311	134.64	136.19	138.76	11.04769084	35.2216239	13.94577312	359.0536575	0.891592064	15.3644899	2.685642488	31.7096264	12.71912651	161.8798187	0.961983311	1.42484169	5.845867239	30.33914993	14.50276311	462.907252	0.778728803	22.30342436	472.0581055
1998	Chinook_1	0.926089561	0.673411068	0.62363896	116.01	118.99	125.84	16.50233982	23.28649212	12.15619176	221.6330828	0.909726718	11.57903406	5.388713598	16.47037562	10.52623863	89.67572021	0.940230286	0.901768494	7.827654161	21.11601171	12.72366683	281.9791361	0.839171072	16.77839613	300.8494873
1999	Chinook_1	0.933498789	0.6440518	0.601221575	121.06	123.27	129.55	15.34908157	24.84555804	12.51363856	208.5366336	0.926728249	11.65984389	4.460633345	19.59851642	10.97312603	99.10372162	0.96206826	1.083430195	7.75849174	21.18066698	13.11939955	269.2292633	0.860644897	17.36858368	273.2830505
2000	Chinook_1	0.934128531	0.491964452	0.459558031	131.06	133.15	136.33	12.89917924	30.00482797	13.99807903	192.2661029	0.938069833	11.68468107	3.307569943	25.86380102	12.75286827	87.11137543	0.971442997	1.214183807	7.015308201	23.6310689	14.55499999	248.8124034	0.87929367	17.53622659	256.7235718
2001	Chinook_1	0.901998114	0.668820721	0.603275029	110.85	115.27	123.55	20.30370936	19.65049962	11.61719356	106.9310028	0.902305322	9.162345988	7.732205547	11.81471181	9.812289238	40.84489517	0.877699685	0.642381001	9.065834157	17.72747057	12.18252468	138.8234444	0.87396268	13.34401735	150.6756744
2002	Chinook_1	0.930664983	0.692019062	0.644037909	119.9	122.82	129.7	15.680272	24.53646591	11.87192815	177.3372116	0.940441281	11.39164284	4.828399539	18.02926746	10.54598541	70.11482849	0.967599273	1.07222271	7.846530214	20.92437974	12.28840812	234.8616511	0.888030926	17.06499465	242.4504547
2003	Chinook_1	0.933996581	0.625510205	0.584224393	130.58	133.05	140.1	13.88954074	27.98336534	12.94375944	189.1425182	0.933400933	11.46981124	4.058642268	21.32613473	11.54360847	76.90997314	0.95915066	1.04174099	7.218223877	23.03570869	13.57815647	240.9558792	0.878643284	16.90962474	260.7068481
2004	Chinook_1	0.911677585	0.720735875	0.657078742	107.4	111.8	120.19	20.04435213	19.42595846	10.84661627	156.8628693	0.934568724	10.65870864	7.491854139	12.13189929	9.239259338	60.71099243	0.944861388	0.831694698	8.787384219	18.19309401	11.32144101	202.0887909	0.893276095	15.75589188	219.9562683
2005	Chinook_1	0.920659327	0.577970625	0.532114046	122.67	125.34	131.08	15.45239247	24.87703169	13.42231921	160.7789759	0.934611333	10.75613764	4.737477459	18.55627983	12.15538731	67.1325058	0.947854865	0.95613308	7.759533256	20.92396858	13.89541594	206.7044169	0.890881052	15.93471718	216.4258423
2006	Chinook_1	0.944676789	0.727941282	0.687669233	121.51	123.64	130.82	14.39976376	26.76108028	11.59064014	235.8189278	0.921862606	11.9877989	3.853836223	22.4557847	10.42948494	127.8444931	0.962502337	1.132489204	7.580875888	22.13471165	11.95247412	291.8727773	0.848927726	17.79081662	297.8620911
2007	Chinook_1	0.920351544	0.605417304	0.55719675	120.87	123.23	129.47	15.70214823	24.37049418	13.15608788	184.3533156	0.936246174	11.46169359	4.957941048	17.81328382	11.89204922	68.44199371	0.965548635	1.094354916	7.662223019	21.24761167	13.6193374	243.8244171	0.879951119	17.13318952	253.0918427
2008	Chinook_1	0.902274752	0.731506469	0.660019817	107.41	112.13	120.36	20.81229638	18.99225373	10.70697124	141.630179	0.911723226	9.860057541	8.151316971	11.1369262	9.57006855	60.82829208	0.902300012	0.678269243	8.886300884	18.05682375	11.04602242	181.1583989	0.875437617	14.2479349	192.9043579

Table 4-9. Snake River_MO3_Chinook_SAL_HW_Wildfish Raw_Data

Year	Species	InRivSurvSNK	InRivSurvLCol	InRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
SCN MO3-RESSIM-SAL-HW																						
1929	Chinook_1	0.928357245	0.663241138	0.615724715	124.99	127.68	135.22	4.620796092	18.69584258	11.09575596	54.09363785	0.926754498	0.75318675	8.239862502	19.73869295	12.64982144	143.4582901	0.897204896	13.82458091	155.3191376	0.721357667	0.479128455
1930	Chinook_1	0.905715686	0.669794688	0.606643556	103.93	109.4	117.55	7.829573594	11.69708146	9.682554626	59.33450851	0.933146691	0.663420486	9.006323993	17.48631561	11.43564685	148.2828293	0.905412883	13.47640864	156.6886139	0.667089083	0.493489616
1931	Chinook_1	0.897166759	0.673322238	0.60408233	106.55	111.67	119.89	8.50026194	10.74549776	9.566019058	42.97081604	0.917611587	0.655017328	9.133262418	17.29348145	11.54120938	133.7082278	0.888176262	12.97230148	142.1733398	0.68359845	0.506085085
1932	Chinook_1	0.929680119	0.738292445	0.686375809	117.64	120.5	127.92	4.995455891	17.43620728	10.32642632	82.57201233	0.970048988	1.024285984	7.953401983	20.77201338	11.68748871	272.6408437	0.863793353	17.21590281	287.9810181	0.775746599	0.561399976
1933	Chinook_1	0.927657514	0.618050463	0.573339156	131.16	133.78	140.84	4.46476157	19.48336896	11.63727741	56.05530777	0.977275312	1.101433849	7.21811083	22.94945364	13.71609894	217.1445516	0.905762891	16.87788757	226.084259	0.689152871	0.452978439
1934	Chinook_1	0.921984172	0.63430988	0.584823669	114.54	117.26	123.05	5.161730133	16.98495696	11.14434586	78.89875641	0.962951398	1.109517002	7.910318844	20.61534151	12.78478209	307.4966736	0.842089842	17.69121091	314.8917542	0.655469419	0.491222539
1935	Chinook_1	0.928366336	0.589334152	0.547117987	125.64	128.12	135.22	4.243967913	20.44746447	11.80034485	62.74397888	0.97624929	1.038751221	7.412624091	22.16636332	13.94932238	216.542689	0.904879669	16.62836742	228.7690125	0.66520685	0.41529457
1936	Chinook_1	0.94292368	0.725787635	0.684362348	116.42	118.93	126.3	4.132692635	20.95292767	10.02758312	127.4037766	0.977493989	1.1084198	7.855603978	21.14027477	11.43790976	291.1034139	0.861323029	17.60401789	302.5303955	0.747185788	0.578085168
1937	Chinook_1	0.919801304	0.671146326	0.617321266	124.7	127.36	134.41	5.835220024	15.54447275	10.68247204	54.94858475	0.945712519	0.810753727	8.06501469	20.20556713	12.69368696	171.4309845	0.902765075	14.81843249	185.1851654	0.718340843	0.486177493
1938	Chinook_1	0.9428013	0.629521195	0.5935134	129.62	131.99	136.6	3.458891086	24.76891889	11.4953577	108.5496277	0.969272459	1.14256773	6.970343128	24.20331774	13.50309261	294.8815918	0.855849624	17.72454214	304.1505737	0.68442386	0.500519153
1939	Chinook_1	0.932663434	0.731213437	0.681976035	116.26	119.3	126.59	4.777873665	18.23326605	10.25021286	84.20984497	0.97961868	0.95206461	8.087913424	20.14072318	11.32936859	227.6637472	0.901059459	16.67254194	237.4466248	0.743088443	0.565992173
1940	Chinook_1	0.897181013	0.742712704	0.666347736	95.01	101.29	110.51	9.067651533	10.05293569	8.90916481	83.4686203	0.863576818	0.572818279	9.460835293	16.85600007	10.30773735	196.2595113	0.822981685	14.14470164	207.3538208	0.727145559	0.527705986
1941	Chinook_1	0.918098565	0.493396161	0.452986307	132.94	135.1	136.13	4.073638529	21.2303918	13.41648827	57.05632095	0.962566257	0.89277029	7.49218528	21.56433934	14.66070016	182.6404419	0.910226603	15.4824791	189.6040039	0.579117487	0.338307767
1942	Chinook_1	0.935438284	0.671149153	0.627818612	135.78	137.98	144.35	4.391121432	20.29452976	11.2254137	82.89598694	0.965047085	0.956099224	7.113450147	23.64040405	13.0600117	235.5717392	0.881979436	16.31633027	248.7467804	0.714020939	0.532304464
1943	Chinook_1	0.935659055	0.711297359	0.665531815	122.41	124.62	130.88	4.952138975	18.10939747	10.18534355	122.8862	0.960627377	1.063215733	7.834138677	21.07599561	12.05594778	286.7305196	0.853049695	17.32240311	291.9794312	0.749021977	0.563169822
1944	Chinook_1	0.931310454	0.590925301	0.55033491	130.65	133.04	140.48	4.167114973	20.84824354	11.71320038	62.59826965	0.951079655	0.863035774	7.579258025	21.58965751	13.79551586	165.8682454	0.913728426	14.90815695	173.5161591	0.67228397	0.423043543
1945	Chinook_1	0.924807161	0.689729067	0.63786638	118.92	122.12	129.29	5.181002282	17.04313545	10.72434158	67.20752563	0.950236261	0.799880028	8.039165817	20.33454015	12.31391048	203.023379	0.891943653	15.49829809	220.8336029	0.725533353	0.532332943
1946	Chinook_1	0.935184073	0.771101909	0.721122224	110.64	113.62	121.65	5.259769082	16.71379025	9.310554695	114.8619568	0.964967299	0.97758646	8.329153091	19.90520286	10.59236765	320.6518351	0.841193825	17.63082536	335.6883545	0.784962064	0.571880426
1947	Chinook_1	0.927380933	0.690091069	0.6399773	110.45	113.93	121.7	5.478531554	16.12173416	9.992050362	86.89625397	0.975447917	0.955011559	8.201914877	19.67619356	12.03587262	258.8485896	0.881453454	17.00418901	274.0377502	0.712865347	0.532115202
1948	Chinook_1	0.945119325	0.630634255	0.596024622	132.96	134.96	138.86	3.100323163	27.59181269	12.01188374	133.5401215	0.973454964	1.3467103	6.212298058	28.01236613	13.74781593	402.7114919	0.841107508	21.22118648	422.3431396	0.682546329	0.501276969

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1949	Chinook_1	0.941611146	0.57467434	0.541119764	126.06	128.17	134.11	3.166792646	26.95728627	12.16335049	118.1861816	0.971138489	1.203732204	6.761429861	25.21350864	14.31419945	330.6573639	0.840229799	18.30280765	355.2485352	0.647447379	0.424858619
1950	Chinook_1	0.94036978	0.687996791	0.646971392	132.28	134.4	140.46	3.772573136	22.84777049	11.26592464	89.06238098	0.978500319	1.076886272	6.988166861	24.20840262	12.89646228	267.0198491	0.874024898	17.15627495	283.9216003	0.746000954	0.524038509
1951	Chinook_1	0.940750052	0.646071863	0.607792138	130.78	132.73	139	3.752009198	23.14820785	11.39031487	105.1453979	0.962851048	1.160851383	6.658380553	25.74358342	13.61442757	341.0569051	0.828355054	18.19307852	356.8728027	0.700071326	0.507302038
1952	Chinook_1	0.948563121	0.724390861	0.687130455	125.29	127.26	133.33	3.539834403	24.41712368	10.65001907	157.7332123	0.952232862	1.073069286	7.074994273	24.33571603	12.19411977	355.3974406	0.815536181	18.17764521	369.6945496	0.766291828	0.56966498
1953	Chinook_1	0.932248763	0.670684269	0.62524458	132.34	134.84	141.54	4.667881675	18.88274721	11.04626389	82.66471863	0.963035846	1.003823853	7.136217594	23.47014072	13.06417243	255.5237986	0.868219296	16.66242027	270.4333191	0.700204153	0.530137758
1954	Chinook_1	0.942225263	0.690524188	0.650629334	139.47	141.18	145.81	3.857077681	22.60513913	11.16204472	101.815036	0.961155427	1.094530773	6.591175959	26.00215234	12.97707033	310.8389537	0.843387206	17.71063169	320.8485107	0.739217437	0.548357117
1955	Chinook_1	0.939907352	0.649376869	0.610354094	135.09	137.18	143.15	3.834919341	22.61800312	11.27868443	84.46255035	0.973273134	1.015513134	7.003823698	23.97905391	13.45767927	236.9499054	0.889005661	16.6441342	249.4746857	0.710309469	0.498224031
1956	Chinook_1	0.942830813	0.730517814	0.688754705	117.66	119.99	126.59	4.175037801	20.7840104	10.15770817	138.2622681	0.960046601	1.195939445	7.436139166	22.84295589	11.65557337	391.1296692	0.815131992	19.64155881	407.0189819	0.74529955	0.598098587
1957	Chinook_1	0.93420003	0.712891317	0.66598309	117.2	120.63	126.48	4.874808751	18.01972988	10.44516907	121.3573898	0.958111489	1.010146332	7.471507877	22.06259203	11.87573687	318.8364512	0.847169886	18.07206059	334.7771301	0.724474882	0.586036635
1958	Chinook_1	0.945098289	0.677484047	0.640289013	127.42	129.53	134.74	3.369606204	25.3395453	11.3269207	118.6450653	0.97117933	1.12254343	6.706416637	25.75250368	12.97368447	334.4650167	0.838060091	18.29690504	355.6206055	0.721605223	0.541177968
1959	Chinook_1	0.937574189	0.618540239	0.579927363	136.17	138.11	143.74	3.689203463	23.2951907	11.81298332	81.67079468	0.978894567	1.168298054	6.679508828	25.37194204	13.89189736	285.24322	0.864681234	17.72503026	295.7714539	0.680907938	0.472769548
1960	Chinook_1	0.939273595	0.643443154	0.604369164	134.4	136.23	141.46	3.949062288	21.99997941	11.22958927	87.2541687	0.973897505	1.129856777	6.921292625	24.31964034	13.52531926	263.1848272	0.874287566	17.33599822	272.0845642	0.708676601	0.488229596
1961	Chinook_1	0.919747768	0.655184248	0.60260425	118.75	121.99	128.36	5.695669383	15.6826935	10.75580101	61.61362991	0.969704497	0.983410835	7.83823806	20.7723757	12.90828292	236.7375488	0.886421273	16.64094766	246.044754	0.689868878	0.505605335
1962	Chinook_1	0.936064364	0.702404429	0.657495756	119.62	122.22	129.44	4.443298809	19.54585256	10.53264713	89.14200134	0.982349348	1.115723515	7.789803714	21.19423823	12.25125249	248.4126867	0.886856963	17.22060442	254.2181549	0.742019176	0.527336656
1963	Chinook_1	0.922118709	0.634666021	0.585237412	118.22	121.31	127.76	5.453058347	16.24292243	10.84863815	68.49351196	0.95689857	0.851952267	8.091965444	19.92364453	12.95043262	198.5020243	0.901066542	15.5339032	208.074707	0.671159652	0.489117992
1964	Chinook_1	0.942494274	0.626186666	0.590177347	133.63	135.81	142.01	3.510752045	24.59205289	11.49808865	92.38935547	0.971550941	1.038137913	6.662766531	25.67829191	13.98245637	273.5558395	0.866659204	17.07802057	288.6371155	0.714211087	0.451514877
1965	Chinook_1	0.941251681	0.531608693	0.500377576	144.43	145.95	145.77	2.765829861	30.83941682	13.28970165	135.6426117	0.95936054	1.166245174	6.334494241	27.24293899	14.3451252	328.1638082	0.822462718	17.9994429	335.7718811	0.597366596	0.418367164
1966	Chinook_1	0.91776341	0.710897239	0.652435474	111.14	115.02	123.11	6.198017053	14.27082342	10.03481083	60.78222275	0.964766836	0.850830936	8.59162011	18.60154749	11.3954277	186.8302892	0.908937355	15.27993361	197.0668335	0.716803651	0.550772086
1967	Chinook_1	0.927480631	0.721887857	0.669537006	125.08	128.22	135.24	5.019380093	17.31911221	10.62183495	56.82792053	0.961050284	0.904004383	7.594456963	21.87951701	11.98006455	224.894165	0.889247576	16.05786689	238.1805573	0.744087681	0.550486151
1968	Chinook_1	0.921347794	0.433878443	0.399752947	139.77	141.64	143.16	3.302830435	25.87403081	14.55237217	69.4795929	0.95501703	0.969315243	6.919244632	23.69058379	15.31413603	219.2219823	0.877092779	15.81810188	229.0761261	0.574595784	0.283075587
1969	Chinook_1	0.937039861	0.679561201	0.636775933	117.41	119.97	126.7	4.547307834	19.23751374	10.33544292	112.4046646	0.969492793	1.145501614	7.639783129	21.72053702	12.68086195	315.5476278	0.841802905	17.97409534	322.7494507	0.724912853	0.536266298
1970	Chinook_1	0.933650678	0.691826851	0.645924608	127.1	129.39	135.9	4.516891666	19.27573168	10.89266911	86.61368408	0.948676729	0.861142731	7.501571	22.1127754	12.47384771	224.7757111	0.874355048	15.67931422	233.5615387	0.712595866	0.547157878
1971	Chinook_1	0.950421234	0.635299045	0.603801702	138.89	140.6	144.3	2.661568828	31.93759469	12.33267479	152.385495	0.95882988	1.256460953	5.781855084	31.1080233	13.9498388	419.086085	0.786630968	19.87769381	424.659668	0.70157818	0.504828537
1972	Chinook_1	0.942491373	0.648699162	0.611393364	125.5	127.69	133.13	3.54624708	24.20599601	11.46660709	119.6628113	0.975463521	1.250487137	6.699467972	25.29543562	13.5370868	365.7953695	0.837643961	19.73050499	367.8673706	0.691404906	0.518435254
1973	Chinook_1	0.913193272	0.61408111	0.560774738	121.06	124.33	129.92	6.078401223	14.72326771	11.07201538	50.61755295	0.925488114	0.808424759	8.168217577	19.74445656	13.03069035	158.1300176	0.88098368	14.15889899	165.07901	0.637086951	0.479877248
1974	Chinook_1	0.945961269	0.603413462	0.570805765	135.51	137.44	142.07	2.917803772	29.21484027	12.35430679	135.994458	0.959305787	1.263627911	6.121632688	28.68479882	14.3066783	396.8688456	0.806306402	19.77745104	401.187439	0.67070397	0.45585484
1975	Chinook_1	0.94676303	0.609510385	0.5770619	145.26	147.18	150.99	2.866186619	29.72577534	12.36120605	125.9185928	0.968297374	1.197625542	6.140501022	28.30116526	14.07195505	326.4931183	0.831149876	18.15639861	333.5541992	0.671157847	0.48701996
1976	Chinook_1	0.94451281	0.74312619	0.701892206	121.33	123.77	130.81	3.954241969	21.83101861	10.26920013	120.8968262	0.974516821	1.160975838	7.361222409	23.04344136	11.80036942	323.5615031	0.843233585	18.17840799	334.282074	0.782579656	0.600045344
1977	Chinook_1	0.909786448	0.529277181	0.481529207	129.65	132.32	137.5	5.047585279	17.38200224	12.73987713	37.89460449	0.933469534	0.80447979	7.985307954	20.08758073	14.26131884	138.8086065	0.90008078	13.67112811	144.9246216	0.592638734	0.363757509
1978	Chinook_1	0.923525729	0.747897091	0.690702206	109.73	113.34	121.59	6.247914135	14.36029351	9.533019066	87.91951752	0.969607198	0.940094376	8.417582348	19.16923826	11.06944895	243.0313288	0.87990578	16.7283872	256.3052368	0.756154021	0.564197621
1979	Chinook_1	0.916696722	0.746069712	0.683919659	112.4	115.78	124.12	6.556150682	13.72775406	9.737675476	61.28513336	0.945919383	0.732594442	8.617976129	18.82313951	11.0458498	200.5341899	0.888174961	15.30992802	223.416626	0.753047969	0.538413724
1980	Chinook_1	0.94623682	0.642519129	0.607975257	136.29	138.34	144.08	3.151192054	27.12809575	11.69546432	110.1160034	0.959941113	1.145692348	6.437539287	26.9974705	13.81822348	330.3928019	0.83071511	18.0730621	336.8589783	0.699804957	0.510350432
1981	Chinook_1	0.916968267	0.55128142	0.505507568	128.43	130.94	130.37	5.086183272	17.48265757	12.68612442	78.56468964	0.946115041	0.917032146	7.46695824	21.72565671	13.92365456	233.9461085	0.867104063	15.89580504	243.1517181	0.614237855	0.40212988
1982	Chinook_1	0.942309848	0.547253599	0.515682456	142.91	144.55	146.01	2.856555156	29.84335955	13.15684605	125.3093582	0.968404937	1.232223797	6.099171758	28.41383437	14.73233239	351.9441427	0.823171328	18.77408663	356.706543	0.654313961	0.402114933
1983	Chinook_1	0.934794136	0.640977757	0.599182248	123.11	125.5	130.4	4.240389757	20.52435274	11.36320229	101.2793457	0.969927776	1.057750702	7.302077278	22.68159313	13.23401642	278.8687744	0.858584056	17.22675276	286.9714355	0.669317688	0.512554673
1984	Chinook_1	0.94400516	0.611266742	0.577038959	129.19	131.42	136.5	3.102400057	27.42957441	12.14361057	123.3448364	0.97795428	1.134802437	6.91223751	24.35974867	13.65117757	269.8986257	0.87006711	17.458378	275.0627747	0.674789431	0.472922856
1985	Chinook_1	0.929962644	0.752493125	0.699790496	109.72	112.84	121.24	5.816444643	15.33226732	9.259793091	107.2824631	0.968920612	1.007415676	8.597940758	18.76483995	10.82669671	237.3315506	0.889238606	16.85472155	239.8343658	0.756317351	0.567001846
1986	Chinook_1	0.930119178	0.611817909	0.569063571	122.65	125.02	127.55	4.704209402	18.72195743	11.27041702	104.3336731	0.968245518	1.040338707	7.66722165	21.1335347	12.96167421	254.2948914	0.870465845	17.00908756	256.8279724	0.639497506	0.492320634

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1987	Chinook_1	0.916999568	0.558061895	0.511742517	117.95	120.58	126.56	4.629806578	18.81898763	12.31899204	57.82825012	0.972962296	1.033363342	7.704874985	21.12582988	13.7583677	250.3982417	0.880652914	16.8565189	264.8221741	0.615427684	0.405420252
1988	Chinook_1	0.907851691	0.734673837	0.666974885	109.15	112.86	121.19	7.910552666	11.72246198	9.335994148	59.47561111	0.953155231	0.779426765	8.818678841	18.08733034	10.89493942	183.342308	0.910386682	15.20033487	190.3459778	0.72821502	0.543624293
1989	Chinook_1	0.940908683	0.569677379	0.536014393	141.85	143.9	148.51	3.409482844	24.97608008	11.81730518	78.12469025	0.982060456	1.162176704	6.814088196	24.73973231	14.29627609	242.4506811	0.893027226	17.32799371	246.5485077	0.668755265	0.40903777
1990	Chinook_1	0.923189594	0.435609729	0.402150369	131.6	133.82	138.24	3.431225017	24.8303309	13.88313637	62.96385422	0.979002941	1.137556171	7.10595274	22.97903123	15.33722814	212.4357808	0.908875664	16.71885204	211.2241821	0.590973204	0.275269244
1991	Chinook_1	0.92111316	0.641417595	0.590818188	123.59	126.65	131.76	5.417795964	16.39552016	11.0617485	60.4889595	0.965980363	1.000993538	7.508171231	21.89041704	13.11829869	250.6120046	0.877359817	16.7591478	252.1783447	0.676031145	0.504924243
1992	Chinook_1	0.910810052	0.546076249	0.497371737	121.11	123.73	128.33	4.775075763	18.23057276	12.79803829	49.30284119	0.960463846	0.874329376	7.924595751	20.20892302	13.72724899	192.4604289	0.906869034	15.59798845	198.3365326	0.592840117	0.406568109
1993	Chinook_1	0.933821883	0.729584783	0.681302236	120.74	123.53	131.05	4.602341816	18.79821446	10.44984303	78.15470886	0.951518726	0.757965136	7.924098767	20.89588734	11.63792626	221.8816961	0.889297575	15.80519867	240.2672272	0.763356593	0.558999401
1994	Chinook_1	0.924724046	0.479909104	0.443783488	128.68	130.92	136.18	3.671446666	23.33482813	12.9633976	60.64072266	0.976173246	1.078376007	7.224264994	22.74149917	14.63220263	213.3206762	0.906580091	16.6626579	221.3425751	0.567297063	0.346396058
1995	Chinook_1	0.931189519	0.649613199	0.604913002	127.36	129.61	135.21	4.729979694	18.64473668	11.09065399	92.08553772	0.959877551	0.969075108	7.436397344	22.11887845	13.0687232	240.9718882	0.874117325	16.31101433	250.9286652	0.677863385	0.520884012
1996	Chinook_1	0.936483339	0.536556902	0.502476599	140.7	142.07	143.9	2.894296721	29.45435112	13.74603443	122.2700714	0.958481181	1.168589115	6.343264647	27.05190433	14.66326014	331.6008403	0.824040045	18.04080296	342.4441833	0.632749284	0.404299767
1997	Chinook_1	0.946430549	0.566202454	0.535871299	134.64	136.19	138.76	2.685642488	31.7096264	12.71912651	161.8798187	0.961773491	1.42484169	5.846291997	30.33602254	14.50329383	462.8523	0.801067054	22.30143468	471.9979858	0.649493542	0.431130159
1998	Chinook_1	0.926089561	0.674060213	0.624240126	116.01	118.99	125.79	5.388713598	16.47037562	10.52623863	89.67572021	0.954813766	0.901768494	7.788991205	21.14025883	12.71329308	281.4712499	0.854088823	16.76849063	300.2525635	0.718533039	0.532163184
1999	Chinook_1	0.933498789	0.644595396	0.601729022	121.06	123.27	129.54	4.460633345	19.59851642	10.97312603	99.10372162	0.972421694	1.083430195	7.731935576	21.20799847	13.11705494	269.2231191	0.872255584	17.36833064	273.2650757	0.704899032	0.494131822
2000	Chinook_1	0.934128531	0.492768224	0.460308857	131.06	133.15	136.31	3.307569943	25.86380102	12.75286827	87.11137543	0.982615006	1.214183807	6.992782906	23.6628869	14.55346775	248.8222631	0.888805687	17.53608322	256.7334595	0.582181795	0.365186945
2001	Chinook_1	0.901998114	0.67206265	0.606199243	110.85	115.27	123.45	7.732205547	11.81471181	9.812289238	40.84489517	0.90403831	0.642381001	8.965012729	17.79765763	12.16131115	138.6550992	0.887004584	13.33443483	150.5421448	0.696145273	0.497621998
2002	Chinook_1	0.930664983	0.692929399	0.644885127	119.9	122.82	129.67	4.828399539	18.02926746	10.54598541	70.11482849	0.979590333	1.07222271	7.813864246	20.95505902	12.28302606	234.8389867	0.897038917	17.06477912	242.4254303	0.719674477	0.543354184
2003	Chinook_1	0.933996581	0.626327312	0.584987568	130.58	133.05	140.06	4.058642268	21.32613473	11.54360847	76.90997314	0.97288202	1.04174099	7.188043348	23.06658436	13.57679001	240.7525558	0.88894245	16.90704155	260.4354248	0.67832258	0.480427483
2004	Chinook_1	0.911677585	0.722304189	0.658508539	107.4	111.8	120.13	7.491854139	12.13189929	9.239259338	60.71099243	0.961347878	0.831694698	8.730858922	18.23702933	11.31112766	202.0129801	0.901996771	15.75253987	219.833252	0.726250121	0.547512194
2005	Chinook_1	0.920659327	0.57965492	0.533664709	122.67	125.34	131.02	4.737477459	18.55627983	12.15538731	67.1325058	0.966418314	0.95613308	7.713847525	20.96974997	13.88730796	206.5040741	0.901550005	15.9283212	216.1983643	0.655532076	0.435535704
2006	Chinook_1	0.944676789	0.728140899	0.687857806	121.51	123.64	130.8	3.853836223	22.4557847	10.42948494	127.8444931	0.971383309	1.132489204	7.556248277	22.15573469	11.94847743	291.8438721	0.861277779	17.78990555	297.8026123	0.779831681	0.558928451
2007	Chinook_1	0.920351544	0.606394036	0.558095687	120.87	123.23	129.44	4.957941048	17.81328382	11.89204922	68.44199371	0.977652192	1.094354916	7.633205943	21.27814302	13.61476469	243.7468211	0.889269928	17.13241227	253.0018616	0.65905552	0.452165632
2008	Chinook_1	0.902274752	0.733048509	0.661411162	107.41	112.13	120.28	8.151316971	11.1369262	9.57006855	60.82829208	0.919988394	0.678269243	8.810917564	18.10950351	11.03706344	180.9872665	0.886600057	14.23927522	192.7246399	0.723946129	0.558159279

5521 **Table 4-10. Snake River Steelhead_MO3_Wildfish_Raw_Data**

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
SCN MO3-Steelhead-SAL-HW																						
1929	Steelhead	0.896404826	0.57219035	0.512914191	128.47	130.27	137.12	4.393150523	19.64609822	11.05545006	63.82778244	0.982632887	0.793209839	8.328929938	20.77013038	12.70908244	165.2178116	0.946995318	14.46935479	176.1290894	0.635994963	0.395027466
1930	Steelhead	0.754506966	0.446434311	0.336837797	140.16	140.21	143.9	3.86003042	22.08241311	13.21075382	62.70593262	0.985576141	0.905415058	7.678334981	22.01112095	15.08399041	159.0707677	0.951663693	14.5319651	164.8411407	0.502351442	0.240046535
1931	Steelhead	0.819409272	0.458975423	0.376088718	138.02	139.24	144.36	3.587064728	23.73527577	12.62741623	58.86043243	0.990219724	0.958304501	7.43275062	22.60556987	15.13726981	161.9846242	0.957180421	14.92655834	167.0583496	0.536485475	0.250273738
1932	Steelhead	0.91996341	0.649212346	0.597251603	121.13	123.49	129.16	4.242455661	20.46083254	10.53812847	99.57953033	0.988763583	1.09147625	6.5642519	27.65612496	12.20318778	292.7756602	0.910047382	17.64748637	304.4317932	0.717040501	0.464734673
1933	Steelhead	0.891480232	0.585149624	0.521649323	127.65	129.55	135.13	4.456168808	19.43170886	11.33985081	68.18749084	0.989073682	1.023069382	7.004742913	25.46742892	13.36325423	247.8490067	0.931248983	16.95366081	263.3229675	0.638590025	0.41803955
1934	Steelhead	0.708992631	0.487274981	0.345474371	138.63	138.2	139.61	3.76440233	22.63763276	14.37220631	59.37915726	0.986854625	1.198201275	5.974547252	29.33341021	15.45164076	285.1780446	0.905493965	17.56161229	290.4157715	0.502606531	0.252600751
1935	Steelhead	0.892439992	0.568780313	0.507602298	125.94	127.93	134.38	4.002016	21.47374829	11.40548744	67.98436737	0.993132329	1.019650269	7.16366668	24.52938334	13.51748625	221.4864477	0.944690824	16.59884659	232.6940002	0.632765953	0.379483616

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1936	Steelhead	0.850459035	0.615519331	0.523473976	122.36	122.51	126.33	4.524609543	19.16133342	11.11823978	115.172731	0.978297222	1.08417511	6.847507112	26.79613432	12.33980719	285.7381541	0.89881588	17.2086331	297.7406616	0.614812654	0.416851566
1937	Steelhead	0.909755063	0.583936217	0.53123893	119.71	122.47	130.25	5.189643942	16.7677542	10.47388992	50.86909637	0.975555384	0.73988719	8.805743955	20.0964587	12.27655935	163.9306361	0.941904436	14.36937634	177.5213165	0.656662977	0.395091012
1938	Steelhead	0.913491572	0.630050305	0.575545644	123.24	124.98	129.12	4.058421768	21.31636419	10.93256416	111.5926208	0.980600774	1.078533363	6.265449606	28.88492154	12.6768961	309.0633392	0.897590826	17.66275565	321.1536865	0.690139304	0.448150204
1939	Steelhead	0.802366318	0.541705575	0.434646307	136.79	137.22	140.63	3.784023359	22.54554946	12.28020897	77.29988403	0.990398324	1.119676781	7.0004149	24.85591609	13.55895726	217.2592646	0.941746821	16.69557858	222.8695526	0.55901917	0.33225473
1940	Steelhead	0.82349798	0.546992593	0.450447295	128	127.86	130.79	4.235048972	20.33053601	11.9209219	83.53600616	0.988514972	1.053679466	7.144379333	24.67277149	13.68392642	225.1434631	0.937396894	16.70084667	232.7225494	0.554697113	0.345230135
1941	Steelhead	0.832127208	0.504266707	0.419614047	129.36	130.73	135.77	3.899196826	21.98794612	13.08317108	55.46320648	0.991073382	0.87036314	7.520124942	22.83302499	14.51827113	181.8326035	0.954566091	15.45406675	189.7847443	0.551939979	0.288343674
1942	Steelhead	0.917552221	0.628229877	0.576433719	120.49	122.66	128.8	4.779930487	18.22255614	10.32886944	83.53708801	0.987992167	0.931820011	7.64486187	23.29221131	11.92450428	215.9066315	0.943158627	16.20077324	224.6229248	0.685450254	0.443419254
1943	Steelhead	0.920615211	0.614598601	0.565808821	127.41	129.18	133.97	3.660147779	23.40638228	10.95284805	113.5797653	0.986106718	1.110214424	6.38473323	27.8385642	12.94294373	284.1959178	0.910037011	17.47139057	293.8853149	0.687115113	0.426675698
1944	Steelhead	0.903470054	0.542602786	0.490225368	121.5	123.8	131.1	4.845276706	17.91073999	10.64998608	51.74303818	0.979177606	0.768539858	8.816180743	19.54381663	12.97972536	143.5545247	0.949272662	13.87258673	151.6450348	0.619918796	0.347872411
1945	Steelhead	0.89414054	0.577464351	0.516334286	130.17	131.62	136.48	3.835825458	22.43425551	11.48583412	82.97876587	0.98991282	0.945573616	7.2543758	24.3381576	13.37719472	223.1079356	0.937719891	16.2422967	237.8478851	0.638278256	0.393691244
1946	Steelhead	0.922775542	0.656694446	0.605981574	123.41	125.26	129.45	4.164284848	20.83603337	10.51072006	111.1220093	0.978738654	1.084479046	6.11627008	30.02581722	12.14476029	333.7866007	0.88352409	17.95499404	346.4668579	0.729689476	0.469275654
1947	Steelhead	0.797575669	0.541477883	0.431869584	134.55	134.31	137.01	3.663355961	23.34518438	12.81149673	113.1097534	0.976684475	1.142481327	6.093876682	29.28562637	14.53567791	304.3712311	0.887621462	17.51115513	312.6004944	0.553927564	0.317657177
1948	Steelhead	0.903118334	0.631508482	0.570326888	134.03	135.54	140.69	3.209396958	26.63107371	11.7688179	145.9042328	0.981186414	1.365327549	5.400612846	33.96383038	13.74026092	426.7423147	0.869012952	22.2957557	447.7825623	0.681039441	0.438819051
1949	Steelhead	0.917591166	0.634941196	0.582616433	121.81	123.51	128.26	4.032340311	21.49701404	10.71792965	126.4264862	0.981630754	1.116067791	6.16496218	29.67362489	12.67351087	331.7122192	0.886970262	18.09997145	347.686554	0.697088265	0.469823995
1950	Steelhead	0.912985126	0.635848622	0.580520334	124.46	126.38	132.84	4.443659849	19.464192	10.67598476	91.72471313	0.987944984	1.039714432	7.047333196	25.44040628	12.09106127	255.8590088	0.923167417	16.98757807	269.9475403	0.702310099	0.450698362
1951	Steelhead	0.907930829	0.616968696	0.560164899	122.66	124.58	129.85	4.211160481	20.53115501	11.02642021	101.0824066	0.984333587	1.128641605	6.20365715	29.27401681	13.07548253	315.8403269	0.89308845	17.80695756	329.6502686	0.676759742	0.438115394
1952	Steelhead	0.930403833	0.665599477	0.619276304	124.93	126.49	131.21	3.523328915	24.39091469	10.622118	157.7349426	0.971730149	1.086239433	5.840829216	31.48488805	12.13607788	357.28125	0.867849191	18.16727495	369.9491882	0.732174399	0.482229524
1953	Steelhead	0.91486358	0.605341868	0.553805229	127.19	129.18	136.26	3.912724376	22.08310465	11.01538754	88.15855408	0.988940966	0.969183064	6.837144502	26.24403497	13.15240224	261.2819468	0.923655113	16.92334445	278.2255554	0.665670714	0.438956999
1954	Steelhead	0.920909794	0.661644135	0.609314564	117.12	119.93	126.32	5.48339463	16.06096309	9.953236961	88.78773804	0.979803216	0.964610481	7.297733769	24.99782339	11.35567649	263.4781723	0.917634259	16.85397768	276.7589722	0.723441781	0.469584186
1955	Steelhead	0.921401486	0.602808879	0.555428997	124.58	126.71	133.4	4.100961283	21.03157386	10.66366043	75.5759552	0.991218686	0.91504631	7.644723326	23.15299778	12.63486481	210.1589533	0.945569684	16.02073574	224.2655182	0.666780732	0.418928344
1956	Steelhead	0.923707759	0.665863282	0.615063081	129.3	130.96	135.47	3.705699094	23.23676113	10.84546814	140.7667145	0.975665498	1.260844994	5.468505844	33.69276815	12.50887648	406.4331207	0.861614853	20.13580306	425.0817261	0.718689536	0.482012951
1957	Steelhead	0.912058643	0.655641868	0.597983833	123.68	125.44	130.57	4.441955186	19.57622505	10.6985424	129.0360443	0.974527824	1.077175713	6.391599946	28.72532428	12.24531603	343.9087067	0.885906845	18.62470357	359.8193359	0.692491335	0.464518845
1958	Steelhead	0.914431104	0.634604223	0.58030184	128.65	130.25	135.07	3.725073703	23.05621371	11.13103008	121.8859909	0.980503166	1.110761166	6.24333062	29.38095123	12.81690645	329.7268728	0.887094229	18.15130695	346.9906006	0.683843497	0.465045155
1959	Steelhead	0.89208689	0.613460243	0.54725984	119.53	121.69	126.24	5.627502717	15.54205756	10.72065678	74.9362381	0.975803876	1.015288353	7.13815093	25.50587703	12.56462987	263.1998316	0.909591645	16.87416252	274.5951538	0.665244553	0.439899415
1960	Steelhead	0.922308219	0.638167018	0.588586686	120.6	122.97	129.39	4.520997494	19.15787331	10.28928757	78.78773651	0.992888153	1.079260635	7.179466464	24.88390571	12.01974773	244.9225006	0.934343924	17.10478131	255.4190216	0.716399578	0.431868076
1961	Steelhead	0.902179407	0.60371928	0.544663102	123.79	125.95	132.53	4.385648131	19.70446374	11.00650787	69.32971191	0.987746227	1.029169464	6.825082563	26.32627311	13.10548846	271.1297379	0.920370559	17.31652832	282.6332703	0.662015289	0.421937837
1962	Steelhead	0.914574859	0.59429912	0.543531033	129.55	131.39	136.98	3.489296585	24.46415093	11.24126205	88.10972443	0.994562316	1.155988216	6.594088994	26.88694682	13.44529915	255.4711482	0.929607123	17.3652571	261.3048706	0.682464363	0.396034598
1963	Steelhead	0.892552256	0.565790702	0.504997768	133.49	135.4	142.46	3.54872144	24.1229229	11.79104404	88.84111328	0.989487457	0.971642017	6.773732163	26.08661714	13.88234043	244.9379476	0.926648239	16.53789616	257.5479431	0.638980145	0.367248218
1964	Steelhead	0.910044643	0.590657588	0.537524774	131.58	133.47	139.4	3.701803245	23.1592305	11.25650406	93.43356323	0.98772887	1.001938248	6.942563869	25.48777044	13.37106673	251.6714223	0.922464301	16.61736727	263.9472656	0.663831449	0.412042734
1965	Steelhead	0.913610686	0.630493035	0.576025174	131.74	133.53	138.43	4.191693738	20.67736427	11.00301476	126.7678345	0.97758975	1.075537586	6.155276738	29.63252103	12.82973512	322.467687	0.882045647	17.689768	332.0551147	0.680446272	0.462168687
1966	Steelhead	0.882724024	0.57459971	0.507212968	130.04	131.7	137.16	3.621065386	23.54895478	11.65660858	68.36349335	0.994591486	1.049771309	7.033034168	24.80028466	13.42401044	219.2739003	0.94637388	16.63656537	226.5662384	0.658326665	0.361696335
1967	Steelhead	0.891776763	0.619869732	0.552785423	133.7	135.23	140.8	4.346973307	19.85887816	11.26246243	88.02864838	0.977092147	1.000310135	6.910654821	25.83280788	12.71362289	280.2549947	0.902856876	16.9868083	289.3380432	0.665178631	0.438761601
1968	Steelhead	0.833762784	0.538012412	0.448574726	120.06	121.04	126.31	6.023260608	14.49283743	11.95480881	60.48068314	0.949843776	0.730220032	8.685131043	20.06627703	13.15001059	180.5535177	0.904026449	13.75874488	188.7473755	0.567501239	0.348369581
1969	Steelhead	0.911440591	0.608828437	0.55491095	133.28	134.98	140.07	3.040269211	28.01316254	11.6565588	130.6308746	0.976312828	1.213567162	5.435539432	33.39408176	13.97409185	371.5631866	0.866227289	18.85858011	378.5861206	0.693738183	0.420336623
1970	Steelhead	0.916631182	0.615224101	0.563933595	124.14	126.61	134.23	4.484038122	19.35404671	10.59582996	84.63358154	0.981658483	0.838075256	7.778035529	22.75969266	12.27600447	223.7584712	0.923213452	15.51108917	233.4108124	0.67916912	0.43482883
1971	Steelhead	0.89302811	0.631374077	0.563834799	139.89	141.17	145.18	3.31407994	25.79185861	11.97907238	146.3385956	0.970946169	1.223018837	5.224903345	34.96538724	13.57395347	406.21993	0.84994333	19.54330603	412.9869995	0.671413056	0.430797126
1972	Steelhead	0.902140297	0.637185459	0.574830679	128.84	130.39	135.19	4.229539245	20.46731952	11.2472826	124.4462631	0.980565143	1.229454613	5.651298977	32.33838828	13.12061024	383.3737233	0.872650981	19.86900043	385.5175781	0.679108414	0.469003459

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1973	Steelhead	0.884094208	0.550659624	0.486834984	117.72	120.58	129.09	5.420190036	16.08074657	10.77659855	50.5571907	0.970337832	0.782455254	8.780433103	19.67366429	12.92595021	155.2285716	0.934637219	14.05164997	161.3557739	0.606970037	0.369026977
1974	Steelhead	0.899441774	0.625077685	0.562220982	134.42	135.93	140.43	3.663339466	23.43826014	11.63127136	126.604895	0.97342732	1.203693771	5.41818957	33.46835929	13.51336686	380.5458934	0.86195448	19.20689106	386.7110291	0.675611635	0.434314725
1975	Steelhead	0.923859465	0.648018005	0.598677567	116.08	118.91	125.67	5.084749795	17.24105092	9.985352707	83.58813782	0.9897874	0.907075596	7.656961821	23.68241752	11.55098232	235.9888535	0.937657426	16.5305961	247.2622681	0.719684797	0.457385912
1976	Steelhead	0.927083727	0.668911762	0.620137209	124.16	125.96	131.04	4.339301363	20.02067125	10.3811409	131.3689972	0.975753379	1.117785358	6.230949216	29.3560437	11.90744702	328.9560852	0.882868926	17.99498018	333.1289978	0.724328737	0.498617897
1977	Steelhead	0.854830545	0.507916062	0.434182164	121.4	123.31	130.15	5.134325884	16.92021407	11.73026485	36.76270905	0.971774149	0.759212065	8.925983585	19.11760693	13.56092087	134.0347252	0.943731358	13.44835385	141.4520569	0.562492852	0.315867929
1978	Steelhead	0.896432857	0.604916457	0.542266987	135.22	136.82	141.78	3.572484337	23.95701216	11.62664471	94.80915222	0.992163098	1.138587379	6.384977207	27.45971185	13.284434	264.6935883	0.924999595	17.45861832	273.6483154	0.66325162	0.40498694
1979	Steelhead	0.914074822	0.628674519	0.574655549	122.38	124.56	130.71	4.639955707	18.70907814	10.59845524	79.38390961	0.984645069	0.919882011	7.518155225	24.01438388	12.09575748	232.9874395	0.930137356	16.23743725	247.1830444	0.711156709	0.449857714
1980	Steelhead	0.915560722	0.64622455	0.591657815	117.37	119.98	124.99	5.150686406	17.09334119	10.20369568	87.52772064	0.976709783	0.924421883	7.029357277	26.49639245	12.01251539	287.3805974	0.902963152	16.91244427	306.3229675	0.69153917	0.462253495
1981	Steelhead	0.813910324	0.526165034	0.428251153	138.32	139.03	143.97	3.643664837	23.52584149	13.57654171	89.95480957	0.97933166	0.988533783	6.491647698	26.99447945	14.90098111	264.7968216	0.91081051	16.69239219	273.5896606	0.552763216	0.308463138
1982	Steelhead	0.89943063	0.616141411	0.554176457	128.49	130.06	135.33	4.399626836	19.67876374	11.18741302	110.3999908	0.97991153	1.117410278	6.333283961	28.78731367	13.02074289	314.4502411	0.890233765	17.85340754	322.8909607	0.661396827	0.438200375
1983	Steelhead	0.909481507	0.620331505	0.564180032	127.95	129.68	134.55	4.556219198	19.11260473	10.90520668	102.5412827	0.982633114	1.036968708	6.596256636	27.50247394	12.86991978	290.219752	0.904457996	17.31657489	301.9002991	0.662619152	0.444448087
1984	Steelhead	0.917008205	0.626049254	0.574092302	126.31	128.16	133.36	4.227654658	20.47733254	10.76446934	123.5200653	0.985661614	1.047274971	6.830230214	26.49914548	12.43791199	266.8156153	0.914784978	17.07453903	275.0581055	0.688786915	0.45148162
1985	Steelhead	0.922143076	0.634497566	0.585097537	122.99	124.9	131.05	4.212798946	20.49175795	10.4731781	95.66685638	0.993110919	1.034306049	7.230438568	24.6442372	12.02175824	235.3912811	0.939843973	16.97562011	242.7809753	0.709160187	0.461108762
1986	Steelhead	0.902688245	0.594979116	0.537080654	128.25	129.89	134.55	4.393635534	19.71052003	11.12368107	106.907579	0.988083303	1.054391479	6.722778492	26.497897	13.2116313	263.4075368	0.918498337	17.1319046	268.0259705	0.645456471	0.431588746
1987	Steelhead	0.746476783	0.506059933	0.377761991	129.38	128.85	131.3	4.569509588	18.76929503	13.29232025	53.87142487	0.980275393	1.024452209	7.223487042	24.49196435	14.34355847	228.9732768	0.923014661	16.22441196	235.3372498	0.504362548	0.276041043
1988	Steelhead	0.902621686	0.579881895	0.523413974	131.7	133.72	139.36	3.902253382	21.89821221	11.27122421	62.38008804	0.99237119	0.945582294	7.460412778	23.21123038	13.06718365	190.0762431	0.955778013	15.8938454	195.8269806	0.649266146	0.389531616
1989	Steelhead	0.926397269	0.6650208	0.616073453	115.62	118.23	124.41	4.655301481	18.70846247	10.01159401	98.01724091	0.993217671	1.056023026	6.976107083	26.29237139	11.40716076	273.5014165	0.920243482	17.33704662	281.1698608	0.729673791	0.466829841
1990	Steelhead	0.745597087	0.474864484	0.354057576	136.93	136.62	138.52	3.96621979	21.54801205	13.97490025	67.22151794	0.984207523	1.066629696	6.733239718	25.93604192	15.26287778	238.7786382	0.924222618	16.64313968	244.7165985	0.502565578	0.257815648
1991	Steelhead	0.877002869	0.597313044	0.523845254	122.91	124.29	128.8	5.363547124	16.28073083	11.08968525	65.26640167	0.97376889	0.961120796	7.12695536	25.38820966	12.9226621	256.1004512	0.910779456	16.57790073	256.1395264	0.622701801	0.418842909
1992	Steelhead	0.77424172	0.490696872	0.37991799	130.56	131.26	135.29	4.13420777	20.70583975	13.44504623	50.56856384	0.985313332	0.95418129	7.432457373	23.37077823	14.62282928	195.4266052	0.944981923	15.84318209	197.9950409	0.505057022	0.283503405
1993	Steelhead	0.920211266	0.633943738	0.58336217	125.22	127.24	134.07	4.2174256	20.55351174	10.50654125	98.73529968	0.981555343	0.870842648	7.389689006	24.41386211	11.98845784	253.91996	0.916448762	16.25932868	264.7316895	0.698906455	0.444052405
1994	Steelhead	0.827803541	0.531643004	0.440095961	127.31	128.07	131.98	4.7330103	18.21650736	11.68439541	60.06785583	0.983887458	0.9752985	7.769652776	22.62711231	13.56304995	194.1081619	0.944515824	15.84584697	200.0101624	0.559372941	0.335729916
1995	Steelhead	0.908746887	0.592635337	0.538555518	121.8	123.93	130.47	4.426675737	19.62098932	10.81963711	87.48014526	0.989782321	0.947387218	7.407452643	23.97555011	12.96274233	228.0972239	0.93589897	16.22116502	239.1461639	0.653703473	0.405524276
1996	Steelhead	0.877078161	0.616550471	0.540762953	129.45	130.63	133.75	4.436069004	19.56990464	11.83000622	121.2668213	0.973672843	1.074608707	6.026314557	30.05009111	13.01077096	330.6763814	0.879690925	17.81742827	343.4128113	0.642904358	0.440931688
1997	Steelhead	0.912725992	0.643923376	0.587725602	135.72	137.14	140.92	3.386271462	25.34920596	11.54818172	168.031073	0.970996034	1.42218523	4.844352908	37.99200177	13.65971041	468.9469503	0.841754397	22.44833422	475.1591492	0.692605785	0.46719943
1998	Steelhead	0.906900917	0.602587508	0.546487163	129.15	130.78	135.79	3.337499209	25.65949105	11.59333324	121.8556549	0.979257667	1.062734127	6.006689675	30.23161477	13.7414314	324.8388163	0.886165162	17.73034509	336.7099609	0.687306628	0.41846539
1999	Steelhead	0.893815669	0.595030232	0.531847345	134.06	135.92	142.04	3.757216603	22.89420596	11.72446156	105.5274368	0.98576175	1.089112186	6.143010169	29.10077516	13.64578549	302.4578044	0.902340849	17.69154565	315.5550842	0.664015013	0.412017188
2000	Steelhead	0.824931131	0.557161531	0.459619892	130.36	130.8	134.16	4.224003628	20.3734445	12.00434418	87.68536072	0.984187686	1.138268375	6.684954569	26.50044161	13.60553296	256.4916178	0.919210911	17.12368774	265.757782	0.577725442	0.359450427
2001	Steelhead	0.887249814	0.523773786	0.464718194	130.47	132.4	138.82	4.152715206	20.73571502	11.52562504	57.93331604	0.985485792	0.843837357	7.896692567	21.62671677	13.89762529	163.7508443	0.952697535	14.73141964	172.219162	0.597719821	0.353800444
2002	Steelhead	0.910358766	0.616942096	0.561638646	124.63	126.59	131.4	4.436862983	19.50474867	10.76114769	76.34583435	0.988982272	1.076717091	6.938207559	25.62714146	12.57362286	253.9883092	0.92872416	17.23500061	264.1842346	0.670026908	0.442031061
2003	Steelhead	0.904135963	0.588270552	0.531876562	126.39	128.41	134.65	4.038047165	21.3457172	11.20576553	79.72070923	0.990386903	1.011466408	6.964268513	25.33419635	13.27935632	243.8407974	0.934437195	16.92016856	262.9431763	0.657872429	0.413764427
2004	Steelhead	0.897717118	0.560253103	0.502948801	131.04	132.94	138.95	3.646626271	23.49613398	11.65357285	76.13249359	0.995143247	1.055051708	6.862370744	25.30407886	13.95194117	226.0559362	0.944763601	16.80724573	247.2705688	0.647893563	0.382017541
2005	Steelhead	0.847636736	0.52316738	0.443455891	130.84	132.07	137.09	3.679081395	23.34269015	12.91405163	79.7695343	0.992021084	1.001525784	6.988527745	24.75461613	14.57389657	217.2708486	0.942850262	16.31297414	224.1720581	0.607037163	0.320992881
2006	Steelhead	0.919592042	0.661156729	0.607994466	123.39	125.04	129.75	4.640461057	18.8351272	10.41577911	131.9135956	0.977856886	1.103369999	6.311378852	29.06700254	11.98360809	327.2440948	0.888694108	18.05902004	338.9646301	0.711538666	0.483634659
2007	Steelhead	0.856724783	0.565605943	0.484568629	119.84	121.62	126.88	4.516054206	19.25804403	11.9668602	62.26437759	0.993400764	1.07820425	6.971380718	25.22022076	13.69916789	236.2321192	0.940188219	17.0453976	244.1781616	0.600561271	0.363532554
2008	Steelhead	0.893723276	0.598397532	0.534801802	130.37	131.68	137.64	3.928961128	21.99711958	11.46669712	104.263472	0.980663323	0.972412586	6.90284624	25.67813058	13.25769726	279.2753042	0.908605347	16.87077363	294.5507202	0.641787377	0.427433185

5522 **Table 4-11. Snake River MO3 Steelhead Wildfish SAL HW Raw Data HW**

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
SCN MO3-Steelhead-SAL-HW																						
1929	Steelhead	0.896404826	0.57219035	0.512914191	128.47	130.27	137.12	4.393150523	19.64609822	11.05545006	63.82778244	0.982632887	0.793209839	8.328929938	20.77013038	12.70908244	165.2178116	0.946995318	14.46935479	176.1290894	0.635994963	0.395027466
1930	Steelhead	0.754506966	0.446434311	0.336837797	140.16	140.21	143.9	3.86003042	22.08241311	13.21075382	62.70593262	0.985576141	0.905415058	7.678334981	22.01112095	15.08399041	159.0707677	0.951663693	14.5319651	164.8411407	0.502351442	0.240046535
1931	Steelhead	0.819409272	0.458975423	0.376088718	138.02	139.24	144.36	3.587064728	23.73527577	12.62741623	58.86043243	0.990219724	0.958304501	7.43275062	22.60556987	15.13726981	161.9846242	0.957180421	14.92655834	167.0583496	0.536485475	0.250273738
1932	Steelhead	0.91996341	0.649212346	0.597251603	121.13	123.49	129.16	4.242455661	20.46083254	10.53812847	99.57953033	0.988763583	1.09147625	6.5642519	27.65612496	12.20318778	292.7756602	0.910047382	17.64748637	304.4317932	0.717040501	0.464734673
1933	Steelhead	0.891480232	0.585149624	0.521649323	127.65	129.55	135.13	4.456168808	19.43170886	11.33985081	68.18749084	0.989073682	1.023069382	7.004742913	25.46742892	13.36325423	247.8490067	0.931248983	16.95366081	263.3229675	0.638590025	0.41803955
1934	Steelhead	0.708992631	0.487274981	0.345474371	138.63	138.2	139.61	3.76440233	22.63763276	14.37220631	59.37915726	0.986854625	1.198201275	5.974547252	29.33341021	15.45164076	285.1780446	0.905493965	17.56161229	290.4157715	0.502606531	0.252600751
1935	Steelhead	0.892439992	0.568780313	0.507602298	125.94	127.93	134.38	4.002016	21.47374829	11.40548744	67.98436737	0.993132329	1.019650269	7.16366668	24.52938334	13.51748625	221.4864477	0.944690824	16.59884659	232.6940002	0.632765953	0.379483616
1936	Steelhead	0.850459035	0.615519331	0.523473976	122.36	122.51	126.33	4.524609543	19.16133342	11.11823978	115.172731	0.978297222	1.08417511	6.847507112	26.79613432	12.33980719	285.7381541	0.89881588	17.2086331	297.7406616	0.614812654	0.416851566
1937	Steelhead	0.909755063	0.583936217	0.53123893	119.71	122.47	130.25	5.189643942	16.7677542	10.47388992	50.86909637	0.975555384	0.73988719	8.805743955	20.0964587	12.27655935	163.9306361	0.941904436	14.36937634	177.5213165	0.656662977	0.395091012
1938	Steelhead	0.913491572	0.630050305	0.575545644	123.24	124.98	129.12	4.058421768	21.31636419	10.93256416	111.5926208	0.980600774	1.078533363	6.265449606	28.88492154	12.6768961	309.0633392	0.897590826	17.66275565	321.1536865	0.690139304	0.448150204
1939	Steelhead	0.802366318	0.541705575	0.434646307	136.79	137.22	140.63	3.784023359	22.54554946	12.28020897	77.29988403	0.990398324	1.119676781	7.0004149	24.85591609	13.55895726	217.2592646	0.941746821	16.69557858	222.8695526	0.55901917	0.33225473
1940	Steelhead	0.82349798	0.546992593	0.450447295	128	127.86	130.79	4.235048972	20.33053601	11.9209219	83.53600616	0.988514972	1.053679466	7.144379333	24.67277149	13.68392642	225.1434631	0.937396894	16.70084667	232.7225494	0.554697113	0.345230135
1941	Steelhead	0.832127208	0.504266707	0.419614047	129.36	130.73	135.77	3.899196826	21.98794612	13.08317108	55.46320648	0.991073382	0.87036314	7.520124942	22.83302499	14.51827113	181.8326035	0.954566091	15.45406675	189.7847443	0.551939979	0.288343674
1942	Steelhead	0.917552221	0.628229877	0.576433719	120.49	122.66	128.8	4.779930487	18.22255614	10.32886944	83.53708801	0.987992167	0.931820011	7.64486187	23.29221131	11.92450428	215.9066315	0.943158627	16.20077324	224.6229248	0.685450254	0.443419254
1943	Steelhead	0.920615211	0.614598601	0.565808821	127.41	129.18	133.97	3.660147779	23.40638228	10.95284805	113.5797653	0.986106718	1.110214424	6.38473323	27.8385642	12.94294373	284.1959178	0.910037011	17.47139057	293.8853149	0.687115113	0.426675698
1944	Steelhead	0.903470054	0.542602786	0.490225368	121.5	123.8	131.1	4.845276706	17.91073999	10.64998608	51.74303818	0.979177606	0.768539858	8.816180743	19.54381663	12.97972536	143.5545247	0.949272662	13.87258673	151.6450348	0.619918796	0.347872411
1945	Steelhead	0.89414054	0.577464351	0.516334286	130.17	131.62	136.48	3.835825458	22.43425551	11.48583412	82.97876587	0.98991282	0.945573616	7.2543758	24.3381576	13.37719472	223.1079356	0.937719891	16.2422967	237.8478851	0.638278256	0.393691244
1946	Steelhead	0.922775542	0.656694446	0.605981574	123.41	125.26	129.45	4.164284848	20.83603337	10.51072006	111.1220093	0.978738654	1.084479046	6.11627008	30.02581722	12.14476029	333.7866007	0.88352409	17.95499404	346.4668579	0.729689476	0.469275654
1947	Steelhead	0.797575669	0.541477883	0.431869584	134.55	134.31	137.01	3.663355961	23.34518438	12.81149673	113.1097534	0.976684475	1.142481327	6.093876682	29.28562637	14.53567791	304.3712311	0.887621462	17.51115513	312.6004944	0.553927564	0.317657177
1948	Steelhead	0.903118334	0.631508482	0.570326888	134.03	135.54	140.69	3.209396958	26.63107371	11.7688179	145.9042328	0.981186414	1.365327549	5.400612846	33.96383038	13.74026092	426.7423147	0.869012952	22.2957557	447.7825623	0.681039441	0.438819051
1949	Steelhead	0.917591166	0.634941196	0.582616433	121.81	123.51	128.26	4.032340311	21.49701404	10.71792965	126.4264862	0.981630754	1.116067791	6.16496218	29.67362489	12.67351087	331.7122192	0.886970262	18.09997145	347.686554	0.697088265	0.469823995
1950	Steelhead	0.912985126	0.635848622	0.580520334	124.46	126.38	132.84	4.443659849	19.464192	10.67598476	91.72471313	0.987944984	1.039714432	7.047333196	25.44040628	12.09106127	255.8590088	0.923167417	16.98757807	269.9475403	0.702310099	0.450698362
1951	Steelhead	0.907930829	0.616968696	0.560164899	122.66	124.58	129.85	4.211160481	20.53115501	11.02642021	101.0824066	0.984333587	1.128641605	6.20365715	29.27401681	13.07548253	315.8403269	0.89308845	17.80695756	329.6502686	0.676759742	0.438115394
1952	Steelhead	0.930403833	0.665599477	0.619276304	124.93	126.49	131.21	3.523328915	24.39091469	10.622118	157.7349426	0.971730149	1.086239433	5.840829216	31.48488805	12.13607788	357.28125	0.867849191	18.16727495	369.9491882	0.732174399	0.482229524
1953	Steelhead	0.91486358	0.605341868	0.553805229	127.19	129.18	136.26	3.912724376	22.08310465	11.01538754	88.15855408	0.988940966	0.969183064	6.837144502	26.24403497	13.15240224	261.2819468	0.923655113	16.92334445	278.2255554	0.665670714	0.438956999
1954	Steelhead	0.920909794	0.661644135	0.609314564	117.12	119.93	126.32	5.48339463	16.06096309	9.953236961	88.78773804	0.979803216	0.964610481	7.297733769	24.99782339	11.35567649	263.4781723	0.917634259	16.85397768	276.7589722	0.723441781	0.469584186
1955	Steelhead	0.921401486	0.602808879	0.555428997	124.58	126.71	133.4	4.100961283	21.03157386	10.66366043	75.5759552	0.991218686	0.91504631	7.644723326	23.15299778	12.63486481	210.1589533	0.945569684	16.02073574	224.2655182	0.666780732	0.418928344
1956	Steelhead	0.923707759	0.665863282	0.615063081	129.3	130.96	135.47	3.705699094	23.23676113	10.84546814	140.7667145	0.975665498	1.260844994	5.468505844	33.69276815	12.50887648	406.4331207	0.861614853	20.13580306	425.0817261	0.718689536	0.482012951
1957	Steelhead	0.912058643	0.655641868	0.597983833	123.68	125.44	130.57	4.441955186	19.57622505	10.6985424	129.0360443	0.974527824	1.077175713	6.391599946	28.72532428	12.24531603	343.9087067	0.885906845	18.62470357	359.8193359	0.692491335	0.464518845
1958	Steelhead	0.914431104	0.634604223	0.58030184	128.65	130.25	135.07	3.725073703	23.05621371	11.13103008	121.8859909	0.980503166	1.110761166	6.24333062	29.38095123	12.81690645	329.7268728	0.887094229	18.15130695	346.9906006	0.683843497	0.465045155
1959	Steelhead	0.89208689	0.613460243	0.54725984	119.53	121.69	126.24	5.627502717	15.54205756	10.72065678	74.9362381	0.975803876	1.015288353	7.13815093	25.50587703	12.56462987	263.1998316	0.909591645	16.87416252	274.5951538	0.665244553	0.439899415
1960	Steelhead	0.922308219	0.638167018	0.588586686	120.6	122.97	129.39	4.520997494	19.15787331	10.28928757	78.78773651	0.992888153	1.079260635	7.179466464	24.88390571	12.01974773	244.9225006	0.934343924	17.10478131	255.4190216	0.716399578	0.431868076
1961	Steelhead	0.902179407	0.60371928	0.544663102	123.79	125.95	132.53	4.385648131	19.70446374	11.00650787	69.32971191	0.987746227	1.029169464	6.825082563	26.32627311	13.10548846	271.1297379	0.920370559	17.31652832	282.6332703	0.662015289	0.421937837
1962	Steelhead	0.914574859	0.59429912	0.543531033	129.55	131.39	136.98	3.489296585	24.46415093	11.24126205	88.10972443	0.994562316	1.155988216	6.594088994	26.88694682	13.44529915	255.4711482	0.929607123	17.3652571	261.3048706	0.682464363	0.396034598
1963	Steelhead	0.892552256	0.565790702	0.504997768	133.49	135.4	142.46	3.54872144	24.1229229	11.79104404	88.84111328	0.989487457	0.971642017	6.773732163	26.08661714	13.88234043	244.9379476	0.926648239	16.53789616	257.5479431	0.638980145	0.367248218

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
1964	Steelhead	0.910044643	0.590657588	0.537524774	131.58	133.47	139.4	3.701803245	23.1592305	11.25650406	93.43356323	0.98772887	1.001938248	6.942563869	25.48777044	13.37106673	251.6714223	0.922464301	16.61736727	263.9472656	0.663831449	0.412042734
1965	Steelhead	0.913610686	0.630493035	0.576025174	131.74	133.53	138.43	4.191693738	20.67736427	11.00301476	126.7678345	0.97758975	1.075537586	6.155276738	29.63252103	12.82973512	322.467687	0.882045647	17.689768	332.0551147	0.680446272	0.462168687
1966	Steelhead	0.882724024	0.57459971	0.507212968	130.04	131.7	137.16	3.621065386	23.54895478	11.65660858	68.36349335	0.994591486	1.049771309	7.033034168	24.80028466	13.42401044	219.2739003	0.94637388	16.63656537	226.5662384	0.658326665	0.361696335
1967	Steelhead	0.891776763	0.619869732	0.552785423	133.7	135.23	140.8	4.346973307	19.85887816	11.26246243	88.02864838	0.977092147	1.000310135	6.910654821	25.83280788	12.71362289	280.2549947	0.902856876	16.9868083	289.3380432	0.665178631	0.438761601
1968	Steelhead	0.833762784	0.538012412	0.448574726	120.06	121.04	126.31	6.023260608	14.49283743	11.95480881	60.48068314	0.949843776	0.730220032	8.685131043	20.06627703	13.15001059	180.5535177	0.904026449	13.75874488	188.7473755	0.567501239	0.348369581
1969	Steelhead	0.911440591	0.608828437	0.55491095	133.28	134.98	140.07	3.040269211	28.01316254	11.6565588	130.6308746	0.976312828	1.213567162	5.435539432	33.39408176	13.97409185	371.5631866	0.866227289	18.85858011	378.5861206	0.693738183	0.420336623
1970	Steelhead	0.916631182	0.615224101	0.563933595	124.14	126.61	134.23	4.484038122	19.35404671	10.59582996	84.63358154	0.981658483	0.838075256	7.778035529	22.75969266	12.27600447	223.7584712	0.923213452	15.51108917	233.4108124	0.67916912	0.43482883
1971	Steelhead	0.89302811	0.631374077	0.563834799	139.89	141.17	145.18	3.31407994	25.79185861	11.97907238	146.3385956	0.970946169	1.223018837	5.224903345	34.96538724	13.57395347	406.21993	0.84994333	19.54330603	412.9869995	0.671413056	0.430797126
1972	Steelhead	0.902140297	0.637185459	0.574830679	128.84	130.39	135.19	4.229539245	20.46731952	11.2472826	124.4462631	0.980565143	1.229454613	5.651298977	32.33838828	13.12061024	383.3737233	0.872650981	19.86900043	385.5175781	0.679108414	0.469003459
1973	Steelhead	0.884094208	0.550659624	0.486834984	117.72	120.58	129.09	5.420190036	16.08074657	10.77659855	50.5571907	0.970337832	0.782455254	8.780433103	19.67366429	12.92595021	155.2285716	0.934637219	14.05164997	161.3557739	0.606970037	0.369026977
1974	Steelhead	0.899441774	0.625077685	0.562220982	134.42	135.93	140.43	3.663339466	23.43826014	11.63127136	126.604895	0.97342732	1.203693771	5.41818957	33.46835929	13.51336686	380.5458934	0.86195448	19.20689106	386.7110291	0.675611635	0.434314725
1975	Steelhead	0.923859465	0.648018005	0.598677567	116.08	118.91	125.67	5.084749795	17.24105092	9.985352707	83.58813782	0.9897874	0.907075596	7.656961821	23.68241752	11.55098232	235.9888535	0.937657426	16.5305961	247.2622681	0.719684797	0.457385912
1976	Steelhead	0.927083727	0.668911762	0.620137209	124.16	125.96	131.04	4.339301363	20.02067125	10.3811409	131.3689972	0.975753379	1.117785358	6.230949216	29.3560437	11.90744702	328.9560852	0.882868926	17.99498018	333.1289978	0.724328737	0.498617897
1977	Steelhead	0.854830545	0.507916062	0.434182164	121.4	123.31	130.15	5.134325884	16.92021407	11.73026485	36.76270905	0.971774149	0.759212065	8.925983585	19.11760693	13.56092087	134.0347252	0.943731358	13.44835385	141.4520569	0.562492852	0.315867929
1978	Steelhead	0.896432857	0.604916457	0.542266987	135.22	136.82	141.78	3.572484337	23.95701216	11.62664471	94.80915222	0.992163098	1.138587379	6.384977207	27.45971185	13.284434	264.6935883	0.924999595	17.45861832	273.6483154	0.66325162	0.40498694
1979	Steelhead	0.914074822	0.628674519	0.574655549	122.38	124.56	130.71	4.639955707	18.70907814	10.59845524	79.38390961	0.984645069	0.919882011	7.518155225	24.01438388	12.09575748	232.9874395	0.930137356	16.23743725	247.1830444	0.711156709	0.449857714
1980	Steelhead	0.915560722	0.64622455	0.591657815	117.37	119.98	124.99	5.150686406	17.09334119	10.20369568	87.52772064	0.976709783	0.924421883	7.029357277	26.49639245	12.01251539	287.3805974	0.902963152	16.91244427	306.3229675	0.69153917	0.462253495
1981	Steelhead	0.813910324	0.526165034	0.428251153	138.32	139.03	143.97	3.643664837	23.52584149	13.57654171	89.95480957	0.97933166	0.988533783	6.491647698	26.99447945	14.90098111	264.7968216	0.91081051	16.69239219	273.5896606	0.552763216	0.308463138
1982	Steelhead	0.89943063	0.616141411	0.554176457	128.49	130.06	135.33	4.399626836	19.67876374	11.18741302	110.3999908	0.97991153	1.117410278	6.333283961	28.78731367	13.02074289	314.4502411	0.890233765	17.85340754	322.8909607	0.661396827	0.438200375
1983	Steelhead	0.909481507	0.620331505	0.564180032	127.95	129.68	134.55	4.556219198	19.11260473	10.90520668	102.5412827	0.982633114	1.036968708	6.596256636	27.50247394	12.86991978	290.219752	0.904457996	17.31657489	301.9002991	0.662619152	0.444448087
1984	Steelhead	0.917008205	0.626049254	0.574092302	126.31	128.16	133.36	4.227654658	20.47733254	10.76446934	123.5200653	0.985661614	1.047274971	6.830230214	26.49914548	12.43791199	266.8156153	0.914784978	17.07453903	275.0581055	0.688786915	0.45148162
1985	Steelhead	0.922143076	0.634497566	0.585097537	122.99	124.9	131.05	4.212798946	20.49175795	10.4731781	95.66685638	0.993110919	1.034306049	7.230438568	24.6442372	12.02175824	235.3912811	0.939843973	16.97562011	242.7809753	0.709160187	0.461108762
1986	Steelhead	0.902688245	0.594979116	0.537080654	128.25	129.89	134.55	4.393635534	19.71052003	11.12368107	106.907579	0.988083303	1.054391479	6.722778492	26.497897	13.2116313	263.4075368	0.918498337	17.1319046	268.0259705	0.645456471	0.431588746
1987	Steelhead	0.746476783	0.506059933	0.377761991	129.38	128.85	131.3	4.569509588	18.76929503	13.29232025	53.87142487	0.980275393	1.024452209	7.223487042	24.49196435	14.34355847	228.9732768	0.923014661	16.22441196	235.3372498	0.504362548	0.276041043
1988	Steelhead	0.902621686	0.579881895	0.523413974	131.7	133.72	139.36	3.902253382	21.89821221	11.27122421	62.38008804	0.99237119	0.945582294	7.460412778	23.21123038	13.06718365	190.0762431	0.955778013	15.8938454	195.8269806	0.649266146	0.389531616
1989	Steelhead	0.926397269	0.6650208	0.616073453	115.62	118.23	124.41	4.655301481	18.70846247	10.01159401	98.01724091	0.993217671	1.056023026	6.976107083	26.29237139	11.40716076	273.5014165	0.920243482	17.33704662	281.1698608	0.729673791	0.466829841
1990	Steelhead	0.745597087	0.474864484	0.354057576	136.93	136.62	138.52	3.96621979	21.54801205	13.97490025	67.22151794	0.984207523	1.066629696	6.733239718	25.93604192	15.26287778	238.7786382	0.924222618	16.64313968	244.7165985	0.502565578	0.257815648
1991	Steelhead	0.877002869	0.597313044	0.523845254	122.91	124.29	128.8	5.363547124	16.28073083	11.08968525	65.26640167	0.97376889	0.961120796	7.12695536	25.38820966	12.9226621	256.1004512	0.910779456	16.57790073	256.1395264	0.622701801	0.418842909
1992	Steelhead	0.77424172	0.490696872	0.37991799	130.56	131.26	135.29	4.13420777	20.70583975	13.44504623	50.56856384	0.985313332	0.95418129	7.432457373	23.37077823	14.62282928	195.4266052	0.944981923	15.84318209	197.9950409	0.505057022	0.283503405
1993	Steelhead	0.920211266	0.633943738	0.58336217	125.22	127.24	134.07	4.2174256	20.55351174	10.50654125	98.73529968	0.981555343	0.870842648	7.389689006	24.41386211	11.98845784	253.91996	0.916448762	16.25932868	264.7316895	0.698906455	0.444052405
1994	Steelhead	0.827803541	0.531643004	0.440095961	127.31	128.07	131.98	4.7330103	18.21650736	11.68439541	60.06785583	0.983887458	0.9752985	7.769652776	22.62711231	13.56304995	194.1081619	0.944515824	15.84584697	200.0101624	0.559372941	0.335729916
1995	Steelhead	0.908746887	0.592635337	0.538555518	121.8	123.93	130.47	4.426675737	19.62098932	10.81963711	87.48014526	0.989782321	0.947387218	7.407452643	23.97555011	12.96274233	228.0972239	0.93589897	16.22116502	239.1461639	0.653703473	0.405524276
1996	Steelhead	0.877078161	0.616550471	0.540762953	129.45	130.63	133.75	4.436069004	19.56990464	11.83000622	121.2668213	0.973672843	1.074608707	6.026314557	30.05009111	13.01077096	330.6763814	0.879690925	17.81742827	343.4128113	0.642904358	0.440931688
1997	Steelhead	0.912725992	0.643923376	0.587725602	135.72	137.14	140.92	3.386271462	25.34920596	11.54818172	168.031073	0.970996034	1.42218523	4.844352908	37.99200177	13.65971041	468.9469503	0.841754397	22.44833422	475.1591492	0.692605785	0.46719943
1998	Steelhead	0.906900917	0.602587508	0.546487163	129.15	130.78	135.79	3.337499209	25.65949105	11.59333324	121.8556549	0.979257667	1.062734127	6.006689675	30.23161477	13.7414314	324.8388163	0.886165162	17.73034509	336.7099609	0.687306628	0.41846539
1999	Steelhead	0.893815669	0.595030232	0.531847345	134.06	135.92	142.04	3.757216603	22.89420596	11.72446156	105.5274368	0.98576175	1.089112186	6.143010169	29.10077516	13.64578549	302.4578044	0.902340849	17.69154565	315.5550842	0.664015013	0.412017188
2000	Steelhead	0.824931131	0.557161531	0.459619892	130.36	130.8	134.16	4.224003628	20.3734445	12.00434418	87.68536072	0.984187686	1.138268375	6.684954569	26.50044161	13.60553296	256.4916178	0.919210911	17.12368774	265.757782	0.577725442	0.359450427

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow	monte_q975	monte_q025
2001	Steelhead	0.887249814	0.523773786	0.464718194	130.47	132.4	138.82	4.152715206	20.73571502	11.52562504	57.93331604	0.985485792	0.843837357	7.896692567	21.62671677	13.89762529	163.7508443	0.952697535	14.73141964	172.219162	0.597719821	0.353800444
2002	Steelhead	0.910358766	0.616942096	0.561638646	124.63	126.59	131.4	4.436862983	19.50474867	10.76114769	76.34583435	0.988982272	1.076717091	6.938207559	25.62714146	12.57362286	253.9883092	0.92872416	17.23500061	264.1842346	0.670026908	0.442031061
2003	Steelhead	0.904135963	0.588270552	0.531876562	126.39	128.41	134.65	4.038047165	21.3457172	11.20576553	79.72070923	0.990386903	1.011466408	6.964268513	25.33419635	13.27935632	243.8407974	0.934437195	16.92016856	262.9431763	0.657872429	0.413764427
2004	Steelhead	0.897717118	0.560253103	0.502948801	131.04	132.94	138.95	3.646626271	23.49613398	11.65357285	76.13249359	0.995143247	1.055051708	6.862370744	25.30407886	13.95194117	226.0559362	0.944763601	16.80724573	247.2705688	0.647893563	0.382017541
2005	Steelhead	0.847636736	0.52316738	0.443455891	130.84	132.07	137.09	3.679081395	23.34269015	12.91405163	79.7695343	0.992021084	1.001525784	6.988527745	24.75461613	14.57389657	217.2708486	0.942850262	16.31297414	224.1720581	0.607037163	0.320992881
2006	Steelhead	0.919592042	0.661156729	0.607994466	123.39	125.04	129.75	4.640461057	18.8351272	10.41577911	131.9135956	0.977856886	1.103369999	6.311378852	29.06700254	11.98360809	327.2440948	0.888694108	18.05902004	338.9646301	0.711538666	0.483634659
2007	Steelhead	0.856724783	0.565605943	0.484568629	119.84	121.62	126.88	4.516054206	19.25804403	11.9668602	62.26437759	0.993400764	1.07820425	6.971380718	25.22022076	13.69916789	236.2321192	0.940188219	17.0453976	244.1781616	0.600561271	0.363532554
2008	Steelhead	0.893723276	0.598397532	0.534801802	130.37	131.68	137.64	3.928961128	21.99711958	11.46669712	104.263472	0.980663323	0.972412586	6.90284624	25.67813058	13.25769726	279.2753042	0.908605347	16.87077363	294.5507202	0.641787377	0.427433185

5523 **Table 4-12. Snake River_MO3_Steelhead_Wildfish_SAL_W_Raw_Data**

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
MO3-Steelhead-SAL-W																										
1929	Steelhead	0.896404826	0.571039917	0.511882937	128.47	130.27	137.14	14.69040318	29.80104248	12.26719148	131.9614964	0.966898258	9.812928268	4.393150523	19.64609822	11.05545006	63.82778244	0.974110901	0.793209839	8.325703539	20.77532741	12.71041298	165.2558823	0.944337017	14.47081327	176.1743622
1930	Steelhead	0.754506966	0.445931262	0.336458243	140.16	140.21	143.9	13.47813004	31.41538465	14.51984692	125.9850028	0.971818669	9.894554581	3.86003042	22.08241311	13.21075382	62.70593262	0.980686951	0.905415058	7.676576369	22.01295795	15.08405574	159.0710602	0.950338036	14.53180631	164.8411865
1931	Steelhead	0.819409272	0.458468214	0.375673105	138.02	139.24	144.35	12.94878586	32.33893092	14.37843459	126.0581147	0.975764879	10.09352599	3.587064728	23.73527577	12.62741623	58.86043243	0.985122597	0.958304501	7.430862457	22.60805598	15.13711115	161.9909617	0.955849608	14.92684746	167.0647125
1932	Steelhead	0.91996341	0.648825389	0.596895617	121.13	123.49	129.15	12.80120362	32.87117245	11.76084593	226.7127756	0.956338653	11.94096463	4.242455661	20.46083254	10.53812847	99.57953033	0.986093152	1.091476255	6.562688716	27.65688017	12.20236142	292.7534739	0.909712543	17.6472524	304.4034424
1933	Steelhead	0.891480232	0.584862239	0.521393124	127.65	129.55	135.13	13.43024553	31.73575821	12.76906545	188.5101525	0.965664268	11.46474927	4.456168808	19.43170886	11.33985081	68.18749084	0.986501265	1.023069382	7.002431899	25.46972724	13.36310768	247.8376668	0.931132505	16.95358578	263.3063965
1934	Steelhead	0.708992631	0.486899033	0.345207826	138.63	138.2	139.62	11.68831963	34.68677586	15.11423629	205.5833372	0.953352554	11.80981626	3.76440233	22.63763276	14.37220631	59.37915726	0.983420825	1.198201275	5.973354764	29.3362088	15.45294841	285.1776174	0.904972027	17.56307713	290.414032
1935	Steelhead	0.892439992	0.568527258	0.507376461	125.94	127.93	134.37	13.13129661	32.08763834	12.89805814	169.9154505	0.972983233	11.13160787	4.002016	21.47374829	11.40548744	67.98436737	0.990592241	1.019650269	7.161100432	24.5321205	13.51721954	221.4830983	0.944801132	16.59886614	232.6900024
1936	Steelhead	0.850459035	0.615153753	0.523163068	122.36	122.51	126.32	13.37226599	31.99789668	12.00554235	227.6449416	0.947737443	11.65316159	4.524609543	19.16133342	11.11823978	115.172731	0.975376761	1.084175116	6.845698081	26.79758604	12.33924675	285.7288717	0.898573518	17.20836957	297.729248
1937	Steelhead	0.909755063	0.582934194	0.530237334	119.71	122.47	130.26	15.98717996	28.32357712	11.80798531	127.3985122	0.962780105	9.797025187	5.189643942	16.76775423	10.47388992	50.86909637	0.968173623	0.739887191	8.802955754	20.09958681	12.27727111	163.9454905	0.939676225	14.36970027	177.538147
1938	Steelhead	0.913491572	0.629452101	0.574999189	123.24	124.98	129.13	12.31380271	33.74314323	12.17873921	240.9947248	0.947262338	12.06180471	4.058421768	21.31636419	10.93256416	111.5926208	0.976840365	1.078533363	6.265184641	28.88492303	12.67711544	309.0469716	0.8962454	17.66308657	321.1336060
1939	Steelhead	0.802366318	0.541582389	0.434547467	136.79	137.22	140.62	12.74495174	32.64615233	13.18779148	168.3353697	0.971105209	11.15679455	3.784023359	22.54554946	12.28020897	77.29988403	0.988464439	1.119676781	6.997837365	24.85919797	13.55832451	217.2661413	0.942191809	16.695714	222.8780975
1940	Steelhead	0.82349798	0.546841307	0.450322712	128	127.86	130.79	13.35300651	31.68594351	13.18409395	176.3523216	0.968566622	11.17214523	4.235048972	20.33053601	11.9209219	83.53600616	0.98658694	1.053679466	7.142016239	24.67560984	13.684069	225.1424789	0.937833438	16.70150312	232.7208252
1941	Steelhead	0.832127208	0.503737219	0.419173446	129.36	130.73	135.78	13.36938569	31.65449569	14.10769027	138.9375202	0.975161276	10.39265425	3.899196826	21.98794612	13.08317108	55.46320648	0.986245465	0.870363147	7.517467774	22.836874	14.51884794	181.8448893	0.953505298	15.45467186	189.7972870
1942	Steelhead	0.917552221	0.627840222	0.57607619	120.49	122.66	128.79	14.41910315	30.19668935	11.48618119	170.7191195	0.970182423	10.90007683	4.779930487	18.22255614	10.32886944	83.53708801	0.984999812	0.931820011	7.642332897	23.29446025	11.92397992	215.9031448	0.942926079	16.20080868	224.6186981
1943	Steelhead	0.920615211	0.614077813	0.565329376	127.41	129.18	133.98	12.02230027	34.12352866	12.38153321	225.2550218	0.954753688	11.82585185	3.660147779	23.40638228	10.95284805	113.5797653	0.982401347	1.110214424	6.383756667	27.83944706	12.94324907	284.1781362	0.909091065	17.47166268	293.8611755

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1944	Steelhead	0.903470054	0.541207943	0.488965169	121.5	123.8	131.12	15.63605687	28.61288358	12.33884668	113.0638065	0.965468556	9.408438018	4.845276706	17.91073999	10.64998608	51.74303818	0.968567264	0.768539858	8.813144244	19.54814187	12.98106003	143.5787404	0.945620914	13.87370284	151.6728058
1945	Steelhead	0.89414054	0.576922248	0.51584957	130.17	131.62	136.49	13.05012961	32.38505635	12.84752757	177.7131097	0.967704288	10.95538126	3.835825458	22.43425551	11.48583412	82.97876587	0.98515538	0.945573616	7.251101561	24.34368619	13.37795035	223.1308111	0.937013775	16.24321922	237.8730774
1946	Steelhead	0.922775542	0.655895	0.605243865	123.41	125.26	129.44	12.27909513	34.00281059	11.71827977	257.3234449	0.939967935	12.30365852	4.164284848	20.83603337	10.51072006	111.1220093	0.974023485	1.084479046	6.116214268	30.02521818	12.14410003	333.778595	0.881572475	17.95494731	346.4560547
1947	Steelhead	0.797575669	0.540885825	0.431397373	134.55	134.31	137.01	11.71702075	34.85703654	14.00953123	237.9927455	0.94125651	11.88470095	3.663355961	23.34518438	12.81149673	113.1097534	0.97232554	1.142481327	6.094646141	29.28435935	14.53563754	304.3618571	0.885994087	17.51255353	312.5887756
1948	Steelhead	0.903118334	0.631305389	0.570143471	134.03	135.54	140.69	10.55981775	38.09768976	13.17186655	333.9721407	0.936447889	15.01345338	3.209396958	26.63107371	11.7688179	145.9042328	0.979774594	1.365327549	5.39969667	33.96816029	13.74065876	426.8279521	0.868566344	22.30034447	447.8822632
1949	Steelhead	0.917591166	0.634372325	0.582094442	121.81	123.51	128.25	12.18857423	34.13829041	12.13196571	262.2676424	0.943072362	12.43976821	4.032340311	21.49701404	10.71792965	126.4264862	0.978182292	1.116067791	6.164983585	29.67255352	12.67280149	331.6941121	0.885350287	18.09996668	347.6619873
1950	Steelhead	0.912985126	0.635457779	0.580163501	124.46	126.38	132.84	13.48336121	31.58020181	11.71838331	201.1007069	0.961538	11.46444702	4.443659849	19.464192	10.67598476	91.72471313	0.984980965	1.039714432	7.045705281	25.44235245	12.09090662	255.8538691	0.922771196	16.98868052	269.9395142
1951	Steelhead	0.907930829	0.616369772	0.559621118	122.66	124.58	129.85	12.40424615	33.63288076	12.46608141	242.5362429	0.946559727	12.16466675	4.211160481	20.53115501	11.02642021	101.0824066	0.980360174	1.128641605	6.203357816	29.27416354	13.07579199	315.8279978	0.891672671	17.8077507	329.6332092
1952	Steelhead	0.930403833	0.66459178	0.618338739	124.93	126.49	131.21	11.35887052	35.93475138	11.72425359	288.7621896	0.929921563	12.59262535	3.523328915	24.39091469	10.622118	157.7349426	0.966235697	1.086239433	5.842468381	31.48243413	12.13604196	357.28007	0.864620755	18.16772699	369.9448547
1953	Steelhead	0.91486358	0.604863365	0.553367463	127.19	129.18	136.27	12.70982394	33.08275918	12.54663195	204.6941823	0.961469105	11.50668877	3.912724376	22.08310465	11.01538754	88.15855408	0.984715104	0.969183064	6.834892482	26.24720046	13.15260172	261.2789459	0.922832231	16.92359845	278.2189331
1954	Steelhead	0.920909794	0.661244028	0.608946102	117.12	119.93	126.3	14.79098624	30.05340737	10.99621698	204.3438557	0.956318391	11.44937801	5.48339463	16.06096309	9.953236961	88.78773804	0.977041471	0.964610481	7.295789771	24.99873909	11.35473903	263.4564692	0.917208294	16.85367537	276.7309875
1955	Steelhead	0.921401486	0.602268958	0.554931513	124.58	126.71	133.4	13.71990601	31.27772219	12.09313447	166.5437306	0.971612875	10.82916185	4.100961283	21.03157386	10.66366043	75.5759552	0.986783171	0.91504631	7.641855322	23.1567349	12.63532925	210.1684723	0.944777449	16.02111959	224.2757568
1956	Steelhead	0.923707759	0.665256989	0.614503043	129.3	130.96	135.48	11.15779965	36.54559224	12.04162298	316.0960312	0.929616962	13.95741708	3.705699094	23.23676113	10.84546814	140.7667145	0.972359431	1.260844994	5.470093057	33.69120031	12.50961304	406.4513397	0.858806868	20.13726346	425.0957947
1957	Steelhead	0.912058643	0.655116728	0.597504874	123.68	125.44	130.56	12.82195249	33.07223746	11.81478725	272.3798054	0.939958743	12.87788486	4.441955186	19.57622505	10.6985424	129.0360443	0.971823204	1.077175713	6.392706625	28.72279211	12.24508826	343.898763	0.883384575	18.62545125	359.8013916
1958	Steelhead	0.914431104	0.634091248	0.579832759	128.65	130.25	135.06	11.94066089	34.70194219	12.34675833	260.549802	0.9428544	12.49372935	3.725073703	23.05621371	11.13103008	121.8859909	0.977464724	1.110761166	6.243437193	29.37893042	12.81623046	329.7028198	0.885439843	18.1510663	346.9575806
1959	Steelhead	0.89208689	0.613008303	0.546856671	119.53	121.69	126.24	14.76778347	30.15628582	12.03590952	199.065039	0.95097919	11.40426036	5.627502717	15.54205756	10.72065678	74.9362381	0.972634828	1.015288353	7.138924807	25.50613699	12.56564871	263.2004064	0.908422544	16.87761482	274.5927429
1960	Steelhead	0.922308219	0.637874888	0.588317251	120.6	122.97	129.39	13.69646057	31.20276382	11.56604201	188.2282273	0.968487421	11.47125973	4.520997494	19.15787331	10.28928757	78.78773651	0.990476831	1.079260635	7.177119248	24.88618735	12.01937548	244.9141494	0.934406737	17.10504611	255.4072266
1961	Steelhead	0.902179407	0.603335601	0.544316955	123.79	125.95	132.52	13.18393351	32.18154346	12.50072799	203.4429616	0.960180708	11.77518913	4.385648131	19.70446374	11.00650787	69.32971191	0.984991562	1.029169464	6.823941484	26.3265859	13.10534016	271.1065089	0.919595521	17.31670062	282.6031494
1962	Steelhead	0.914574859	0.594138511	0.543384145	129.55	131.39	136.98	12.04290108	34.21184552	12.81871768	197.3885351	0.967485057	11.62434677	3.489296585	24.46415093	11.24126205	88.10972443	0.992872059	1.155988216	6.591903883	26.88953721	13.44484234	255.4638316	0.930072029	17.36542559	261.2952271
1963	Steelhead	0.892552256	0.565345186	0.504600121	133.49	135.4	142.46	12.27116186	33.82649701	13.24885055	193.6091505	0.963256385	11.19430143	3.54872144	24.1229229	11.79104404	88.84111328	0.98587724	0.971642017	6.771930575	26.08834697	13.88220739	244.9275767	0.926034003	16.53777138	257.5349426
1964	Steelhead	0.910044643	0.590160707	0.53707259	131.58	133.47	139.4	12.60285743	33.15701848	12.76793991	199.7732271	0.960731907	11.30988073	3.701803245	23.1592305	11.25650406	93.43356323	0.984154284	1.001938246	6.940950558	25.48944899	13.37088076	251.6681188	0.921579401	16.61735519	263.9403992
1965	Steelhead	0.913610686	0.629833609	0.575422716	131.74	133.53	138.43	12.32088589	33.94780255	12.29197018	255.38157	0.939238242	12.11537303	4.191693738	20.67736427	11.00301476	126.7678345	0.973510313	1.075537586	6.15517012	29.63224419	12.82986371	322.4585775	0.880297412	17.69013834	332.0427246
1966	Steelhead	0.882724024	0.574365486	0.507006213	130.04	131.7	137.16	12.61358846	32.98686254	12.93779312	166.8604088	0.974249985	11.12703167	3.621065386	23.54895478	11.65660858	68.36349335	0.991987193	1.049771309	7.030211627	24.80395581	13.42392826	219.2793859	0.946594139	16.63671479	226.5714874
1967	Steelhead	0.891776763	0.619167066	0.552158802	133.7	135.23	140.79	13.22597993	32.06110972	12.31103182	214.9551343	0.947856699	11.65162502	4.346973307	19.85887816	11.26246243	88.02864838	0.972778695	1.000310135	6.909792483	25.83360641	12.71366739	280.2532043	0.901017034	16.98683853	289.3319397
1968	Steelhead	0.833762784	0.537151541	0.447856964	120.06	121.04	126.33	16.69867621	27.51154098	12.82771533	139.7531981	0.938026828	9.454073702	6.023260608	14.49283741	11.95480881	60.48068314	0.944121838	0.730220032	8.682859577	20.06958108	13.15027205	180.5879059	0.901961118	13.75906738	188.7899323
1969	Steelhead	0.911440591	0.608080323	0.554229089	133.28	134.98	140.07	10.42942146	38.33578401	13.26190072	288.1538402	0.931372217	13.06856319	3.040269211	28.01316254	11.6565588	130.6308746	0.972158599	1.213567162	5.437374316	33.38939944	13.97395102	371.5442505	0.863070244	18.85852321	378.5610046
1970	Steelhead	0.916631182	0.61409177	0.562895665	124.14	126.61	134.25	14.23804001	30.50239954	11.81106744	178.0109002	0.956729467	10.58697483	4.484038122	19.35404671	10.59582996	84.63358154	0.974328196	0.838075256	7.775784224	22.76421079	12.27672784	223.8004303	0.920428882	15.51220163	233.4580688

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1971	Steelhead	0.89302811	0.630541584	0.563091359	139.89	141.17	145.18	10.49255757	38.22305845	13.11152363	315.489599	0.922002839	13.61467123	3.31407994	25.79185861	11.97907238	146.3385956	0.966742754	1.223018837	5.227717862	34.96089115	13.57466586	406.2317403	0.845721215	19.54440562	412.9949951
1972	Steelhead	0.902140297	0.636711596	0.574403188	128.84	130.39	135.19	11.8616612	34.99206515	12.5640876	292.3843596	0.936512104	13.57053082	4.229539245	20.46731952	11.2472826	124.4462631	0.977871096	1.229454613	5.652454056	32.33640582	13.12094402	383.3801015	0.870302548	19.8700091	385.5190125
1973	Steelhead	0.884094208	0.549208852	0.485552365	117.72	120.58	129.12	16.17233185	28.03116051	12.33934239	119.7222947	0.956114262	9.499737916	5.420190036	16.08074657	10.77659855	50.5571907	0.960029137	0.782455254	8.776689447	19.68054163	12.92711322	155.299174	0.930909137	14.05418976	161.4383545
1974	Steelhead	0.899441774	0.624284421	0.561507487	134.42	135.93	140.43	11.04653275	36.65177157	12.94926664	291.926651	0.928405174	13.23532758	3.663339466	23.43826014	11.63127136	126.604895	0.968927085	1.203693771	5.419813067	33.46581328	13.51407115	380.5506388	0.858839711	19.20763842	386.7105408
1975	Steelhead	0.923859465	0.647633015	0.59832189	116.08	118.91	125.67	14.74587251	29.94705897	11.17241246	185.0690057	0.968413076	11.16902048	5.084749795	17.24105092	9.985352707	83.58813782	0.986825144	0.907075596	7.654547423	23.68420261	11.55060228	235.9760844	0.937276651	16.53046974	247.2454376
1976	Steelhead	0.927083727	0.66823646	0.619511148	124.16	125.96	131.03	12.5692744	33.42762487	11.48622635	259.6373825	0.938790509	12.30300062	4.339301363	20.02067125	10.3811409	131.3689972	0.971814954	1.117785358	6.231880978	29.35485936	11.90723133	328.9482981	0.88066557	17.99603844	333.1175842
1977	Steelhead	0.854830545	0.506443257	0.432923166	121.4	123.31	130.17	16.03478179	28.07751044	13.05351714	101.3601641	0.959751274	9.172592657	5.134325884	16.92021407	11.73026485	36.76270905	0.959896874	0.759212065	8.922971085	19.12217536	13.56270027	134.0565478	0.939505806	13.44926604	141.4758759
1978	Steelhead	0.896432857	0.604640457	0.542019572	135.22	136.82	141.78	11.91455506	34.29546643	12.80969231	206.2044558	0.964249994	11.70258604	3.572484337	23.95701216	11.62664471	94.80915222	0.98975966	1.138587379	6.383111857	27.46213798	13.28427315	264.687856	0.925116976	17.45926269	273.6417542
1979	Steelhead	0.914074822	0.628239301	0.574257727	122.38	124.56	130.72	14.14882667	30.70227465	11.69282607	182.3484633	0.963218864	10.99587468	4.639955707	18.70907814	10.59845524	79.38390961	0.981194937	0.919882011	7.515181372	24.01798066	12.09591357	232.9941279	0.929848744	16.23763514	247.1893158
1980	Steelhead	0.915560722	0.645451314	0.590949871	117.37	119.98	124.99	14.17213319	31.18689993	11.5412272	222.1810047	0.947370619	11.57847922	5.150686406	17.09334119	10.20369568	87.52772064	0.971062088	0.924421883	7.027485929	26.4989383	12.01237059	287.383873	0.901313037	16.91275962	306.3248291
1981	Steelhead	0.813910324	0.52554532	0.427746761	138.32	139.03	143.96	12.07088548	34.10274941	14.51237154	205.0335246	0.95193521	11.34885454	3.643664837	23.52584149	13.57654171	89.95480957	0.974466491	0.988533783	6.490720512	26.99484941	14.90078926	264.7761408	0.909126918	16.69235849	273.5643311
1982	Steelhead	0.89943063	0.615619054	0.553706634	128.49	130.06	135.32	12.71402641	33.18509397	12.48168734	244.371073	0.943899721	12.20259816	4.399626836	19.67876374	11.18741302	110.3999908	0.976657236	1.117410278	6.334201425	28.78578727	13.02107096	314.4323527	0.888552	17.85542806	322.8688049
1983	Steelhead	0.909481507	0.619883864	0.563772911	127.95	129.68	134.54	13.1288569	32.45745749	12.29673065	226.7495352	0.951245393	11.83033531	4.556219198	19.11260473	10.90520668	102.5412827	0.979575503	1.036968708	6.595966898	27.50187407	12.86992311	290.1987915	0.903259675	17.31736803	301.8720093
1984	Steelhead	0.917008205	0.625765414	0.573832019	126.31	128.16	133.36	13.04480805	32.43497449	11.98255232	217.8652671	0.957495468	11.50864465	4.227654658	20.47733254	10.76446934	123.5200653	0.983325167	1.047274971	6.828872018	26.50080877	12.43759855	266.8076909	0.914718598	17.07592916	275.0482788
1985	Steelhead	0.922143076	0.634256659	0.584875386	122.99	124.9	131.05	13.43859627	31.57825135	11.61112901	187.3058859	0.971143837	11.33642193	4.212798946	20.49175795	10.4731781	95.66685638	0.991009057	1.034306049	7.227683693	24.64713211	12.02141094	235.3883794	0.940161766	16.97558101	242.7770844
1986	Steelhead	0.902688245	0.594550628	0.536693863	128.25	129.89	134.55	13.09313963	32.23737845	12.59580292	209.3644338	0.959243208	11.58007022	4.393635534	19.71052003	11.12368107	106.907579	0.984920347	1.054391479	6.722394064	26.49775632	13.21190659	263.3848216	0.917467376	17.13381863	267.9951477
1987	Steelhead	0.746476783	0.505773066	0.377547851	129.38	128.85	131.3	13.76637621	31.05257493	14.04319845	168.3345604	0.958828236	10.951234	4.569509588	18.76929503	13.29232025	53.87142487	0.977344573	1.024452209	7.221199922	24.49481226	14.34364557	228.9779104	0.922812204	16.22440561	235.3420563
1988	Steelhead	0.902621686	0.579504614	0.523073432	131.7	133.72	139.36	13.32203571	31.71900886	12.56176267	145.8022605	0.977039052	10.65818095	3.902253382	21.89821221	11.27122421	62.38008804	0.989153194	0.945582294	7.457929961	23.21398356	13.06708066	190.0783056	0.955464125	15.89397049	195.8286591
1989	Steelhead	0.926397269	0.664796527	0.615865687	115.62	118.23	124.41	13.64540346	31.52288884	11.08965383	212.3228809	0.962908796	11.65472235	4.655301481	18.70846247	10.01159401	98.01724091	0.991396689	1.056023026	6.973574802	26.29494385	11.40660222	273.4951248	0.920623322	17.33699958	281.1626282
1990	Steelhead	0.745597087	0.474648491	0.353896532	136.93	136.62	138.51	12.65184842	32.81525955	14.85986805	179.3041447	0.960842354	11.20487162	3.96621979	21.54801205	13.97490025	67.22151794	0.981518626	1.066629696	6.731493987	25.93729849	15.26178217	238.7616043	0.924033235	16.64286184	244.6963959
1991	Steelhead	0.877002869	0.59679563	0.52339148	122.91	124.29	128.78	14.47335794	30.48821077	12.40262549	187.9787243	0.950566232	11.2106593	5.363547124	16.28073083	11.08968525	65.26640167	0.969998372	0.961120796	7.125718343	25.38798326	12.92166773	256.0743535	0.909656028	16.57759333	256.1080933
1992	Steelhead	0.77424172	0.490383641	0.379675473	130.56	131.26	135.29	13.52663567	31.35552539	14.29576193	144.3361097	0.9698715	10.6165108	4.13420777	20.70583975	13.44504623	50.56856384	0.981991863	0.954181296	7.429714419	23.37445593	14.623185	195.4363073	0.944707225	15.84347634	198.0050201
1993	Steelhead	0.920211266	0.632925429	0.582425111	125.22	127.24	134.08	13.59366623	31.56992337	11.58059556	202.262582	0.954100336	11.14881614	4.2174256	20.55351174	10.50654125	98.73529968	0.974922895	0.870842648	7.388041213	24.41722758	11.98913002	253.9434636	0.913797706	16.25999912	264.7550354
1994	Steelhead	0.827803541	0.531351637	0.439854767	127.31	128.07	131.98	14.47837869	30.03766078	13.02091994	147.6908635	0.969318403	10.64168562	4.7330103	18.21650736	11.68439541	60.06785583	0.980907679	0.9752985	7.767056376	22.62992239	13.56300735	194.1123047	0.944320043	15.84593693	200.0139771
1995	Steelhead	0.908746887	0.592188681	0.53814962	121.8	123.93	130.48	13.81177753	31.10469246	12.35187217	181.5303901	0.967459448	10.97301344	4.426675737	19.62098932	10.81963711	87.48014527	0.986372507	0.947387218	7.404938459	23.97839651	12.96270116	228.0995255	0.9354286	16.22127978	239.147522
1996	Steelhead	0.877078161	0.615724429	0.54003845	129.45	130.63	133.75	12.44544799	33.67332566	12.67935487	259.0679692	0.936080281	12.25352836	4.436069004	19.56990464	11.83000622	121.2668213	0.968479455	1.074608707	6.02707161	30.05011559	13.01149336	330.6813405	0.87712127	17.81916173	343.4185181
1997	Steelhead	0.912725992	0.643458548	0.587301342	135.72	137.14	140.93	10.19197518	39.30454961	13.01722057	363.378224	0.919678041	15.42506501	3.386271462	25.34920596	11.54818172	168.031073	0.968839431	1.42218523	4.846818946	37.98874912	13.66071256	468.9846547	0.838549554	22.45047681	475.2016907

Year	Species	lnRivSurvSNK	lnRivSurvLCol	lnRivSurv	MedDayLGR	MedDayConfl	MedDayBON	meanTravelTime	meanMigRate	meanTemp	meanFlow	meanFSpill	meanGas	SNKTravelTime	SNKMigRate	SNKTemp	SNKFlow	SNKFSpill	SNKGas	LCTravelTime	LCMigRate	LCTemp	LCFlow	LCFSpill	LCGas	BonFlow
1998	Steelhead	0.906900917	0.601887022	0.545851892	129.15	130.78	135.79	11.30724543	36.06225659	13.10460813	256.5141176	0.941349136	12.18099741	3.337499209	25.65949105	11.59333324	121.8556549	0.974756372	1.062734127	6.006902918	30.22985231	13.74107583	324.8168081	0.884184559	17.73003006	336.6830444
1999	Steelhead	0.893815669	0.594501831	0.531375052	134.06	135.92	142.04	11.85955728	34.61554398	13.07157217	236.3191536	0.951224791	12.09714491	3.757216603	22.89420596	11.72446156	105.5274368	0.982365906	1.089112186	6.143094279	29.09935741	13.6460735	302.4278666	0.900886416	17.69173161	315.5150146
2000	Steelhead	0.824931131	0.556958468	0.459452379	130.36	130.8	134.16	12.88489687	32.47881181	13.13036755	198.2044242	0.959053057	11.50074544	4.224004628	20.37344455	12.00434418	87.68536072	0.982182956	1.138268375	6.684191749	26.50257865	13.6058917	256.4974238	0.919304729	17.12521998	265.7667847
2001	Steelhead	0.887249814	0.52294785	0.463985382	130.47	132.4	138.84	13.99965039	30.68835331	13.19695881	127.9569114	0.971107858	9.966864347	4.152715206	20.73571502	11.52562504	57.93331604	0.978329206	0.843837357	7.893892735	21.63122255	13.89833816	163.7743759	0.950644324	14.73255483	172.2448273
2002	Steelhead	0.910358766	0.616677521	0.561397787	124.63	126.59	131.39	13.35859008	31.73186094	12.07606132	193.1916286	0.964734388	11.58098364	4.436862983	19.50474867	10.76114769	76.34583435	0.986728215	1.076717091	6.936025716	25.62897842	12.57294257	253.9735031	0.928773522	17.23485851	264.1651001
2003	Steelhead	0.904135963	0.587968439	0.531603411	126.39	128.41	134.65	12.97119824	32.36773198	12.66671753	190.723453	0.967502049	11.45682519	4.038047165	21.3457172	11.20576553	79.72070923	0.98791306	1.011466408	6.962341554	25.33547975	13.27903112	243.8197556	0.934244315	16.9199454	262.9151917
2004	Steelhead	0.897717118	0.560094069	0.502806034	131.04	132.94	138.95	12.45744734	33.26364764	13.26545429	177.3298225	0.974075586	11.28693438	3.646626271	23.49613398	11.65357285	76.13249359	0.993168795	1.055051708	6.859718755	25.30734066	13.95177682	226.0572713	0.94520243	16.80732616	247.2725983
2005	Steelhead	0.847636736	0.52285382	0.443190105	130.84	132.07	137.09	12.61516074	32.98096231	14.09226193	170.1905583	0.971397379	10.95984985	3.679081395	23.34269015	12.91405163	79.7695343	0.988760328	1.001525784	6.986027204	24.75823172	14.57412704	217.2787654	0.942627261	16.31330252	224.1812439
2006	Steelhead	0.919592042	0.660580536	0.607464604	123.39	125.04	129.75	12.95549957	32.84438801	11.54980333	261.0300369	0.942389122	12.36151535	4.640461057	18.83512721	10.41577911	131.9135956	0.974347353	1.103369999	6.311602302	29.06721581	11.98368835	327.2444916	0.886952817	18.06009102	338.9604187
2007	Steelhead	0.856724783	0.565398439	0.484390855	119.84	121.62	126.88	13.46164923	31.53172234	13.20548848	176.1893193	0.971265814	11.38523354	4.516054206	19.25804403	11.9668602	62.26437759	0.991027617	1.07820425	6.968790829	25.22302901	13.69871505	236.2296727	0.940430661	17.04551776	244.1757355
2008	Steelhead	0.893723276	0.597704034	0.534182007	130.37	131.68	137.64	12.79607765	32.79168086	12.75771366	221.3850822	0.951376293	11.69298611	3.928961128	21.99711958	11.46669712	104.263472	0.976369822	0.972412586	6.902672775	25.67764118	13.25759125	279.2654114	0.906236847	16.87066269	294.5325928

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Columbia River System Operations Environmental Impact Statement

Appendix F
Vegetation, Wetlands, and Wildlife

CHAPTER 1 - INTRODUCTION

This appendix covers vegetation, wetlands, and wildlife within the CRSO study area. This includes wildlife habitat, wildlife species, and special status plant and animal species (excluding fish). Wildlife communities and habitat vary widely over the Columbia River basin and the study area used to describe existing conditions within the affected environment; however, many elements are common throughout the study area. These common elements are discussed in this introduction. Project-and reach-specific information are provided in Section 2.0. Special status species are discussed in Section 3.0 and references are identified in Section 4.0.

This Appendix also describes the study area and the tools and methods used to describe existing conditions and potential effects. Developed lands such as roads, towns, and other urban and industrial areas are not discussed in this Appendix. These developed areas provide low value to wildlife. Figure 2-1 identifies the projects considered in the CRSO study within the context of the Columbia River Basin.

1.1 STUDY AREA

The study area used to describe existing conditions and assess the range of potential impacts to vegetation, wetlands, and wildlife is based on the H&H model extent boundary. The area of analysis extends upstream of each project dam to the maximum operating pool or the U.S. border with Canada. The downstream extent of the study area is defined by either the maximum operating pool of the next downstream CRSO project or where the effects of an alternative are no longer analyzed. Chapter 3 Section 3.13 provides maps for the study areas by Project.

1.2 LAND COVER TYPES AND BROAD WILDLIFE HABITAT CATEGORIES

Six land cover types are defined for this study: upland, open water, wetlands, coastal, barren (i.e., reservoir drawdown zone), and , islands.

Land cover types in the study area that would not be affected by any of the proposed alternatives and/or that are of little to no value to wildlife (i.e., developed lands) are not discussed in this appendix. The land cover types that are the focus of this analysis are those that include vegetation and wildlife habitat elements that are sensitive to changes in water surface elevation (WSE) and river flows. The proposed alternatives are most likely to affect these attributes as a result of varying project operations and changes in the availability, accessibility, and distribution of these habitats affect a wide variety of wildlife species. A general description for each of the six land cover types is provided below. Table 1-1 shows the vegetation/wildlife habitat types within each of the land cover types.

Land cover and vegetation and type are used in this study as proxies for wildlife habitat. This is considered a reasonable approach given the size of the study area and the importance of evaluating regional and study-area wide effects of the project. Therefore, for the purpose of this analysis, the term “habitat type” (e.g. wetland or upland forest) is considered a vegetation

type used by wildlife groups for breeding, nesting, feeding, or sheltering. Vegetation types are differentiated from one another by their structure, form, and species composition. Generally speaking, vegetation can broadly be defined by dominant plant species which co-occur in an area and which are shaped by climate patterns, substrate types and disturbance regimes. The habitat types described herein are different from species-specific habitats, which are unique to individual species and may include multiple habitat types (e.g. wetlands, forests, marine systems) necessary to complete their lifecycle.

Two primary geographic datasets were used to identify land cover, vegetation, and wildlife habitat within the study area: the Northwest Habitat Institute (NWHI) land cover classifications and the U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI). These datasets were combined in a geographic information system (GIS) environment where the digital NWI data provided the source for all wetland habitats in the study area and the NWHI dataset was the source for identifying all other habitat types across the study area.

In addition to the NWHI and NWI datasets, the analysis used estimates of the ordinary high water (OHW) level under existing conditions to define the spatial extents of the Columbia River channel and that of the major tributaries channel. The 50 percent annual exceedance probability (AEP) water surface profile, generated by the USACE for all of the detailed hydraulic reaches and the pools at Libby, Hungry Horse, and Dworshak reservoirs, are used as a proxy for OHW. This profile was used to define the extents of the river channel under normal conditions and does not reflect out-of-bank flow conditions. The AEP profile also extends to the operational pools as well, which are not influenced by river flow but rather project operations and the water level downstream of a dam. Often linked with the 2-year water level, the 50 percent AEP profile represents water surface elevations that have a 50 percent chance of being exceeded on a given year.

1.2.1 Northwest Habitat Institute Land Cover

The NWHI data layer was developed through a collaborative, science-based and peer-reviewed approach to synthesize comprehensive vegetation communities into 32 unique land cover classifications across the Columbia River Basin (Johnson and O'Neil 2001). The 32 unique habitat types were classified according to standards developed by the U.S. Federal Geographic Data Committee (FGDC), Vegetation Subcommittee to support the U.S. National Vegetation Classification (http://usnvc.org/). Both the FGDC standards and classification are maintained through a partnership sponsored by the FGDC to bring together federal agencies and non-profit organizations, including the Ecological Society of America, NatureServe (FGDC 2006). The goal of the classification is to develop, implement and manage a scientifically credible system to classify vegetation across the nation.

The Johnson and O'Neil habitat types are classified by plant associations assessed from remotely sensed aerial imagery using the FGDC recognized vegetation classification system (Grossman et al. 1998; Anderson 1998). The classification system uses consistent metrics to catalogue vegetative communities which are similar to one another into larger-order groupings, and includes agricultural and urban land cover types. Johnson and O'Neil (2001) used these

habitat types and additional data about wildlife species using these habitats to establish a statistically relevant matrix of wildlife-habitat associations.

1.2.2 National Wetland Inventory Maps

The NWI data and digital maps are developed in collaboration with USGS and are a publically available resource providing information on the abundance, distribution, and physical characteristics of wetlands across the United States. The NWI maps are produced from high altitude aerial imagery in conjunction with other data sources and field observations where wetlands are identified based on vegetation, visible hydrology and geographical characteristics.

The NWI maps are developed using aerial imagery and the resulting maps are dependent on the resolution of the imagery and accuracy of the data interpretation. For example, submerged aquatic vegetation or seagrasses are not consistently detected in aerial imagery and therefore cannot be mapped or included as part of the dataset. However, the NWI dataset is the most consistent and widespread source of wetland data available for the purpose of mapping wetland habitats at the scale of this analysis. The NWI dataset was therefore used to locate and identify wetlands across the Columbia River Basin, with the exception of submerged aquatic vegetation.

1.2.3 Regulatory Definitions

In developing the land cover type definitions and the approach used in the CRSO EIS, the team was mindful of both regulatory and scientific standards and the various ways that the information developed as part of this analysis will be used in the CRSO EIS and related environmental reviews and compliance. Therefore, some key definitions for wetlands and other waters of the United States (US) are discussed below.

1.2.3.1 Wetlands

There are two federal definitions of wetlands.

- USFWS Definition

  The USFWS defined wetlands as transitional areas "between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water" and must have one or more of the following attributes: 1) at least periodically, the land supports predominantly hydrophytes; 2) the substate is predominantly undrained hydric soil; and 3) the substrate is nonsoil and is saturated with water or covered b shallow water at some time during the growing season of each year" (Cowardin et al. 1979). This definition is used to broadly identify wetland habitats in order to identify potential wetland areas for planning purposes based on aerial imagery and aerial photographs. The imagery data is managed by the USFWS on the National Wetland Inventory (NWI) Maps. The wetland areas are approximated and are not verified from field observations.

- Cowardin system

The Cowardin system (1979) classifies wetlands into different types, many of which are found throughout the Columbia River Basin, based upon the driving hydrologic regime: marine, estuarine, lacustrine, riverine, and palustrine. Estuarine wetlands and tidal marshes are associated with brackish waters near the Columbia River Estuary at the mouth of the Columbia River and the Pacific Ocean. Lacustrine wetlands are vegetated fringes that do not cover more than 30 percent of a lake or reservoir. Riverine wetlands are vegetated shallow areas below the river or stream shoreline where there is persistent or seasonal vegetation. Examples may include cattail fringes, willows, and lily pads or unvegetated cobble-bars and mudflats. Palustrine wetlands are wet areas that rely on groundwater or seasonal flooding from a river. Examples of palustrine wetlands include marshes, swamps, bogs, or fens.

1.2.3.2 Clean Water Act, Section 404

The second definition concerns Section 404 of the Clean Water Act, where wetlands are defined as "those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support….a prevalence of vegetation typically adapted for life in saturated soil conditions." This definition narrows wetlands to a distinct boundary based on three parameters: soil characteristic, hydrology regimes, and vegetation.

1.2.3.3 Definitions Used in the CRSO EIS

For the purposes of this analysis, wetland are identified using the latest version of NWI maps and updated 2013 Cowardin et al. system (FGDC 2013; USFWS 2016). The NWI maps are used to identify and differentiate between broad wetland types across the Columbia River Basin. Field verification of wetland boundaries would be needed prior to Section 401 certification and permitting, if additional actions are warranted.

1.2.3.4 Waters of the United States

The regulatory definition of waters of the US includes the wetlands discussed above. It also includes open waters in reservoirs and open waters in rivers and streams.

1.3 THE "RIPARIAN" CONUNDRUM

The terms "riparian," "riparian zone," and "riparian vegetation" are useful for some purposes but can also be confusing. Some people refer to woody vegetation that occurs along rivers and streams as "riparian" vegetation. Other people consider both woody and herbaceous vegetation along rivers and streams to be riparian vegetation. For still others, the term riparian simply means an area proximate to a river or stream. Riparian zones are transitional areas between a flowing and non-flowing bodies of water and the upland terrestrial habitat. Riparian zones are frequently inundated and can contain wetlands. In addition, there is no generally agreed upon classification system for riparian vegetation, although a number of systems have been proposed and are in use by individual federal, state, and local agencies. A "Classification of

Wetlands and Deepwater Habitats of the United States" was developed by the Wetlands Subcommittee of the Federal Geographic Data Committee and published in August 2013. This system is in increasing use among Federal agencies and includes vegetation along rivers and streams. For this reason, in the CRSO EIS, we will use the NWI nomenclature to refer to wetlands, including those that occur along rivers and streams. In the NWI system, woody vegetation that occurs along a river or stream which is influenced by the presence of that waterway (typically seasonally inundated) is called Palustrine forested or Palustrine scrub-shrub. Similarly emergent herbaceous vegetation along rivers and streams is identified as palustrine emergent. Since this vegetation can also occur in around isolated ponds and lakes, in this report we may also specify whether the vegetation occurs along rivers and streams or around a pond or lake. These areas are commonly seasonally flooded.

1.4 LAND COVER TYPES USED IN THE CRSO EIS

1.4.1 Uplands

Upland areas consist of a wide variety of vegetation and wildlife habitat types. The term "upland" typically refers to lands above an alluvial floodplain or river channel. For the purpose of this analysis, all lands that are not classified as riparian, wetland, open water, islands, or urban or developed lands are considered uplands. Uplands in the study area include coniferous and hardwood forests, woodlands, grass and scrublands, shrub-steppe, and pasture or agricultural lands. Upland vegetation and wildlife habitat types are identified throughout the study area using the NWHI data and are shown, together with brief descriptions, in Table 1-1.

1.4.2 Barren (Drawdown Zone)

In the Barren cover type, this study focuses on the Drawdown Zone. This is shoreline habitat surrounding reservoirs which is characterized as having no permanent vegetation. A lack of vegetation is generally associated with increased potential for erosion and fluctuating water levels due to reservoir operations. When reservoirs are filled with water, the barren zone is not present, or present only as a minor fringe around the perimeter of the lake. As projects are operated and reservoirs are drawn down, the area surrounding the lake is exposed which may act as a physical barrier to wildlife for the duration the area is exposed.

1.4.3 Wetlands

Wetlands areas are vegetated habitats that are influenced by perennial or seasonally intermittent surface or groundwater. These habitats are usually a transitional area between upland habitats (described above) and wetland habitats (described below) which are characterized with woody tree or shrub species dominating the vegetation community. Furthermore, depending on climatic conditions, riparian vegetation may exhibit increased species diversity or support more vigorous or robust growth forms relative to adjacent upland vegetation, and species composition may differ dramatically between riparian and upland habitats. Because vegetation communities within riparian habitats are dependent on the duration of seasonal inundation, these habitats are sensitive to changes in project operations

influenced by river flows and precipitation patterns. Defining wetlands requires consideration of both ecological and regulatory perspectives. There are two Federal definitions of "wetlands."

1.4.3.1 Wetlands – Forested and Scrub-Shrub

Forested and scrub-shrub wetlands provide important feeding, sheltering and breeding or nesting habitat for fish and wildlife. This vegetation stabilizes river and stream channel banks and reduces erosion. Along rivers and streams this vegetation serves other important ecosystem functions, including providing a shade canopy over stream channels to reduce temperatures, vegetation along the banks may slow surface water and filter sediments to improve water quality. Woody wetlands support a high diversity of fish and wildlife.

1.4.3.2 Wetlands – Emergent Herbaceous

Wetland habitats are important ecological features providing a multitude of benefits to the human environment and a unique variety of fish, wildlife, and plant species that are adapted to survive at least part of their life cycle in aquatic environments. Wetlands can be classified based on a dominant vegetation (e.g. conifer or deciduous) or substrate type (e.g. cobble, gravel, bedrock). While local hydrologic conditions typically vary over time, plant species and soil characteristics tend to reflect the long term hydrologic conditions of a site and can help identify wetland types when local hydrology is absent. Wetland vegetation can persist under seasonal or permanent inundation, although some vegetation communities can also tolerate extended periods of drying during a portion of the year or multiple years. Wildlife use of wetland habitats varies, where some species are dependent on wetlands for their entire lifecycle, whereas other species are incidental and occur

1.4.4 Water

The Water cover type includes rivers and streams, lakes, reservoirs, bays and estuaries. In the study area, the water cover type (also referred to as "Open Water") is composed primarily of the Columbia River and its major tributaries, and project reservoirs. This cover type is found throughout the length of the study area. A suite of wildlife species and groups (e.g. birds, mammals, and fish) use open water as primary foraging habitats, migration corridors, or temporary refuge from predators. In some location of the study area, open water habitats are available seasonally, but freeze over, and are therefore inaccessible to terrestrial or avian wildlife, in the winter.

Aquatic vegetation that is submerged for its entire lifecycle provide important food resources and shelter for several classes of vertebrates, including mammals, birds, fish, reptiles, and amphibians. Within each of these classes are many species. Aquatic invertebrates also find occupy areas of aquatic vegetation as well as the sediments and water column. Similar to wetland, submerged aquatic vegetation communities are dependent on water depths and inundation patterns, light availability, and flow conditions.

1.4.5 Islands

Island are bodies of land completely surrounded by water. In the CRSO study area islands occur in reservoirs and also in the Columbia River. Individual islands or groups of islands may contain one of the cover types identified above, or it may contain a mosaic of these cover types.

Depending on the size, elevation, and available habitat types, islands can support a wide variety of plant and wildlife species. For example, islands may provide important breeding habitat for nesting colonial water birds where terrestrial predators do not have ready access to the island. However, the availability of island habitats to support wildlife is dependent on pool elevations and whether habitats are inundated during part of the year. If islands are inundated, the timing or seasonality, water depth, and the duration of inundation are important factors influencing habitat value and use by wildlife. The H&H model results provide information on the timing, depth and duration of inundation for purpose of describing seasonal availability of these habitats for different wildlife species for some islands in the study area (Table 1-1).

Table 1-1. Land Cover, Vegetation and Wildlife Habitat Types

Habitat Type	Brief Description
Uplands	
Agriculture, Pasture, and Mixed Environs[1]	Cropland, orchards, vineyards, nurseries, pastures, and grasslands modified by heavy grazing; associated structures.
Alpine Grasslands and Shrublands[1]	Grassland, dwarf-shrubland, or forb dominated, occasionally with patches of dwarfed trees.
Eastside (Interior) Grasslands[1]	Coniferous forests and woodlands; Douglas-fir commonly present, up to 8 other conifer species present; understory shrub and grass/forb.
Eastside (Interior) Canyon Shrublands[1]	Mix of tall (5 ft) to medium (1.6 foot) deciduous shrublands in a mosaic with bunchgrass or annual grasslands.. Canopies almost always closed. Mallowleaf ninebark a major dominant.
Eastside (Interior) Mixed Conifer Forest[1]	Coniferous forests and woodlands; Douglas-fir commonly present, up to 8 other conifer species present; understory shrub and grass/forb.
Lodgepole Pine Forest and Woodlands[1]	Lodgepole pine dominated woodlands and forests; understory various; mid- to high elevations.
Montane Mixed Conifer Forest[1]	Valley bottom to mid-elevation forest belts of Douglas-fr, western larch, grand fir, ponderosa and lodgepole pine, and western hemlock.
Ponderosa Pine and Eastside White Oak Forest and Woodlands[1]	Ponderosa pine dominated woodland or savannah often with Douglas-fir; scrub, forb, or grass understory; lower elevation forest.
Shrub-steppe[1]	The major vegetation on average sites in the Columbia Plateau.
Upland Aspen Forest[1]	Quaking aspen (*Populus tremuloide*s) is the characteristic and dominate tree in this habitat.
Westside Lowland Conifer-Hardwood Forest[1]	Low-elevation. The most extensive habitat in the lowlands on the westside of the Cascades, except in southwestern Oregon. Forest, or rarely woodland, dominated by evergreen conifers, deciduous broadleaf trees, or both. Western hemlock, Douglas-fir are the most characteristic species and one or both are typically present. Others: western redcedar, Sitka spruce, red alder, bigleaf maple.

Habitat Type	Brief Description
Westside Oak and Dry Douglas-Fir Forest and Woodlands[1]	Primarily found in the Willamette valley, Puget Lowlands, and Klamath Mountains ecoregions. Forest or woodland dominated by evergreen conifers, deciduous broadleaf trees, evergreen trees. Canopy structure varies from single to multi storied. Dominated by one or more of the following: Douglas-fir, Oregon white oak, Pacific madrone, lodgepole pine, California black oak.
Water	
Riverine Open Water	Defined as the river bank to river bank at Ordinary High Water, approximately 2-year water event. See also Wetlands – Emergent Herbaceous, Riverine (described below).
Reservoir Open Water	Defined as the reservoirs' full pool. Note that habitat included in this category may overlap with habitat included under Wetlands – Emergent Herbaceous, Lacustrine (described below).
Estuarine Open Water	Defined as the shore to shore at Ordinary High Tide.
Wetlands - Forested and Scrub-Shrub	
Palustrine Forested[2]	The Class Forested Wetland is characterized by trees. Trees are defined as woody plants at least 20 ft in height. All water regimes are included except subtidal.
Eastside (Interior) Riparian Wetlands[1]	Along perennial and intermittent rivers and streams. Also appears in impounded wetlands and along lakes and ponds. Shrublands, woodland and forest, less commonly grasslands; often with multilayered canopy with shrubs, graminoids, forbs below. Black cottonwood, quaking aspen, white alder, peachleaf willow are dominate. May include water birch, shining willow, and mountain alder. Each can be the sole dominate in the stands. Conifers can occur in this habitat but rarely in abundance,
Montane Coniferous Wetlands[1]	Forested wetlands or floodplains with a persistent winter snow pack, ranging from moderately to very deep. Forest or woodland (>30% tree canopy cover) dominated by evergreen conifers; deciduous trees may be co-dominate; understory dominated by shrubs, forbs, grasses. Pacific silver fir, mountain hemlock, Alaska yellow-cedar on the westside; Engelmann spruce, subalpine fir, lodgepole pine, western hemlock or western red cedar on the eastside.
Westside Riparian Wetlands[1]	Characterized by wetland hydrology or soils, periodic riverine flooding, or perennial flowing freshwater. Typically occupies patches or linear strips within a matrix of forest or regrowing forest. Red alder is the most widespread tree species. Other deciduous broadleaf trees that commonly dominate or co-dominate include black cottonwood, bigleaf maple, Oregon ash, white alder, some willows...
Palustrine Scrub-shrub[2]	The Class Scrub-Shrub Wetland includes areas dominated by woody plants less than 20 ft tall. The "shrub" life form actually includes true shrubs, young speciments of tree species that have not yet reached 20 ft in height, and woody plants (including tree species) that are stunted because of adverse environmental conditions. All water regimes except subtidal are included.
Wetlands - Emergent Herbaceous	
Lacustrine[2]	Permanently flooded lakes and reservoirs, and intermittent lakes. Typically, there are extensive areas of deep water and there is considerable wave action. Islands of Palustrine wetlands may lie within the boundaries of Lacustrine wetlands. The Lacustrine System includes wetlands and deepwater habitats with all of the following characteristics: (1) situated in a topographic depression or a dammed river channel; (2) lacking trees, shrubs, persistent

Habitat Type	Brief Description
	emergent, emergent mosses or lichens with 30 percent or greater areal coverage; and (3) total area of at least 20 acres. Similar wetlands and deepwater habitats totaling less than 20 acres are also included in the Lacustrine System if an active wave-formed or bedrock shoreline feature makes up all or part of the boundary, or if the water depth in the deepest part of the basin equals or exceeds 8.2 ft at low water.
Palustrine Emergent[2]	Palustrine wetlands may be situated shoreward of lakes, river channels, or estuaries; on river floodplains; in isolated catchments; or on slopes. The Emergent Wetland Class is characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants. All water regimes are included except subtidal and irregularly exposed.
Riverine Emergent Nonpersistent[2]	The Riverine System includes all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by trees, shrubs, persistent emergent, emergent mosses, or lichens, and (2) habitats with water containing ocean –derived salts of 0.5 pt or greater. Nonpersistent emergent are emergent hydrophytes whose stems and leaves are evident above the water surface, or above the soil surface if surface water is absent, only during the growning season or shortly thereafter. During the dormant season, there is no obvious sign of emergent vegetation.
Estuarine Emergent[2]	Tidal wetlands that are usually semienclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. The salinity may be periodically increased above that of the open ocean by evaporation. Occur from the mouth of the river or bay upstream from the ocean to where ocean-defived salts measure less than 0.5 ppt during the period of average annual low
Barren	
Drawdown Zone	The shoreline surrounding reservoirs which is characterized by having no permanent vegetation. When reservoirs are completely filled with water, the barren zone is not visible.
Islands	
River Islands	Islands are present in parts of the Columbia River. Substrate, vegetation, and suitability as wildlife habitat also vary, and may be typical of herbaceous wetlands, foresterd and scrub-scrub wetlands, or uplands cover types.
Reservoir Islands	Islands are present in some reservoirs. Substrate, vegetation, and suitability as wildlife habitat also vary, and may be typical of herbaceous wetlands, foresterd and scrub-scrub wetlands, or uplands cover types.

[1] Wildlife habitat classification

[2] National Wetlans Invetory wetlands classification

Approximate acreages of the different plant communities in the study area by reach is shown in the table below (Table 1-2).

Table 1-2. Acreages of Land Cover, Vegetation and Wildlife Habitat Types located in the Study Area.

Habitat Type	Total Acres	Region A			Region B		Region C		Region D			
		HH	Lib	Alb	GC	CJ	Dw	4LSR	MC	JD	Dal	Bon
Uplands												
Agriculture, Pasture, and Mixed Environs1	206,581	29,661	40,076	8,272	12,852	4,956	404	4,059	19,596	9,425	1,079	76,202
Alpine Grasslands and Shrublands1	1,721	69	340	1,199	0	0	113	0	0	0	0	0
Eastside (Interior) Grasslands1	30,220	11,860	5,369	6,480	3,488	0	1,344	0	0	0	0	1,679
Eastside (Interior) Canyon Shrublands1	43	0	0	0	0	0	0	0	0	43	0	0
Eastside (Interior) Mixed Conifer Forest1	50,405	6,687	12,243	22,936	3,151	0.1	5,219	0	0	0	0	169
Lodgepole Pine Forest and Woodlands1	1,226	395	642	137	52	0	0	0	0	0	0	0
Montane Mixed Conifer Forest1	736	131	9	0	0	0	0	0	0	0	0	596
Ponderosa Pine, Eastside White Oak Forest, Woodlands1	40,837	226	11,410	7,618	17,054	28	3,488	11	58	96	2	846
Shrub-steppe1	132,313	35	0	0	16,719	3,956	1,863	26,885	41,551	30,210	8,773	2,321
Upland Aspen Forest1	4,271	2,542	1,160	439	130	0	0	0	0	0	0	0
Western Juniper, Mountain Mahogany Woodlands	319	0	0	0	0	0	319	0	0	0	0	0
Westside Lowland Conifer-Hardwood Forest1	83,798	20	515	24	0	0	42	0	0	0	0	83,197
Westside Oak and Dry Douglas-Fir Forest and Woodlands1	821	0	0	0	0	0	0	0	0	0	0	821
Total Acres of Uplands in Study Area	*553,291*	*51,626*	*71,764*	*47,105*	*53,446*	*8,940*	*12,792*	*30,955*	*61,205*	*39,774*	*9,854*	*165,831*
Water												
Open Water	600,568	28,824	34,011	106,067	79,983	18,496	15,190	33,181	51,306	45,083	6,776	181,651
Wetlands - Forested and Scrub-Shrub												
Palustrine Forested2	26,810	795	1,908	2,434	74	1	9	52	949	350	51	20,188
Eastside (Interior) Riparian Wetlands1	19,248	12,285	1,413	1,443	74	643	0	662	2,286	356	28	58
Montane Coniferous Wetlands1	24,626	0	0	19,430	565	0	0	0	0	0	0	4,631
Westside Riparian Wetlands1	39,625	0	0	0	0	0	0	0	0	0	0	39,625
Palustrine Scrub-shrub2	15,250	663	838	1,009	51	18	62	45	704	266	38	11,559
Total Acres of Forested and Scrub-Shrub Wetlands	*125,559*	*13,743*	*4,159*	*24,316*	*764*	*662*	*71*	*759*	*3,939*	*972*	*117*	*76,061*
Wetlands - Emergent Herbaceous												
Palustrine Emergent2	66,332	3,507	3,044	20,299	364	134	35	160	1,603	683	68	36,435
Estuarine Emergent2	6003	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6003
Coastal												
Coastal Dunes and Beaches	170	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	170
Coastal Highlands and Islets	387	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	387
Barren												
Drawdown Zone	*	*	*	*	*	*	*	*	*	*	*	*
Islands												
Islands	*	*	*	*	*	*	*	*	*	*	*	*

[1] Northwest Habitat Institute

[2] National Wetlands Inventory wetlands classification

*Unable to determine acreage

1.5 INTRODUCED AND INVASIVE PLANTS IN STUDY AREA

Introduced and invasive plants are present throughout the study area. They occur most often disturbed lands. The land cover and vegetation type descriptions do not capture the presence of these species. A review of published and unpublished literature was conducted to identify introduced and invasive species expected to occur through out the CRSO study area.

Cheatgrass (*Bromus tectorum*) is a widespread, non-native species that often invades areas following heavy grazing and/or fire and replaces native plant species. Other widespread invasive species include Dalmatian toadflax (*Linaria dalmatica*), knapweed species (*Centaurea* spp.), Russian thistle (*Salsola tragus*), mullein (*Verbascum thapsus*), clover, and several species of the mustard family (Brassicaceae).

In forest and scrub-shrub wetlands common introduced plant species include Himalayan blackberry (*Rubus armeniacus*), St. John's wort (*Hypericum perforatum*), whitetop/hoary cress (*Cardaria draba*), reed canarygrass (*Phalaris arundinacea*), Siberian elm (*Ulmus pumila*), purple loosestrife (*Lythrum salicaria*), clover species (*Trifolium* sp.), kochia (*Kochia scoparia*). Common introduced invasive trees often found near waterways, include Russian olive (*Elaeagnus angustifolia*), black locust (*Robinia pseudoacacia*).

1.6 WILDLIFE

The Columbia Basin provides important habitat for a diversity of wildlife species. Hundreds of wildlife species use the Columbia River, estuary, and tributaries for breeding, nesting, feeding, and sheltering, including amphibians, reptiles, birds, and mammals. For the analysis, species were grouped into the following broad categories: birds, mammals, reptiles and amphibians, and invertebrates. Information was gathered from published and unpublished reports and discussions with local professional wildlife biologists. The reach writeups below provide species information for each project.

1.6.1 Introduced and Invasive Species

Non-native and invasive plants are currently damaging biological diversity and ecosystem integrity across the Columbia Basin and within the study area. Invasive plants cause displacement of native plants; reduction of habitat and forage for wildlife; changes to plant composition in sensitive areas such as wetlands; loss of sensitive species; impaired water quality; reduced soil productivity and increased erosion; and changes in the intensity and frequency of fires. Invasive plants spread through the air and water; on vehicles, animals, and humans, and all lands are at risk of invasive plants. A few of the most common invasive plants in the study area are cheatgrass (*Bromus tectorum*), flowering rush (*Butomus umbellatus*), reed canary grass (*Phalaris arundinacea*), and Eurasian watermilfoil (*Myriophyllum spicatum*).

Aquatic species are of particular concern, since they spread rapidly and can quickly alter the function of an ecosystem. Quagga mussels (*Dreissena bugensis*) and zebra mussels (*Dreissena polymorpha*) are invasive, fingernail-sized mollusks that are native to fresh waters in Eurasia.

They spread by drifting in water currents and attaching to watercraft. They negatively impact ecosystems in many ways causing harm to the environment, the economy, or to human health. They filter out algae that native species need for food and they attach to and incapacitate native mussels. The threat of zebra mussels at hydropower facilities relates to the species ability to quickly colonize underwater infrastructure such as screens, trash racks, and water delivery systems, which has the potential to render fish passage and protection facilities inoperable. The Columbia River Basin is the last U.S. river system free of these mussels (Oregon Live 2018). Strict boating inspection and widespread educational materials and training are essential to keeping these species out of the system. Oregon and Washington have both established rapid response plans for these mussels (WDFW 2014, ODFW 2013).

Throughout the study area, the action agencies are involved with cooperative weed management efforts, invasive species prevention and eradication, and vegetation treatments. The alternatives proposed herein would not change or impact their ability to continue with these efforts or affect their ability to conduct invasive species management efforts at Projects or participate on cooperative weed management efforts. The alternatives may impact vegetation communities and increase or expose bare ground. Where this may occur, and where weeds are a concern, impacts are discussed.

The following list of invasive fish and wildlife species describes all species that may be found within the study area (Table 1-3). If these species are present in the study area, they may require control measures. These species include:

Table 1-3. Invasive Fish and Wildlife Species that Could be Present in the Columbia River System Operations Study Area

Common Name	Scientific Name
American bullfrog	*Rana catesbeiana*
Apple Maggot	*Rhagoletis pomonella*
Asellid Isopod	*Caecidotea racovitzai*
Asian Clam	*Corbicula fluminea*
Black Rat	*Rattus rattus*
Brown Rat	*Rattus norvegicus*
Calanoid Copepod	*Eurytemora affinis*
Chinese Mystery Snail	*Cipangopaludina chinensis*
Common Carp	*Cyprinus carpio*
Common Snapping Turtle	*Chelydra serpentine*
Eurasian Collard Dove	*Streptopelia decaocto*
European ear snail	*Radix auricularia*
European Starling	*Sturnus vulgaris*
Feral Horses	*Equus ferus*
Feral Sheep	*Ovis aries*

Common Name	Scientific Name
Feral Swine	*Sus scrofa*
Flathead Minnow	*Pimephales promelas*
Golden Shiner	*Notemigonus crysoleucas*
Goldfish	*Carassius auratus*
Grass Carp	*Ctenopharyngodon idella*
Gypsy Moth	*Llymantria dispar dispar*
House Sparrow	*Passer domesticus*
Mute Swan	*Cygnus olor*
New Zealand Mudsnail	*Potamopyrgus antipodarum*
Northern Crayfish	*Orconectes virilis*
Nutria	*Myocastor coypus*
Red Swamp Crayfish	*Procambarus clarkia*
Red-Eared Slider	*Trachemys scripta elegans*
Rock Pigeon	*Columba livia*
Siberian Prawn	*Exopalaemon modestus*
Virginia Opossum	*Didelphis virginiana*
Western Mosquitofish	*Gambusia affinis*

Species that have not yet become established in the Mid-Columbia River regional planning area but have the potential to be introduced include the Asian Carp, Emerald ash borer, European chafer, longhorned beetles, northern snakehead fish, and overbite clam. At this time zebra mussels (*Dreissena polymorpha*) and quagga mussels (*D. rostriformis*) have not been reported in the Columbia River system. The Corps conducts surveys (veliger sampling) in the study area, and the Idaho State Department of Agriculture conducts boat inspections to monitor for thes species.

A review of published and unpublished literature was conducted to identify these plant species (Table 1-4). The most common noxious and invasive weed species are:

Table 1-4. Most Common Noxious and Invasive Weed Species in the Columbia River System Operations Study Area

Common Name	Scientific Name
Black Locust	*Robinia pseudoacia*
Bull Thistle	*Cirsium vulgare*
Canada Thistle	*Cirsium arvense*
Cheatgrass	*Bromus tectorum*
Common Brassbuttons	*Cotula coronopifolia*
Dalmatian Toadflax	*Linaria dalmatica*
Diffuse Knapweed	*Centaurea diffusa*

Common Name	**Scientific Name**
Waterweed	*Elodea spp.*
Eurasian Milfoil	*Myriophyllum spicatum*
Flowering Rush	*Butomus umbellatus*
Himalayan Blackberry	*Rubus armeniacus*
Japanese Knotweed	*Reynoutria japonica*
Medusahead	*Taeniatherum caput-medusae*
Punctureveine	*Tribulus terrestris*
Purple Loosetrife	*Lythrum salicaria*
Reed Canary Grass	*Phalaris arundinacea*
Russian Knapweed	*Centaurea repens*
Russian Olive	*Elaeagnus angustifolia*
Scotch Broom	*Cytisus scorparius*
St. John's Wort	*Hypericum perforatum*
Tansy Ragwort	*Jacobaea vulgaris*
Western False Indigo	*Amorpha fruticosa*
Whitetop	*Lepidium draba*
Yellow Starthistle	*Centaurea solstitialis*

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CHAPTER 2 - PROJECTS AND REACHES

2.1 HUNGRY HORSE DAM, FLATHEAD LAKE AND UPPER FLATHEAD RIVER

2.1.1 Study Area

The study area used to describe the existing conditions and assess the range of potential impacts for wildlife and habitat features includes lands associated with Hungry Horse Reservoir, the South Fork Flathead River below the dam, and the Flathead River from the confluence with the South Fork to Flathead Lake. The study area is within the Flathead River Subbasin within the Pend Oreille Watershed. The South Fork basin covers 1,663 square miles and originates in the Bob Marshal Wilderness south of Glacier National Park in northwestern Montana and is the most western tributary of the Columbia River (Figure 2-1). The Flathead Basin is located in a broad valley of northwestern Montana, between two ranges of the Rocky Mountains. The Flathead River is formed by three main tributaries originating along the west slope of the continental divide. These tributaries join before flowing into Flathead Lake.

The land surrounding Hungry Horse Reservoir and the South Fork Flathead River below the dam is managed by the Flathead National Forest. Downstream of the town of Hungry Horse, MT, the land surrounding the Flathead River is mostly privately owned. The affected environment includes the river reaches below the dam because of the potential for operations to affect water quality, flow, and other hydrologic conditions in the South Fork Flathead and Flathead rivers downstream of the dam.

The study area encompasses a wide diversity of habitats from around the reservoir, through the valley bottom, to Flathead Lake. These habitats, in turn, provide niches for a diverse array of birds, mammals, amphibians, and reptiles. Approximately 308 species of birds, 69 species of mammals, eight species of amphibians, nine species of reptiles, and 23 species of fish occur in the Flathead watershed (Northwest Power Planning Council, 2000, p. 22; Ratti 1990; CSKT 2000). Table 1-3, above, displays the land cover, vegetation, and habitat types acreages in the study area.

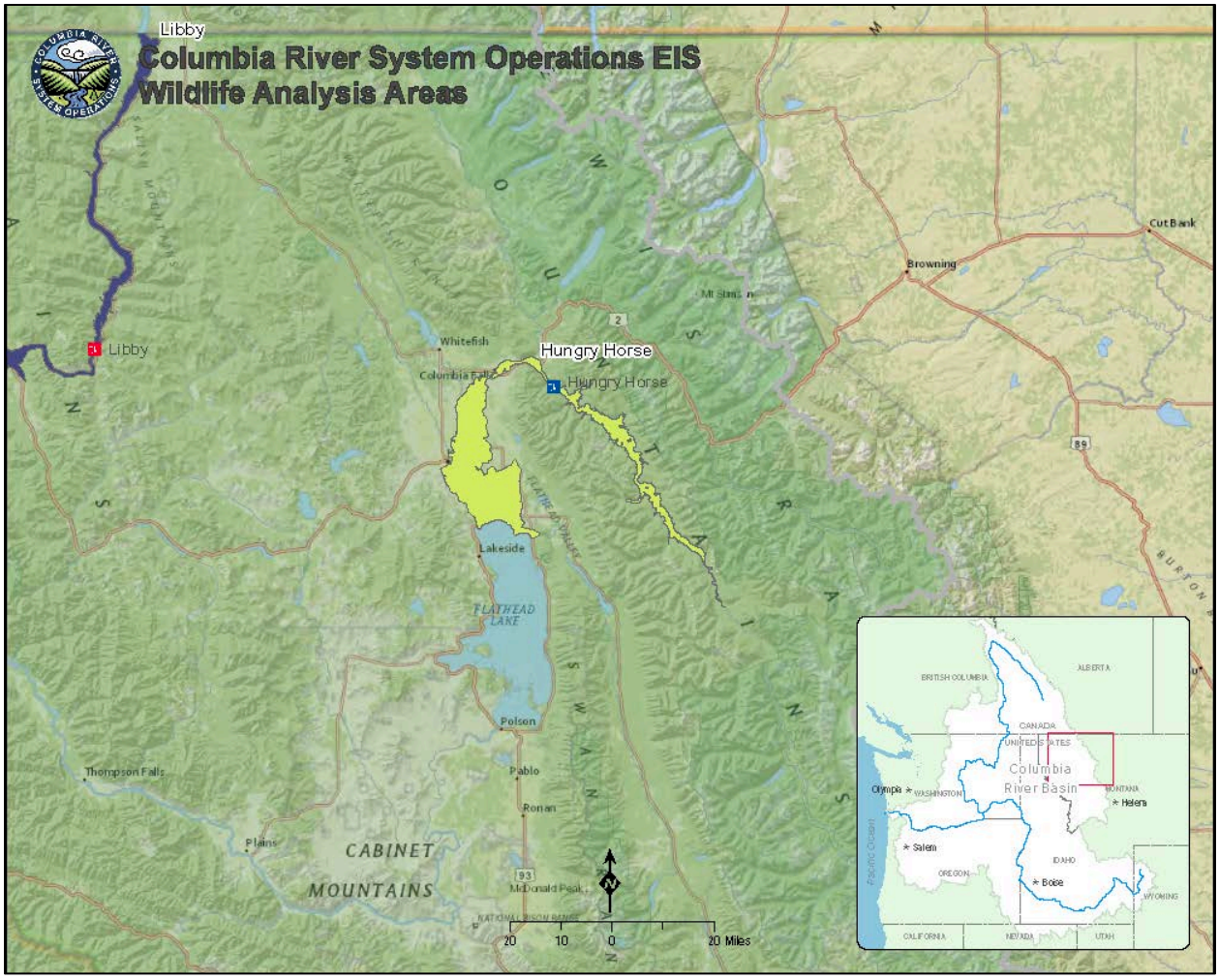

Figure 2-1. Hungry Horse Dam, Flathead Lake and Upper Flathead River

2.1.2 Land Cover

2.1.2.1 Uplands

The upland areas surrounding Hungry Horse study area support many diverse habitats. Upland grasslands, meadows and floodplain terraces are dominated by bluebunch wheatgrass, rough fescue, Idaho fescue, and blue grass. Upland shrubland is dominated by the presence of several species including serviceberry, bitterbrush, Rocky Mountain maple, *ceanothus*, and snowberry. Alpine forests dot the uppermost rims, along the side slopes and valley floors cool moist forests of Douglas-fir, larch, and ponderosa pine are interspersed with western hemlock and western red cedar. The understory is characterized by serviceberry, red-osier dogwood, and chokecherry.

Upland habitat along the Flathead River below the town of Hungry Horse is dominated by agricultural lands and urban areas. Within the 200-year event inundation area there are no upland habitat subcategories.

2.1.2.2 Barren Zone/Drawdown Area (Hungry Horse Reservoir only)

The extent of the barren zone, or drawdown area at Hungry Horse depends upon the season and operations for flood risk management (FRM). It extends from high pool elevation, around 3558 to 3559 to a low elevation around 3512 to 3520.

2.1.2.3 Wetland – Forested and Scrub-Shrub

In the Hungry Horse study area there are approximately 13,743 acres of Forested and Scrub-Shrub wetland habitat. It is dominated by deciduous shrub and deciduous tree cover types with a dense understory of grasses, forbs and shrubs. The overstory is a mix of montane riparian composed primarily of black cottonwood and willows with western hemlock, ponderosa pine, and western red cedar.

2.1.2.4 Wetlands – Emergent Herbaceous

There are 3,507 acres of emergent wetland habitat in the study area.

The MFWP 2016 Report on Aquatic Invasive Species Monitoring detected many common species in this study area, including: reed canary grass, common water moss, water mudwort, *Chara* spp., white waterbuttercup, slender leaved pondweed, puzzlegrass, leafy pondweed, white-stemmed pondweed, horned pondweed, Potamogeton spp., slender water-nymph and water smartweed (MFWP 2017).

2.1.2.5 Water

There are 28,824 acres of opern water in the study area which provides habitat for waterfowl and other wildlife. Communities of aquatic plants are similar to those found downstream at Flathead Lake. The species commonly found are pondweed, parrotweed, duckweed, and the invasive *Elodea*, knotweed, and milfoil. Curly leaf pondweed and flowering rush, both invasive plants, are found in the Flathead River near Fennon Slew (MFWP 2017).

2.1.2.6 Islands

There are 11 islands, providing mostly coniferous habitat, within Hungry Horse Reservoir, totaling 334 acres. The islands are ringed by barren areas during drawdowns. The South Fork Flathead Riverbelow the dam does not have islands. The Flathead River in the study area may have islands, or channel braiding, but none of the alternatives influence the island habitat within the Flathead.

2.1.3 Wildlife

2.1.3.1 Birds

Montana Partners-In-Flight Bird Conservation Plan (MPIF, 2000) classified breeding bird species based on their priority for conservation actions within the state. Table 2-1 lists the highest priority breeding bird species that are found in the Flathead River subbasin along with their habitats and abundance. All neotropical migrant birds are also considered target species, as are wood ducks, common goldeneye, and sandhill cranes.

396 **Table 2-1. Bird species in the subbasin considered a high priority for conservation**

Species	Priority[1]	Habitat	Abundance
Common Loon	I	Wetland	Uncommon
Horned Grebe	II	Wetland	Uncommon
Trumpeter Swan	I	Wetland	Rare
Harlequin Duck	I	Riparian	Uncommon
Barrow's Goldeneye	II	Wetland, riparian	Uncommon
Hooded Merganser	II	Wetland, riparian	Common
Bald Eagle	II	Wetland, riparian	Common
Northern Goshawk	II	Forest	Uncommon
Peregrine falcon	II	Wetland, riparian	Rare, unique
Ruffed grouse	II	Riparian	Common
Columbian Sharp-tailed grouse	II	Riparian	Extirpated
Long-billed Curlew	I	Grassland	Uncommon
Flammulated owl	I	Forest	Rare
Black swift	II	Riparian	Unique, rare
Vaux's swift	II	Riparian, forest	Common
Calliope hummingbird	II	Riparian, forest, shrubland	Abundant
Lewis's woodpecker	II	Forest	Rare
Red-naped Sapsucker	II	Riparian, forest	Abundant
Williamson's Sapsucker	II	Forest	Uncommon
Three-toed woodpecker	II	Forest	Common
Black-backed woodpecker	I	Forest	Uncommon
Pileated woodpecker	II	Forest	Common
Olive-sided flycatcher	II	Forest	Common
Willow flycatcher	II	Riparian	Common
Hammond's flycatcher	II	Forest	Abundant
Cordilleran flycatcher	II	Riparian	Uncommon
Brown creeper	I	Forest	Uncommon
Winter wren	II	Forest	Common
Veery	II	Riparian	Uncommon
Red-eyed vireo	II	Riparian	Common
Lazuli bunting	II	Riparian, shrubland	Common
Brewer's sparrow	II	Shrubland	Rare
Grasshopper sparrow	II	Grassland	Rare

397 [1]Priority Levels from Montana Bird Conservation Plan: Level I species exhibit declining populations and require
398 conservation plans; Level II species are under fewer threats; may be declining or stable but still must be monitored.

RAPTORS

Great horned owls, goshawks, red-tailed hawks, ospreys, and bald eagles are represented near the reservoir. Areas used for feeding and resting by eagles include portions of the river below the dam and the upper end of the river valley above the reservoir (USACE et al., 1995).

WATERBIRDS, SHOREBIRDS AND WATERFOWL

Waterfowl seen at the project area include the Canada goose, mallard, wood duck, Barrow's goldeneye, common merganser, and a variety of other dabbling and diving duck species (USACE et al. 1995). Some shorebird species seasonally inhabit the dam area for feeding and as a rest stop during southern migration. Species include the common snipe, spotted sandpiper,and lesser yellowlegs (USACE et al. 1995). Island, backwater sloughs, and gravel bars are used by Canada geese for nesting, brooding and loafing sites. Riparian and mixed forest, islands, bottomland meadows, and riparian shrubland in the project area offer suitable nesting habitat for a variety of duck species. Cavity nesting species use cottonwood and conifer trees in bottomland forest types. The mallard was the most common breeding waterfowl species using bottomland meadows, riparian shrublands, and beaver pond areas prior to the project, but is far less numerous now. The harlequin duck is known to nest along swift streams and rivers in northwestern Montana including the Flathead River (USACE et al. 1995).

The Flathead River and delta at Flathead Lake provides an important migratory stopover area for migrating birds and is an Audubon Important Bird Area, a critical area for bird conservation. During migration over 220 species use the open water of the river, delta, and slough. The area is an important refueling stop for tens of thousands of Central and Pacific migratory birds with northern pintail, American wigeon, tundra swan, and Canada goose being the most common. Offshore habitats are important overwintering areas for to 2,000 mixed diving ducks each year as well as both tundra and trumpeter swans. It is also a major staging and roosting area for gulls during both spring and fall migration (Audubon 2018).

PASSERINES

The bird life of the area is representative of coniferous forests, including such species as the mountain chickadee, woodpeckers, swallows, wrens, bluebirds, finches, red-breasted nuthatch, common flicker, American robin, hermit thrush, red-eyed vireo, fox sparrow, pine siskin, and dark-eyed junco (USACE et al. 1995). Island wildlife includes common flickers, belted king fishers, and several other species of small birds (USACE et al. 1995). The gray jay, cliff swallow, poorwill, rufous hummingbird, pileated woodpecker, dipper, western meadowlark, and northern oriole are a few of the many non-game birds that can be found in the Flathead region. Species such as the white-winged crossbill, northern shrike, and the common redpoll use the region during the winter (USACE et al. 1995).

GALLINACEOUS BIRDS

Ruffed grouse, spruce grouse, and blue grouse are all known to occur in the South Fork drainage. The ruffed grouse and blue grouse are common in the riparian areas, while spruce grouse are common in coniferous forests along the valley walls. Ruffed grouse prefer open hardwood stands with moderately dense herbaceous and sapling understory for courtship, nesting and broods. Blue grouse typically breed in open stands of conifers interspersed with openings of herbaceous cover (USACE et al. 1995)

Spruce grouse inhabit mixed coniferous forests, generally preferring subalpine spruce-fir and lodgepole pine. Spruce grouse also inhabit spruce-fir forests interspersed with fire induced serial stands of western larch and lodgepole pine (USACE et al. 1995).

Wild turkey, ring-necked pheasant, and ruffed grouse are the principal game birds of the Flathead Riverbasin (USACE et al. 1995).

2.1.3.2 Mammals

TERRESTRIAL

The pine marten inhabits mature coniferous timber with small openings. Bottomland and lower valley slopes of old growth with fire-caused openings, provide the most preferred of marten habitat. Lynx prefer the dense seral stands of lodgepole pine due to the high densities of showshoe hare, their preferred prey. Snowshoe hares reach their highest densities in these seral forests. Other mammals include weasel, skunk, and raccoon (USACE et al. 1995).

Black bears are present along the riparian areas and lower benches. The large cottonwood trees located along the bottoms provide preferred type of denning sites. The riparian zones provide abundant lush vegetative forage during the spring, and an abundant late summer and fall food supply of berries and mast. Grizzly bears also reside in the project area. Grizzly bears select low level riparian areas after spring emergence because of the available succulent forage. In some areas big game carrion is an important source of spring food. During the summer period grizzly bears move up to higher elevations as the snow recedes. The fall period is spent in preparation for denning and the bears are forced back down to the lowland habitats for available food. The mountain lion is known to occur in a variety of upland and bottomland areas (especially white-tailed deer habitat) where they feed on deer and elk. The bottomland and open shrubland slopes offer important winter range for prey species (USACE et al. 1995).

During the winter, elk require habitats that provide food, escape cover and thermal cover. Elk prefer habitats that support mountain maple, serviceberry, willow, chokecherry, dogwood, and ceanothus. Elk of the project area are not limited in the availability of summer range. A scattered population of mule deer exists around the project area. The deer are widely distributed in the summer with use in all the drainages. During the winter, the deer tend to concentrate on the open shrublands along south- and westfacing slopes where abundant forage is located. The white-tail deer population uses a wide variety of habitats throughout

spring, summer, and fall. Winter ranges are in the south and west facing slopes along the east side of the drainage. Fires during the early portion of this century created extensive shrublands and conifer regeneration which, when combined with adjacent thermal cover, provide excellent winter range. The further succession of thick lodgepole pine stands has caused a slight decline in white-tail deer numbers (USACE et al. 1995).

The intermixture of forest, grassland, cropland and water in the Flathead River and valley provide excellent cover and forage for white-tailed deer; the main large animal of the valley. The white-tailed deer use a wide variety of habitats throughout the year. Elk and moose are also present in stable but smaller populations (USACE et al. 1995).

Black bears are present along the riparian areas and lower benches. The large cottonwood trees located along the bottoms provide preferred denning sites. The riparian zones provide abundant lush vegetative forage during the spring, and an abundant late summer and fall food supply of berries and mast. The mountain lion is known to occur in a variety of upland and bottomland areas, where they feed on deer and elk (USACE et al. 1995).

AQUATIC

The most common aquatic animals of the area include beaver, muskrat, river otter, and mink. Beaver prefer riparian habitats along the South Fork and its tributaries, which has traditionally supported moderate populations of beaver. Optimal habitats for beaver are those areas where willow or poplars are available along permanent water courses (generally the larger tributaries). Muskrat probably use aquatic and streamside habitats along both the South Fork and its tributaries. Otters appear to be numerous along the river and use both the river and its tributaries. Backwater sloughs, streams, lakes, reservoirs, and beaver dens could also be important habitat for otters. Mink occur along the South Fork where they forage in riparian vegetation, overhanging banks, and log jams (USACE et al. 1995).

Muskrat, river otter, beaver, and mink use habitats along the upper Flathead River and along the north shore of Flathead Lake. Muskrats prefer slough and pond habitats and avoid the braided river section (USACE et al. 1995).

2.1.3.3 Reptiles and Amphibians

Amphibians are present in many of the wet habitats, especially wetland and riparian habitats. Species include the Columbia spotted frog, western toad, Rocky mountain tailed frog, chorus frog, long-toed salamander and tiger salamander. Two species of garter snakes (common and western terrestrial), prairie rattlesnake, bull snake, racer, and rubber boa also occur.

2.1.3.4 Invertebrates

Biotic diversity is severely reduced and community composition is grossly altered in the South Fork of the Flathead River, as caused by Hungry Horse Dam (Perry and Graham 1981). Invertebrate fauna is dominated by Dipterans (true flies). Other invertebrates include mayflies,

stone flies, and caddisflies. In comparison to the South Fork, other portions of the Flathead River have diverse invertebrate populations and communities (Perry and Graham 1981).

2.1.3.5 Introduced and Invasive Species

Wildlife Aquatic Invasive Species have not been recorded in the reservoir or the Flathead River within the study area (Schmidt and McLane 2017).

2.2 LIBBY DAM AND LAKE KOOCANUSA

2.2.1 Study Area

The study area used to describe existing conditions and assess the range of potential impacts to wildlife and habitat features includes Libby Dam, Lake Koocanusa and the Kootenai River (Figure 2-2). The study area is within the Middle Kootenai and Lower Kootenai watersheds of the Kootenai River Basin, an international watershed encompassing nearly 18,000 square miles of British Columbia, northwest Montana and northern Idaho. The upstream extent of the study area includes Libby Dam, and the maximum pool of Lake Koocanusa and potentially affected tributary mouths, north to the U.S. – Canada border. Downstream extent includes the Kootenai River as it flows through the canyon and braided reach of Montana, the meandering reach of Idaho, north until the U.S. – Canada border. Cover, vegetation, and habitat types for this study area are identified in Table 2-2.

Libby Dam is entirely within the Northern Rocky Mountains region. The Rocky Mountains are characterized by rugged mountains, numerous river valleys and canyons, small glacial lakes, and large, low elevation lakes or reservoirs. Primary upland vegetation consists of xeric and mesic forests with Douglas-fir, western hemlock, lodgepole pine, ponderosa pine, Englemann spruce and western redcedar. Wetland and riparian areas are scattered but can be locally significant to wildlife.

In the northernmost segment of Lake Koocanusa, the reservoir is approximately two miles wide and the gorge is characterized by sloping, rolling terrain with extensive flat areas at or below pool level. The town of Rexford, Montana, is nearly seven miles south of the border and is an approximate geographic place mark for the change in the reservoir width. Downstream of Rexford, Lake Koocanusa occupies a narrow gorge averaging one mile in width. The gorge consists of steep, coniferous forests with flat benches at the mouths of tributary streams. Downstream of Libby Dam the land is characterized by relatively flat terraces between the river banks and steep, mountain slopes. The Kootenai River Valley can be described by the rugged, heavily forested, northwest-oriented mountain ranges separated by narrow linear valleys.

Table 1-2 above shows the acres of the different habitat types within the Libby Dam study area.

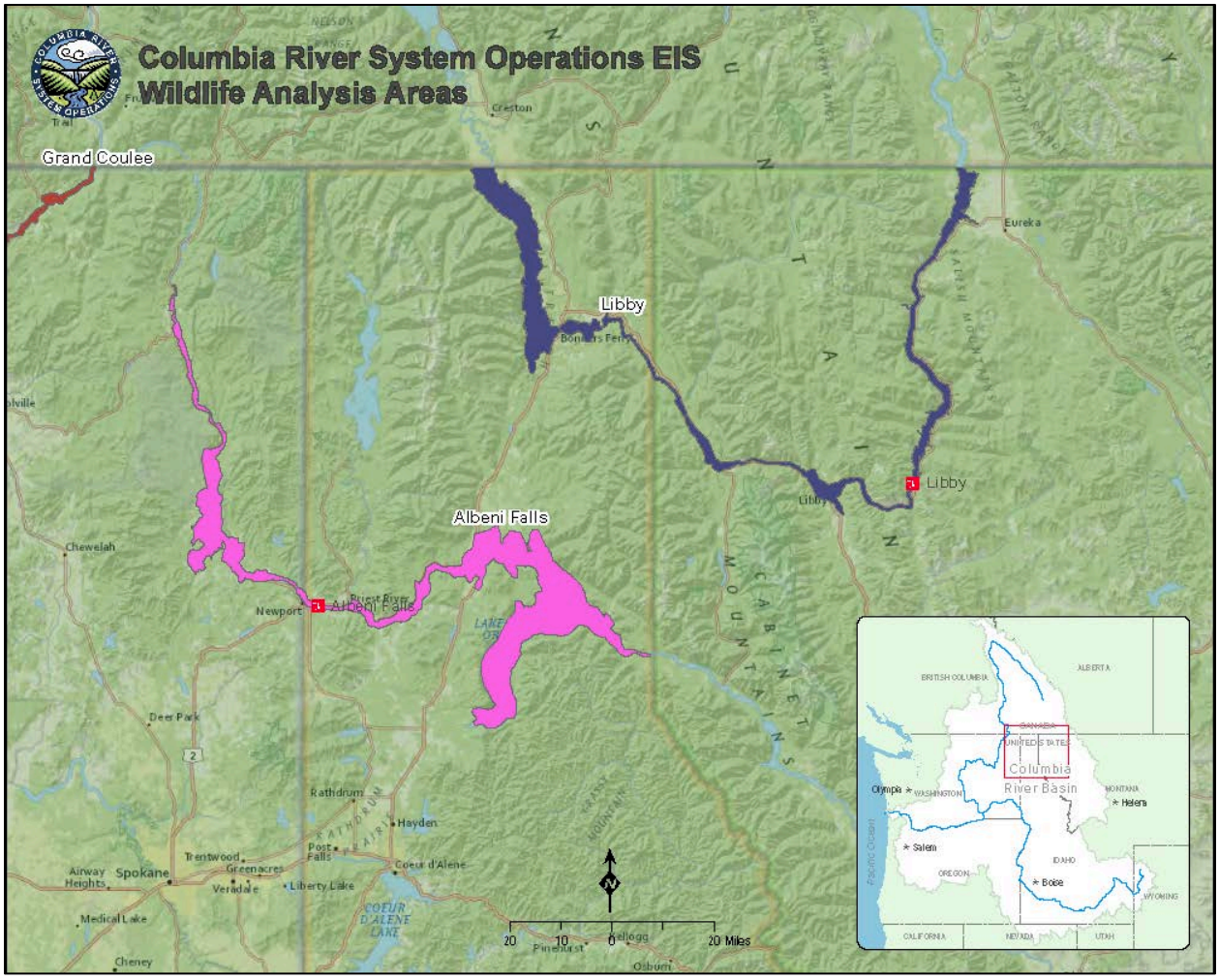

Figure 2-2. Libby Dam and Lake Koocanusa

2.2.2 Land Cover

2.2.2.1 Uplands

There are two forest systems that occur in the study area: Rocky Mountain Lodgepole Pine Forest and Rocky Mountain Ponderosa Pine Woodland and Savanna. Fire is frequent is these forests and stand-replacing fires force pines to rapidly colonize and develop into dense, even-aged stands. Ponderosa pines occur on warm, dry, exposed sites in the foothills of the Rocky Mountains at the ecotone between grasslands or shrublands, and more mesic coniferous forests. The ponderosa pine system is characteristic of an open forest with a grassy understory. Prolonged drought, beetle kill and exotic invasion rapids change the system dynamics.

The most prevalent grassland system in the study area is the Rocky Mountain Lower Montane, Foothill, and Valley Grassland system. They occur in small meadows, large open parks surrounded by conifers, and as extensive foothill and valley grasslands.

Wildfires are more prevalent in the xeric forest types. In the year 2000, two large fires burned on the banks of Lake Koocanusa within the Kootenai National Forest. The Stone Hill and Cliff Point fires burned nearly 20,000 acres about 65 miles northeast of Libby (Small and Tanke 2009). The area is in post-fire recovery, however burn scars remain. Early successional plant species have since colonized the areas, improving the habitat quality for wildlife. The northernmost reach of the fires nearly burned the Montana Highway 37 side of Koocanusa Bridge, which spans the reservoir (Montana Office of Tourism 2018).

2.2.2.2 Lake Koocanusa and Libby Dam Habitat

Lake Koocanusa lies in a valley between north-south trending mountain ranges. Consequently, the forested slopes above the river are predominantly east and west-facing slopes. The aspect of the slopes at Libby Dam predominantly controls the ability of vegetation to colonize in the hot, dry summers. South-facing slopes receive the highest amount of sunlight per day, and are the hottest and driest. Vegetation on these slopes is sparse and includes ponderosa pines, and relatively few understory plans, including roses and ninebark. Ground cover is composed of primarily grasses and other herbaceous plants.

In contrast, north-facing slopes receive little to no direct sunlight, and tend to be cooler and steeper. These slopes receive moisture from morning dew and typically do not dry in the afternoon. Slopes with greater moisture-holding abilities have higher plant diversities with lush, dense vegetation. North-facing slopes tend to contain 85 percent Douglas-fir and 15 percent western larch, with a large number of understory plants including serviceberry (*Amelanchier alnifolia* and *Amelanchier utahensis*), ocean spray (*Holodiscus bicolor*) and shade tolerant herbaceous and woody plants.

The east- and west-facing slopes tend to show a gradation of community makeup encompassing a wide range of variability within the Douglas-fir/western larch/ponderosa pine (*Pinus ponderosa*) association. West-facing slopes are generally slightly drier than east-facing and are more open in structure. East- and west-facing slopes have the greatest diversity of vegetation; common understory plants include mallow-leaf ninebark (*Physocarpus malvaceus*), snowberry (*Symphoriocarpos albus*), kinnikinnick (*Arctostaphylos uva-ursi*), longleaf and creeping Oregon grape (*Berberis nervosa* and *B. repens*), ocean spray, mock azalea (*Rhododendron menziesii*) and serviceberry. Due to high plant diversity and the increased availability of habitat and food resources, more wildlife are present on these slopes.

South-facing slopes along the Kootenai River are characterized by scattered, open stands of ponderosa pine, and a limited amount of Douglas-fir. Understory species are bitterbrush (*Purshia* sp.), western serviceberry, chokecherry, Oregon grape and white spiraea (*Spiraea betulifolia*) and Douglas spiraea (*Spiraea douglasii*). Major forbs present yarrow (*Achillea millefolium*), arrowleaf balsamroot (*Balsamorhiza sagittata*) and dogbane (*Apocynum* sp.) with bluebunch wheatgrass (*Pseudoroegneria spicata*) and rough fescue (Festuca campestris) grasses mixed in.

North-facing slopes in the Lower Kootenai are densely timbered with mountain maple, Douglas-fir, western larch and lodgepole pine. Understory shrubs consist of mock orange (*Philadelphus coronarius*), ninebark, snowberry and kinnikinnick. Forbs include heartleaf arnica (*Arnica cordifolia*), Sego lily (*Calochortus* sp.), lupine (*Lupinus* sp.) and yarrow. The predominant grass in the various meadows on the Kootnenai is pine grass with inclusions of brome (*Bromus* sp.) grasses, bluegrass (*Poa pratensis*), Junegrass (*Koeleria macrantha*), Idaho fescue (*Festuca idahoensis*), needlegrass (*Nassella* sp.), and bluebunch wheatgrass.

Floodplain surfaces suitable for natural recruitment and establishment of native trees and shrubs are limited due to the altered hydrology and lack of flood disturbance. The small patches of floodplain that do exist are covered with woody vegetation and a mix of invasive reed canarygrass (*Phalaris arundinacea*) and other non-native grasses. Non-native grasses reduce bank margin roughness, out-compete woody vegetation and reduce potential for sustainable large woody debris recruitment from the banks. Wetland habitat exists in small fragments in lower elevations along the Kootenai River.

Spotted knapweed (*Centaurea stoebe*) is prevalent in this area, with this highest recorded populations in northwestern Montana. Dalmatian toadflax (*Linaria dalmatica*) has invaded the entire state of Montana and occurs in the Libby Dam vicinity. Sulphur cinquefoil (*Potentilla recta*) can grow on the stony soil of exposed slopes near the drawdown zones of Libby Dam (CISM 2014).

There are many species in the family Asteraceae that have the potential for invading the drier, disturbed grassland habitats surrounding Lake Koocanusa. These species include diffuse knapweed (*Centaurea difusa*), yellow starthistle (*Centaurea solstitialis*), common tansy (*Tanacetum vulgare*), and hoary false-alyssum (*Berteroa incana*) (MNHP 2018).

2.2.2.3 Barren Zone/Drawdown Area

Bare sand and mud are exposed during the fall, winter and spring drawdown, and potentially during summers when the reservoir does not refill entirely. Erosion can be a serious problem, particularly during winter wind storms when the substrate is dry. Most of the barren zone which is non-vegetated, has low diversity or provides habitat for non-native invasive plant species.

Gravel bars and some portions of the shorelines are intermittently exposed during low flows and comprise a majority of barren area acreage. Water fluctuations have contributed to increased shoreline erosion of the Kootenai River, particularly in the Idaho reach upstream of Bonners Ferry. Erosion is caused by varying flows through the winter months; a mechanism of bank erosion is high flows resulting in ice forming high on the river banks. As the flow drops, the ice falls and takes bank soils with it.

2.2.2.4 Wetlands – Forested and Scrub-Shrub

Riparian plant species in riparian areas include cottonwood, willow, red-osier dogwood, mountain alder (*Alnus* sp.), birch (*Betula* sp.), serviceberry and ninebark. Riparian areas provide resources and habitat for wildlife and readily available freshwater. These areas produce a rich variety of foods including buds, twigs, catkins, seeds, and fruit. Stream-supported trees provide perches and nesting spots for ospreys and bald eagle. Waterfowl nest among the grasses and/or dense vegetation growth associated with these habitats. Most of the riparian areas around Lake Koocanusa are associated with the tributary streams flowing into the reservoir (USACE et al. 1995). There are 4,159 acres of Forested and Scrub-Shrub wetlands in the study area.

Riparian habitat is discontinuous along the Kootenai River. Habitats (within the floodplain) can be divided into coniferous and deciduous forests. Coniferous forests consist of Douglas-fir and western redcedar. Understory species include Oregon grape, Rocky Mountain juniper (*Juniperus scopulorum*), and Canadian buffaloberry (*Shepherdia canadensis*). Dominant deciduous overstory species include black cottonwood, alder and willow. Understory vegetation includes dogwood (*Cornus* sp.), gooseberry (*Ribes* sp.), chokeberry, ninebark, and serviceberry. Immediately downstream of Libby Dam is the canyon (or confined) reach of the Kootenai. Most of the canyon reach is a geologically restricted channel. Because there are many steep canyon walls, the floodplain is narrow and essentially devoid of wetlands and linear riparian strips.

Along the meandering reach of the Kootenai River in the Okanogan Highlands is primarily agricultural lands. The construction of dikes and levees have effectively disconnected the river from the surrounding floodplain (KTOI 2009).

Small tributaries and streams are typically dominated by Drummond's willow (*Salix drummondiana*), alder, or redosier dogwood shrublands. Lower gradient streams are lined with Geyer's willow (*Salix geyeriana*), Bebb's willow (*Salix bebbiana*), thinleaf alder (*Alder incana*) and rose spirea (*Spiraea douglasii*). Understory vegetation is a lush mix of mesic forbs and graminoids (IDFG 2017).

2.2.2.5 Wetlands – Emergent Herbaceous

The dominant aquatic vegetation type along Lake Koocanusa is emergent vegetation, comprising about 4% of the total shoreline (VAST 2017). Emergent Vegetation generally refers to grasses, horsetail (Equisetum sp.), sedge, or other plants tolerant of flooding (VAST 2017). There are 3,044 acres of Emergent Herbaceous Wetlands in the study area.

Downstream of Libby Dam through the canyon reach of the Kootenai, there are many steep canyon walls which restrict the floodplain extent; therefore, this reach is devoid of wetlands (CRT 2014). The canyon reach flows through the Kootenai National Forest. There are several wetlands near the town of Troy, Montana. Wetland types include freshwater emergent wetlands, freshwater ponds and freshwater forested/shrub wetland (NWI). Near the town of Libby, Montana, there are also several wetland areas beyond the banks of the Kootenai. The

middle distinct river reach is the braided reach. This reach extends from the confluence with the Moyie River, near the town of Moyie Springs, Idaho, to the town of Bonners Ferry, Idaho. Several distinct channels, islands, and numerous gravel bars were created due to the relatively broad floodplain

This subbasin includes the meander reach which flows north through Idaho, downstream of Bonners Ferry, to the Canadian border. The river gradient flattens and the floodplain widens to create a single channel. The Kootenai National Wildlife Refuge is located in the meander reach of the river, and is within the study area. The Kootenai National Wildlife Refuge near the Selkirk Mountains of northern Idaho was established as a migratory waterfowl refuge. Five miles west of Bonners Ferry, the refuge contains 2,774 acres of wetlands, meadows, riparian forests and cultivated agricultural fields. Wetlands along the Kootenai River and Myrtle Creek include open-water ponds, seasonal cattail-bulrush marshes, tree-lined ponds and rushing creeks. The refuge provides habitat for over 220 bird species including bald eagles, mallards, northern pintail, and teal. Forty-five species of mammals utilize the refuge habitat, including moose, elk, deer, bear and otter (USFWS 2015).

The Kootenai National Wildlife Refuge and the remnants of the Kootenai River floodplain contain depressional wetlands. Depressional wetlands are any wetlands found in a topographic depression and include vernal pools, old oxbows, disconnected river meanders and constructed wetlands. These wetlands support emergent marsh or tree or shrub-dominated swamps. Marshes are composed of broad-leaf cattail (*Typha latifolia*), tall bulrush species (*Schoenoplectus* sp.), panicled bulrush (*Scirpus microcarpus*), and other emergent species. Swamps are characterized by western redcedar, Engelmann spruce, rose spirea, and thinleaf alder. Reed canarygrass is the most abundant invasive plant on the Refuge, forming dense monocultures in seasonally flooded wetlands, wet pastures, and the understory of open canopy riparian forests (USFWS 2015). Swamps with high-water table may contain devilsclub (*Oplopanax horridus*) and American skunkcabbage (*Lysichiton americanus*). Amphibians, including the western toad, waterbirds, marshbirds, and waterfowl all use depressional wetlands for breeding and foraging habitats (IDFG 2017).

2.2.2.6 Water

The Kootenai River downstream of Libby Dam is characterized by a combination of riffles, pools and slow moving, broad, meandering river sections. The reach between Fisher River and Libby Dam offers a variety of habitats including deep water, shallow rapids and mid-stream islands and side channels. This reach is deficient in the following habitat features: cover, complexity, spawning substrate, and macroinvertebrate habitat. Cover and complexity in the form of wood-formed pools is sparse. The supply of large wood to the reach has been eliminated by the dam, which has resulted in reduced channel boundary roughness and simplification of edge habitat. There are 34,011 acres of Open Water in the Libby study area.

Didymosphenia geminata, a non-native aquatic stalked diatom also known as “Didymo” or “rocksnot”, has become established at a nuisance/noxious density in the Kootenai River downstream of Libby Dam. Unlike most algae, *Didymosphenia geminata* biomass increases in

low-nutrient conditions via stalk formation, and dominates stream surfaces by covering substrate with mat formations up to three inches thick in the Kootenai River. This in turn blocks sunlight and can interrupt ecological processes, which decreases habitat quality and reduces the abundance and diversity of native flora and fauna. Increases in these dense blooms coincide with a decline in trout density in the Kootenai River downstream of Libby Dam (USACE et al. 1995).

Filamentous algae and pond lily (*Nuphar* sp.) are common in the Kootenai River ecosystem, where flows are slack and water is shallow.

There are many invasive plant species capable of spreading into Lake Koocanusa and the Kootenai River, such as reed canary grass and curly-leaf pondweed (*Potamogeton crispus*), which is a noxious weed that spreads from plant fragments remaining of boat trailers and recreational equipment. Pondweed is spreading rapidly and is present in neighboring counties.

Eurasian water-milfoil (*Myriophyllum spicatum*) inhabits open waters of reservoirs and tolerates moving water, and is present in Lincoln County. It is likely that this water-milfoil species has invaded Lake Koocanusa. Eurasian water-milfoil spreads through boat trailers but also waterfowl. It can also disperse between water bodies through wind and water flow. Eurasian milfoil displaces native aquatic plant communities by forming thick underwater stands of tangled stems and mats of vegetation. The American water-lily (*Nymphaea odorata*) inhabits lakes, ponds, and valleys and has been recorded in the county (MNHP 2018).

Aquatic invasive plant species found specifically in the Idaho segment of the Kootenai River include Eurasian watermilfoil, flowering rush, and curly pondweed. These aquatic species often form dense mates that prevent the establishment of native plants and degrade wildlife and fish habitat (IDFG 2017). These species degrade upland, wetland and riparian habitats.

One of the most abundant invasive plants in the study area is reed canarygrass (*Phalaris arundinaceae*). While reed canarygrass is native to the Pacific Northwest, an aggressive hybrid used as a forage grass species, has outcompeted the native species. The invasive forms dense monocultures in seasonally flooded wetlands, wet pastures, and the understory of open canopy riparian forests (USFWS 2015). Yellow iris (*Iris pseudacorus*) grows in marshes and wet meadows, and has been recorded in southern Lincoln County. Salt-cedar (*Tamarix ramosissima*) is a deciduous shrub with small pink flowers that inhabits meadows along rivers, streams, ponds, and plains. Salt-cedar is invading Montana east to west and may invade Lincoln County in the near future.

2.2.2.7 Islands

A diversity of plant species create island habitat within Lake Koocanusa. Overstory species include Douglas-fir, western larch and western redcedar. The understory consists of Rocky Mountain juniper, common juniper (*Juniperus communis*), birch, ninebark, snowberry and Oregon grape. These islands support a limited range of wildlife species.

The Yarnell Islands in Lake Koocanusa can be accessed for recreational purposes. At high water levels there are two islands, and at low water level there is just one (assessed www.Libbymt.com). Visitors launch from the boat ramps and can camp at one of eight primitive campsites. Due to the recreational capacities of these islands and disturbance caused by visitors, the habitat quality for wildlife is reduced. Other islands known to have existed in Lake Koocanusa but are now seasonally or permanently inundated include Cedar Island, Kins Island, Murray Island, and Whites Island (USGS 2018a).

Islands developed from the gravel bars on the Kootenai River are maintained in early successional stages through water level fluctuations. A variety of shrubs, forbs, and grasses do eventually colonize these areas and include willow, sweetclover (*Melilotus* sp.), cocklebur (*Xanthium* sp.) and thistle (*Cirsium* sp.). The bars and vegetated islands are vital habitat for numerous shorebirds, ducks, and geese.

2.2.3 Wildlife

Typical wildlife species in the Northern Rocky Mountains Region include mergansers, sandpipers, waterfowl, osprey, bald eagles, beaver, otter, deer, elk, and bighorn sheep. Deer and elk eat the twigs and foliage of Oregon grape, snowberry, ponderosa pine, and Douglas fir. White-tailed deer show a preference for kinnikinnick, the fruit of which is also eaten by blue grouse. Red squirrels are insectivorous during spring and summer, but rely upon seeds of Douglas fir and ponderosa pine during fall and winter. Black bears feed upon berries, tubers, insects, small mammals, and honey. Several bat species breed in the Kootenai River Basin and are commonly seen at dawn and dusk when they are out foraging for insects. Although the understory vegetation is diverse, the overstory vegetation is primarily composed of coniferous trees, and the bird life is therefore representative of a coniferous forest. Common species include mountain chickadee, red-breasted nuthatch, northern flicker, American robin, and dark-eyed junco.

2.2.3.1 Birds

RAPTORS

Great-horned owls, goshawks, and red-tailed hawks inhabit the forests surrounding the reservoir.

Osprey and bald eagles perch in the tall bankside cottonwood and Douglas-fir trees along the riparian areas below the mouth of the Fisher River, and bald eagles nest along the Fisher and Kootenai Rivers in Montana. Migratory and wintering concentrations of bald eagles occur below Libby Dam. Great-horned owl, goshawk, red-tailed hawk, and short-eared owl are other common raptors that inhabit the area.

WATERBIRDS, SHOREBIRDS AND WATERFOWL

No colonial nesting birds are known to occur in the Kootenai River (USACE et al. 1995). Some shorebird species seasonally use the Kootenai River area for feeding and as a rest stop during southern migration. Species include the common snipe, spotted sandpiper, and lesser yellowlegs. Common snipe and spotted sandpiper may nest near the river. The Kootenai River Basin lies primarily within the Pacific Flyway. Mallards, harlequin ducks, pintail, American widgeon, teal, gadwall, goldeneye, American coot, common merganser, tundra swan, and Canada goose constitute the principal waterfowl species. The ten mile reach of the river below Libby Dam does not receive heavy use by waterfowl, although occasionally flocks of up to 30 waterfowl feed and rest on the slower moving backwater areas near the river islands, Harlequin ducks nest in smaller tributary streams, and possibly along the Kootenai River as well. Canada goose and duck nesting occurs on some of the river islands and among the grasses and/or dense vegetation growth associated with these habitats.

PASSERINES

The bird life of the area is representative of coniferous forests including species such as the mountain chickadee, woodpeckers, swallows, wrens, bluebirds, finches, red-breasted nuthatch, common flicker, American robin, hermit thrush, red-eyed vireo, fox sparrow, pine siskin, and dark-eyed junco (USACE et al. 1995). Most of these species are insectivorous, but red-breasted nuthatches also eat Douglas-fir and ponderosa pine seeds. Additional species include downy and pileated woodpeckers, common nighthawk, western tanager, cordilleran flycatcher, American robin, Swainson's thrush, northern flicker, house sparrow, and Steller's jay. River habitats support belted kingfisher, redwing blackbird, yellow warbler and the American dipper, while island wildlife include common flickers and belted kingfishers.

GALLINACEOUS BIRDS

Ruffed and blue grouse are known to occur around Lake Koocanusa along an elevational gradient. These upland game birds prefer to eat the kinnikinnick fruit. Ruffed grouse are the most common species occurring at lower elevations, while the blue grouse prefer more mountainous areas (USACE et al. 1995).

Upland game in Kootenai River basin include ruffed, blue and spruce grouse, ring-necked pheasants, and mourning doves. Chukar, sharp-tailed grouse and Hungarian partridges also occur in the basin. Agricultural lands near Bonner's Ferry support moderate number of ring-necked pheasants and migrating mourning doves. The wild turkey can also be found along the river.

2.2.3.2 Mammals

TERRESTRIAL

Commons mammals around Lake Koocanusa include raccoon, cottontail rabbits, porcupine, marten, bobcat, weasel, coyote, mountain lion and black bear. Local small mammals include shrews, voles, bushy-tailed woodrat, deer mouse and the house mouse. In the past decade, gray wolves have been tracked inhabiting the forested uplands in the northern reaches of Lake Koocanusa near the Canada border. Occasionally badger are sighted along the reservoir and tributaries. Big horn sheep have been reported into the mountains east of Lake Koocanusa and near Kootenai Mountain. Reservoir island mammals include red and flying squirrels, along with small mammals like mice and voles.

Survey work was conducted at Libby Dam in 2011 to document bat activity and diversity. The presence of bats and associated guano at the visitor center was a public annoyance and Corps biologists wanted to encourage them to roost away from the public. Nine-species were documented: little brown myotis, long-eared myotis, California myotis, western small-footed myotis, Yuma myotis, silver-haired bat, hoary bat, Townsend's big-eared bat and big brown bat. Surveys were conducted at five sites on Corps property including the Downstream Trail, Ripley, Souse Gulch, the Visitor Center, and a warehouse. The trail captured the greatest number of bat calls, with all nine species detected (USACE 2012).

Weasels, skunks and raccoons are abundant along the Kootenai River. Martens use heavily forested localities at higher elevations and wooded areas at lower elevations. Fishers have been spotted along the smaller tributaries near the town of Libby. Northern flying squirrels have also been reported in Libby (MNHP 2018).

Higher elevations of the slopes are the preferred summer range of deer, sheep and elk. The lower bottomland elevations provide winter habitat for big game. The north- facing slopes are generally used for escape and bedding cover by big game, primarily because of the lack of sunlight to the forest floor (due to the denser overstory vegetation). In addition, these slopes in the project area tend to be relatively steep, which likely discourages use by big game predators to some degree. The availability of grass on south-facing slopes makes them important seasonal feeding areas for mule deer and elk. White-tailed and mule deer favor the snowberry for its shoots and foliage, but also eat the shoots and foliage of Oregon grape, Ponderosa pine, and Douglas-fir. White-tailed deer also show an additional preference for kinnikinnick fruit. Moose seek the bottomlands for the twigs and foliage of the red-osier dogwood, willows, alder and birch. A moderate number of mountain lions, and black and grizzly bear are found throughout this region.

Principal big game animals in the Kootenai River basin are white-tailed deer, mule deer, elk, black bear and moose. Less common species are grizzly bears, mountain goats, bighorn sheep, and woodland caribou. Grizzly bears inhabit the roadless backcountry of the extreme northeast and northwest corners of the basin. Black bears can be found from the Douglas-fir forests of the

mountains to the wet meadow riparian areas by the river. White-tailed deer are abundant within the region with the largest concentration inhabiting the river basins and bottomlands.

Mule deer are less numerous and found at higher elevation in scattered herds. Elk herds are small, widely dispersed, and occur primarily in the Moyie and Fisher rivers' drainages, and the Dunn Creek drainage. Elk also occur in the Boulder Creek and Alexander Creek drainages. Herds use the north and east facing slopes at higher elevations. Moose prefer the bottomlands along lakes and streams and early successional habitat. Winter range is restricted to narrow areas along the Kootenai River and the lower reaches of lateral drainages on south and west facing slopes. Migration to winter range generally occur during late October or early November. During normal winters elk and sometimes moose, are in direct competition with deer for food and cover on winter range.

AQUATIC

American mink, river otter and muskrats reside along the shore of Lake Koocanusa. However, populations remain small due to the extensive barren drawdown area between the water in the reservoir and shoreline vegetation during most of year (i.e. when the reservoir is less than full).

Beaver, muskrat, mink and river otter constitute the principal mammals inhabiting the Kootenai River basin. Beaver colonies are found primarily along the Kootenai mainstem downstream of Bonners Ferry and along certain gradient tributaries. Diked agricultural lands near Bonners Ferry support the bulk of muskrat populations. Small number of mink and river otters occur along main watercourses in the timbered areas of the basin.

2.2.3.3 Reptiles and Amphibians

Amphibians around the reservoir include a few species of salamanders (*Ambystoma* sp.), frogs (*Rana* sp., *Lithobates* sp., and *Pseudacris* sp.), and the western toad (*Anaxyrus boreas*). Reptiles include the painted turtle (*Chrysemys picta*), common garter snake (*Thamnophis sirtalis*), rubber boa (*Charina bottae*), western skink (*Plestiodon skiltonianus*), and the northern alligator lizard (*Elgaria coerulea*). Amphibians inhabiting land along the river include a few species of salamanders and frogs, including the Pacific tree frog (*Pseudacris regilla*), and the western toad. The western tiger salamander (*Ambystoma mavortium*) has been spotted in the Lower Kootenai. Reptiles include the painted turtle, garter snake, rubber boa, western skink, and the northern alligator lizard. Amphibians are closely tied to the river and its sloughs while reptiles can be found from upland coniferous forests to the mats of emergent plant bed in river sloughs.

Terrestrial snake species include the North American racer (*Coluber constrictor*) and the terrestrial garter snake (*Thamnophis elegans*). These species occur in a wide variety of habitats including grasslands and coniferous forests, and do not require emergent wetland or riparian habitat (MNHP 2018).

The Corps conducted a species inventory for reptiles and amphibians near Libby Dam in 2013. The survey was conducted to determine presence of suitable habitat for the Montana state-

listed Coeur d'Alene salamander. Fifteen sites on Corps-managed land near Libby Dam and along the upper Kootenai River were surveyed. Three amphibian species and two reptile species were detected. These species include the long-toed salamander (*Ambystoma macrodactylum*), western toad, Pacific tree frog, Western skink and terrestrial garter snake. The western toad and western skink are both considered species of concern by Montana State (Lucas 2013).

The American bullfrog (Lithobates catesbeianus) are a non-native invasive species found in both Montana and Idaho. American bullfrogs live in larger bodies of quiet water and are voracious feeders. In the Northwest they have so far been unable to invade colder, higher elevation waters. However, in the Bitterroot Valley, bullfrogs have virtually wiped out native amphibians from the low valley ponds and wetlands. Bullfrogs have been implicated in extirpations of native frogs and turtles, and declines in waterfowl production as they often consume ducklings (MNHP 2018).

2.2.3.4 Invertebrates

TERRESTRIAL

Bumblebees are commonly seen around the reservoir and Kootenai River gathering pollen and nectar from flowering understory shrubs and forbs. Three species have been documented within the past five years: two-from bumble bee (*Bombus bifarius*), fuzzy-horned bumble bee (*Bombus mixtus*) and the half-black bumble bee (*Bombus vagans*) (MTNHP).

The meadow slug (Deroceras laeve) and the subalpine mountainsnail (Oreohelix subrudis) have been reported near Libby Dam (MNHP 2018). Common terrestrial invertebrates include ants, termites, grasshoppers, crickets, and beetles (Bug Guide 2018).

AQUATIC

The Kootenai River from Libby Dam to the Idaho state line continuing downstream towards Bonners Ferry, Idaho, can be classified as a Large Intermountain Glaciated Valley River type. This Aquatic Ecological System has diagnostic aquatic macroinvertebrate species characterized by main channel, fast current stonefly and caddisfly species: giant salmonfly (*Pteronarcys californica*), golden stone (*Hesperoperla pacifica), Brachycentrus americanus, Arctopsyche grandis, Hydropsyche, Glossosoma, Lepidostoma* and the tipulids: *Hexatoma and Antocha*. Mayflies are diverse in this system and contain many genera, including: *Baetis, Ephemerella, Serratella, Rhithrogena, Drunella and Epeorus* (MNHP 2018).

As the Kootenai becomes sediment-impaired, degraded or dewatered, the waters warm and the macroinvertebrate communities shift to mayfly (*Baetis tricaudatus* and *Plauditus sp.*), caddisfly (*Brachycentrus sp*. and *Amiocentrus aspilis*), beetle (*Optioservus sp., Narpus sp.* and *Lara sp.*) and dipteran species. Additional indicator species include net-spinning caddisflies (*Hydropsyche),* snail-cased caddisflies *(Helicopsyche borealis),* and black flies *(Prosimulium*)

(MNHP 2018). These macroinvertebrates support large bodied sucker, trout, and minnow species.

A diversity of dragonflies, darters, and meadowhawks occur on Lake Koocanusa. These species include the white-faced meadowhawk (*Sympetrum obtrusum*), striped meadowhawk (*S. pallipes*), black meadowhawk (*S. danae*), variegated meadowhawk (*S. corruptum*), Canada darner (*Aeshna canadensis*), paddle-tailed darner (*A. palmata*), black-tipped darner (*A. tuberculifera*), shadow darner (*A. umbrosa*) and the zigzag darner (*A. sitchensis*).

Populations of the pearlshell mussel have been reported in the Kootenai River, but populations may be in decline due to the loss of their native host fish the Western Cutthroat Trout (MNHP). Signal crayfish occur in the tributaries.

The virile crayfish (*Orconectes virilis*) is native to eastern Montana but has been invading westward. They are found in permanent bodies of water deep enough not to freeze solid or experience low oxygen levels. The non-native species have been included on the Global Invasive Species database due to their impacts on native species. There is the potential for other non-native crayfish to be introduced into the Lake Koocanusa and the Kootenai River. These species include the rusty crayfish (*Orconectes rusticus*) and red-swamp crayfish (*Procambarus clarkii*).

2.3 ALBENI FALLS DAM AND PEND OREILLE LAKE

2.3.1 Study Area

The study area used to describe the existing conditions and assess the range of potential impacts for wildlife and habitat features includes lands associated with the Albeni Falls Dam and includes Pend Oreille Lake and immediately upstream into the Clark Fork River where it enters the lake, along with the reach from Albeni Falls Dam downstream to the top of the maximum pool at the upstream extent of Frank D. Roosevelt Lake (formed by Grand Coulee Dam). Much of Pend Oreille Lake is surrounded by the Idaho Panhandle National Forests. Habitat types in the study area are described above in the introduction summarized in Table 2-2. Wetland communities comprise about 22 percent of the Albeni Falls study area and 4 percent of Pend Oreille lake shoreline.

The Clark Fork-Pend Oreille River Basin is a mountainous area dominated by conifer forests, situated mainly in western Montana but also in portions of northern Idaho, northeastern Washington, and two small areas in British Columbia, Canada (Figure 2-3). The basin comprises a total area of 25,960 square miles, of which 24,200 square miles are upstream of the Albeni Falls Dam. Approximately 80 percent of the basin area is covered by coniferous forests. At higher elevations (above 3,600 feet), mature forests are dominated by Douglas fir, western redcedar, western hemlock, subalpine fir, grand fir, and western white pine. At lower elevations, ponderosa pine, lodgepole pine, and western larch dominate.

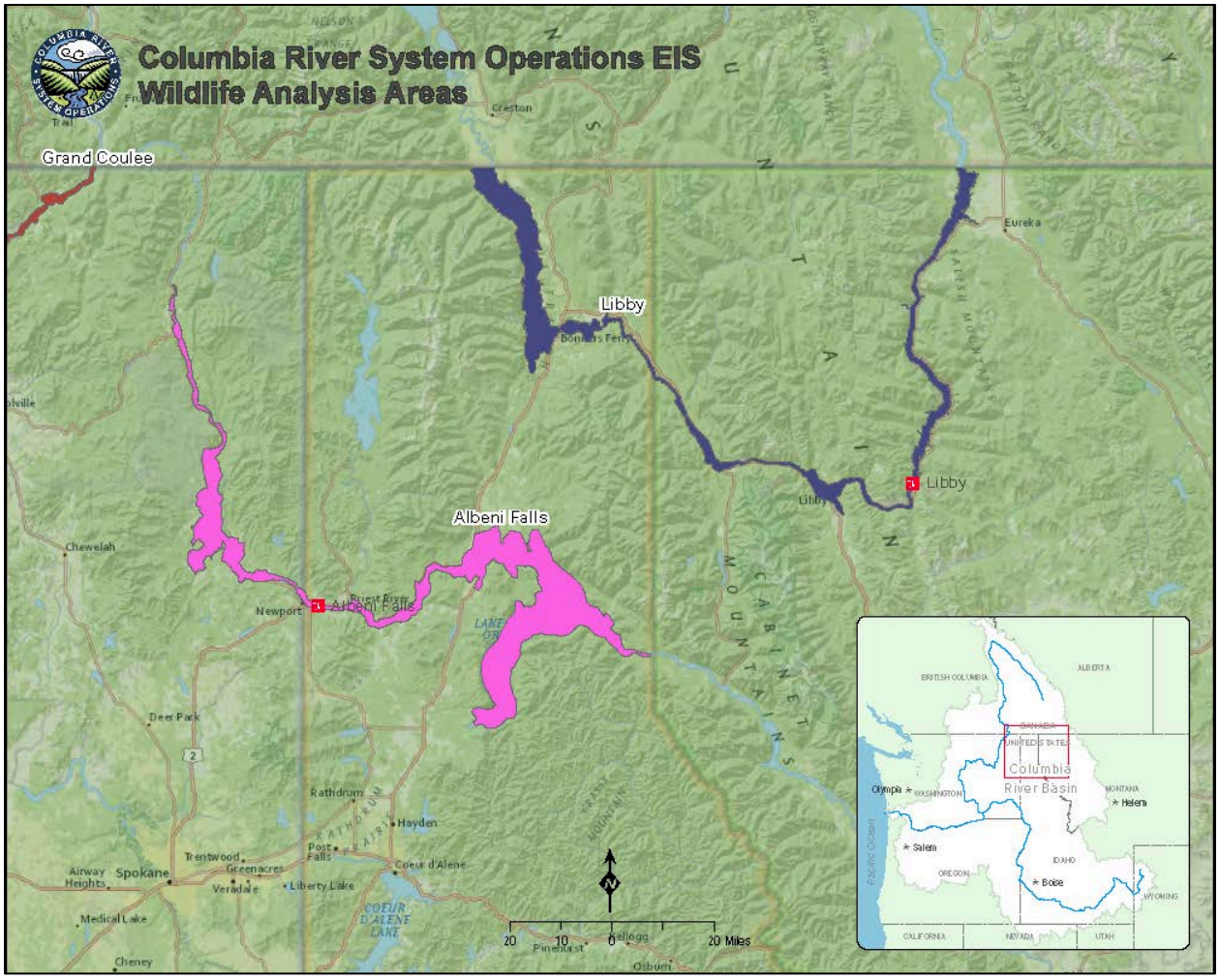

Figure 2-3. Albeni Falls Dam and Pend Oreille Lake

Lake Pend Oreille is a natural lake. Though construction of Albeni Falls Dam did not raise the level of the lake over natural elevations, operations of the dam have dramatically changed the natural environment of the lake by altering hydrology.

At the summer lake elevation of 2062.5 feet the shoreline is heavily influenced by humans. This includes the presence of human-made structures such as retaining walls, riprap bank protection, boat ramps, and imported sand beaches. In these areas, vegetation includes lawns and ornamental plantings. Some portions of the shoreline remain in a more natural condition and include features such as native rock or gravel bars, and herbaceous and forested wetlands. These natural areas may be particularly sensitive to fluctuations in lake level.

Nine Wildlife Management Areas are located along the shores of Pend Oreille Lake or on tributaries immediately upstream of the lake and within the study area. A list of these areas and their terrestrial, water and total acreage is provided in Table 2-2. No USFWS or State Fish and Game lands are located in the immediate vicinity of the lake. The 4,046 acres of project lands at Pend Oreille Lake that are licensed for wildlife management to the Idaho Department of Fish

and Game (IDFG) are largely wetlands, consisting primarily of wet meadows, shallow marsh, deep marsh, and submerged aquatic beds (USACE 2017).

Table 2-2. Wildlife Management Areas at Lake Pend Oreille (Carlisle and Miller 2015)

Property	Terrestrial Acreage	Water Acreage	Total Acreage
Priest River WMA[1]	51.1	86.3	137.4
Riley Creek WMA[1]	78.4	120.1	198.4
Strong Island WMA	18.9	11.8	30.7
Hoodoo Creek WMA	47.8	34.2	82.0
Morton Slough WMA and Morton Slough Access Area	98.3	303.6	401.9
Hornby Creek WMA	9.2	21.7	30.9
Ponder Point WMA	5.1	0.5	5.6
Pack River WMA	126.8	1,247.1	1,374.0
Clark Fork WMA	573.7	735.5	1,309.2
Totals	**1,093.2**	**2,588.9**	**3,682.0**

[1]Includes associated Recreation Area acreage.

2.3.2 Land Cover

Table 2-2, above, shows the acres of the different habitat types within the Albeni Falls Dam study area.

2.3.2.1 Uplands

At lower elevations, including near the water's edge, ponderosa pine (*Pinus ponderosa*) and western larch (*Larix occidentalis*) dominate, with western red cedar (*Thuja plicata*), Douglas fir (*Pseudotsuga menziesii*), and grand fir also prevalent. Northern Idaho coniferous forests are highly diverse and typically include multiple coniferous species, along with deciduous species in many areas. Common deciduous trees in the area include paper birch (*Betula papyrifera*), aspen *(Populus tremuloides*), willow (*Salix* spp.), black cottonwood (*Populus balsamifera* ssp. *Trichocarpa*), and red alder (*Alnus rubra* Bong.). Most of the forests around Pend Oreille Lake are second growth, ranging from 15 to over 100 years old. Forest understory is well established in open canopy forests. Alder, hawthorn (*Crataegus* spp.), snowberry (*Symphoricarpos albus*), dogwood (*Cornus sericea* L.), and service berry (*Amelanchier alnifolia*) predominate. These areas are important nesting and feeding habitats for numerous large and small birds and mammals (USACE, Seattle District 2017). Most of the forest in the study area is second growth and most of the forested area is grazed by livestock. About one-fourth of the basin area is devoted to farming.

Terrestrial non-native invasive plants are also present along the shoreline and in the vicinity of the lake. Common plants include: yellow devil hawkweed (*Hieracium floribundum*), diffuse

knapweed (*Centaurea diffusa*), spotted knapweed (*Centaurea bierbersteinii*), dalmation toadflax (*Linaria dalmatica*), yellow hawkweed (*Hieraceium pretense*), sulfur cinquefoil (*Potentilla recta*), bull thistle (*Cirsium vulgare*), Canada thistle (*Cirsium arvense*), and St. Johnswart (*Hypericum perforatum*).

2.3.2.2 Barren Zone/Drawdown Area

The Pack River delta and the Clark Fork River delta are barren during the winter drawdown period. In addition, much of the shoreline in the northern portion of the lake is exposed and barren during the drawdown. Soils of the Clark Fork delta are sandy. The remainder of the barren areas of the lake are primarily fine-textured. Recent soil stabilization, increased elevation, and planting efforts in Clark Fork River delta have focused on restoring ecosystem health. The delta will be discussed further under Riparian Habitat.

Wave and wind erosion have had dramatic effects, particularly in areas where shoreline vegetation has been lost. Seasonal fluctuations may be the greatest cause of erosion, resulting in sloughing of banks that become waterlogged in summer, then collapse under their own weight as the reservoir drops in elevation.

2.3.2.3 Wetlands – Forested and Scrub-Shrub

More moist conditions exist along lands immediately adjacent to the Lake. Reflecting this, the composition of the surrounding forest shows areas with significant inclusions of deciduous trees. Common deciduous trees in these forests include paper birch, aspen, willow, black cottonwood, and red alder. Shrubs include various willows and red-osier dogwood. There are approximately 24,300 acres of Forested and Scrub-Shrub wetlands, of which approximately 1,400 are Eastside Riparian Wetlands.

Some areas along the shore are wetlands dominated by trees and/or shrubs. Typically called a swamp, wooded wetland, or forested wetland. This includes portions of the Clark Fork delta, which has been the focus of soil stabilization and rehabilitative planting with native trees, shrubs, and herbaceous plants for ecological restoration. The soils are saturated during the growing season and at certain times of the year standing water is common. Waterlines are visible on the trunks of trees and rocks. Common woody plants include western red cedar black cottonwood, and paper birds. Shrubs include common snowberry, red-osier dogwood, Sitka alder, and Wood's rose.

2.3.2.4 Wetlands – Emergent Herbaceous

Wetlands occur throughout the shoreline of Pend Oreille Lake and comprise about 4% of the landcover, most of which are on ACOE project lands. As discussed above, roughly 3,780 acres of the project lands are licensed for wildlife management to the IDFG. An extensive discussion of wetland habitat and vegetation around the Lake can be found in the 1983 Albeni Falls Dam EIS. In general, functional wetlands around the lake, including in the Clark Fork Delta, have largely

disappeared from elevations between 2062.5 and 2055 feet due to holding the summer lake elevation to 2062.5 for several months.

Wetlands that still exist between 2051 and 2056 feet elevations are the lacustrine, littoral type. Native species likely to occur within this band include Chara (*Char*a sp.), northern watermilfoil (*Myriophyllum sibiricum*), coontail (*Ceratophyllum demersum*), elodea (*Eloda Canadensis*), leafy pondweed (Potamogeton foliosus) and other native pondweeds (*Potamogeton* and *Stuckenia* spp.). Wet meadows may be populated by sedge and rush, shallow marsh commonly supportcattail and reed canary grass, and deep marsh may containwater lily.

Flowering rush is an emergent aquatic perennial considered an invasive noxious weed. This species was first confirmed in the lake in 2008, covering nearly 12 acres at the Clark Fork Driftyard. In 2011, the plant had increased its extent to approximately 20 acres in the Clark Fork Driftyard area. Other smaller infestations exist around the lake and the Pend Oreille River. It is found in riparian zones, wetlands, and aquatic environments to depths of about 13 feet, including a few plants found in Oden Bay (Hull 2011). Transport through water and ice have been identified as important dispersal mechanisms for flowering rush (Eckert et al. 2003). It probably originated from sources upstream as most of the upstream water bodies have substantial populations of rush within the largest population in Flathead Lake (Parkinson et al. 2010). Fluctuating lake water levels and, in particular, drawdowns that expose unvegetated sediments provide ideal sites for its establishment (Delisle et al. 2003). Therefore, existing Albeni Falls Dam operations, especially during spring refill and fall drawdown, likely contribute to the spread of flowering rush around the lake.

Numerous wetlands exist downstream of Albeni Falls Dam. These areas are periodically inundated at higher river flows. As discharge varies, wetlands, particularly littoral wetlands, may alternatively be dewatered and inundated. In the study area, there are approximately 20,300 acres of emergent herbaceous wetlands.

2.3.2.5 Water

There are approximately 106,067 acres of open water in the study area. Lake Pend Oreille is one of the largest and deepest natural lakes in the United States. In shallower portions of the lake submerged aquatic beds cover roughly 8,000 acres. The beds are dominated by chara (*Chara* spp.) and stonewort (*Nitella* spp.), and also include pondweed (*Potamogeton* spp.) and arrowhead (*Saggitaria latifolia*).

Pend Oreille Lake and River upstream of Albeni Falls Dam are impacted primarily by two invasive aquatic plants, Eurasian watermilfoil (*Myriophyllum spicatum*) and flowering rush (*Butonmus umbellatus*). These plants are discussed in greater detail below. Curly-leaf pondweed (*Potamogeton pseudacorus*) is also present (Lake Commission 2018). In some herbaceous wetlands around the lake, yellow-flag iris (*Iris pseudacorus*) and reed canarygrass (*Phalaris arundinacea*) are present. These introduced invasive species outcompete and displace the native vegetation.

Eurasian watermilfoil is a rooted perennial dicot and is considered an invasive noxious weed. Watermilfoil was identified in the Pend Oreille River upstream of Albeni Falls Dam in 1992 (Dupont and Bennett 1993). It is currently located in most bays throughout the lake and numerous areas along the shoreline of the Pend Oreille River. Eurasian watermilfoil has been found at depths of 3 to almost 30 feet, with most at 6 to 25 feet (Madsen and Wersal 2008). It is primarily spread through the water (the plant is easily broken and the floating parts can easily re-establish at other locations). Eurasian watermilfoil can be killed by freezing and desiccation (i.e. by exposure of the substrate above water in winter).

2.3.2.6 Islands

Islands in the deeper parts of Pend Oreille Lake are all composed of rock. Over geologic time these rock islands have become forested, primarily by coniferous trees. They are characterized by having steep slopes rising abruptly out of the water. The forests are all rather small, generally less than a few acres with the exception of Warren Island, which is close to 80 acres in size. By contrast, the delta areas (i.e. Clark Fork, Pack River, Priest River) have relatively large, low-lying islands composed mainly of river sediments, and dominated by broad-leaved deciduous trees (for list of species see riparian vegetation, this section). In addition, except where stabilized by recent restoration efforts, these islands are rapidly being eroded by the high summer lake levels, due to seasonal fluctuations, and to wind and wave action along the island shorelines. Approximately 1,000 acres of islands occur in Lake Pend Oreille, including the Clark Fork delta.

2.3.3 Wildlife

2.3.3.1 Birds

A large number of birds, some of which are permanent residents, are found in and around the lake, which is a major stopover area for migratory waterfowl in both spring and fall. Some species of waterfowl and bald eagles overwinter on the lake because the lake does not freeze over its entirety. Numerous species of birds, including upland gallinaceous birds, and birds of prey, nest near the lakeshore (Carlisle, et al. 2015).

Surveys conducted from August 2014 to June 2015 resulted in detection of 157 bird species. During the June surveys, 3,383 individual birds of 113 species were identified. The ten most abundant species were Canada goose, common yellowthroat, song sparrow, yellow warbler, cedar waxwing, tree swallow, California gull, red-eyed vireo, willow flycatcher, and gray catbird. During the June 2-15 aquatic transect surveys, 399 birds of 27 species associated with aquatic/wetland habitats. The ten most abundant species were Canada goose, Ring-billed gull, western grebe, great blue heron, California gull, osprey, spotted sandpiper, mallard, bald eagle, and double-crested cormorant.

Overall bird density was comparable across regions and primary habitat types. Several species were more abundant in either the eastern or western regions as well as in certain primary habitats. For example, most individual species showed a higher density in the eastern half of

the area whereas black-capped chickadee, brown-headed cowbird and cordilleran flycatcher were found in higher densities in the western half.

RAPTORS

Turkey vulture is among the most common raptor observed at Lake Pend Oreille. Bald eagles and osprey are relatively numerous. Other species observed include: Peregrine falcon, Swainson's hawk, Northern harrier, Cooper's hawk, red-tailed hawk, and American kestrel. Five species of owl have been observed near the Lake: Northern pygmy owl, barred owl, Western screech, Northern saw-whet owl, and great horned owl.

Owls and hawks nest in riparian trees and open woodlands, and hunt small birds and mammals in forested areas and open grasslands. Riparian cottonwood areas and nearby evergreen forests are important nesting habitats for the osprey, whereas shallow water habitats are of particular importance as foraging areas. The osprey is an area resident from mid-March through October. Bald eagles winter in large numbers around the lake from October through March. The perch in tall trees and snags in riparian habitat or on surrounding hillsides. Their major food sources are spawned kokanee salmon, weakened waterfowl, and carrion.

WATERBIRDS, SHOREBIRDS AND WATERFOWL

During surveys conducted in 2014 and 2015, 21 species of waterbird were observed at Lake Pend Oreille (Carlisle, et. al. 2016). Among these are various grebes, gulls, coots, American avocet, great blue heron, American white pelican, double-crested cormorant, and American bittern. Great blue herons are a resident species and may nest near the lake, preferring a large riparian cottonwood grove in the Clark Fork Delta. Although several species of gulls have been reported in the area, but most are noted as migrants or uncommon summer residents.

Eleven species of shorebird have been observed at Lake Pend Oreille. These include various sandpipers, plovers, and Virginia rail. The largest shorebird populations occur during migration, with the greatest concentrations occurring in spring when the shoreline mudflats are most extensive and northward migrating shore birds pass through. Nesting species include killdeer and spotted sandpiper.

Lake Pend Oreille supports large flocks of migratory and resident waterfowl, especially in the deltas. Twenty-five species of waterfowl, including Canada goose, tundra swan, mallard, pintail, redhead, three species of teal, American wigeon, and wood duck, are prominent. Lake Pend Oreille is a major spring and fall stop for migratory waterfowl of the Pacific Flyway. The fall and winter waterfowl surveys conducted by IDFG indicate numbers of duck and Canada geese peak each year in November at an estimated 24,000 ducks and 2,200 geese. Concentrations of redhead ducks, which use (principally) Oden Bay through early winter, have numbered as many as 17,000 birds, estimated by IDFG to be almost 98 percent of the statewide count and approximately 20 percent of the total Pacific Flyway redhead population. The concentrations at Oden Bay are believed to be due to extensive stands of chara and nitella (benthic algae), on which they feed.

While most waterfowl species are migrants or winter residents only, several species of ducks (including mallard, American wigeon, and three species of teal), and the Canada goose nest on and around the lake. Permanent and summer resident waterfowl nest in marshes and adjacent riparian or upland habitats. Emergent vegetation, submerged vegetation, and shoreline habitats are also important for rearing activities and for food resources. The shallow water and abundant food supply make the principal areas at Morton Slough, Pack River, Oden Bay, Hoodoo Creek, and Clark Fork River. Ellisport Bay, Sandpoint Bay, and the Pend Oreille River between the Highway 95 long bridge and Dover Peninsula particularly attractive for resting and feeding by both resident and migratory waterfowl.

PASSERINES

Eighty four species of passerines have been observed at Lake Pend Oreille. Nesting species in riparian habitats and delta islands include warbling vireo, yellow warbler, common yellowthroat, thrushes, swallows, bobolink, and numerous others. Red-winged blackbirds, long-billed marsh wrens, American bitterns, and sora rails are the most common breeding passerine species in marsh areas. The mix of species in coniferous forests differs. Common species include red-breasted nuthatch, solitary vireo, yellow-rumped warbler, golden-crowned kinglet, western tanager, and many others. Wintering passerine species are Jess abundant and include ravens and dippers. While not classified as Passerines, five species of woodpecker have been observed at Lake Pend Oreille, as well. These are hairy woodpecker, downy woodpecker, northern flicker, pileated woodpecker, red-napped sapsucker. Downy woodpecker is known to nest in riparian habitats and delta islands

GALLINACEOUS BIRDS

These birds generally prefer upland habitats for food, cover, and nesting, but may be found in riparian cover as well. Gallinaceous birds occurring near Lake Pend Oreille include ruffed grouse, mourning dove, rock pigeon (not native), California quail, Merriam's turkey, and the Eurasian collared-dove (not native). Blue grouse are abundant at higher elevations (Carlisle et al., 2016).

2.3.3.2 Mammals

TERRESTRIAL

Large mammals in the vicinity include elk, moose, mule and white-tailed deer, mountain goat, bighorn sheep, and black bear. Coyotes, fox, lynx and badger have been identified in the forests around the lake. The large mammal species generally spend their summers in the forested mountains and come to lower elevations in the winter months, but they have been reported in areas around Lake Pend Oreille at all times of year. White-tailed deer spend both summer and winter seasons in forested and open lands near the Lake and prefer habitat in the Clark Fork and Pack River Deltas. Mountain goats winter in small numbers on the hills and bluffs bordering the lake near Bay View at the extreme southern end of the lake. A sparse population of grizzly bear and mountain lion is also present in the Lake Pend Oreille region. Raccoon, Marmot, mink,

and weasel are found in the area, as are shrew, mice, squirrels, and rabbits. Idaho University professor Barry Keller reported populations of Townsend's big-eared bat near Lake Pend Oreille during the summer (Minard 2000). Other bats are expected to be present in the study area.

AQUATIC

Aquatic mammals including beaver, river otter, muskrat, and mink may be found in study area. The river otter is uncommon, and beaver, muskrat, and mink are not abundant. Beaver activity is higher in slough and river areas than in the Lake. Muskrat are found primarily at the Pack River Delta. Mink den in riparian habitats and along tributary drainages, but forage chiefly in marsh areas.

2.3.3.3 Reptiles and Amphibians

The variety of aquatic, riparian and upland habitats supports several species of reptiles and amphibians but in numbers notably less than in warmer regions of the United States. According to the IDFG, approximately 14 species live in the northern Idaho Panhandle Region (IDFG 1994). Of the reptiles, there are several species of lizards, non-poisonous snakes, and native painted turtle (*Chrysemys picta*). Amphibians common in the area are Pacific chorus frogs (*Pseudacris regila*) and western toads (*Bulo boreas*), both of which live near water. Other amphibians in the area are Pacific tree frog, leopard frog, Pacific giant salamander, tiger salamander, tailed frog, long toed salamander (*Ambystoma macrodactylum*), and Coeur d'Alene salamander (*Plethodon idahoensis*). Populations of painted turtles, western skink and alligator lizard, rubber boa, gopher and garter snakes are present in numbers notably less than in warmer areas of the United States. Invasive bullfrogs are present at the Lake.

2.3.3.4 Invertebrates

Common insects present in the study area include dragonflies, mosquitos, butterflies and moths. Asian clams (*Corbicula fluminea*) are present in Ellisport Bay (near the town of Hope) and Sam Owen. This infestation has the potential to expand or be transported via boat to another parts of the lake. There is also an invasive crayfish that has spread down from the Clark Fork River (Lakes Commission 2018). At this time zebra mussels (*Dreissena polymorpha*) and quagga mussels (*D. rostriformis*) have not been reported in the Columbia River system. The Corps conducts surveys (veliger sampling) in the reservoir, and the Idaho State Department of Agriculture conducts boat inspections to monitor for thes species.

2.4 GRAND COULEE DAM AND LAKE ROOSEVELT

2.4.1 Study Area

The study area used to describe the existing conditions and assess the range of potential impacts for wildlife and habitat features includes lands associated with the Grand Coulee Dam and the maximum pool at the upstream extent of Frank D. Roosevelt Lake (Figure 2-4). Grand Coulee Dam forms Franklin D. Roosevelt Reservoir, a 151-mile long lake with 660 miles of

shoreline and a surface area of more than 82,000 acres at full pool (elevation 1,290 feet) (USBR 1977; 1984). The study araea includes the reservoir up to the Canada/US border, and the river reaches influenced by the Project, including the lower reaches of the Sanpoil River (nine miles), Spokane River (32 miles), Colville River (two miles). Kettle River (11 miles), and about 20 to30 miles of other tributary streams, (USBR 1976). Land cover, vegetation, and habitat types in the study area are identified in Table 1-2.

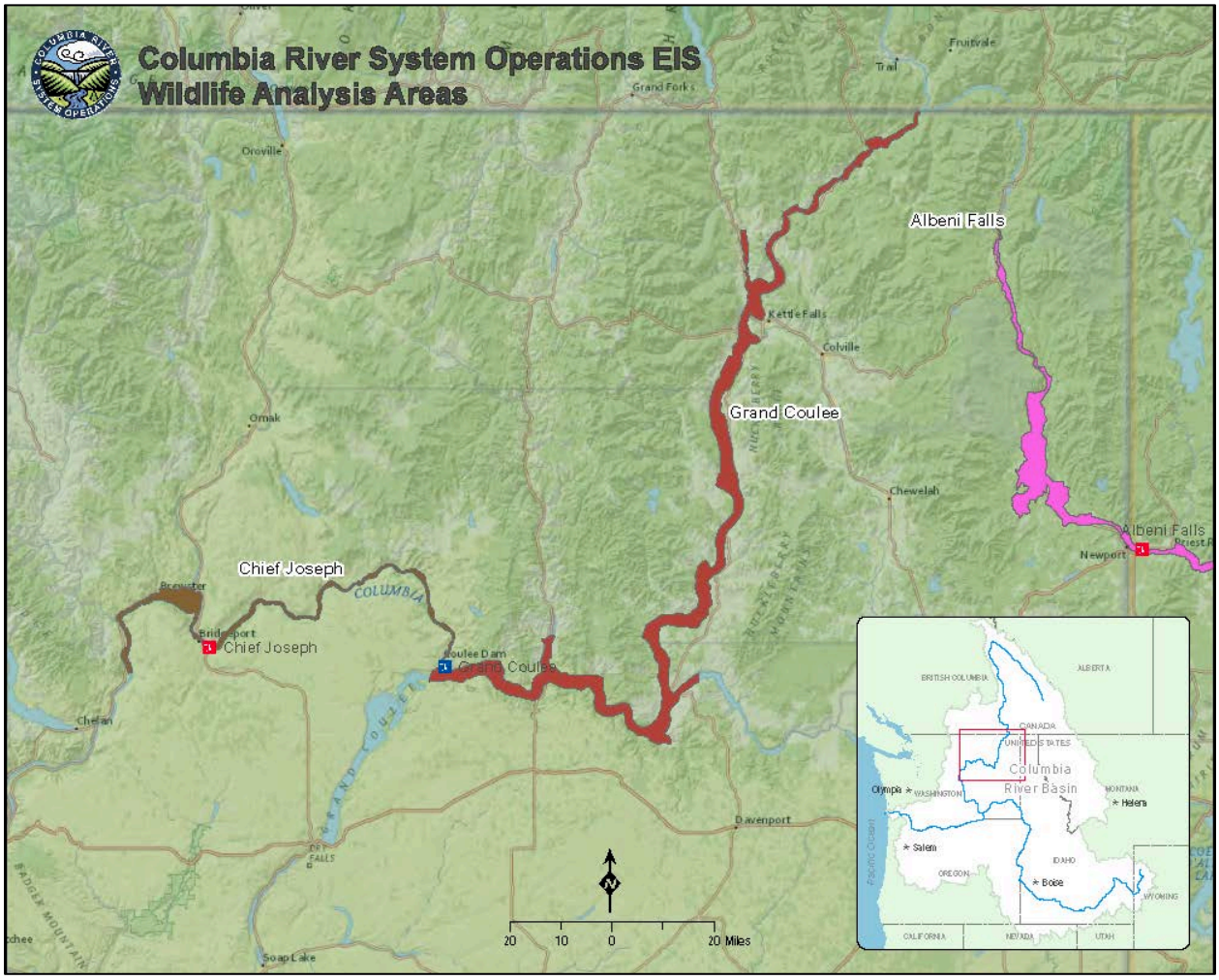

Figure 2-4. Grand Coulee Dam and Lake Roosevelt

Roosevelt Lake is noteworthy for its history of landslide activity along many miles of reservoir shoreline (Jones and Peterson, 1961). The annual cycle of soil saturation, followed by extensive drawdown and lesser short-term fluctuations, has led to continued erosion and slumping of the soil mantle on steeper slopes prevalent in this major river canyon. The steep, unstable shoreline substantially limits habitat development and use by wildlife (Creveling and Renfrow, 1986).

2.4.2 Land Cover

Table 1-2, above, shows the acres of the different habitat types within the Grand Coulee Dam study area.

2.4.2.1 Uplands

The extensive Roosevelt Lake environment overlaps two very different ecological and physiographic zones (USACE et al., 1995)). The southern reaches of the reservoir are in the Columbia Basin (Franklin and Dyrness, 1973) and are characterized by shrub-steppe vegetation. Northern reaches, which extend to the Canadian border, lie within the Okanogan Highlands and are characterized by forest vegetation. The area and vegetation are further described in USACE et al. 1995.

The lower (southern) reach of Roosevelt Lake from the dam (RM 596) to RM 634 is shrub-steppe and runs east-west, generally with bitterbrush communities on north-facing slopes and sagebrush communities on south-facing slopes. Rabbitbrush is common in much of this area. Between RM 634 and 675, the reservoir runs north-south and ponderosa pine and bitterbrush are characteristic, with serviceberry on dry sites and redstem ceanothus in moist areas and on north-facing slopes. From RM 675 to 706, the vegetation can be characterized as open stands of ponderosa pine/pinegrass habitat, with Douglas-fir and ponderosa pine occurring on north-facing slopes. Bitterbrush occurs in the lower part of this reach, but not in the upriver portion. Canyon slopes are heavily vegetated with redstem and evergreen ceanothus and serviceberry. Rogers (1941) describes the upper reach (RM 706-745) forest as largely second growth ponderosa pine, Douglas-fir and western larch, with a grass shrub understory. Sumac is abundant in some sites. Nearer the Canadian border, there is a mixed forest of paper birch, aspen, lodgepole pine, and Douglas-fir.

2.4.2.2 Barren Zone/Drawdown Area

Acreage of exposed, unvegetated soil present at different drawdown levels can be calculated from an elevation/acreage model for the project.

Widlife and wildlife habitat along the reservoir shoreline are influenced by project operations and level of drawdown.

The average inshore slope below full pool and upper reaches of the reservoir are relatively gradual (5 to 8 degrees), but varies substantially from site to site and decreases in an upstream direction. However, nearer to the dam the area below full pool becomesteep (approximately 45 degrees). More gradual sloped areas may become exposed mudflats or wetlands during drawdown of the pool.

2.4.2.3 Wetland - Forested and Scrub-Shrub

Roosevelt Lake lacks extensive riparian habitat. With few exceptions the pre-impoundment riparian vegetation at Grand Coulee, especially large-branched deciduous trees of high wildlife value, has not been re-established on the shoreline of the reservoir (USACE et al. 1995). Based on habitat mapping, there are 764 acres of Forested and Scrub-Shrub wetlands in the study area, inclusive of riparian and coniferous wetlands.

Dry climate, reservoir drawdown, wave action, steep shoreline slopes and related erosion and landslide activity are principal factors preventing riparian re-establishment (USACE et al. 1995). Reservoir shoreline vegetation is perched well above the water level during the spring drawdown and the early portion of the growing season. As a consequence, despite a moister climate in the northern reaches, riparian areas are typically associated with small streams and spring areas where the source of water is from precipitation, snow melt, or ground water discharge rather than reservoir. These areas are also typically more gently-sloping and protected from erosion forces, and are characterized by silt accumulation. Opportunities to establish further riparian zones at Lake Roosevelt appear limited (USACE et al. 1995).

The primary cottonwood riparian stands occurring in the northern portion of the reservoir are composed of an understory of birch, alder, red-osier dogwood, alder buckthorn, and lesser shrubs such as thimbleberry, poison ivy and Wood's rose (USACE et al. 1995).

The great scarcity of riparian habitat along Roosevelt lake is an indication of the lack of suitable sites, soil conditions and the detrimental effects of the water regime. Based on these problems and projections from the literature and current knowledge, riparian stands are probably in relatively stable condition at present, with no evidence of expansion.

2.4.2.4 Wetlands – Emergent Herbaceous

Emergent wetlands are also limited in extent at Lake Roosevelt. They are restricted by the steep shorelines, seasonal drawdowns, and shorter-term fluctuations that also influence other habitat types. There are approximately 360 acres of emergent wetlands within the study area. These occur along the reservoir shoreline primarily in embayments, the mouths of small streams, and in the confluences of larger tributary streams. Areas containing significant wetland types include the mouths of the Colville River and Kettle River and nearby upper reservoir shallows. Most other wetlands are small and scattered in isolated areas such as Mill Creek (Spokane River arm), Big Sheep Creek, Fifteenmile Creek, Onion Creek, Spring Creek, and other sites.

2.4.2.5 Water

At full pool Lake Roosevelt provides 80,000 acres of open water surface area.

Fluctuating reservoir levels in Lake Roosevelt prevents growth of submerged aquatic vegetation. The steeply-sloping nearshore areas in much of the reservoir are another obvious limiting factor (USACE et al. 1995). Although some submerged plant beds are known to establish during extended high water elevations, these are very limited according to local experts.

Approximately 46 acres of shallow water area occur within the study area. This is where submerged plants such as waterweed (*Elodea* sp.) may develop to varying degrees.

2.4.2.6 Islands

There are 28 islands in Lake Roosevelt which provide approximately 130 acres of island habitat Much of the island acreage is classified under NWI as uplands. These areas are commonly the tops of hills or ridges that were isolated by water in the reservoir. The islands support no riparian vegetation (USACE et al. 1995).

Islands were historically important in this area, receiving use by aquatic mammals, shorebirds, waterfowl, and other species. They were particularly important as secure nesting sites for Canada geese and as deer fawning areas. Islands are still important in the reservoir, but their value and use by wildlife is limited by the annual spring drawdown. Vegetation development is inhibited, the barren drawdown zone restricts wildlife use, and some islands become more accessible to predators. There evidently is little Canada goose nesting on remaining islands (USACE et al. 1995).

2.4.3 Wildlife

About 350 species of wildlife are found in the vicinity of Roosevelt Lake (USACE et al. 1995). There are approximately 75 species of mammals, 200 species of birds, 15 species of reptiles and 10 species of amphibians in the Lake Roosevelt area (Lake Roosevelt Forum, 2018). Many of these use the riparian, wetland, and island habitats along the reservoir shoreline for part or all of their life requisites (USACE et al. 1995).

The overall wildlife values of Roosevelt Lake are limited because of the Lake's storage function and substantial seasonal drawdowns which have adversely affected shoreline habitat development and use. Important habitats are generally confined to tributary stream reaches, embayments and backwaters, and islands. Conditions are much less favorable on the main pool where steep, eroding banks are prevalent. Islands are important in part because only 28 remain from a pre-dam count of 114. In general, riparian and wetland habitats exist only as small, scarce units scattered throughout the reservoir.

2.4.3.1 Birds

RAPTORS

Raptors such as: osprey, golden eagle, bald eagle, prairie falcon, red-tailed hawk, northern harrier, and American kestrel (Lake Roosevelt Forum, 2018) are present and fairly common throughout the study area.

Bald eagles are an important reservoir area resource, with a recent wintering population estimate of about 250 birds in the Roosevelt Lake area. Reservoir use appears to be increasing based on winter surveys, and nesting has been increasing from 8 to 24 territories during the time period of 1994 to 2000 (Stinson, et al. 2007). Although the bald eagle is well-known at the reservoir, other raptors such as golden eagle and prairie falcon commonly use cliff sites in the area. There is relatively low use of the shoreline by osprey for nesting.

Several important areas for raptors include:

The lower Kettle River between Barstow and the confluence near Kamloops is generally recognized as an important site for a variety of wildlife species. Its backwater areas and bayous contain riparian stands and shallows with emergent wetland vegetation, which provides for waterfowl, common bald eagle prey, and is a bird concentration area. The Keller area is known for its bald and golden eagle nest sites, and Sterling Valley to Hawk Creek butte which is known for osprey nests. Hawk Creek is also known for its Bald eagle perching sites. Other notable areas for raptors include Whitestone Rock, the Sandpoil River, areas around Gifford Ferry and Kettle Falls.

WATERBIRDS, SHOREBIRDS AND WATERFOWL

Water birds include: mallards, pintails, teal, goldeneyes, redhead canvasback, western grebe, coot, lesser scaup, common merganser, common loon, and Canada geese.

Shorebirds include: plovers, northern killdeer, spotted sandpiper, gulls, snipe, common grebes and yellowlegs (Lake Roosevelt Forum 2018).

Great Blue heron and bank swallow are representative colonial nesting birds at Grand Coulee. Herons use a wide range of habitat types and are a familiar resident at Roosevelt Lake (USACE et al. 1995).

Bank swallows may have benefited from the creation of the reservoir and the increased insect foraging area over water (USACE et al. 1995). Populations of these colonial species are also believed to be relatively stable in numbers, since the reservoir has been in place for many decades.

Shorebird use of Roosevelt Lake is limited and related mostly to the water level during spring and fall migration. Numbers of species may use the lake and surrounding barren zone at that time. Species likely to nest include killdeer and spotted sandpiper (USACE et al. 1995).

While waterfowl use of Roosevelt Lake is noteworthy, the reservoir is not generally considered by local biologists to be a major waterfowl resource management area. Production is substantially limited by the scarcity of islands, wetland habitat, and shoreline usable for waterfowl activities, as well as by the severe spring drawdowns. The most significant use appears to be in open water areas as a resting or wintering area for migrants, however density of wintering ducks is also considered low because of cold winter conditions and lack of adequate food supplies (USACE 1992).

Characteristic waterfowl species or groups identified for Grand Coulee are Canada goose, mallard, and diving ducks such as scaup. Nesting and feeding habitat for geese and mallards is said to be very limited (USACE et al, 1995). Riparian habitat used for duck nesting is in very short supply as are wetlands and other feeding areas. Islands, which are of particular importance as secure nest sites for geese, support little nesting because of their limited

occurrence and the drawdown problems of land bridging and barren mudflat formation which lead to predation and restricted use.

Shallower areas in upper reaches and tributaries support some seasonally flooded emergent wetlands that are potential nesting and grazing areas. However, drawdowns are particularly damaging to these areas since islands are more easily bridged and the more gently-sloping shoreline is separated from the vegetation by large expanses of barren soil. In other parts of the reservoir, steep and eroding banks are common place and are a barrier to shoreline use by geese with goslings or duck broods. Waterfowl use of the reservoir is mostly as a temporary stopover during migration periods.

Although riparian and wetland habitat has established slowly at Lake Roosevelt, the reservoir has been in place and under a similar operating regime long enough that these habitats have probably reached a certain degree of equilibrium. There is no information suggesting significant trends in waterfowl use.

PASSERINES

Passerines include swallows, finches, jays, chickadees, kinglets, ravens, magpies, robins, sparrows, blackbirds, and juncos.

The downy woodpecker, red-winged blackbird, and yellow warbler are considered representative of nongame bird species at Roosevelt Lake. They primarily use riparian and emergent wetland habitats potentially impacted by changes in operational water regimes. Their nesting and feeding activities in relation to trees, shrubs, emergent aquatic vegetation, and other factors are important in determining their survival and density at the reservoir.

The Lincoln area is notable for upland species that include Lewis' woodpecker.

GALLINACEOUS BIRDS

Grassland birds include western sage grouse, Columbia sharp-tailed grouse, mourning dove, blue grouse, band-tailed pigeon, pheasant and turkey.

Game birds such as chukar, Hungarian partridge, mourning dove, ring-necked pheasant, and California quail eat a variety of seeds, agricultural grasses (i.e wheat, oats, and corn) and insects. The pheasant and quail are found most commonly near agricultural lands and generally do not venture far into shrub-steppe areas. Upland game birds such as sharp-tailed grouse, ring-necked pheasant, and California quail may also harvest the catkins of willows, alders, and birches, and also eat the new buds. The upper (northern) end of Lake Roosevelt can also support some numbers of grouse such as blue, ruffed, and/or spruce.

2.4.3.2 Mammals

TERRESTRIAL

Large mammals include black bear, elk, mountain lion, whitetail deer, mule deer, and moose. California Bighorn Sheep were recently introduced to the area. Smaller mammals include: beaver, river otter, muskrat, mink, badger, raccoon, skunk, bobcat, coyote, red fox, porcupine, cottontail rabbits, ground squirrels, chipmunks, yellow-bellied marmot, pika, bats, gophers, rats, and deer and house mice.

Representative species of mammals include the porcupine, least chipmunk, yellow pine chipmunk, striped skunk, bushy-tailed woodrat, deer mouse, sagebrush voles, cottontail rabbits, yellow-bellied marmots, bobcats, badgers, coyotes, cougar, and several species of mice, and bats. Most of these are resident in the conifers. Mammals found in the shrub-steppe habitats of the project area (i.e. bobcat, badger, coyote) are predators, feeding primarily on rodents, as well as bird eggs and carrion. Rabbits and marmots eat grasses and herbaceous plants, and in winter may eat bark and twigs of woody plants as well. Marmots are restricted to rocky areas where they can find refuge among the many tunnels in the rocks. Small mammals such as the sagebrush vole and least chipmunk feed primarily on green vegetation (USACE et al. 1995).

Prior to the construction of Grand Coulee Dam, lower elevation areas of the Columbia River corridor were critical winter range habitat for big game. Low elevation areas around the reservoir are important for deer wintering areas, and in some areas, for elk winter range. Riparian or shoreline areas containing deciduous or evergreen trees are used by big game for feeding, fawning, summer and winter thermal cover, and as corridors (USACE et al. 1995).

Big game species are not as dependent as other wildlife species on habitats bordering the reservoir, but may still be significantly affected by habitat losses or changes in human use and disturbance patterns caused by reservoir operation. For these reasons, deer and elk foraging and wintering are considerations when reservoir operations change (USACE et al. 1995).

AQUATIC

The beaver and otter are representative of the aquatic mammals at Lake Roosevelt. This wildlife group must be able to travel between the water body and terrestrial vegetation, and thus can be significantly affected by reservoir operation. The shoreline interface is a critical component of aquatic mammal habitat suitability. Islands are also of importance when present (USACE et al. 1995).

At present, most shoreline at Roosevelt Lake is of little value to aquatic mammals because of its steep ness and instability (erosion), and lack of vegetation. Additionally, drawdown of the reservoir in more gently-sloping areas creates large, barren mudflats which separate water and vegetated shoreline, in creasing the animals' energy expenditure and vulnerability to predation,

or even preventing use of an area. Otter can also be affected by loss of aquatic invertebrates such as crayfish, a primary food source (USACE et al. 1995).

Barnaby Island and Barnaby Creek areas near the reservation line are noted for suitable shoreline habitat for species such as beaver, muskrat, and some otter use occurs in and near the mouths of tributary streams (Lake Roosevelt Forum 2018).

2.4.3.3 Reptiles and Amphibians

Reptiles and amphibians found in the Lake Roosevelt watershed include sage brush lizard, western rattlesnake, gopher or bull snake, western terrestrial garter snake, bullfrog, western toad and various salamanders (Lake Roosevelt Forum 2018). In the Colombia River System Operation Review EIS the spotted frog and long-toed salamander were selected as representative species when analyzing potential effects of reservoir operation modifications on amphibians at Roosevelt Lake because these species have both an aquatic larval stage and a terrestrial adult stage (USACE et al., 1995). Very small seasonal ponds and pools can be used by long-toed salamanders and small permanent ponds can be used by spotted frog during breeding season. Increased drawdowns or fluctuations can remove these sources of water that provide oviposition and larval development sites for these and other amphibian species. Other species include western skink and Pacific chorus frog (USACE et al. 1995).

2.4.3.4 Invertebrates

A study conducted by the State Of Washinton's Department of Ecology in 1986 sampled the aquatic macroinvertebrates of Lake Roosevelt and the Colombia River. It found that the vast majority of the invertebrates present were true flies, more specifically the Family Chiromidae. The abundance was fairly low, as was the diversity, as measured by the Shannon Index (Johnson 1991). In studies done by the Bonneville Power Administration, measureing the biota of Lake Roosevelt, a total of 10 benthic macroinvertebrate families from 7 orders were found in the substrate samples from Lake Roosevelt, and a total of 2 benthic macroinvertebrate orders were found in emergence traps (Voeller 1993). These included Diptera, Odonata, Amphipods, snails, clams, worms, and Trichoptera (Voeller 1993)

2.5 CHIEF JOSEPH DAM AND RUFUS WOODS LAKE

2.5.1 Study Area

The study area used to describe the existing conditions and assess the range of potential impacts for wildlife and habitat features extends from just below Grand Coulee Dam downstream below CJD to Wells Dam, located about midway between the communities of Pateros and Chelan (see Figure 2-5). The study area extends laterally out from the midline of the river to include lands adjacent to the Columbia River, CJD, RWL, and the mouths of its primary tributaries. The lateral extent of the study area has been determined based on H&H modeling. The largest of the tributaries are: Nespelem River (the primary tributary that persistently flows into RWL) which enters RWL; Foster Creek, which enters the Columbia River

at CJD and Okanogan River, which enters the Columbia River from the north, 5 miles east of Brewster, between the Wells Dam (downstream) and CJD (upstream).

The study area is entirely within the Columbia Plateau Ecoregion. CJD and RWL lie in a steep-sided canyon of the Columbia River valley which ranges in width from two to four miles. The north side of the valley rises sharply to the Okanogan Highlands, 1,000 feet or more above the Columbia River. The south side of the valley rises in a series of terraces and benches climbing to the Columbia Plateau surface. The majority of the shoreline is treeless with a dry land shrub-steppe cover. Numerous canyons and deep draws support isolated stands of pine and deciduous trees and shrubs. Rangeland and irrigated orchards on upland benches and sixteen project wildlife mitigation sites along the lakeshore provide patches of greenery. Table 1-2 identifies the land cover, vegetation, and wildlife habitat types and associated acreages in the study area.

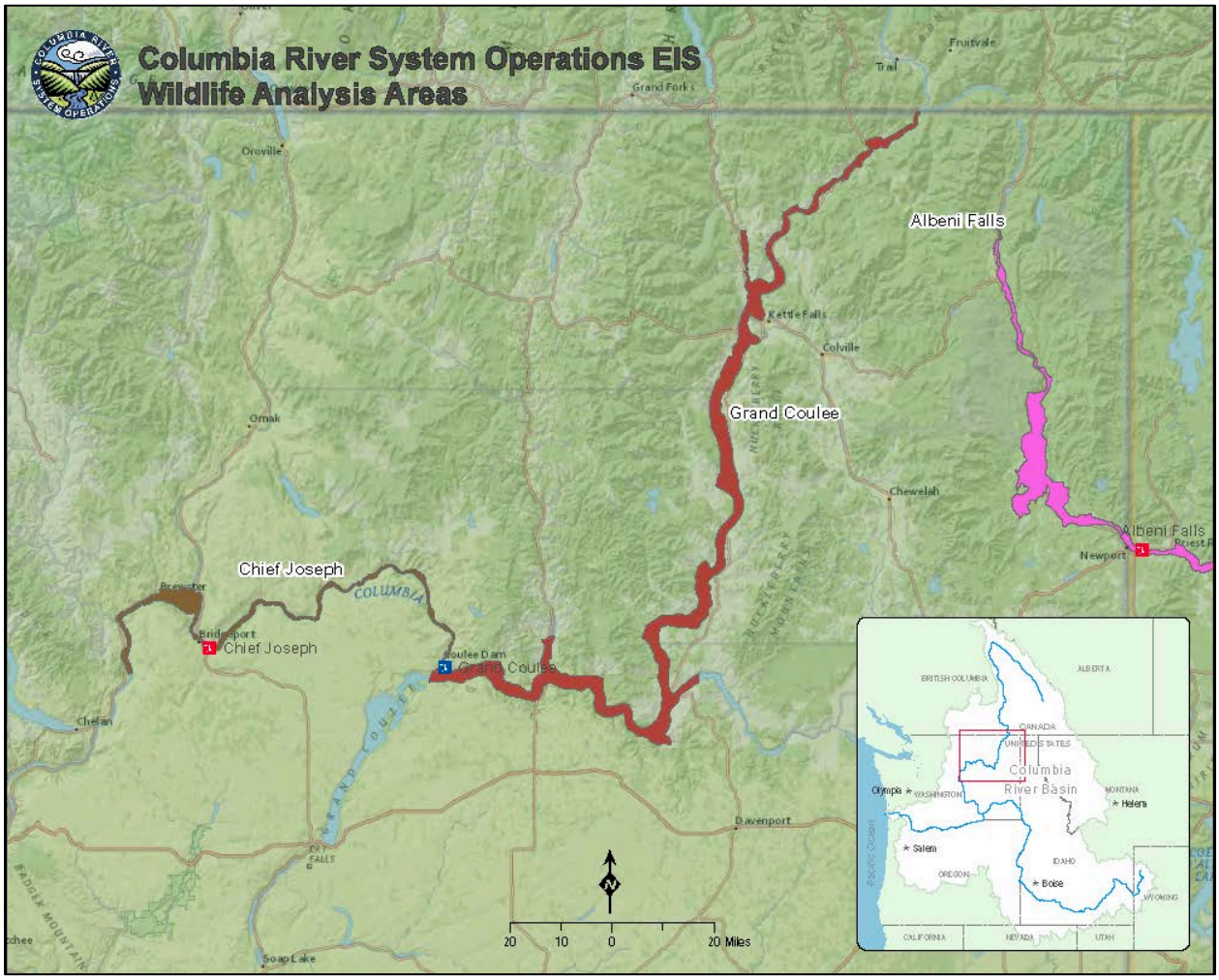

Figure 2-5. Chief Joseph and Rufus Woods Lake Study Area.

2.5.2 Land Cover

2.5.2.1 Uplands

Shrub-steppe habitat is the most extensive cover type along RWL except where interrupted by rock out-crops, drainages, or human development. There are approximately 4,000 acres of shrub-steppe habitat in study area. Shrub-steppe plant and animal species must be capable of dealing with arid conditions and wildfire. Soils tend to be sand to loam-sand and highly vulnerable to wind/water erosion. The shrub component is dominated by big sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus nauseosus*), serviceberry (*Amelanchier alnifolia*), currant species (*Ribes* spp.), and antelope bitterbrush (*Purshia tridentata*) while Idaho fescue (*Festuca idahoensis*), Indian ricegrass (*Achnatherum hymenoides*), Sandberg bluegrass (*Poa secunda*), Thurber's needlegrass (*Achnatherum thurberianum*), needle-and-thread (*Hesperostipa comata*), sand dropseed (*Sporobolus cryptandrus*), bluebunch wheatgrass (*Pseudoroegneria spicata*), and bottlebrush squirrel tail (*Elymus elymoides*) make up the primary native grass species. Common forbs include arrowleaf balsamroot (*Balsamorhiza sagittata*), yarrow (*Achillea millefolium*), various buckwheats (*Eriogonum* spp.), blanket flower (*Gaillardia aristata*), various parsleys (*Lomatium* spp.), and lupine species (*Lupinus* spp.).

Ponderosa pine savannah is similar to the shrub-steppe habitat and composed of much the same shrub, grass, forb, and non-native species. However, Ponderosa pine savanna typically occurs where soil is slightly higher. Like shrub-steppe habitat, pine savanna has been identified as a priority habitat in the region due to threats of conversion to farming and other development (IWJV 2005). Along RWL, savannah is mostly found in the upstream extents towards Grand Coulee Dam. There are approximately 30 acres of Ponderosa pine forest in the study area. As the name implies, the primary tree component of this habitat is Ponderosa pine (*Pinus ponderosa*), often with serviceberry (*Amelanchier* spp.), bitterbrush (*Purshia tridentate*), elderberry (*Sambucus* spp.), snowberry (*Symphoricarpos albus*), and Wood's rose (*Rosa woodsii*). The sparse spatial arrangement (low stocking density in the tree and shrub layers) is often maintained by intermittent fire, minimal precipitation, and topography resulting in canopy coverage ranging from 10 to 60 percent. As with forest and scrub-shrub wetlands and emergent herbaceous wetlands, Ponderosa pine savannas can produce and sustain trees and therefore are suitable for the production of snags. WDFW has identified areas with copious and dispersed snags (and logs) as priority habitat. Snags are a unique and important part of the ecosystem. Ants, termites, and other insects colonize dead trees and provide food for woodpeckers and bears. Bats also utilize snags for roosting.

Grasses identified in Section 1.0 Introduction, that are common to disturbed areas are likely present in the CJD study area. Similarly, forested and shrub-shrub wetlands in the study area are expected to include at least some of the introduced invasive species common to these (see Section 1.0). Introduced Russian olive (*Elaeagnus angustifolia*), elms, and yellow-flag iris (*Iris pseudacorusis*) have been documented from the study area (USACE 2015).

2.5.2.2 Barren Zone (Drawdown Zone)

Barren areas are sparse along RWL, due to only one to two foot daily fluctuations. Those barren areas that exist are on the steep slopes that are also areas of chronic erosion. Landslides and erosion are common on the steep canyon walls, which are partially filled with thick deposits of fine-grain sediments. Glacial lake and old landslide deposits tend to slough more easily than other materials, but well-drained sands and gravels tend to be quite stable, even if of considerable height. Several major prehistoric and historic landslides have occurred in the project area. The post-glacial Bridgeport Slide occurred upstream of the project. It is presently administered and monitored by USACE and public access to the area is discouraged. Slides along the upstream portion of RWL became active during the middle and late 1940's. They slowed after 1953, due to lesser tailwater fluctuations, probably as a result of the raised lake levels at Grand Coulee Dam. In 1970, construction for the third powerplant at Grand Coulee precipitated additional sliding. Measures to control those slides are under study by the Bureau of Reclamation. Furthermore, impoundment of RWL has caused slides near Bridgeport State Park and upstream of China Creek (RM 575) on the south bank. Reservoir operation and upland irrigation have resulted in a lesser degree of sloughing along the reservoir periphery. Riprapping to stabilize the slide area is currently being tested.

2.5.2.3 Wetlands – Forested and Scrub-Shrub

There are approximately 660 acres of Forested and Scrub-Shrub in the study area. They occur in areas with permanent or intermittent inundation: draws, seeps, upland depressions, creeks, along the edge of water bodies, and downhill of irrigation runoff.

2.5.2.4 Wetlands – Emergent Herbaceous

Common plants present in local wetlands include cattails (*Typha latifolia*), horsetail (*Equisetum* spp.), bulrush (*Schoenoplectus* spp. or *Scirpus* spp.), and sedges (*Carex* spp.), as well as the majority of species (both native and non-native) found in forested and scrub-shrub wetlands.

Based on mapping for this study, there are approximately 130 acres of Emergent Herbaceous Wetlands in the Chief Joe Dam study area. The fluctuation of Rufus Woods Lake is monitored closely to minimize drastic fluctuations in water levels. Despite this, wetlands have only formed at a few locations, almost always at alluvial fans or at a stream/river confluence.

2.5.2.5 Water

Rufus Woods Lake consists of approximately 18,500 acres of open water. Aquatic vegetation in Rufus Woods Lake is not abundant because the rocky shoreline, steep slopes in many areas, and the water level fluctuations effectively limit available habitat. A narrow band of aquatic vegetation is present along much of the shoreline of the reservoir. Five species of submerged aquatic plants have been observed in the lake, including elodea (*Elodea* spp), Eurasian watermilfoil (*Myriophyllum spicatum*), sago pondweed (*Stuckenia pectinata*), curly leaf pondweed (*Potamogeton crispus*), and watercress (*Nasturtium officinal*e). Excepting

watercress, which has been observed only at RM 575.2, these species have been observed the entire length of the lake, from RM 591 downstream. The most abundant aquatic plant in the lake is elodea, and Eurasian watermilfoil is more abundant than sago pondweed and curly leaf pondweed.

Three of the five species of submerged aquatic plants present in the study area are introduced invasive species. These are Eurasian watermilfoil, curly leaf pondweed, and watercress. Some species or elodea are also introduced invasive plants. Sago pondweed, although a native species, is categorized as weedy.

2.5.2.6 Islands

There are several islands in Rufus Woods Lake. Two of them were constructed by USACE as mitigation to replace goose nest sites lost to the pool raise. Most of the islands are small, and are often used by geese for nesting. Buckley Bar, near RM 587, is about 40 acres in size and is wooded with small juniper trees. This island is used by Canada geese and other birds for nesting, and by mule deer for fawning.

2.5.3 Wildlife

2.5.3.1 Birds

In 2015, a study was conducted to record the number of breeding birds at CJD (USACE 2016). Sixty-eight different species were detected during the four consecutive weeks of point counts on the CJD project. The birds were observed in the following habitats: Irrigated, for Riparian, and Shrub-Steppe. Table 2-4 and Table 2-5 denote the habitat generalists and habitat specialists, respectively, observed during the four-week period.

RAPTORS

Raptors common to the CJD study area include Northern harrier, northern goshawk, red-tailed hawk, osprey, American kestrel, merlin, bald eagle, golden eagle, western screech owl, great horned owl (Bentler 2014). Live Ponderosa pines are the primary nesting structures for bald eagles along RWL. Golden eagles can nest in pines; however, they tend to nest in rock cliff faces bordering the lake. Eagles utilize snags for hunting, fishing, or resting. Snags, especially those with a large diameter (≥ 12 inches diameter), also provide nesting locations for the cavity nesting American kestrel.

WATERBEIRDS, SHOREBIRDS AN WATERFOWL

Waterbirds, such as killdeer, spotted sandpiper, great egret, American white pelican, sandhill crane, and great blue heron, Canada goose, common loon, tundra swan (Bentler 2014) are present in the CJD study area. Several waterfowl species including mallard, common merganser, American widgeon, and Canada geese utilize wetlands in the study area for feeding, nesting, cover, and breeding.

PASSERINES

Common passerines in the CJD study area are those that nest near water: yellow-breasted chat, yellow warbler, and eastern kingbird. Western kingbird and finches also utilize pines in eastern Washington for nest building. Other bird species that utilize wetlands in the RWL area for nesting and breeding include the red-winged blackbird and common loon.

GALLINACEOUS BIRDS

Sharp-tailed grouse are found at the edge of pine zones in the CJD study area (Table 2-3 and Table 2-4).

Table 2-3. Generalist avian species recorded in 2015 CJD survey.

Common Name	Scientific name	Common Name	Scientific name
American crow	*Corvus brachyrhynchos*	European starling	Sturnus vulgaris
American goldfinch	*Spinus tristis*	Horned lark	Eremophila alpestris
American kestrel	*Falco sparverius*	House finch	Carpodacus mexicanu
American robin	*Turdus migratorius*	House wren	Troglodytes aedon
American wigeon	*Anas americana*	Killdeer	Charadrius vociferus
Barn swallow	*Hirundo rustica*	Mallard	Anas platyrhynchos
Bewick's wren	*Thryomanes bewickii*	Mourning dove	Zenaida macroura
Black-capped chickadee	*Poecile atricapillus*	Northern flicker	Colaptes auratus
Brewers blackbird	*Euphagus cyanocephal*	Northern rough wing swallow	Stelgidopteryx serripe
Brown headed cowbird	*Molothrus ater*	Red breasted nuthatch	Sitta canadensis
Bullock's oriole	*Icterus bullockii*	Ring-necked pheasant	Phasianus colchicus
California quail	*Callipepla californica*	Red-tailed hawk	Buteo jamaicensis
Canada goose	*Branta canadensis*	Say's pheobe	Sayornis saya
Cedar waxwing	*Bombycilla cedrorum*	Song sparrow	Melospiza melodia
Chipping sparrow	*Spizella passerina*	Tree swallow	Tachycineta bicolor
Cliff swallow	*Petrochelidon pyrrhono*	Violet-green swallow	Tachycineta thalassin
Common merganser	*Mergus merganser*	Warbling vireo	Vireo gilvus
Common raven	*Corvus corax*	Western kingbird	Tyrannus verticalis
Common yellow throat	*Geothlypis trichas*	Western wood pee wee	Contopus sordidulus
Coot	*Fulica americana*	White-crowned sparrow	Zonotrichia leucophry
Dark-eyed junco	*Junco hyemalis*	Yellow rumped warbler	Setophaga coronata

1616 **Table 2-4. Specialist species recorded in 2015 CJD Survey, and the habitat associated.**

Species Common Name	Scientific Name	Habitat type	Irrigated	Riparian	Shrub-Steppe
Bald eagle	*Haliaeetus leucocephalus*	Wetland, shoreline, Ponderosa pine	X		
Black-headed grosbeak	*Pheucticus melanocephalus*	Hardwood forest, riparian	X	X	
Belted kingfisher	*Megaceryle alcyon*	Wetlands, sandy river banks	X	X	
Brewer's sparrow	*Spizella breweri*	Steppe, grassland		X	X
Common loon	*Gavia immer*	Lakes, bays, oceans		X	
Eastern kingbird	*Tyrannus tyrannus*	Steppe, ag, wetlands, hardwoods	X	X	
Great blue heron	*Ardea Herodias*	Marshes, low elevation irrigated ag	X		
Grasshopper sparrow	*Ammodramus savannarum*	Steppe, grassland			X
Gray catbird	*Dumetella carolinensis*	Riparian, steppe near rivers	X	X	
Hairy woodpecker	*Picoides villosus*	Hardwood forest		X	
Lark sparrow	*Chondestes grammacus*	Steppe, grassland, Ponderosa pine			X
Lazuli bunting	*Passerina amoena*	Riparian		X	
MacGillivary's warbler	*Geothlypis tolmiei*	Low dense undergrowth		X	
Marsh wren	*Cistothorus palustris*	Fresh and brackish marshes		X	
Nashville warbler	*Oreothlypis ruficapilla*	Open mixed woods, edges, bogs	X		
Osprey	*Pandion haliaetus*	Shoreline, artificial structures	X	X	
Red-winged blackbird	*Agelaius phoeniceus*	Riparian, wetlands	X	X	
Rock wren	*Salpinctes obsoletus*	Cliffs, rocks, riparian, steppe near rivers		X	
Spotted sandpiper	*Actitis macularius*	Pebbly shores, ponds, marshes	X	X	
Spotted towhee	*Pipilo maculatus*	Developed, riparian, wetlands	X		
Swainson's thrush	*Catharus ustulatus*	riparian woodlands	X		
Turkey vulture	*Cathartes aura*	Rock outcroppings, open dry forest		X	
Western meadowlark	*Sturnella neglecta*	Grassland, steppe, Ponderosa pine, ag	X	X	X
Western tanager	*Piranga ludoviciana*	Ponderosa pine, hardwood forest	X		
Wilson's warbler	*Cardellina pusilla*	Thickets and trees along streams	X	X	
Yellow breasted chat	*Icteria virens*	Riparian, wetland, forest/steppe transition	X	X	X
Yellow warbler	*Dendroica petechia*	Riparian	X	X	

2.5.3.2 Mammals

TERRESTRIAL

Shrub-steppe habitat serves the year-round food, cover, mating, and nesting needs of dozens of wildlife species. The WDFW has identified habitat dominated by forbs and bunchgrasses (eastside steppe) and habitat dominated by bunchgrasses and well-spaced shrubs (shrub-steppe) as a priority habitat. Common species that utilize shrub-steppe include yellow-bellied marmot (*Marmota flaviventris*), and mule deer. Secondary consumers such as badger (*Taxidea taxus*) and coyote (*Canis latrans*) rely on shrub-steppe habitat for prey as well as cover and nesting/denning.

Ponderosa pine savannah exists in the midst of shrub-steppe and is extremely valuable to wildlife. The taller trees and shrubs offer protective cover and shade including areas for mule deer (*Odocoileus hemionus*) fawning. Riparian habitat offers wildlife thermal and protective cover, food, and mild microclimate. The Washington Department of Fish and Wildlife (WDFW) has identified riverine forested and shrub-scrub wetlands as a priority habitat. Forests, such as the ponderosa pine or the riverine forested wetlands also meets many of the year-round food, cover, and reproductive needs of several species, such as mule deer, bobcats (*Lynx rufus*), or even potentially mountain lion (*Puma concolor*).

AQUATIC

Mammals that utilize the river and reservoir waterways include river otter (*Lontra canadensis*) and beaver (*Castor canadensis*).

2.5.3.3 Reptiles and Amphibians

Western Rattlesnake (*Crotalus oreganus*), gopher snake (*Pituophis catenifer catenifer*), common garter snake (*Thamnophis sirtalis*), western terrestrial garter snake *Thamnophis elegans*), yellow bellied racer (*Coluber constrictor mormon*) are all found in eastern Washington, and could utilize the varied habitat at CJD (Bentler 2014). Western fence lizard (*Sceloporus occidentalis*) and common side-botched lizard (*Uta stansburiana*) are also known to be present (Bentler 2014).

2.5.3.4 Invertebrates

Lorquin's admiral butterfly, mourning cloak butterfly, Milbert's tortoiseshell butterfly, two-tailed swallowtail, Western tiger swallowtail, ornate tiger moth, Riding's forester moth, white-lined sphinx moth, are known to occur in the study area (Bentler 2014).

Exotic leafrollers, which are pests of fruit trees and ornamentals, damage trees by rolling and eating leaves, conifer needles, and shrubs, are common throughout eastern Washington. Zebra and Quagga mussels are not here yet, but could easily be introduced from other nearby lakes (WISE 2011).

2.6 DWORSHAK DAM AND LOWER CLEARWATER RIVER

2.6.1 Study Area

The study area used to describe the existing conditions and assess the range off potential impacts for wildlife and habitat features begins at the northeastern-most extent of the reservoir on the North Fork Clearater River and Little North Fork Clearwater River and the lower portion of their tributaries (Figure 2-6). The study area extends from here downstream below Dworshak dam to the confluence of the Snake River at the Washington-Idaho boarder (between the towns of Clarkston and Lewiston). Lands surrounding Dworshak Reservoir are generally steep, therefore, the lateral extent of the study area is relatively small and close to the shoreline of the reservoir. The southwestern-most portion of the reservoir extending downstream to just north of the town of Lewiston is located on the Nez Perce Reservation. The Dworshak and Clearwater fish hatcheries are in the study area. Land cover, vegetation, and habitat types in the study area are summarized in Table 1-1.

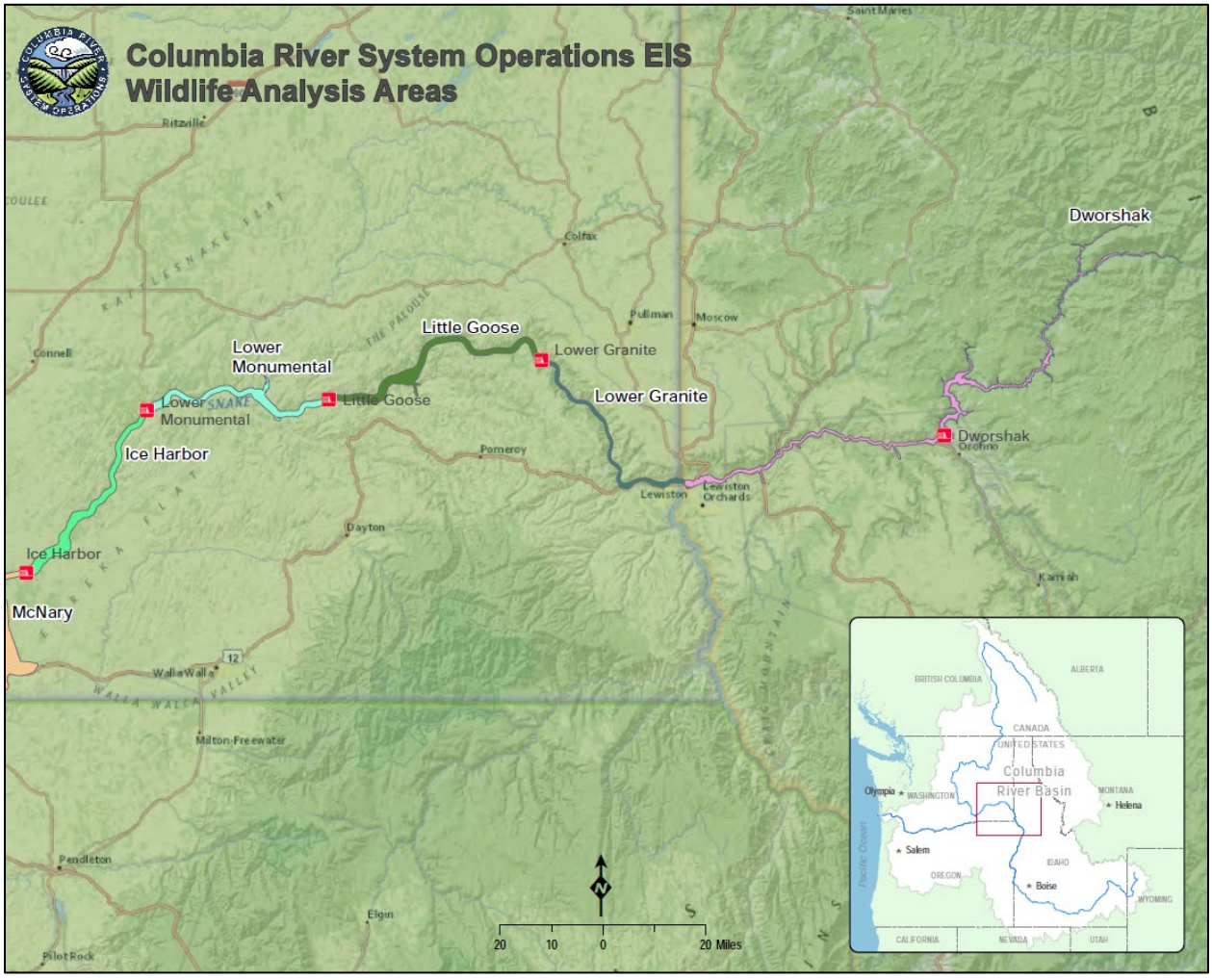

Figure 2-6. Deworshak Dam, Dworshak Reservoir, and Lower Clearwater River Study Area.

2.6.2 Land Cover

2.6.2.1 Uplands

Vegetation surrounding Dworshak Reservoir is primarily dense to open coniferous forest. The lower end of the reservoir is dominated by Douglas-fir (*Pseudotsuga menziesii)* and ponderosa pine (*Pinus ponderosa*) forests. Bunchgrass steppe vegetation extends into the lower reaches of the canyon on the warmer south-facing slopes. Elements of Palouse prairie flora, including several regional endemic species, merge with the moister western red cedar (*Thuja plicata*) forests of the Clearwater Mountains. Major forest cover types include ponderosa pine *(Pinus ponderosa*), Douglas fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and western red cedar.

The upper end of the reservoir is dominated by Douglas-fir, western red cedar (*Thuja plicata*), and western hemlock (*Tsuga heterophylla*) forests. North facing slopes contain denser forests than south facing slopes, which contain open ponderosa pine stands, brush fields, and meadows. Dominant shrubs include mallow ninebark (*Physocarpus malvaceus*), oceanspray (*Holodiscus discolor*), mock orange (*Philadelphus lewisii*), common snowberry (*Symphoricarpos albus*), serviceberry (*Amelanchier alnifolia*), and thimbleberry (*Rubus parviflorus*). Grasses include bluebunch wheatgrass (*Pseudoroegneria spicata*), cheatgrass brome (*Bromus tectorum*), Kentucky bluegrass (*Poa pratensis*), orchardgrass (*Dactylis glomerata*), and timothy (*Phleum pretense*). Bracken fern (*Pteridium aquilinum*) is a dominant and aggressive colonizer that occurs throughout the area, typically invading areas that have been disturbed sites.

The Corps conducts vegetation treatments in the study area to create brushfields for increasing winter forage for elk. USACE has an ongoing obligation under the Fish and Wildlife Coordination Act to mitigate for loss of Rocky Mountain elk winter range caused by the creation of Dworshak reservoir. The brushfields are part of the mitigation approach agreed to by Corps, U.S. Fish and Wildlife Service, and Idaho Department of Fish and Game, as presented in USACE' 1977 Design Memorandum No. 15, *Plan for Development of Rocky Mountain Elk Habitat* (DM 15) (USACE 1977).

The forests along the Dworshak reservoir also support many sensitive plant species. These include broad-fruit mariposa (*Calochortus nitdus*), pine broom rape (*Orobanche pinorum*) and western starflower (*Trientalis latifolia*). In addition, Palouse thistle (*Cirsium brevifolium*) and Jessica's aster (*Aster jessicae*) are sensitive species found in dry forests or forest openings. More mesic forests at Dworshak support clustered lady's slipper (*Cypripedium fasciculatum*), inactive tube lichen (*Hypogymnia inactive*), Herre's ragged lichen (*Platismata herrei*). Bank monkeyflower (*Mimulus clivicola*) can be found on rock outcrops within the forests. These species are not dependent on the reservoir water levels.

The lower Clearwater River flows through a canyon that runs primarily east-west, resulting in predominantly trees and shrubs on the north facing slopes and grassland on the south facing slopes. Segments of the river are bounded by either U.S. Highway 12, a local road or a railroad. In many places there is only rock riprap between these transportation corridors and the river.

Other segments support woody and herbaceous vegetation, agricultural land, or urban development.

Ponderosa pine and bluebunch wheatgrass has been seriously depleted throughout the lower river by livestock grazing. Only small areas remain on very steep upland slopes or in other areas protected from livestock use. This vegetation type has largely been replaced by Ponderosa pine/cheatgrass association. The community is an open Ponderosa pine forest of sapling to large trees up to 40 feet tall. Understory consists of bluebunch wheatgrass (*Agropyron spicatum*), red three-awn (*Aristida longiseta*,) Idaho fescue (*Festuca Idahoensis*), and sand dropseed (*Sporobolus croptandrus*). This community includes large grass openings with some areas dominated by cheatgrass (*Bromus tectorum*) and large colonies of weeds including bouncingbet (*Saponaria officinalis*), spotted knapweed (*Centaurea maculosa*), yellow starthistle (*C. Solstitialis*), and butter-and-eggs (*Linaria vulgaris*).

Notable invasive plants throughout the study area are cheatgrass brome, Kentucky bluegrass, orchardgrass, timothy, bracken fern, tree-of-heaven, and black locust (*Robinia pseudoacacia*). Black locust is a species that does very well in the canyons and is expected to spread.

2.6.2.2 Barren Zone (Drawdown Zone)

Barren rocky slopes devoid of soil and vegetation are characteristic of Dworshak Reservoir below high pool. Where tributaries enter the reservoir some deltas form and are intermittently colonized by herbaceous wetland plants when conditions permit, but are otherwise bare.

The lower Clearwater River fluctuates about seven feet as measured at the Spalding gauge about 29 miles downstream of Dworshak Dam at the confluence of Lapwai Creek and Clearwater River. The lowest flows are observed in August when Dworshak is still maintained for recreation.

Water level fluctuations along the lower Clearwater River are regulated by outflow from Dworshak Dam. The North Fork of the Clearwater drains roughly 30% of the Clearwater basin. Because most of the flow within the basin is uncontrolled, “normal” spring flooding still occurs to some degree on the lower Clearwater River (Lichthardt 1992). Peak flows occur in May with the spring freshet.

2.6.2.3 Wetlands – Forested and Scrub-Shrub

Aproximately 70 acres of Forested and Scrub-Shrub wetlands surround the reservoir and line the tributaries and springs in the study area. These deciduous forests are dominated by red alder (*Alnus rubra*). The understory is typically an herbaceous layers that may be comprised of the following sensitive species: naked rhizomnium moss (*Tripterocladium leucocladulum*), deerfirn (Blechnum spicant), Herre’s ragged lichen (*Platismatia herrei*), Henderson’s sedge (*Carex hendersonii*), Constance’s bittercress (*Cardmine constancei*), Case’s cordalis (*Corydalis caseana ssp. hastata*), and white shooting star (*Dodecatheon dentatum*).

Along the lower Clearwater River below Dworshak Dam, forests are comprised of mature deciduous trees, frequently black cottonwood (*Populus trichocara*), with an understory of native Idaho fescue (*Festuca idahoensis*) and the introduced invasive spotted knapweed (Centraurea maculosa). Trees occur in small, widely scattered groups or in narrow bands along rivers and creeks. In some areas, notably where tributaries enter Clearwater, grazing has influenced the vegetation, which may be dominated by shrubs with a weedy forb layer. Bare cobble is exposed in some spots. Much of the soil surface is covered by a well developed cryptogamic crust.

2.6.2.4 Wetlands – Emergent Herbaceous

A variety of emergent herbaceous wetlands are present in the study both in the vicinity of the reservoir and downstream of the Dworshak Dam. Idaho Partners In Flight (IPIF) has designated non-riverine wetlands as high priority habitat. IPIF has a goal to achieve a net increase in the number of wetland acres in Idaho. A large number of small isolated wetlands are present in the study area. Beaver, waterfowl, frogs and toads, and many land bird species are dependent on wetland communities.

At Dworshak Reservoir low lying, flat tributary deltas support emergent herbaceous wetland vegetation during the spring months, but experience die off for most of the remaining year as the reservoir level drops. Along the shorelines of the reservoir, herbaceous wetlands are interspersed among the forested wetlands. Sensitive species found within these emergent herbaceous wetland habitats include deerfern (*Blechnum spicant*), Henderson's sedge (*Carex hendersonii*), Constance's bittercress (*Cardamine constancei*), Case's corydalis (*Corydalis caseana ssp. hastata),* and white shooting star (*Dodecatheon dentatum*).

Common wetland species throughout the study area include black cottonwood *(Populus trichocarpa*), red-osier dogwood (*Cornus stolonifera*), tree-of-heaven (*Ailanthus altissima*), box elder (*Acer negundo*), black raspberry (*Rubus* sp.), poison ivy (*Rhus radicans*), sourweed (*Rumex acetosella*), rush (*Juncus* sp.) rough hairgrass (*Agrostis scabra*), morning glory (*Convolvulus arvensis*), annual sunflower (*Helianthus annuus*), smooth mullein (*Verbascum blattaria*), goldenrod (*Solidago* sp.), and common purslane (*Portulaca oleracea*).

Downstream of Dworshak Dam on the lower Clearwater River, wetlands are present on some of the islands in the study area. These wetlands are discussed in the "Islands" section.

2.6.2.5 Water

There are approximately 15,200 acres of open water in the Dworshak Dam study area. During the winter, ice can form on the reservoir. If the reservoir is drawn down after ice has formed, the reservoir water no longer supports the ice. This can lead to sheets of ice dropping onto the shoreline within the barren zone. Deer and elk have broken through the ice sheets that cover the lake during the winter migration and subsequently drowned.

There are no submerged aquatic beds within the Dworshak Reservoir or in the study area below the dam on the lower Clearwater River.

2.6.2.6 Islands

In Dworshak Reservoir one 0.57-acre island forms when the water is high. During normal drawdown, a landbridge connects this island to the mainland.

Twenty five islands totaling 265 acres are present in the lower Clearwater River. These islands are covered by a mix of forested and scrub-shrub wetlands and emergent herbaceous wetlands. Many types of wildlife use these islands. Waterfowl nest/breed here. Deer, aquatic mammals, raptors, songbirds, and other wildlife capable of swimming to the islands are known to use them.

Lichthardt (1992) describes vegetation and habitat conditions on the lower and Middle Cottonwood Islands. Her work provides the foundation for this section. Within the study area below Dworshak Dam BLM and Idaho Department of Fish and Game manage several islands in the lower Clearwater River for ecological values and waterfowl production as part of their Habitat Management Plan. These islands have been designated a Research Natural Area and Area of Critical Environmental Concern by the Bureau of Land Management because of their suitability as ecological reference areas and their value for educational and research uses. A high density of Canada geese nesting boxes is maintained on these islands. The islands are only accessible by water (Lichthardt 1992).

Lichthardt (1992) notes that these islands taper gradually to river level on their upstream ends and drop abruptly at their downstream ends, forming steep rock banks. Cobble bars, which are typically covered by water during spring runoff, are found at the upstream ends of each island. Sand may be present in spaces between the cobbles or may cover the rocks to a depth sufficient to support plants. At the highest elevations, sandy soils of variable depth covers layers of cobble, gravel, sand.

At their lowest extent these bars are characterized by a willow thicket community. Willows are the single dominant species within this zone, forming a dense to open shrub layer 4 to 6 feet tall. The willow community is flooded intermittently throughout the summer due to fluctuations caused by Dworshak dam. Debris caught in branches of the willows indicates they are totally submerged at times.

The BLM has identified five plant communities, which reflect the elevation gradient and its associated flooding frequency and duration. From wettest to driest (lowest to highest elevation) these are: coyote willow (*Salix exigua*), hairy goldaster (*Chrysopsis villosa*), Louisiana sagewort (*Artemisia ludiviciana*), black cottonwood/Idaho fescue (*Populus trichocarpa/Festuca idahoensis*), and Ponderosa pine/bluebunch wheatgrass (*Pinus ponderosa*/*Agropyron spicatum*).

Because rivers are natural corridors for plant dissemination it is not surprising to find a high percentage of weeds and several exotic shrubs and trees on islands in the Clearwater River. Presently, the most serious weed problem on the river is the abundance of spotted knapweed. Spotted knapweed usually invades where there is soil disturbance, and is commonly found on sand bars and it may have invaded the island grasslands after a fire or a flooding event. It is able to spread rapidly. Annual flooding of cobble bar communities keeps them virtually free of noxious weeds.

2.6.3 Wildlife

2.6.3.1 Birds

RAPTORS

IDFG surveys (Bowers and Nadeau 2002) documented 16 species of raptor in the Dworshak Reservoir study area. These include eagles, hawks, ospreys, falcons, and owls. Four species are listed by the state: bald eagle, Swainson's hawk, merlin, and flammulated owl. A large population of bald eagles winter along the reservoir, but only five nests have been documented. Over 150 osprey nests have been observed (USACE 2015). Bald eagles primarily feed on fish, but also use ducks and carrion when available. Osprey feed exclusively on kokanee (*Oncorhynchus nerka*), trout, and other available fish species. Bald eagles winter along the entire reach feeding on fish, waterfowl, and carrion. The highest concentration of bald eagles in the study area is downstream of Dworshak Dam, where they feed largely on kokanee that pass through the turbines. Good perch sites are furnished by mature trees, and releases from Dworshak keep the lower Clearwater ice-free throughout the winter.

WATERBIRDS, SHOREBIRDS AND WATERFOWL

A total of 42 waterfowl and shorebird species were observed on Dworshak Reservoir during terrestrial resource surveys conducted by the IDFG (Bowers and Nadeau 2002). Fourteen species of these waterfowl and shorebirds are currently listed as "Species of Greatest Conservation Need" (IDFG 2015 updated 2017).

Wood duck (*Aix sponsa*), mallard (*Anas platyrhynchos*), common merganser (*Mergus merganser*), Canada goose (*Branta canadesnsis*), and green-winged teal (*Anas crecca*) nest along the reservoir, particularly near the tributaries at the upper end. Most brooding likely occurs within the lower reach under reservoir influence on a combination of managed and naturally vegetated sites. USACE maintains and irrigates two pastures in this and other agricultural areas. The reservoir is primarily used as a stop-over during spring and fall migration, with peak waterfowl occurrence in the late fall, winter, and spring. Some feeding by geese and puddle ducks occurs along the exposed shoreline during the winter drawdown. However, the extreme fluctuations in pool level limit the growth of aquatic vegetation along the shoreline, reducing the amount of food available for waterfowl.

Most shorebird use is confined to the tributaries and upper end of the reservoir. Shorebirds observed along Dworshak Reservoir include the Common snipe (*Gallinago gallinago*), marbled godwit (*Limosa fedoa*), solitary sandpiper (*Tringa solitaria*), American avocet (*Recurvirostra americana*), great blue heron (*Ardea Herodias*), and killdeer (*Charadrius vociferous*). Spotted sandpiper (*Actitus macularia*) and killdeer are known to nest at reservoir (USACE 2015).

Below Dworshak Dam, waterfowl commonly nest on islands of the lower Clearwater River. The number of nesting geese on these islands has tripled since 1981. As many as 82 nesting structures have been erected in recent years to protect geese from high flows and predation and approximately 50 percent of the structures are used. Some geese may winter along the reservoir-influenced portion of the river. Hundreds of wintering ducks are also found in the portion of the study area below the dam. Some common merganser nesting occurs on the islands.

Shorebirds forage along the Clearwater River below the day. Great blue herons frequent the shallow water shorelines, but there are no known great blue heron rookeries along this reach. Some spotted sandpiper (*Himantopus mexicanus*) nest along limited beach areas and islands. The seven foot annual water level fluctuation provides suitable shoreline foraging habitat for these birds.

PASSERINES

Downy woodpeckers (*Picoides pubescens*) and black-capped chickadees (*Poecile atricapillus*) nest and feed in the forested wetlands around the Dworshak Reservoir. These and other species are dependent on creation of snags to provide suitable nest sites. Some downy woodpecker (*Picoides pubescens*) nesting cavity sites are available in snags found amongst clumps of mature cottonwood (*Populus trichocarpa*) and willow stands along the river and tributaries. Regeneration of this habitat type is limited due to attenuation of periodic flood flows. Downy woodpeckers and other gleaner species feed primarily in these habitats because they provide the highest habitat diversity within a primarily arid ecotype. Most bird species found in this region are dependent on cottonwood/willow habitats for at least a part of their life cycle.

Below the dam, yellow warblers (*Setophaga petechia*) nest and feed in the shrub-scrub wetlands, primarily areas with willows. This habitat is present in small patches along the river. Many of these patches are too small to be mapped but still have significant food and cover value for warblers and other species.

GALLINACEOUS BIRDS

Six gullinaceous birds were documented during IDFG surveys: mourning dove (*Zenaida macroura*), California quail (*Callipepla californica*), ruffed grouse (*Bonasa umbellus*), blue grouse (*Dendragapus obscurus*), spruce grouse (*Dendragapus Canadensis*), and wildl turkey (*Meleagris gallopavo*). One male mountain quail was observed at Magnus Bay in September 1977. Mountain quail were also reported near Reeds Creek in 1990 and 1993. Of these species,

only the mountain quail is classified as a special status species in Idaho. Wild turkesy are not native to Dworshak in 1985, howebver, 16 wild turkeys were released by IDFG in the Canyon Creek drainage. In 1993, additional releases of wild turkeys were made near Orofino Creek (26 birds) and Whiskey Creek (22 birds) to supplement the population. Wild turkey populations are now thriving (USACE 2015).

Wild turkeys have been intentially introduced and are managed as a game species in the study area.

2.6.3.2 Mammals

TERRESTRIAL

Surveys conducted by IDFG documented 39 species of mammals in the study area. Two of these are on Idaho's "Species of Greatest Conservation Need" list (IDFG 2015 updated 2017): Townsend's big-eared bat (*Corynorhinus townsendii*) and gray wolf (*Canis lupus*). Sightings of fisher (*Mares pennant*) and wolverine (*Gulo gulo*) have also been reported to Dworshak staff (USACE 2015). Canada lynx (*Lynx canadensis*) is also recognized as a species of concern.

Over 1,000 Rocky Mountain elk (*Cervus elaphus nelsoni*) have been observed wintering in the study area on project lands around Dworshak Reservoir. Mitigation actions have been taken to assure sufficient browse is available to sustain the elk populations. The elk are not dependent on the reservoir or habitat immediately adjacent to the reservoir. The reservoir can create a hazard to elk in winter due to formation of ice. It is not unusual to observe animals having broken through the ice and drowned (USACE 2015).

Whitetailed deer (*Odocoileus virginianus*) also winter along the reservoir. Ice poses a hazard to white-tailed deer as well, because coyotes (*Canis latrans*) have been known to chase then onto the ice. White-tailed deer are more prevalent in this area than mule deer (*Odocoileus hemionus*). Most deer occurrence along the lower Clearwater River is in side canyons with minimal evidence of occurrence in either the riverine corridor or on islands (Asherin and Orme 1978). This may be due to the abundance of water in the side canyons coupled with very minimal security cover afforded by narrow bands of trees and shrubs along the river (Asherin and Orme 1978).

In addition to Townsend's big-eared bat, several other bat species may be present in the study area. These include pallid bats (*Antrozous pallidus*), fringed myotis (*Myotis thysanodes*), California Bat (*Macrotus californicus*), silver-haired bat (*Lasionycteris noctivagans*), and Yuma myotis (*Myotis yumanensis*). These bats forage on stream insects such as midges, caddisflies, and mayflies and can roost up to two miles from the river and reservoier in moist forests.

AQUATIC

In the reservoir, river otter (*Lontra canadensis*) and related species are confined to the upper reservoir and tributaries. Below the dam, river otters are present in and adjacent to dense

forest and shrub habitats located near the river and tributaries. Otter feed in shallow water and den in previously excavated sites near the water, or within boulder piles, rock outcrops, or dense logjam-type litter.

North American beaver (*Castor canadensis*), mink (*Neovison vison*), and muskrat (*Ondatra zibethicus*) are present in the study area below Dworshak Dam. No beaver lodges have been observed and bank denning is exclusively used. Den sites are usually associated with well-developed forest and shrub habitat along the river. Beaver feed on abundant scrub-shrub willow and the bark of saplings.

2.6.3.3 Reptiles and Amphibians

Several reptile and amphibian species occur near the reservoir in association with shallow water areas, pools, shallow lake edges, or upstream tributaries. Reptiles present at or near Dworshak Reservoir include rubber boa (*Charina bottae*), racer (*Coluber constrictor*), common garter snake, (*Thamnophis sirtalis*), western terrestrial garter snake (*Thamnophis elegans*), gopher snake (*Pituophis catenifer catenifer*), western rattlesnake (*Crotalus viridis*), northern alligator lizard (*Elgaria coerulea*), and western skink (*Plestiodon skiltonianus*).

Amphibians known to the area include bull frog (*Lithobates catesbeianus*), Pacific tree frog (*Pseudacris regilla*), and Columbia spotted frog (*Rana luteiventris*). These species occur in association with submerged aquatic vegetation or seasonal emergent herbaceous wetlands and ponds. Long-toed salamander (*Ambystoma macrodactylum*) and western toad (*Anaxyrus boreas*) occur in seasonal wetlands or scrub shrub wetlands. At higher elevations, tailed frogs (*Ascaphus truei*) occur in riffles and pools of tributary streams. The Coeur d' Alene salamander (*Plethodon idahoensis*) is a state species of special concern and occurs in the upper reaches of the Dworshak reservoir (S. Stephens, ICDC, pers. comm.).

Below the dam, Western garter snake and ring-necked snake (*Diadophis punctatus*) are reptile species expected to be present in the study area, including along the river and tributaries (Asherin and Orme 1978 and S. Stephens, ICDC, pers. comm.).

Western toad is expected to be present in or near permanent ponds, herbaceous emergent wetlands, lakes, and still-water off-channel riverine habitats, as well as river edges. Long-toed salamanders are also found in these habitats. Bullfrog, pacific tree frog, and Columbia spotted frog may be present in or near seasonal emergent herbaceous wetlands and ponds.

Bullfrogs are a notable introduced invasive species.

2.6.3.4 Invertebrates

Information about invertebrate species in the study area is not readily available. Dworshak reservoir is likely devoid of benthic fauna due to the magnitude of annual drawdown. Any benthic populations would be associated with the tributaries enter the reservoir. High water velocities, sharp temperature changes, and flow fluctuations resulting from operation of

Dworshak Dam likely affect the resident insect populations (Fleck et al. 1978). Hydroelectric peak-induced flow fluctuations could destabilize benthic community structure to marked by fewer species, changes in dominance, relationships among species, and in the available energy for higher trophic levels (MacPhee and Brusven 1973).

2.7 LOWER SNAKE RIVER PROJECTS: LOWER GRANITE LOCK AND DAM, LITTLE GOOSE LOCK AND DAM, LOWER MONUMENTAL LOCK AND DAM, ICE HARBOR LOCK AND DAM

2.7.1 Study Area

The study area used to describe the existing conditions and assess the range of potential impacts for wildlife and habitat features includes the lands associated with the lower Snake River beginning at Ice Harbor Dam (RM 9.7) upstream until the confluence of the Snake River and the Clearwater River at RM 140 near the City of Lewiston, Idaho (Figure 2-7).

The study area includes Lower Granite Lock and Dam and Lower Granite Lake, Little Goose Lock and Dam and Lake Bryan, Lower Monumental Lock and Dam and Lake Herbert G. West and Ice Harbor Lock and Dam and Lake Sacajawea. There are three significant tributaries of the Lower Snake within the study area including the Palouse River (RM 59.5), Tucannon River (RM 62), and Deadman Slough (RM 83). The Clearwater River (RM 140) while a major tributary of the lower Snake is included in the Dworshak Dam study area (Section 2.6 Dworshak Dam and the Lower Clearwater River).

The lower Snake River is within the Columbia Plateau Ecoregion characterized by sagebrush steppe and grasslands. The semi-arid climate supports native shrub-steppe vegetation and drought-tolerant plant communities. More than half of the shrub-steppe has been converted to agriculture (WHCWG 2010).

Within the Lower Snake River Projects (LSRP) study area, there are Habitat Management Units (HMUs) that provide habitat for wildlife species (Table 2-5). There are 62 HMUs scattered along the Snake River from Ice Harbor Dam to the upper extent of the Lower Granite pool. Of those, ten are intensively managed and irrigated (USACE 2002). Some HMU lands were acquired under a compensation plan authority to address losses to wildlife resources incurred during the construction and operation of the lower Snake River dams (USACE 2011). These lands were compensated for in the Lower Snake River Fish and Wildlife Compensation Plan of 1975, of which 23,620 acres of land were designated for HMUs (USACE 2014).

Table 2-5. Habitat Management Units (HMUs) on the Lower Snake River

HMUs	River Mile	HMUs	River Mile
Charbonneau	11	Ridpath	76
Big Flat	15	New York Bar	81
Fishhook	18	Lower Deadman	83
Lost Island	19	Central Ferry	83.5
Hollebeke	25	Willow Bar	88

HMUs	River Mile	HMUs	River Mile
Snake River Junction	26	Penawawa	91.5
Walker	30	Rice Bar	93
Skookum	48	Swift Bar	97
55 Miles	55	Illia	102
Lyons Ferry	59.5	Kelly Bar	119
Tucannon	62.5	Nisqually John	123
John Henley	68	Chief Timothy	132.5

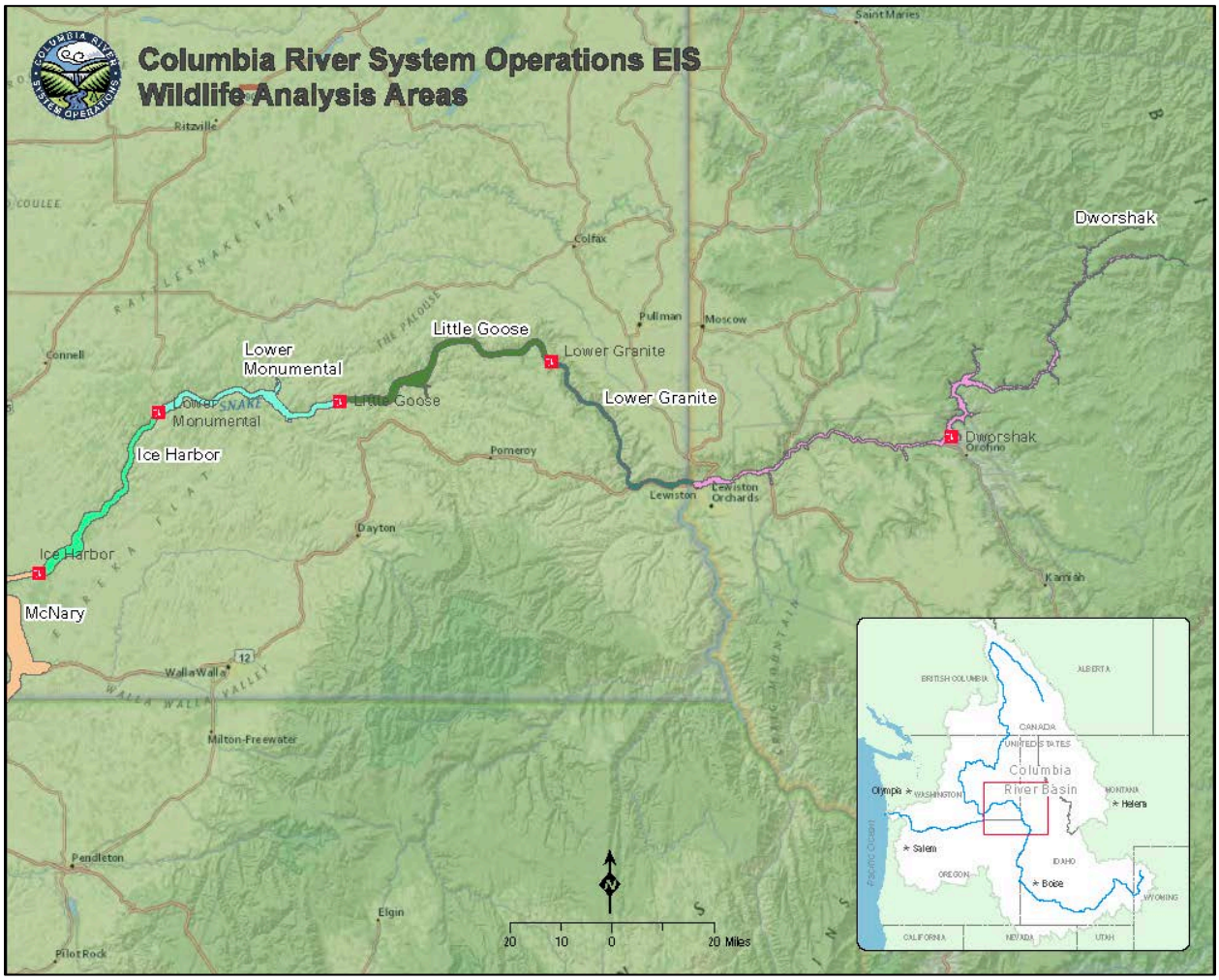

Figure 2-7. Lower Snake River Projects: Lower Granite Lock and Dam, Little Goose Lock and Dam, Lower Monumental Lock and Dam, Ice Harbor Lock and Dam Study Area.

2.7.2 Land Cover

Table 1-2 above shows the acres of the different habitat types within the Lower Snake River study area.

2.7.2.1 Uplands

The primary upland habitat types in the lower Snake River project area includes steppe and shrub-steppe vegetative communities (Franklin and Dryrness 1973). Steppe communities are dominated by bunchgrasses such as bluebunch wheatgrass (*Pseudoroegneria spicata*). Shrub-steppe habitats consist of one or more layers of perennial grass with a discontinuous overstory of shrubs. These communities are co-dominated by sagebrush such as big sagebrush (*Artemisia tridentata*). While the dominating upland habitat in the LSRP study area is shrub-steppe, small remnants of ponderosa pine (*Pinus ponderosa*) and white oak (*Quercus alba*) forest and woodlands exist in the project area. There are 31,000 acres of upland habitat in the LSRP study area.

The WDFW Wildlife Management Program conducted a three-year survey recording bird species on 55 transects throughout Washington's shrub-steppe community to correlate habitat suitability with species present. Concurrent vegetation surveys determined the percent vegetative cover of shrubs, trees, grasses and forbs. Surveys were completed in Franklin, Walla Walla, and Benton counties. The LSRP study area intersects the shrub-steppe habitat that was sampled (WDFW 1996). Data collected by the WDFW survey accurately depicts the current plant species growing in the isolated and fragmented shrub-steppe upland habitat.

Commonly occurring shrubs and trees in eastern Washington's shrub-steppe include serviceberry (*Amelanchier alnifolia*), black sagebrush (*Artemisia arbuscula*), scabland sagebrush (*A. rigida*), common sagebrush (*A. tridentata*), threetip sagebrush (*A. tripartita*), creeping Oregon grape (*Berberis repens*), rubber rabbitbrush (*Ericameria nauseosus*), yellow rabbitbrush (*E. viscidiflorus*), oceanspray (*Holodiscus discolor*), granite prickly phlox (*Linanthus pungens*), cottonwood (*Populus* spp.), cherry (*Prunus* spp.), antelope bush (*Purshia tridentata*), golden currant (*Ribes aureum*), Nooktka rose (*Rosa nutkana*), greasewood (*Sarcobatus vermiculatus*), common snowberry (*Symphoricarpos albus*), and gray horsebrush(*Tetradymia canescens*) (WDFW 1996).

Grasslands are primarily composed of bluebunch wheatgrass, great basin wild rye (*Elymus cinereus*), Idaho fescue (*Festuca idahoensis*), Sandberg's bluegrass (*Poa secunda* ssp*. secunda*), squirrel tail grass (*Elymus elymoides*), needle and thread grass (*Stipa comata*), and western needlegrass (*Stipa occidentalis*). Perennial forbs that occurred in at least 20 percent of the plots sampled and occurring in the LSRP study area include: *Phlox* sp., *Lomatium* sp., yarrow (*Achillea millefolium*), lupine (*Lupinus* sp.), *Erigeron* sp., buckwheat (*Eriogonum* sp.), vetch (*Astragalus* sp.), threadleaf sedge (*Carex filifolia*), paintbrush (*Orthocarpus* sp.) (WDFW 1996).

Upland native plant communities are adapted to the arid climate; most plants become dormant through summer and winter. Some larger shrubs can tap into deep subsurface water and actively grow throughout the hot, dry summers. A critical component of native grassland and shrub-steppe plant communities is the cryptogamic or microbiotic crust. Cryptogams are plants that reproduce by spores and/or those that are non-photosynthetic. This combination of mosses, lichens, liverworts, algae, and bacteria stabilize the soil against wind and water erosion,

and enrich the soil by providing carbon and nitrogen, limiting essential nutrients (Kane 2002, USFWS 2013).

The upland areas surrounding the projects are typical of the semi-arid intermountain ecotype found in the Columbia Basin Province, which is dominated by rabbitbrush, cheatgrass and remnant bunchgrasses and forbs. Drastic increases in dry-land agriculture and irrigation has reduced the once expansive native grasslands and shrub-steppe habitats. Some non-irrigated crops grown in the Deadman Creek watershed are winter wheat and barley, spring grain, peas and bluegrass seed. Domestic livestock are pastured on upland areas not suitable for cropland.

Within the Columbia subbasin, ponderosa pine habitat currently covers a wide range of seral conditions. Ponderosa pines occur on warm, dry sites at elevations ranging from sea level to 6,000 feet. Bark beetle infestation has contributed to massive mortality rates of large pines in the basin (NPCC 2004). The shaded, moist microclimates of the canyon draws, in the upper reaches of Little Goose and Lower Granite Dam may support small stands of conifers, including ponderosa pine and white oak woodlands. Under a contract for operation and maintenance of the HMUs, occasionally ponderosa pines with a red (*Alnus rubra*) or white alder (*A. rhombifolia*) understory are planted. Pine survival is dependent upon seasonal conditions and water availability (USACE 2018).

The encroachment of noxious weeds like cheatgrass have degraded the quality of native plant communities within the uplands of the lower Snake River subbasin. Cheatgrass outcompetes native plants for water and space, as they produce copious quantizes of seeds and produce nearly four times the biomass as native grasses (Kane 2002). Cheatgrass disrupts the natural fire regime because it is the first to germinate on disturbed soil, is highly flammable and provides a thick, continuous fuel load, as well as dries out early in the season. Increased periodicity in the fire cycle lessen the chances of native plant communities from recolonizing these areas (USFWS 2013). St. John's wort (*Hypericum perforatum*), yellow starthistle (*Centaurea solstitialis*) and knapweeds (*Centaurea* sp.) are also invading the native bunchgrass grasslands in the lower Snake River project area. Scotch thistle (*Onopordum acanthium*) invades disturbed upland habitat including roadsides and campgrounds that are within the LSRP study area.

2.7.2.2 Barren Zone/Drawdown Area

The lower Snake River projects operate as run-of-river dams which results in virtually non-existent drawdown areas. There is a small band of barren zone that is periodically and irregularly inundated, primarily within the upper two feet of the operating range. The vast majority of this river stretch exhibits relatively steep topography with very few expanses of mud flats. There are only three areas of significant mudflat development at the mouths of tributaries: the Palouse River (RM 59.5), Tucannon River (RM 62), and Deadman Slough (RM 83). The Clearwater River (RM 140) contributes a significant sediment load, however flows are high in this area and deposition is far enough downstream as to not form mudflats.

Hillslopes within the reservoirs with large toe slopes will likely be enriched by silt and clay depositions (USACE 2014). Deposition on toe slopes could result in high unstable terraces once the reservoirs are drained (Randle et al. 2015). Erosion and sloughing occur primarily along lower lying benches, and deposition of silts occurs at the mouths of the tributaries. Small changes in the maximum operating pool (MOP) allows native scrub-shrubs to invade the exposed band of rich sediment deposited on the barren zone. Scrub-shrubs can endure inundation from November through March.

2.7.2.3 Wetlands – Forested and Scrub-Shrub

The lower Snake River project area contains linear strips of wetlands along the interface between aquatic and terrestrial ecosystems, closely following perennial rivers and streams. Forested and scrub-shrub wetlands are composed of a mosaic of shrublands, woodlands, and forest communities and characteristically have either a deciduous, coniferous, or mixed canopy cover. Scrub-shrub and palustrine forested wetlands are dominated by a canopy of willows and cottonwoods. There are approximately 760 acres of forested and scrub-shrub wetlands in the LSRP study area.

Due to the hot, dry climate in the Snake River subbasin, the extent of riparian vegetation and species present along this reach is entirely dependent on water availability. Soil saturation is typically present during flood events. Precipitation increases with the downstream to upstream elevational gradient, ranging from approximately 9 to 15 inches annually (USACE 1995). Greater precipitation in the upstream reaches facilitates a richer band of wetland vegetation in the side draws and shallow pockets across the canyon slopes. Side drainages with woody vegetation above reservoir levels begin at Central Ferry, Washington and continue upstream (USACE 1975). This change in vegetation frequency becomes evident around RM 85 within the Lower Granite Pool. North facing slopes retain more moisture and often have more diverse and extensive woody vegetation. A total of 345 different species of plants have been documented along the lower Snake River riparian zone (USACE 1976).

Currently the two significant native, wetland plant communities include black cottonwood and coyote willow/false indigo. On irrigated lands adjacent to the Snake River, such as HMUs, Russian olive is the most prevalent tree species and Himalayan blackberry (Rubus armeniacus) is the dominating shrub (USACE 2014). Black cottonwood, white alder (*Alnus rhombifolia*), and netleaf hackberry (*Celtis reticulata*) frequently occur in adjacent wetlands. Mesic shrubland occurs in side draws and near seasonal springs and seeps. Species typical of these areas included black hawthorn, chokecherry (*Prunus virginiana*), and willows, with a forb understory consisting of rushes, sedges, bluebunch wheatgrass, and shrub steppe communities of rabbitbrush, sagebrush, or antelope bitterbrush (*Purshia tridentata*). Wetland vegetation occurs in discontinuous bands along the main river at the bottom of the canyon, at the mouths of tributaries, and in the side canyons associated with seeps and springs. Generally in these wetland fragments, trees grow in small groves or even singly.

Grazing cattle and livestock suppressed woody vegetation in wetland areas. Willows become the principal source of cattle browse when springtime palatable understory sedges and forbs

desiccate and their protein content decreases. Willow seedlings are especially at risk from grazing and trampling. Cattle often break willow shrub branches while seeking shade during hot summer months. Because the movement of cattle is sporadic, the distribution of forested and scrub-shrub wetland varies from year to year (Kovalchik and Elmore, 1991).

The expansion of exotic, invasive species such as western false indigo (*Amorpha* fruticosa) and Russian olive (*Elaeagnus angustifolia*) has fragmented the once continuous scrub-shrub and forested wetland habitat that existed along the Snake River and tributaries. Western false indigo escapes planted areas and forms dense thickets along streams and rivers, outcompeting native wetland species. Species composition has changed reflecting intrusion of invasive species such as Canada thistle (*Cirsium arvense*), black locust (Robinia pseudoacacia), curly dock (*Rumex crispus*), poison hemlock (*Conium maculatum*), and teasel *(Dipsacus fullonum*). Invasive understory plants grow faster than woody vegetation, preventing sunlight from reaching young tree saplings, like cottonwoods. Butterfly bush (*Buddleia davidii*) is an escaped ornamental that forms dense, shrub thickets that displace native vegetation in forested wetlands, often dominanting willow habitat. Tamarisk (*Tamarix ramosissima*) is an aggressive shrub or small tree that grows in wetlands, choking streambeds and causing flooding downstream. There are large infestations reported in eastern Washington (WISC 2009).

2.7.2.4 Wetlands – Emergent Herbaceous

Emergent wetlands generally occur where groundwater saturates the surface soil layer during the growing season. Water availability must be sufficient and frequent to induce the characteristic vegetative, physical, and chemical conditions of emergent wetland communities (USACE 2002). Numerous small pockets of emergent wetland vegetation, less than a half-acre in size, exist in small impoundments and embayments behind roads and railroads. The size of herbaceous wetlands change seasonally, mostly increasing during the growing season. These wetlands are highly dependent upon water availability; water infiltration along the root zone dictates the amount of growth or desiccation.

Emergent wetlands are dominated by cattail (*Typha sp.*) and bulrush (*Scirpus sp*.) with some rushes (*Juncus sp*.), purple loosestrife (*Lythrum salicaria*), western false indigo, sedges (*Carex sp*.), and common reed (*Phragmites australis*). Palustrine emergent wetlands consists of cattail, sedges, and tule (*Schoenoplectus acutus*). There has been an increase in emergent wetland communities since the construction of the LRSP; this is likely due to several factors: 1) abundant slack water which causes sediments carried into reservoirs to accumulate and create good conditions for wetland vegetation development, especially at the mouths of tributaries; 2) several embayments and backwaters which also allow wetland development; 3) drawdowns which allowed wetland vegetation to establish; and 4) runoff and seeps from nearby irrigated HMU's (USACE 2002). There are approximately 160 acres of emergent wetland habitat in the LRSP study area.

There are several Washington Wetlands of High Conservation Value within the LSRP study area. There are at least 20 small wetlands in the Lower Granite pool with known rare plants and nonvascular species with high state conservation value. All of these wetlands contain rare or

state-listed herbaceous plants and/or grass associates. These plants may include blue mountain onion (*Allium diction*), Cusick's milkvetch (A*stralagalus cusickii* var. *cusickii*), Piper's milkvetch (*Astralagus riparius*), Texas bergia (*Bergia texana*), Oregon bolandra (*Bolandra oregana*), sagebrush mariposa lily (*Calochortus macrocarpus* var. *maculosus*), Snake river daisy (*Erigeron disparipilus*), yellow wildrye (*Leymus favescens*), awned halfchaff sedge (*Lipocarpha aristulata*), snake canyon desert-parsely (*Lomatium sandbergii*), Blue Mountain penstemon (*Penstemon pennellianus*), yeti phlox (*Phlox solivaga*), mountain buttercup (*Ranunculus populago*), lowland toothcup (*Rotala ramosior*), and prarie cordgrass (*Spartina pectinata*) (WNHP 2018).

Invasive species such as common reed, reed canarygrass (*Phalaris arundinacea*), Japanese knotweed (*Fallopia japonica*), and western false indigo become a dominant species in some areas. Knotweeds are found throughout Washington State, invading streambeds and riverine systems, dominating all available space, blocking sunlight and devouring all nutrients in wetland habitats. Reed canarygrass forms monotypic stands in stream channels and floodplains throughout the study area. Reed canarygrass is a noxious weed in Washington that continues to displace much of the historic native herbaceous wetland understory. Reed canarygrass's creeping rhizomes form a thick sod layer and stems can grow up to 2 meters tall, blocking sunlight from reaching smaller native plants (TNC 2004). This invasive has outcompeted historically dominant native plants such as small camas (*Camassia quamash*), Nebraska sedge (*Carex nebrascensis*), and blister sedge (*Carex vesicaria*). Flowering rush (*Butomus umbellatus*) is an aquatic, rhizomatous, sedge-like invasive that is capable of colonization drawdown zones where water recedes to expose soil.

2.7.2.5 Water

Open water exists primarily in the four reservoirs: 1) Lake Sacajawea; 2) Lake Bryan; 3) Lake Herbert G. West; and 4) Lower Granite Lake. Open water habitats are found in numerous ponds and embayments, and the tributary confluences with the Palouse and Tucannon River. Aquatic habitats provide essential cover and resources for wildlife species in the LSRP study area. Embayments are formed by the construction of railroads and highways causeways that cut off the surface water of the mainstem Snake River. Hydrologic connectivity is maintained via culverts, small channels, irrigation or groundwater exchange.

Shallow waters in these habitats support productive submergent, emergent and aquatic vegetation communities. Extent of this vegetation type has never been quantified for this reach but is assumed to be limited, correlated with the amount of shallow water present. There are narrow bands of aquatic vegetation along the Snake River in the absence of roads. The upper reaches of the study area have increasingly steep terrain with canyon draws leading to small embayments which support riparian vegetation. These slack waters generally have lower species diversity and high abundance of introduced and invasive aquatic species.

The Ice Harbor pool does support populations of rooted aquatic vegetation such as bulrush (*Scirpus* sp.), spike-rush (*Eleocharis* sp.), false pimpernel (*Lindernia dubia*), longleaf pondweed (*Potamogeton nodosus*) and sago pondweed (*Stuckenia pectinata*) (WSDOE 1996). In the shallows and coves of Lake Bryan, the Little Goose Dam pool, northern mudwort (Limosella

aquatica) and common elodea (*Elodea canadensis*) grow near the town of Central Ferry and Deadman Creek (WSDOE 1997). A diversity of aquatic and submerged vegetation grows near the rocky shoreline of Lower Monumental Dam, including common hornwort (Ceratophyllum demersum), longleaf and sago pondweed, and common elodea. Aquatic plants in the Order Alismatales including pondweeds and arrowleafs grow densely in the shallow littoral zone of the Palouse River. Surveys at Lower Granite Lake found few rooted aquatic plants near Chief Timothy island including several fragments of sago pondweed, northern mudwort, and horned pondweed (*Zannichellia* sp.) (WSDOE 1997) in the shallow portions of the lake. Extent of this vegetation type has never been quantified for this reach but is assumed to be limited, correlated with the amount of shallow water present. There are approximately 33,200 acres of water habitat in the LSRP study area.

Invasive plant species found in the shallow waters of Lake Sacajawea and Lake Herbert G. West include curly-leafed pondweed (*Potamogeton crispus*), Eurasian water-milfoil (*Myriophyllum spciatum*), Brazilian elodea (*Egeria densa*), African elodea (*Lagarosiphon major*), slender-leaved naiad (*Najas minor*), and purple loosestrife (*Lythrum salicaria*) (WSDOE 1996-1997).

2.7.2.6 Islands

There are currently two islands of significant size in the LSRP study area. Silcott Island in Lower Granite Lake is 123 acres and connected to the mainland by a causeway. Chief Timothy State Park on Silcott Island is located off U.S. Highway 12 and contains just over 100 campsites on the southern shore. The campground is irrigated, with shaded uplands and wetland vegetation, which may be considered low quality habitat due to the presence of people. The island is located within the Chief Timothy HMU (USACE 2011).

New York Island in Lake Bryan is approximately 50 acres, isolated and accessible only by boat. The eastern shore of New York Island has forested and herbaceous wetland vegetation habitat. The uplands are scrub-shrub and annual grassland. There are about 20 unnamed islands, some as small as 0.1 acres are present in the slackwaters. Island acreages may fluctuate depending upon dam operations. At least four islands have been created from dredged material disposal (USACE 1995).

Little Goose Lock and Dam was constructed on the former Little Goose land. The island was approximately 1,200 feet below the surrounding Columbia River Plateau surface elevation (The Spokeman-Review 1963).

2.7.3 Wildlife

2.7.3.1 Birds

RAPTORS

Raptor diversity in the LSRP study area is relatively high. Documented species include northern harrier (*Circus cyaneus*), Swainson's hawk (*Buteo swainsoni*), red-tailed hawk (*Buteo*

jamaicensis), ferruginous hawk (*Buteo regalis*), American kestrel (*Falco sparverius*), prairie falcon (*Falco mexicanus*), bald eagle (*Haliaeetus leucocephalus*), and golden eagle (Aquila chrysaetos). Several of these species, including prairie falcon, golden eagle, American kestrel, and Swainson's hawk nest on cliffs and rocky crevices. Ferruginous hawks nest and forage in the open grasslands and shrubby draws (USACE 2002).

Rocklage and Ratti (1998) documented 17 species of raptors in the Lower Granite Pool, including 209 individuals of 12 species during the breeding season. Of these 209 individuals, over 80 percent were one of three species: red-tailed hawk (45 percent), American kestrel (21 percent), and northern harrier (14 percent). Great horned owls (*Bubo virginianus*) and burrowing owls (*Athene cunicularia*) have been reported near the lower Snake River and Lower Granite Lock and Dam (Lewke and Buss 1977), and are likely occasional visitors.

Ferruginous hawks inhabit and breed in the Lower Columbia Basin and surrounding arid lands of southeast Washington. They are a state-listed species that are obligate grassland or desert-shrub nesters that occupy shrub-steppe in the channeled scablands of the Snake River. Ferruginous hawks are sensitive to disturbance and forage on small-medium size mammals beyond the wheat and croplands of the plateau. The largest overwintering populations of prairie falcons in Washington occur in the central Columbia Basin which overlaps with the study area. Prairie falcons nest on the basalt cliffs of the Snake River Gorge and hunt in shrub-steppe habitat that supports abundant prey, including ground squirrels, western meadowlarks (*Sturnella neglecta*), and horned larks (*Eremphila alpestris*). These falcons are specially adapted arid environment of eastern Washington and habituate the upland habitats in the LSRP study area (WDFW 2004).

There are several WDFW designated golden eagle breeding areas along the Snake River (WDFW 2018). These breeding areas increase in frequency towards Lower Granite Dam. The species is uncommon in the transitional phase between montane and shrub-steppe habitats but scattered nest sites can be located on cliffs and in coniferous trees. Grassland and shrub-steppe vegetative communities provide habitat for small to medium mammals such as hares (*Lepus* spp.), ground squirrels, marmots (*Marmota* spp.), mountain beaver (*Aplodontia rufa*), and birds (e.g. pheasant and grouse) that are important prey for the golden eagle (Kochert et al. 2002).

There are several bald eagle territories in southeastern Washington near the Snake River; however, bald eagles are nearly scarce in higher elevations in the Columbia Basin and Palouse Region due to the lack of available nesting habitat. Bald eagles construct nests up to 2 meters in diameter typically in the largest trees in the region. In the arid shrub-steppe habitats in the study area, mature large trees cannot be supported with the limited availability of precipitation (WDFW 2016). No bald eagle nests were documented along the lower Snake River reservoirs. Currently the nearest known nest and winter concentration sites are on the Columbia River bordering the Hanford Reservation. However, wintering bald eagles are commonly seen in the LSRP study area between November and March. The middle and upper Snake River are frequented due to large pockets of old growth coniferous forests. Communal winter roost sites consist of concentrations of eagles within one mile of a large marine or freshwater river or

water body (Anthony et al. 1982). Wintering bald eagles are primarily associated with open water near concentrated food sources. Eagles that overwinter in Washington are particularly dependent upon chum salmon (Oncorhynchus keta) in the fall and early winter, and reliant upon carrion and waterfowl in mid-late winter (WDFW 2016). The lack of mature cottonwood and black locust trees along the reservoir margins, likely limits the ability of bald eagles to successfully perch, nest and forage along the lower Snake River.

WATERBIRDS, SHOREBIRDS AND WATERFOWL

Waterbirds in the LSRP study area include gulls, Caspian terns (*Hydroprogne caspia*), double crested cormorants (*Phalacrocorax auritus*), great blue herons (*Ardea herodias*), black-crowned night herons (*Nycticorax nycticorax*), and white pelicans (*Pelecanus erythrorhynchos*). No known rookeries for any of these species occur on the lower Snake River, with the exception of several locations listed as "possible" breeding sites in the Breeding Bird Atlas of Washington State (Smith et al 1997).

Several waterbird species breed on the large islands at the mouth of the Snake River, near McNary Wildlife Refuge, but the lack of islands or mature forested wetland has prevented these species from breeding along the reservoirs in the LSRP study area. Between 1980 and 2000 the North American population of white pelicans has doubled; however, they are still considered state-listed endangered species in Washington State and habitat along the Columbia River provides the only known nesting sites of white pelicans in the State. White pelicans are occasionally seen in the shallow water areas of the study area, most often on the western edge near Ice Harbor Dam. American white pelicans are now becoming common on Lower Granite Lake up to City of Clarkston.

Common waterbirds seen at the Palouse River include ring-billed gull (*Larus delawarensis*), herring gull (*Larus argentatus*), double-crested cormornant, California gull (*Larus californicus*), caspian tern (*Hydroprogne caspia*), and Forster's tern (*Sterna forsteri*) (eBird, Lyon's Ferry Park). Waterbirds are often seen by visitors at the dams. Mew gull (*Larus canus*), ring-billed gull, glaucous winged gull (*Larus glaucescens*), double-crested cormorant, California gull and herring gull can be seen foraging at Lower Monumental Dam (eBird, 2017). American white pelicans, Caspian terns, double-crested cormorants, mew gull, brown pelican (*Pelecanus occidentalis*), Franklin's gull (*Leucophaeus pipixcan*), Sabine's gull (*Xema sabini*) and Iceland gull (*Larus glaucoides*) frequent Ice Harbor Dam. In 2017, Pacific loon (*Gavia pacifica*) and common loon (*Gavia immer*) were seen on the water surface swimming near the Franklin and Walla Walla county line (eBird, Ice Harbor Dam).

Shorebirds are relatively uncommon breeders along the lower Snake River most likely due to the small amount of sandbars and mudflats available (USFWS 1991, Smith et al. 1997). In 1998, killdeer (*Charadrius vociferus*), spotted sandpiper (*Actitis macularius*), and Wilson's snipe (*Gallinago delicata*) were recorded the area during the breeding season, lesser yellowlegs (*Tringa flavipes*) and greater yellowlegs (*Tringa melanoleuca*) in the fall, and killdeer and long-billed curlew (*Numenius americanus*) in the spring. Fifty-eight individual killdeer were counted

during the spring making them the most abundant shorebird species observed (Rocklage and Ratti 1998).

Since 2015, great blue heron, greater yellowlegs, long-billed dowitcher (*Limnodromus scolopaceus*), lesser yellowlegs, spotted sandpiper and black-necked stilt (*Himantopus mexicanus*) have been reported in Central Ferry, Washington on the banks of Deadman Creek (eBird, Central Ferry). Killdeer, great blue heron, least sandpiper, greater yellowlegs, and great egret (*Ardea alba*) have been spotted at the confluence of the Palouse River. Occasionally sandhill cranes can be seen flying over the lower Snake River (eBird, Lyon's Ferry Park).

Over 30 species of waterfowl have been documented to occur on the lower Snake River (Asherin and Claar, 1976, Lewke and Buss 1977, and Rocklage and Ratti 1998). Ice Harbor usually has the most waterfowl due to is protection as a waterfowl preserve. The most common species of waterfowl observed along the lower Snake River were Canada geese (*Branta canadensis*), mallards (*Anas platyrhynchos*), common goldeneye (*Bucephala clangula*), and American widgeon (*Anas americana*) and although impoundment of the river has not significantly changed waterfowl species composition it has affected the abundance and occurrence. An increase in the abundance of cereal grain fields in both HMUs along the river and in the adjacent uplands has provided a consistent source of food for waterfowl, particularly mallards and Canada geese.

Tributaries of the lower Snake are hotspots for waterfowl and shorebirds. Waterfowl commonly seen since 2016 in the Deadman Creek slough include pied-billed grebe (*Podilymbus podiceps*), western grebe (*Aechmophorus occidentalis*), common goldeneye, Clark's grebe (*Aechmophorus clarkii*), ring-necked duck (*Aythya collaris*), lesser scaup (*Aythya affinis*), American coot (*Fulica americana*), American wigeon (*Mareca americana*), northern pintails (*Anas acuta*), bufflehead (*Bucephala albeola*), wood ducks (*Aix sponsa*) and green-winged teal (*Anas crecca*) (eBird, Central Ferry). Waterfowl commonly seen near the Palouse River include: Canada goose, mallard, common merganser, pied-billed grebe, American coot, American widgeon, hooded merganser, cackling goose (*Branta hutchinsii*), ring-necked duck, blue-winged (*Spatula discors*) and green-winged teal (eBird, Lyon's Ferry Park)

The Canada goose, a species once the focus of mitigation and repopulation in eastern Washington, is now common year-round along the Snake River (USACE 2018). The site of the Chief Timothy HMU was selected for the sufficient land adjacent to water sources and pasture for Canada geese. Trees and shrubs, meadows, pasture, fields, annual fuel plots, water guzzler complexes, and nest structures were incorporated into the habitat components for the species when populations were declining. Swallows Park in Clarkston, WA, is several miles upstream of the study area boundaries. Once a high density recreational swimming hole, Swallows Park has since been closed to the public due to poor water quality. Canada geese populations in the area caused coliform bacteria levels in the Snake River to exceed safe levels (USACE 2018). The bacteria dilutes downstream at the confluence with the Clearwater River and does not pose a hazard in the study area. The success of recolonizing Canada geese in Clarkston is spreading throughout the Snake River HMUs.

Total Canada goose nesting along the lower Snake River is currently about 200 nests per year. New York Island averaged 70 to 80 nests, with declining numbers in recent years. In the early 2000s, New York Island produced an average of 64 successful nests each year. Other smaller islands along the Snake River produce an average of 0.3 - 2.4 nests annually (USACE 2002). Cliff nesting appears to be an increasing trend in response to the loss of predator-free island nesting sites. Artificial nest structures along most of the HMUs have regular annual use. USACE maintains 75 goose nesting tubs located in various shallow water areas in association with HMU's. Goose tubs (large nest boxes elevated above river level on poles) have produced 45 nests on the lower Snake River. An abundance of natural and artificially managed Canada geese brooding pastures are present along the lower Snake River. Current dam operations provides greater emergent wetland habitat and ideal foraging resources (USACE 2002).

Very little mallard nesting has been observed along the lower Snake River most likely due to very limited occurrence of suitable dense nesting cover. What little mallard brooding that may occur is associated with the shallow backwaters and embayments. Significant numbers of mallards, winter on the reservoirs.

PASSERINES

The variety of habitats in the LSRP study area, including natural and managed lands, support a diversity of passerines, the perching birds. Forested, scrub-shrub and emergent herbaceous wetlands on the lower Snake River offer critical stop-over habitat for migrating birds. In the semi-arid Columbia Plateau Ecoregion these wetland habitats are crucial during fall migration.

In 1997-1998 an avian survey was conducted investigating species diversity on 25 sites from Ice Harbor Dam upriver to the confluence of the Snake and Clearwater Rivers. Ninety-two species were detected during the breeding season on the lower Snake River. The most frequently detected species were passerines including the bank swallow (*Riparia riparia*), cliff swallow (*Hirundo pyrrhonota*), red-winged blackbird (*Agelaius phoeniceus*), western meadowlark (*Sturnella neglecta*), and Bullock's oriole (*Icterus bullockii*). In addition, the red-winged blackbird, Bullock's oriole, American goldfinch (*Carduelis tristis*), brown-headed cowbird (*Molothrus ater*), and American robin (*Turdus migratorius*) had the highest densities per area surveyed. The following species were also detected frequently: white-crowned sparrow (*Zonotrichia leucophrys*) and European starling (*Sturnus vulgaris*) (Rocklage and Ratti 2000). Since the survey has been conducted, habitat quality likely remains similar or improved with HMU management. Species present in the study area appear to remain similar.

At RM 30 in the Ice Harbor pool at Walker HMU the following passerines were observed since 2015: western wood-pewee (*Contopus sordidulus*), Say's phoebe (*Sayornis saya*), warbling vireo (*Vireo gilvus*), house wren (*Troglodytes aedon*), Bewick's wren (*Thryomanes bewickii*), golden-crowned kinglet (*Regulus satrapa*), ruby-crowned kinglet (*Regulus calendula*), cedar waxwing (*Bombycilla cedrorum*), American goldfinch, lark sparrow (*Chondestes grammacus*), white-crowned sparrow (*Zonotrichia leucophrys*), song sparrow (*Melospiza melodia*), Lincoln's sparrow (*Melospiza lincolnii*), spotted towhee (*Pipilo maculatus*), orange-crowned warbler

(*Oreothlypis celata*), Nashville warbler (*Oreothlypis ruficapilla*), yellow-rumped warbler (*Setophaga coronata*), and Wilson's warbler (*Cardellina pusilla*) (eBird 2015).

Lyon's Ferry State Park at the confluence of the Palouse River with the Snake River hosts a variety of bird species. In 2018 the following birds were identified at the Palouse River: western wood-pewee, barn swallow, American robin, lesser goldfinch (*Spinus psaltria*), cliff swallow, house finch (*Haemorhous mexicanus*), American goldfinch, red-winged blackbird, brown-headed cowbird, yellow warbler (*Setophaga petechia*), violet-green swallow (*Tachycineta thalassina*), downy woodpecker (*Picoides pubescens*), western kingbird (*Tyrannus verticalis*), common raven (*Corvus corax*), and European starling (*Sturnus vulgaris*). Less frequently seen visitors include yellow-breasted chat (*Icteria virens*), lazuli bunting (*Passerina amoena*), northern rough-winged swallow (*Stelgidopteryx serripennis*), dusky flycatcher (*Empidonax oberholseri*), gray catbird (*Dumetella carolinensis*) and western tanager (*Piranga ludoviciana*) (eBird 2018).

Significant colonies of cliff and bank swallows occur at a number of locations along the river. Bank swallows are usually present wherever there are exposed cutbanks suitable for nesting that are consistently above water level. Cliff swallows nest both on steep rock faces and in the dam structures themselves. Nesting cavities associated with snags and decaying riparian hardwoods are extremely limited along the lower Snake River. Browse of young saplings by deer and elk, and habitat use by beaver can greatly reduce the reestablishment rate of wetland and riparian tree species, such as cottonwood.

Horned larks (*Eremophila alpestris*) and western meadowlarks are the most abundant breeding birds in the sagebrush/bunchgrass habitat. Loggerhead shrikes (*Lanius ludovicianus*), sage thrashers (Oreoscoptes montanus), and sage sparrows (Artemisiospiza nevadensis) are sagebrush obligates and are found in the upland habitat in the LSRP study area. Avian diversity is higher in the forested and scrub-shrub wetland habitats. Red-winged and yellow headed blackbirds are most commonly found chirping in the emergent vegetative communities of the Palouse River. Red-winged blackbirds can be found occupying almost all wetland areas supporting cattail throughout the reach. Other riparian species include kinglets (*Regulus* sp.), warbling vireos, yellow-rumped warblers, and Wilson's warblers. Wintering species in wetland habitats include dark-eyed junco (*Junco hyemalis*), white-crowned sparrow, American robin and Townsend's solitaire (*Myadestes townsendi*) (USFWS 2013).

Loggerhead shrike is a summer resident of eastern Washington. The species is a candidate for state listing. Loggerhead shrikes breed in open country, primarily shrub-steppe and grasslands where there are scattered tall shrubs, fence posts, utility wire, or lookout posts. Shrikes generally nest in dense, thorny trees or shrubs. Loggerhead shrikes avoid riparian zones or within 500 meters of water, possibly to avoid nest predation by magpies (*Pica hudsonia*) and ravens. Common prey includes lizards, small mammals, small birds and insects which are impaled on thorns or fences and retrieved for later consumption (WDFW 2015).

The sage thrasher is a sagebrush obligate and mostly builds nest in big sagebrush or three-tip sagebrush shrub-steppe communities. A short-distance migrant, sage thrashers arrive in

eastern Washington by late March. A candidate for Washington state listing, the sage thrasher is currently a species of concern due to cheatgrass invasion and intensive livestock grazing in the Columbia Plateau ecoregion (WDFW 2015). Sagebrush sparrows prefer sagebrush/bunchgrass shrub-steppe landscapes of the Columbia Basin and is a summer resident in eastern Washington. Sagebrush sparrows forage on the ground for insects, spiders, small fruits and seeds.

GALLINACEOUS BIRDS

Commonly occurring gallinaceous birds in the LSRP study area include ring-necked pheasant, California quail, and chukar. Mourning doves are native to the lower Snake River and reside in upland habitats. Wild turkeys can be seen in the mornings near the Palouse River (eBird 2018). Chukars use a wide variety of habitats including riversides, shrublands, talus areas and uplands. Douglas hackberry, smooth sumac (*Rhus glabra*), and poison ivy (*Toxicodendron radicans*) stands along the Snake River provide cover and access to the biggest limiting factor in the ecoregion, water. Foraging habitats include cheatgrass invaded grasslands and agricultural fields.

Ring-necked pheasants and quail often habituate the irrigated HMUs, like Swift Bar at RM 97. HMU management includes the planting of food plots of sunflower, grains, and corn which attracts gallinaceous birds. The HMU also has a permanent water sources or guzzlers which can sustain populations over the average carrying capacity of the study area. Pheasants also depend on permanent shrub and tall herbaceous cover grown in the regularly irrigated land. There are 960 acres of food plots, meadows, and woody vegetation plots under irrigation in the 10 intensively managed HMUs in the LSRP study area (USACE 2002). Ring-necked pheasant, quail and chukar populations are maintained for hunting in the HMUs.

Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbiansu*) is listed as a threatened species in Washington State and a federal species of concern. Columbian sharp-tailed grouse habitat consists of a mix of perennial bunchgrasses, forbs, and a few shrubs. Shortages of nesting, brood rearing, and wintering habitats are important limiting factors to Columbian sharp-tailed grouse population recovery. Columbian sharp-tailed grouse use riparian areas with deciduous trees and shrubs for cover and food (berries, seeds, buds, and catkins) in the winter when snow covers the ground. The most important riparian trees and shrubs for Columbian sharp-tailed grouse include water birch (*Betula nigra*), serviceberry (*Amelanchier* sp.), chokecherry, rose (*Rosa* sp.), black hawthorn, snowberry (*Symphoricarpos albus*), cottonwood, and aspen (*Populus tremuloides*).

2.7.3.2 Mammals

TERRESTRIAL

Whitetail (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*), mountain lion (*Puma concolor*), Rocky mountain elk (*Cervus canadensis*), striped skunk (*Mephitis mephitis*), black-tailed jackrabbit (*Lepus californicus*), coyotes (Canis latrans), ground squirrels, and porcupines

(*Erethizon dorsatum*) are commonly found in the LSRP study area (USACE 2018). Mammals occupying upland habitat near the lower Snake River occasionally include bobcat (*Lynx rufus*), red fox (*Vulpes vulpes*), and mink. Irrigated HMUs in the LSRP study area are hotspots for terrestrial mammals, especially whitetail and mule deer which are attracted to dense patches of shrubs and planted food plots (USACE 2002).

American badgers (Taxidea taxus) distribution includes portions of eastern Washington from the eastern Cascade foothills to the Idaho border. Badgers are found in grassland, shrub-steppe and a variety of human-impacted land cover types like parkland and agriculture. Coyotes, bears and mountain lions prey upon the badgers (WDFW 2015). Their population size and status in Washington is unknown but there is suitable habitat for the fossorial mammal in the LSRP study area. There are several 'Rocky Mountain' bighorn sheep populations in south-eastern Washington but pneumonia outbreaks continue to cause low lamb recruitment and mortality. Bighorn sheep can occur is xeric shrub-steppe and desert grassland habitats. Habitat must include escape terrain such as cliffs and talus slopes (WDFW 2015. While bighorn sheep primarily are found in upland habitats, they may use tributaries of the Snake River during summertime droughts.

White-tailed Jackrabbit (*Lepus townsendii*) and black-tailed jackrabbit have both declined in the project area due to habitat loss, degradation, fragmentation, competition, and overhunting. White-tailed jackrabbits occur in areas of bunchgrass habitats with sparse shrub cover while black-tailed jackrabbits occur primarily in sagebrush habitats (WDFW 2015). Jackrabbits are considered an ecologically important species because of their role as prey for a wide variety of raptors and mammalian predators.

Eleven small mammal species have been observed in the project area: deer mouse (*Peromyscus maniculatus*), western harvest mouse (*Reithrodontomys megalotis*), Great Basin pocket mouse (*Perognathus parvus*), house mouse (*Mus musculus*), long-tailed vole (*Microtus longicaudus*), montane vole (*Microtus montanus*), northern pocket gopher (*Thomomys talpoides*), vagrant shrew (*Sorex vagrans*), Merriam's shrew (*Sorex merriami*), bushy-tailed woodrat (*Neotoma cinerea*), and Ord's kangaroot rat (*Dipodomys ordii*) (USACE 2002). Evidence suggests small mammals prefer native riparian habitat to other habitat. Asherin and Claar (1976) found the highest small mammal species diversity in the native cattail and shrub willow habitat types. Deer mice made up 74 percent of total captures in a study conducted by Rocklage and Ratti (1998). Townsends' ground squirrel (*Urocitellus townsendii*) and Washington ground squirrel (*Spermophilus washingtoni*) are candidates for state listing and occur in south-central to southeastern Washington. They inhabit native shrub-steppe, grasslands, and large sagebrush patches at forest edges. Ground squirrels are a burrowing species that may occur in small to large colonies. American badgers, raptors and snakes are their primary predators (WDFW 2015).

Deer populations are surveyed extensively in the LSRP study area because they are managed for hunting in Washington, especially in the HMUs. Mule and whitetail deer are the two most commonly hunted species occupying lands in the lower Snake River. Irrigated HMUs near Ice

Harbor and Lower Monumental Dam provide dense shrub cover used for fawning habitat. Planted food plots of cereal grains may be used for foraging. New York Island in Lake Bryan may also provide suitable fawning habitat in years with high precipitation (USACE 2002). Mule deer and white-tailed deer populations in eastern Washington are stable to increasing, at their carrying capacity. Mule deer populations are closely tied to severe winter events and drought. Both species are influenced by the liberal harvest of alfalfa and cereal grains, such as oats, wheat, and barley, which provide forage during lean times. Both species in the study area are susceptible to chronic wasting disease (CWD), epizootic hermorrhagic disease (EHD), and hair loss syndrome (WDFW 2015).

Deer use a wide variety of habitats in the project area, including vegetated draws and pockets of wetland vegetation for cover and fawning, and grasslands for foraging. Greater precipitation near the Lower Granite and Little Goose Dams provides a higher variety of habitats than the drier lands surrounding Lower Monumental and Ice Harbor (USACE 1990). Whitetail deer are most strongly associated with the dense shrub and tree cover provided around Lower Granite reservoir. Aerial winter deer counts conducted by the USACE and WDFW between 1978 and 1988 along the four reservoirs found an average of 3,547 deer per year. Mule deer made up approximately 80 percent of the surveyed population. HMUs are thought to have aided in the deer population recovery by providing browse and excluding livestock from much of the USACE managed lands (USACE 1990).

Documented species of bat in the project area include the Yuma myotis (*Myotis yumanensis*), long-legged myotis (*Myotis volans*), long-eared myotis (*Myotis evotis*), small-footed myotis (*Myotis leibii*), fringed myotis, canyon bat (*Parastrellus hesperus*), and Townsend's big-eared bat (USACE 2002). Townsends's big-eared bat is a Washington state candidate species of concern (WDFW 2017). Other bat species thought to occur based on habitat suitability, their range, and their occurrence in the vicinity include the hoary bat (*Lasiurus cinereus*), little brown bat (*Myotis lucifugus*), pallid bat, California bat (*Macrotus californicus*), and big brown bat (*Eptesicus fuscus*) (USACE 2002).

The majority of bat species can use a variety of roosting sites, including caves, mines, trees, buildings, bridges, dams, and rock crevice. Some bat species may roost two miles from the Snake River. The bat species will forage in a wide variety of habitats including arid grassland, scrub-shrub, ponderosa pine and white oak forests, and rocky areas. Many of the bat species forage on stream insects such as midges, caddisflies, and mayflies.

Townsend's big-eared bat is thought to be dependent on caves or mines for both winter and summer roosting. Townsend's big-eared bats prey primarily on moths and seems to require still lakes, ponds, or pools to obtain water, as it flies low and laps water with its tongue. The canyon bat, is closely associated with steep canyon walls and rock crevices in the project area and utilizes these habitats for roosting (Johnson and Cassidy 1997). Yuma myotis are closely associated with water and tends to forage close to the surface of the water (USACE 2002).

White-nose syndrome (*Pseudogymnoascus destructans*) is a fungus that infects bats in winter during hibernation. The fungus disrupts their thermoregulation, causing frequent interruptions

during hibernation. Frequent awakening burns critical stored fat reserves, and when food is seasonally unavailable the bats starve. Mortality rate for some species has been recorded at 90-100% of populations. White-nose syndrome has been documented in Washington affecting Yumo myotis and little brown bat, and may be affecting bats in the LSRP study area (WISC 2004).

AQUATIC

Aquatic mammal abundance has been reported low along the lower Snake River due to the lack of forested wetlands (USACE 2002). Beaver, river otter, and muskrat are the most commonly seen in the study area. McNary Wildlife Refuge and Brownlee Reservoir support a diversity of aquatic mammal populations due to large tracts of intact wetland habitat (USACE 2002). The two major tributaries of the lower Snake River, the Palouse and Tucannon Rivers, have small groves of black cottonwood, with willows, alders, and dogwoods with dense emergent herbaceous cover. These tributaries are likely the only in the study area to support aquatic mammal survival. Several large vegetated embayments along the river may also provide habitat.

Beaver are dependent on woody riparian growth as a food source. Beaver lodges are rare along the lower Snake River with most denning occurring in banks and in association with at least sapling size trees. Otter denning requirements are not as stringent as the beaver's. Otter use dens previously excavated by other species in close proximity to water. Otters depend are mostly dependent on relatively dense bank cover that can be supplied by vegetation, woody debris, and/or rocks. Heavy riparian vegetation cover provides the best environment for both the cover and feeding.

2.7.3.3 Reptiles and Amphibians

At least sixteen species of amphibians and reptiles have been documented along the Snake River. Five amphibian and eight reptile species during surveys in the study area during a two-year study (Loper and Lohman 1998). Pacific tree frog, bullfrog, western yellow-bellied racer, Great Basin spadefoot (*Spea intermontana*), long-toed salamander, Great Basin gopher snake, night snake (*Hypsiglena torquata*), and painted turtle (*Chrysemys picta*) were the most frequently occurring species (USACE 2002).

Additional species that may occur within the LSRP study area include: tiger salamander (*Ambystoma tigrinum*), northern leopard frog (*Lithobates pipiens*), Woodhouse's toad (*Anaxyrus woodhousii*), short-horned lizard (*Phrynosoma hernandesi*), sagebrush lizard (*Sceloporus graciosus*), rubber boa, and ring-necked snake (USACE 2002). Overall reptile occurrence throughout the project site is limited, although some snake species are dependent on a well-developed riparian zones for availability of prey, cover, and over-wintering.

Both amphibian and reptile species abundance and richness are relatively low at both riparian and uplands sites; however, vegetation types most closely associated with water had the greatest abundance of amphibians. The relative young age of the recovering riparian fringe

beside the reservoirs, the isolation of suitable riparian habitat along the river, and fluctuating water levels may prevent the consistent occurrence of litter, debris, pools, and vegetation that these species could use for breeding, resting, and forage (USACE 2002).

Most amphibians are closely associated with permanent ponds without fish, usually within forested wetland vegetation adjacent to rivers. Tree frog and Columbia spotted frog occur in association with submerged aquatic vegetation of seasonal emergent wetlands and ponds. The Northern leopard frog, a Washington State endangered listed species, requires permanent deep water for overwintering, in proximity to seasonal ponds and wetlands for breeding (WDFW 2017). Northern Leopard frogs are negatively associated with the presence of bullfrogs, carp (*Cyprinus carpio*), and other non-native predatory fish. Large expansion of cattails, bulrush, common reed, reed canarygrass, and purple loosestrife can render breeding habitats unsuitable.

2.7.3.4 Invertebrates

Several species of mollusks have been identified inhabiting the lower Snake River, of which only six are native (Frest and Johannes 1992). The most abundant species observed were the introduced Asian clam (*Corbicula fluminea*) and native Rocky Mountain ridged mussel (*Gonidea angulata*). The California floater (*Anodonta californiensis*), western floater (*Anodonta kennerlyi*), shortface lanx (*Fisherola nuttallii*), and the Columbia pebble snail (*Fluminicola Columbiana*) have been identified by the U.S. Fish and Wildlife Service (USFWS) as species of concern.

Benthic production is usually minimal in shallow-water areas if the water levels fluctuate and expose the organisms. The 1992 Drawdown Test found the presence of freshwater clams and crayfish (*Pacifasticus leniusculus*) were the most noticeable aquatic organisms, other than fish, impacted by the drawdown (USACE 1992). Freshwater clams were found in a variety of substrates including mud and mixed cobble/gravel areas. Densities were observed as much as 36 clams/100 feet of beach. Clam tracks indicated that the clams were moving downslope to the water in response to lowered water. Their ability to move toward the water is dependent on substrate, texture, bank slope, and drawdown rate.

The Northern crayfish (*Orconectes virilis*) is a non-native crustacean that can alter open water habitats, and even impact fish populations. Densities of crayfish in the lower Snake reservoirs have not been quantified, except for limited evaluations in Lower Granite reservoir. Bennett et al. (1983) found the highest densities of crayfish at upstream sites in Lower Granite main channel. Crayfish tend to congregate near the shaded, vegetated shoreline with ample rock crevices for evading predators. Crayfish are an important component to the diet of smallmouth bass (*Micropterus dolomieu*), northern pikeminnow (*Ptychocheilus oregonensis*), and channel catfish (*Ictalurus punctatus*) in the Lower Granite and Little Goose reservoirs (USACE 2002).

Additional non-native species that are outcompeting native invertebrates and negatively impacting the quality of open water habitat include New Zealand mud snails (*Potamopyrgus antipodarum*) and copeods (*Oithona davisae* and *Pseudodiaptomus forbesi*) . Mud snails

dominante river and lakebed habitat by outcompeting native snails and insects and were found in the lower Columbia River in 2002. Invasive copepods have been found in the Columbia River, and likely have invaded the Snake. Both known species replace native copepod species, and potentially can alter entire food webs in the study area. Zebra (*Dreissena polymorpha*) and quagga mussels (*Dreissena rostriformis*) have not yet been reported in Washington (WISC 2009).

2.8 MCNARY DAM AND LAKE WALLULA

2.8.1 Study Area

The study area used to describe the existing conditions and assess the range of potential impacts for wildlife and habitat features includes the entire Lake Wallula, which begins just below the U.S. Department of Energy's Hanford Site at Priest Lake Rapids Dam on the Columbia River and extends 64 miles downstream to McNary Dam (see Figure 2-8). The lake also extends 10 miles up the Snake River to Ice Harbor Lock and Dam. The lake also includes a small portion of the Yakima River. Lake Wallula has a water surface area of 38,800 acres with more than 200 miles of shoreline (USACE 2012). The north side of the dam is in Benton County, WA and the south side is in Umatilla County, OR. Surrounding the lake are 16,908 acres of project (Federal) lands that are used for recreational, wildlife habitat, wildlife mitigation, and water-connected industrial development. In 2005, about 2,400 acres were licensed to either State or local park agencies, and the U.S. Fish and Widllie Service leases about 3,500 acres as part of the McNary National Wildlife Refuge. Port districts own about 1,500 acres for industrial development.

McNary Dam and Lake Wallula are located in the Columbia Plateau Ecoregion. See Section 1.2.2 for a description of characteristic features of this ecoregion. Lake Wallula is located in the Tri-Cities (Kennewick, Pasco, and Richland) area at the confluence of the Yakima, Snake, and Columbia Rivers in the Columbia aisn of Eastern Washington. Lands adjacent to the lake vary from heavily urbanized in the middle portions, to towering vertical basalt cliffs at the downstream end, and long gently sloping shelves in the upper reaches (USACE 2012).

McNary National Wildlife Refuge covers over 15,000 acres along the west bank of Lake Wallula from the confluence of the Snake River to the mouth of the Walla Walla River, and downstream into Oregon. The refuge includes sloughs, ponds, streams, an islands, forested and herbaceous wetlands, and upland shrub-steppe and cliff-tallus habitats. It serves as an anchor for biodiversity in the mid-Columbia Basin (USFWS 2018). McNary NWR is managed as part of the Mid-Columbial River National Wildlife Regute Complex. Table 1-1 identifies the land cover, vegetation, and habitat of the study area. Land cover and vegetation on federal lands immediately adjacent to Lake Wallula are described in the McNary Shoreline Management Plan (USACE 2012).

Figure 2-8. McNary Dam and Lake Wallula Study Area.

2.8.2 Land Cover

Table 1-2 above shows the acres of the different habitat types within the McNary Dam study area.

2.8.2.1 Uplands

There are approximately 50,000 acres of uplands within the study area. Shrub-steppe communities dominate the uplands surrounding the McNary project. Gray rabbitbrush and green rabbitbrush (*Chrysothamnus viscidiflorus*) are the dominate species. Some big sagebrush species are present. Limited associations of sagebrush and bitterbrush are present, usually on flat benches. Introduced Cheatgrass (*Bromus tectorum*) has replaced most of the native bunch grasses.

Introduced plants are common in disturbed areas and in areas historically dominated by native grasses. Other common introduced plants include blackgrass, squirreltail, reed canarygrass,

mustard, dock, and pigweed. The introduced invasive Russian olive (*Elaeagnus angustifolia*) has colonized the Yakima River delta.

2.8.2.2 Barren Zone (Drawdown Zone)

Much of the lower half of Lake Wallula is bordered by steep topography and riprap protecting a road on the east side and railroad on the west side. The shorelines bordering the upper half of the reservoir are relatively flat, especially on the east side between the mouths of the Snake and Walla Walla Rivers. This provides for the creation of extensive mudflats when the pool is operated at or near its minimum. Erosion and landslide potential is minimal throughout the reservoir.

2.8.2.3 Wetlands – Forested and Scrub-Shrub

Forested and scrub-shrub wetlands are found along the Lake Wallula shoreline, backwaters, sloughs and tributaries. Approximately 4,000 acres of Forested and Scrub-Shrub wetlands are found within the McNary study area. Most wetlands occur just below the mouth of the Snake River, in Burbank Slough. Typical wetland taxa include black cottonwoods and willows. The most extensive stand of cottonwood in the project area is located at the mouth of the Walla Walla River. Other common tree species include white alder, red alder, hackberry, and black locust. This vegetation provides critical cover and food for most of the wildlife species found in the study area.

Scrub-shrub wetlands are usually found adjacent to the high water line along protected backwater areas and is dominated by willow species and western false indigo. Moister shrub-scrub communities are dominated by black hawthorn, chokecherry, golden currant (*Ribes aureum*), and red-osier dogwood (*Cornus sericea*). Wood's rose (*Rosa woodsii*) can dominate drier areas.

2.8.2.4 Wetlands – Emergent Herbaceous

Approximately 1,600 acres of emergent wetlands within the McNary study area. Most wetlands occur just below the mouth of the Snake River and Burbank Slough Slough and is found mostly on sandbars, mudflats, and subirrigated areas adjacent to the reservoir. Typical wetland taxa for the region include cattail, bulrush, and sedges. Representative grasses include blackgrass (*Alopecurus myosuroides*), squirreltail (*Elymus elymoides*), and reed canarygrass (*Phalaris arundinacea*). Forbs include mustards, docks, pigweeds, composites, and thistles.

2.8.2.5 Water

In the study area, the most extensive aquatic vegetation beds likely occur in ponds. Common aquatic plants are flowering rush (*Butomus umbellatus*) and Eurasian milfoil (*Myriophyllum spicatum*).

2.8.2.6 Islands

Thirteen named islands are located within Lake Wallula: Badger Island, Casey Island, Clover Island, Crescent Island, Foundation Island, Indian Island, Peavin Island, Strawberry Island, Tanglefoot Island, Two Rivers Islands, Van Skinner Island, Island 19 (Richland Island), and Island 20 (Fencepost Island). Badger Island and Crescent Island, located upstream of McNary Dam near the town of Wallula, are owned and managed by the U.S. Fish and Wildlife Service as part of McNary National Wildlife Refuge. Crescent Island is an artificial island created from dredged materials in 1985 as mitigation for waterfowl nesting habitat lost during construction of the Wallula pulp mill. Today Crescent Island consists of 7.5 acres with a mix of dense upland shrub habitat and bare ground.

Foundation Island also located upstream of McNary Dam near the Town of Burbank, WA is the site of the largest double-crested cormorant colony on the mid-Columbia River. The earliest nesting record on Foundation Island was in 1998 when 100 breeding pairs were counted in the trees at the southern end of the island. By 2004 there were 300 breeding pairs, which grew to 360 pairs in 2006, and then declined to 310 pairs in 2010 (Adkins et al. 2014). All the cormorants in this colony nest in trees along with black-crowned night-herons and great blue herons.

Island 20 (also called Fencepost Island) is on the Columbia River upstream of McNary Dam near the city of Richland is owned and managed by the USACE. Island 20 is colonized by well over 15,000 breeding pairs of California gulls (*Larus californicus*). Once Island 19 had supported a very large mixed colony of ring-billed gulls (*Larus delawarensis*) and California gulls consisting of over 10,000 breeding pairs in the 1990's, but gulls no longer next on this island. On the Columbia Plateau gull declines are associated with declines in suitable colony sites free from human disturbance and predators (Adkins et al. 2014).

2.8.3 Wildlife

2.8.3.1 Birds

RAPTORS

A few bald eagles winter along Lake Wallula feeding primarily on waterfowl and to a lesser extent upland avian species, salmonid carcasses, and other wildlife.

Burrowing owls are a candidate species of concern in the State of Washington. Burrowing owls inhabit open grassland and shrub-steppe habitats in eastern Washington. There are breeding records from most of the non-forested low elevation areas of eastern Washington, but historical information suggests that their range in Washington has undergone a significant contraction in recent decades. Burrowing owls have become uncommon to rare outside of Benton, Franklin, Grant, and western Adams counties.

WATERBIRDS, SHOREBIRDS AND WATERFOWL

Approximately 20 breeding pairs of white pelicans began nesting on nearby Badger Island, which is part of the McNary National Wildlife Refuge, in 1997. By 2016, over 1,600 breeding pairs were documented on this island. This accounts for almost 9 percent of the population of these birds in the western United States (Stinson 2016). An average of 3,118 individuals were counted from aerial photos in May of 2016. Badger Island is currently the only known location of American White pelicans in the State of Washington. Badger Island is closed to both the public and researchers in order to avoid human disturbance to nesting birds that might cause abandonment of the colony. Pelicans nest on the ground in at least three distinct areas of the island: the upstream tip, halfway down the island on the eastern shore, and the interior of the island. Much of the pelican colony is concealed from view from the water and from the air by dense shrub vegetation so the size of the colony is estimated by counts of adults from aerial photos taken of the island. In 1994, a breeding colony established on Crescent Island, which is also part of the McNary NWR. The pelicans stopped nesting there in 1998. In 2010 about 50 pelicans attempted to nest on Crescent Island but all nests failed (Adkins et al. 2014).

A substantial great blue heron rookery is located on Foundation Island. This rookery also contains black-crowned night herons. Great blue herons are commonly observed foraging along shallow shorelines, backwaters, and embayments. Doublecrested cormorants are also present.

Caspian terns have nested on Crescent Island. Adkins, et al. (2014) reported that from 2004 to 2010, the number of breeding paris has varied, ranging from a high of 530 breeding pairs in 2004 to a low of 349 pairs in 2009.

Shorebirds found along the shores of Lake Wallula include the American coot (*Fulica americana*), black- bellied plover (*Pluvialis squatarola*), lesser golden plover (*Pluvialis dominica*), snowy plover (*Charadrius nivosus*), semipalmated plover (*Charadrius semipalmatus*), western sandpiper (*Calidris mauri*), spotted sandpiper, least sandpiper (*Calidris minutilla*), Baird's sandpiper (*Calidris bairdii*), stilt sandpiper (*Calidris himantopus*), pectoral sandpiper (*Calidris melanotos*), killdeer, black-necked stilt (*Himantopus mexicanus*), American avocet, greater and lesser yellowlegs, whimbrel (*Numenius phaeopus*), long-billed curlew (*Numenius americanus*), marbled godwit, sanderling (*Calidris alba*), dunlin (Calidris alpine), short-billed dowitcher (Limnodromus griseus), long-billed dowithcer (*Limnodromus scolopaceus*), common snipe, Wilson's phalarope (Phalaropus tricolor), red-necked phalarope (*Phalaropus lobatus*), and Virginia rail (*Rallus limicola*).

Lake Wallula supports a large population of nesting Canada geese. Number of wintering Canada geese on McNary NWR have been known to peak at about 50,000 with as many as 20,000 additional geese utilizing other areas of the reservoir. Wintering geese use the abundant corn and wheat fields provided on the refuge and surrounding agricultural lands. Most goose nesting occurs on seven islands with a combined average of 130 successful nests. The highest number of successful goose nests (around 73) occur on Badger Island. Some ground nesting has also been observed within the NWR but nests are very susceptible to both avian and ground predators. The U.S. Fish and Wildlife Service erected 30 nesting baskets on the Strawberry

Islands and 19 nesting platforms in McNary NWR to help eliminate predation. The baskets receive about 20 percent use. Adequate habitat for brooding pastures is thought to exist along naturally occurring habitat along Lake Wallula.

In addition to Canada geese, common waterfowl along Lake Wallula include the mallard, gadwall, northern shoveler (*Anas clypeata*), cinnamon teal (*Anas cyanoptera*), blue-winged teal (*Anas discors*), green-wing teal, redhead (*Aythya americana*), canvasback (Aythya valisineria), lesser scaup (*Aythya affinis*), ruddy duck (*Oxyura jamaicensis*), ring-necked duck (*Aythya collaris*), bufflehead (*Bucephala albeola*), and common goldeneye (*Bucephala clangula*), wood duck, pied-billed grebe (*Podilymbus podiceps*), red-necked grebe (*Podiceps grisegena*), and western grebe (*Aechmophorus occidentalis*). Nine boxes have been added to goose structures for mallard use as well as 12 plastic nesting tubs. Some additional duck nesting likely occurs on the more heavily vegetated islands within the reservoir. Very limited brooding may also occur associated with the islands or along shallow backwaters along the reservoir. An attractive brooding area consisting of a complex of backwater ponds and wetlands occurs immediately below the mouth of the Snake River.

PASSERINES

All red-winged blackbird nesting and most of the feeding occurs within wetlands dominated by cattails. Small pockets of cattail occur throughout backwaters along the reservoir.

Yellow Warblers exclusively occupy scrub-shrub habitat provided by willow growth. Many pockets of this habitat type occur along backwaters, embayments, and tributary deltas.

Mature cottonwoods are present near the mouth of the Walla Walla River and pockets along the shoreline make suitable downy woodpecker nesting habitat. Cottonwood regeneration around Lake Wallula is a concern because it normally requires a hydrologic regime characterized by periodic flooding. A stretch of forested riparian areas dominated by Russian olive along the western shoreline up to the mouth of the Yakima River also makes suitable woodpecker nesting habitat.

GALLINACEOUS BIRDS

No native gallinaceous birds noted. Introduced species found in this study area include ring-neck pheasant.

2.8.3.2 Mammals

TERRESTRIAL

The federally listed gray wolf (*Canis lupus*) is known to exist around Lake Wallula. As of December 2016, there were six established wolf packs and one estimated wolf use area totaling around 45 individual wolfs in lands surrounding the project. One of the six wolf packs was newly discovered in 2016, the other five all showed growth since first being discovered

between 2009 and 2014. Four of the six wolf packs had breeding pairs; a breeding pair is a male and a female that have produced at least two pups surviving to Dec 31 (ODFW 2018).

Gray wolves have two main life requisite requirements; 1) an abundance of prey species and 2) isolation from human disturbance. Wolves will take a variety of prey species, but the bulk of their prey is composed of ungulates, mainly deer, elk, and moose (USFWS 1987). Gray wolves are sensitive to human disturbance, particularly near their denning and rendezvous sites. Factors such as road density have been shown to be important indices of levels of disturbance that wolves can tolerate (Mladenoff et al. 1995).

Mule deer are present throughout the project area. Fawning is associated with heavy cover available in palustrine and riverine forested and scrub-shrub wetlands. Islands are used to some extent. Mule deer are only partially dependent on lands near Lake Wallula for food, with increased dependence during winter for sources of browse.

Raccoon foraging and denning requirements are largely dependent on prey found in forest and scrub-shrub wetlands and adjacent shallow water areas.

AQUATIC

Beaver and river otters are present in the studay area. Beaver are found in association with the forested and scrub-shrub wetlands, especially where there is a high proportion of young trees and suitable banks for denning. River otters use dens excavated by other species or riprap where they are located close to water are of suitable size. River otters depend on prey found in shallow waters and are also dependent on relatively dense bank cover of plants, woody debris, and large rocks.

2.8.3.3 Reptiles and Amphibians

Amphibian occurrence in habitats along the reservoir is very low. Vegetated areas along the reservoir are used to some extent by garter and gopher snakes. These areas provide sources of prey, cover, and over-wintering habitat.

2.8.3.4 Invertebrates

Invertebrates found in the study are are those common to the overall CRSO study area.

2.9 JOHN DAY DAM AND LAKE UMATILLA

2.9.1 Study Area

The study area used to describe the existing conditions and assess the range of potential impacts for wildlife and habitat features includes lands associated with John Day, Lake Umatilla, and the mouths of its primary tributaries: Umatilla River, Willow Creek, and John Day River (Figure 2-9). The study area is entirely contained within the Columbia Plateau ecoregion, characterized as a nearly level Pleistocene lake plain that was created by flood waters from

glacial Lake Missoula. Similar to the mid-Columbia River reaches, the river reach between McNary and John Day are the driest and warmest portions of the Columbia River Basin consisting of sagebrush steppe and grasslands. Winds can exceed 20 miles per hour and temperatures can exceed 100° at the height of the summer in the Columbia River Gorge. The John Day and Lake Umatilla reach typically receives less than 12 inches of annual precipitation, the vast majority of which falls between October and February (NPCC 2005).

Between McNary and John Day, the Yakama Indian Nation has Trust lands along the Washington shore and the Confederated Tribes of the Warm Springs have Trust lands along the Oregon shore. In addition to mixed agricultural lands, the Umatilla Ordinance Depot and Boardman Bombing Range are located approximately 3 to 4 four miles from the Oregon shoreline of the Columbia River in this reach. The USFWS Umatilla National Wildlife Refuge (Umatilla NWR) and the Oregon Department of Fish and Wildlife (ODFW) Irrigon Wildlife Area provides significant wildlife habitat along both shorelines of Lake Umatilla, where the refuge is comprised of a multitude of different habitat types supporting a wide diversity of wildlife.

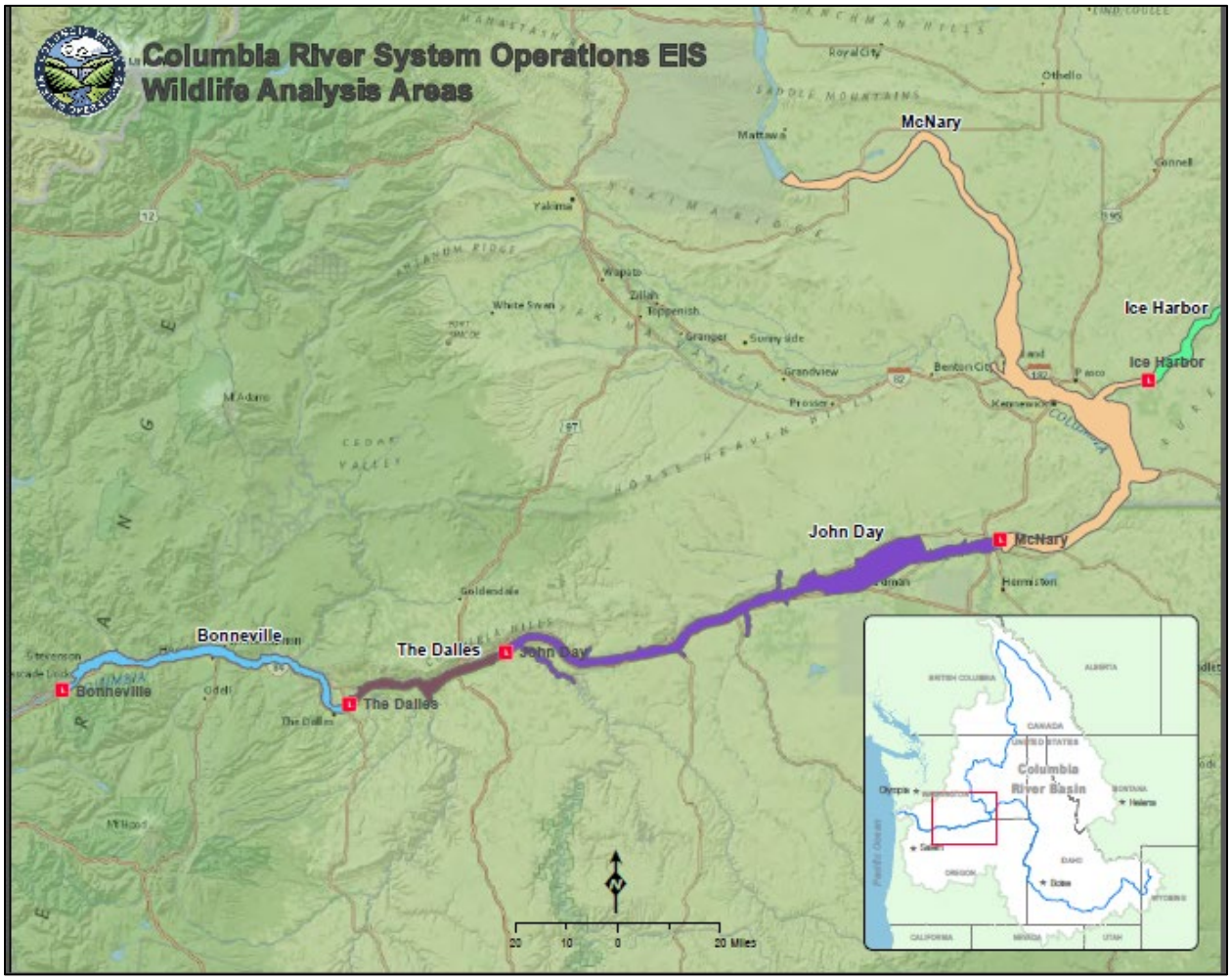

Figure 2-9. John Day Dam and Lake Umatilla Study Area

2.9.2 Land Cover

Table 1-2 above shows the acres of the different habitat types within the John Day Dam study area.

2.9.2.1 Uplands

Uplands adjacent to John Day and Lake Umatilla largely consist of shrub-steppe vegetation and agricultural areas farmed for dryland wheat, alfalfa and barley. Shrub-steppe habitat is often associated with hotter and drier climates, alluvial and sandy soils. Where shrub-steppe habitat occurs in this reach, it is patchy and often intermixed with uplands converted to agriculture and livestock pasture and areas of human development (Johnson and O'Neil 2000). Native vegetation is dominated by characteristic shrub species, consisting of sagebrush (*Artemisia* sp.), bitterbrush, rabbitbrush (*Ericameria* sp.) and short-spine horsebrush (*Tetradymia spinosa*). Native fescues, wheatgrass, bottlebrush squirreltail, needlegrass, sedges, bluegrasses and rye compose mid- and understory bunchgrasses (WDFW and NWHI, 2001) (NHI&NPCC Columbia River Basin Wildlife Habitat Classification). Depending on the relative level of current and historical disturbance, sites can have little forb cover or contain many species. As described in vegetation communities for upriver reaches of the Columbia River, common forbs include arrowleaf balsamroot, yarrow, buckwheat, blanket flower, parsley, and lupine species.

Trees are relatively uncommon in shrub-steppe habitats and where trees do occur they might be isolated individuals or woodland clusters. Ponderosa pine and Oregon white oak (*Quercus garryana*) woodlands occur sporadically in the Lake Umatilla reach of the Columbia River, notably in the vicinity of Plymouth Park, as well as the Umatilla National Wildlife Refuge where native vegetation is largely intact. Similar to other woodland habitats in the Columbia Plateau, the tree canopy is more open (10 to 60 percent) than the dense coniferous forests found in the Rocky Mountains to the east and Cascade Mountains west (Johnson and O'Neil 2000). Understory species in woodland patches consist largely of sagebrush, bitterbrush, and rabbitbrush, in addition to various bunchgrasses, sedges and forbs. There are approximately 100 acres of ponderosa pine and white oak woodlands in upland habitats along Lake Umatilla

Like many upstream reaches on the Columbia Plateau, cheatgrass is widespread across the study area and difficult to eradicate. Other widespread invasive species common in upland include Russian olive, black locust, Himalayan blackberry, Russian knapweed, diffuse knapweed (*Centaurea diffusa*), thistles, toadflaxes, reed canary grass (ODFW 2008 and 2016). In recent years, ODFW has conducted management efforts at the Irrigon Wildlife Area to remove Russian olive and restoring native bunchgrasses to support preservation of shrub-steppe habitat which is listed as a *strategy habitat* under the Oregon Conservation Strategy (ODFW 2016).

2.9.2.2 Barren Zone (Drawdown Zone)

Barren or drawdown zones between McNary andJohn Day are virtually non-existent, as John Day is managed as a run-of-river project. On average, water surface elevations in Lake Umatilla fluctuate less than a foot per day. As a result, there are few areas along the shoreline where

habitat is exposed for prolonged periods of time. However, there are areas where the shoreline is predominantly basalt bedrock or gravel and sand, with limited or no vegetation. Northern wormwood (*Artemisia campestris* var. *wormskioldii*), however, is an example of a perennial plant in the aster family that occupies exposed basalt terraces and sand habitat along the banks of the Columbia River and rocky islands (ODFW 2016, from USFWS 2016).

Where upland shrub-steppe habitats transition abruptly to the river's edge and no forested or scrub-shrub wetlands exists, the shorelines are largely formed by a band of basalt bedrock from prehistoric lava flows with unstable sandy shorelines (Camp et al. 2017 and ODFW 2008). Landslides and erosions are from current reservoir operations and irrigation are uncommon due to the bedrock foundation dominating both the Oregon and Washington shorelines.

2.9.2.3 Wetlands – Forested and Scrub-Shrub

There are approximately 1,000 acres of Forested and Shrub-Scrub wetlands adjacent to the Columbia River. With the exception of the Willow Creek Wildlife Area, the majority of this habitat occurs upstream of RM 262 and is within the boundaries of the Umatilla NWR and the Irrigon Wildlife Area. Downstream of RM 262 on the mainstem Columbia River, the side slopes and channel banks are steep and rocky, precluding soil development to support and sustain vegetation and wildlife habitat. The Willow Creek Wildlife Area provides a mosaic of forested and shrub-scrub wetlands, emergent herbaceous wetlands, and open water slough habitats in an otherwise arid and isolated portion of the river (Figure 2-10).

Within the John Day and Lake Umatilla study area, there are several significant state and federally managed wildlife areas containing vast tracts of intact forested and scrub-shrub wetlands. The Umatilla NWR, spanning the shorelines from RM 261 to 283, was established in 1969 as mitigation for forested and scrub-shrub wetlands and emergent herbaceous wetlands that were lost following construction of John Day. The refuge is spread across 23,555 acres and contains 22 miles of shoreline along Oregon and Washington shores. The refuge is approximately 45 miles upstream from John Day and 9 miles downstream from McNary. The Irrigon Wildlife Area contains 979 acres of forested and scrub-shrub wetlands and emergent herbaceous wetlands spanning 7 miles of riverfront shoreline of the Columbia River between the cities of Irrigon and Umatilla at RM 252. The Willow Creek Wildlife Area contains 646 acres of comprised of land and open water where Willow Creek flows into the Columbia River at RM 252. The Irrigon and Willow Creek Wildlife Areas are managed by ODFW as part of the Columbia River Wildlife Areas, a composition of four sites in the Columbia Plateau region which are managed for wildlife. These managed lands provide important habitat for the conservation of fish and wildlife within this reach of the Columbia River (ODFW 2008).

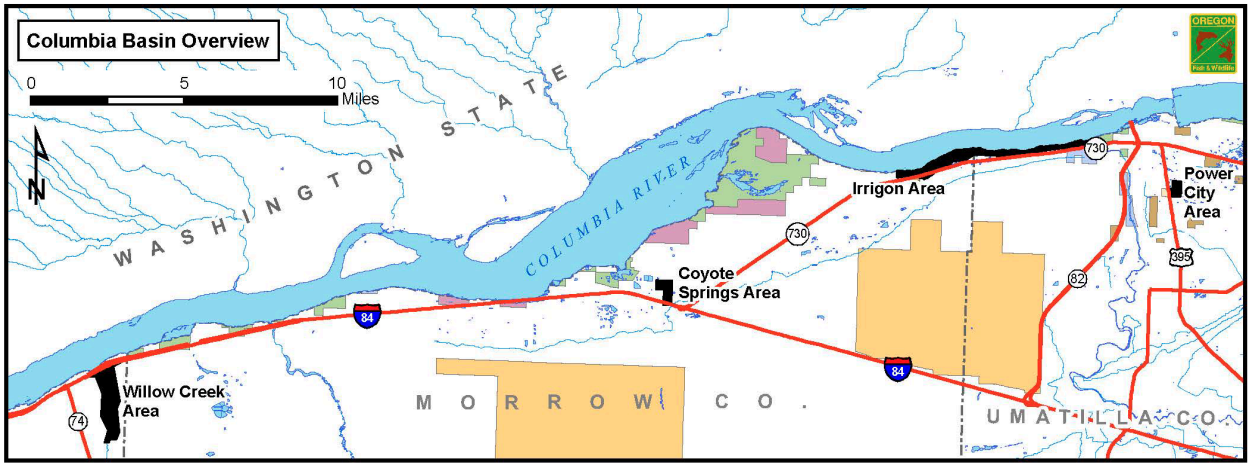

Figure 2-10. The Irrigon and Willow Creek Wildlife Areas as a part of the greater Columbia Basin Wildlife Areas on the Columbia Plateau (ODFW 2008).

Forested and scrub-shrub wetlands occur adjacent to Lake Umatilla in areas along the shoreline with permanent or seasonal inundation or in areas with impounded water and along lakes and ponds. Habitats along Lake Umatilla consists of narrow bands of trees, shrubs, and herbaceous vegetation. In addition, due to the presence of dryland farming in the uplands and irrigation of streamsides and toe-slopes, more water is available in some areas than would occur without agricultural practices, providing an important hydrologic element necessary for maintenance of riparian habitats in arid lands. Successional development is frequently controlled by flooding and fires, and disturbances could occur every 25 to 50 years (Johnson and O'Neil 2000).

Predominant vegetation in the forested and scrub-shrub wetlands of Lake Umatilla consists of a multi-layered mosaic of trees, shrubs and forbs. Trees include conifers and broadleaf deciduous species, including Ponderosa pine, Douglas fir, black cottonwood, quaking aspen, willows (*Salix*, sp.), alders (*Alnus*, sp.) and birch (*Betula* sp.). Riparian areas include a wide variety of shrubs, both shade and sun tolerant, including red-osier dogwood, mountain alder, chockcherry, roses, snowberry, serviceberry, black hawthorne, willows, current (*Ribes* sp.), elderberry and spirea (*Spirea douglasii*). Shrubs can form dense thickets, dominating the understory canopy. The herbaceous layer is highly variable and consists of an assortment of graminoids (grasses) and broadleaf forbs. Common plants include asters, horsetail (*Equisetum* sp.), parsley and parsnip, skunk cabbage, nettles, speedwell (*Veronica* sp.) and violets.

Widespread invasive plant species common in riparian habitats include Russian olive, poison hemlock, black locust, Himalayan blackberry, Japanese knotweed (*Fallopia japonic*), leafy spurge (*Euphorbia esula*), tansy ragwort, crested wheatgrass (*Agropyron cristatum*), and climbing nightshade (*Solanum dulcamara*) (ODFW 2008 and 2016).

2.9.2.4 Wetlands – Emergent Herbaceous

There are approximately 700 acres of emergent wetlands in the John Day study area. Similar to forested and scrub-shrub wetlands in Lake Umatilla, emergent herbaceous wetlands along Lake Umatilla primarily occurs upstream of RM 262 and is found predominantly within the Umatilla

NWR and Irrigon Wildlife Area, as well as isolated pockets along the Columbia River. In this portion of the river, herbaceous wetland habitats are a result of altered landscapes associated with modern agricultural practices and irrigation, in addition to operation of John Day (ODFW 2008). Emergent wetlands, as well as forested and scrub-shrub wetlands, usually occupy sites where seepage from upslope or sub-irrigation maintains hydric soils necessary to support the establishment and growth of wetland plants (FGDC 2013; BPA 1990). Additionally, slackwater areas also support the development of wetland plant communities, examples of which include Patterson and McCormack Sloughs in the Umatilla NWR and the Willow Creek Wildlife Area at RM 252.

Common plants present in freshwater wetlands in Lake Umatilla include cattails (*Typha* sp.), horsetail, bulrush, and a variety of sedges and rushes, in addition to many of the herbaceous species also found within forested and scrub-shrub wetlands (discussed above). In addition, burreed, mannagrass and tufted hairgrass are important wetland grasses supporting wildlife. Trees and shrubs are not typically present in great numbers of density;willows and other woody shrubs may occur in patches along wetland margins. Although aquatic plants are considered important wetland features, they are discussed in greater detail in the following section *Water*.

2.9.2.5 Water

Open water, ponded areas and other embayments, and tributary confluences provide important habitat for fish and wildlife. Embayments are open water areas which are cut off from surface water of the mainstem Columbia River by the construction of highway or railroad causeways. Hydrologic connectivity occurs via culverts, small channels, irrigation or groundwater exchange. Shallow-water areas in these habitats support productive submergent, emergent and aquatic vegetation communities which are important to fish and wildlife. A narrow band of aquatic vegetation is evident in aerial photography in some locations of the Lake Umatilla shoreline, however the spatial extent and species composition of this vegetation has not been formally documented. In addition to embayments, tributaries and ponds reflect slack water conditions immediately adjacent to the river, increasing overall habitat for aquatic plant communities. There are approximately 45,000 acres of open water habitat in the John Day study area.

Slack water sites in Lake Umatilla comprise substantially more acreage than comparable areas in downstream reaches, notably The Dalles Dam reach. There are over a dozen ponded embayments in Lake Umatilla covering thousands of acres. Paterson Slough is the largest embayment (1,043 acres) on the Washington Shore of the Umatilla NWR; McCormack Slough is the largest embayment (494 acres) on the Oregon shore of the Umatilla NWR and the Willow Creek Wildlife Area (200 acres). Open water and off-channel habitat behind Whitcomb Island and Crow Butte Island provide approximately 1,500 acres of open water and wetland habitat supporting submerged aquatic vegetation.

Aquatic plant species in this reach of the river typically include yellow pond lily (*Nuphar lutea*), pondweeds (*Potamogeton* spp.), duckweed (*Lemna* spp.), smartweed (*Polygonum* spp.), wild millet (*Panicum miliaceum*), goosefoot (*Chenopodium* spp.), and swamp timothy (*Crypsis*

schoenoides). Eurasian water-milfoil is common submerged aquatic invasive species. Purple loosestrife is a common invasive plant in wetland and riparian habitats. The Oregon Department of Agriculture (ODA) considers purple loosestrife a Class A weed, wherein the plant occurs in small-enough infestations to make eradication feasible (ODA 2017). Other aquatic invasive plants include purple loosestrife, yellow flag iris (*Iris pseudacorus*), and watercress (*Nasturtium* sp.).

2.9.2.6 Islands

Depending of water surface elevations in Lake Umatilla, there are numerous islands within the Umatilla NWR boundaries, as well as several large islands downstream of the refuge. Island habitats consist of a basalt foundation with varying habitat types depending on soil condition, elevation and frequency of inundation. Island habitats mimic surrounding upland, riparian and wetland habitats with regards to species composition, diversity and assemblage. Higher elevation islands mimic upland, riparian and/or wetland habitat found on the adjacent Washington and Oregon shorelines. Lower elevation islands which may be inundated frequently during the growing season are frequently bare of vegetation and mimic the barren, rocky shorelines.

There are 13 notable island complexes in the John Day reach of Lake Umatilla. Plymouth Island is approximately 180 acres and is located downstream from McNary Dam at RM 288 to 290 in Lake Umatilla. Plymouth Park Campground is located near the small town of Plymouth and features a boat launch and day use area on the island. Blalock Islands, part of the Umatilla NWR, span RM 273 to 277 and consist of several islands: Big Blalock, Little Blalock, Rock Island, Telegraph Island, Monument Island, Sand Island, West Sand Island, Long Walk Island, Upper Long Walk Island, and Cooks Island. All islands and associated beaches on Umatilla NWR are closed to public access to protect cultural resources and wildlife, and are home to many colonial nesting birds. Whitcomb Island is approximately 1,400 acres of islands within the Umatilla NWR where it is located along the Washington shore between RM 266 and 296. USFWS manages the island for cereal crop production, mostly corn, to provide forage for migrating and wintering waterfowl (USFWS 2008). The island's periphery contains woody and herbaceous wetland habitats where an oxbow provides open water and backwater habitats. Downstream from Whitcomb Island is Crow Butte Island, the upstream portion of which is also part of the Umatilla NWR. Crow Butte Island is also located on the Washington shoreline between RM 261 and 264 and the island is approximately 1,300 acres. The downstream portion of the island is managed by the Port of Benton as a recreational park where the majority of the island's shrub-steppe habitat remains intact. The recreational campground is maintained with cottonwood trees and non-native turf grass.

2.9.3 Wildlife

2.9.2.7 Birds

The John Day and Lake Umatilla study area provide significant habitats for a wide diversity of birds. In 2002, the Audubon Society of Portland, in cooperation with the National Audubon

Society, identified the Umatilla NWR as a state-level Important Bird Area (IBA) for its exceptional concentration of waterfowl, wading birds and shorebirds (Audubon 2002).

RAPTORS

The regionally significant wetland and riparian habitats in Lake Umatilla, and particularly within the Umatilla NWR and Irrigon Wildlife Area, provides crucial breeding and wintering habitat habitat raptors. Turkey vultures are common visitors to the study area, breeding and wintering throughout the reach. Both golden and bald eagles are present in the area, with high numbers (upwards of 30) bald eagles overwintering at the Umatilla NWR (Audubon 2018). While golden eagles are present, they are not known to nest within the Study Area; habitat use for golden eagles would occur largely in shrub-steppe and other upland habitats adjacent to the river. Osprey occur in the study area during the breeding season, where nests are often visible on platforms constructed near the shoreline or at the end of pile dikes.

The concentration of riparian habitat near the Umatilla NWR and Irrigon Wildlife Area support breeding and nesting hawks, including red-tailed and Swainson's hawks. Northern harriers, or marsh hawks, are present throughout the year and commonly observed in wetland and marsh habitats. Summer observations are likely fewer because the majority of breeding and nesting activity likely occurs outside of the study area. Accipiters are less common, with only occasional observations of sharp-shinned and Cooper's hawks occurring in the study area. Rough-legged hawks are present during the winter months, where they forage in agricultural habitats adjacent to the Study Area.

Great horned owls are commonly found within this reach. Occasional observations of barn, burrowing, long-eared and short-eared owls occur largely in upland portions of the study area, hunting in adjacent agricultural fields during spring and fall migrations and throughout the winter months.

American kestrals are present year-round at Umatilla NWR, while merlins, peregrines and prairie falcons are observed primarily during spring and fall migrations.

WATERBIRDS, SHOREBIRDS AND WATERFOWL

Tens of thousands of migrating and over-wintering waterfowl use the wetland and open water habitats in Lake Umatilla. The USFWS Pacific Flyway Data Book informs the following discussion (2017). The locally-rare and regionally significant wetland habitats at Umatilla NWR and the Irrigon Wildlife Area provide crucial high quality forage and cover for over-wintering waterfowl. Lake Umatilla supports one of the most significant wintering concentrations of waterfowl in Oregon and Washington, particularly Canada geese and mallards. Other geese overwintering in Lake Umatilla include snow, Ross's, greater white-fronted, and cackling geese, as well tundra swans. In addition to mallards, numerous duck species commonly overwinter in the refuge waters, including Northern shovelers, gadwalls, American widgeon, Northern pintail, green-winged teal, ring-necked duck, redhead, canvasback, bufflehead, common goldeneye, and common merganser. Western and pied-billed grebes frequently overwinter in Lake Umatilla,

while horned and eared grebes are less common during the winter. Other waterbird species overwintering in the study area include Bonaparte's, mew and herring gulls.

In addition to over-wintering habitat, island and shoreline habitats in the refuge boundaries of Lake Umatilla provide protected nesting habitat for nesting colonial waterbirds, such as Caspian and Forster's terns, glaucous-winged, ring-billed and California gulls, and Canada geese, as well as great blue heron and black-crown night heron rookeries. Other common nesting waterbird species include American white pelican, double-crested cormorant, great egret, and American bittern, Viriginia rail and sora (rail). Other common nesting duck species include wood ducks, cinnamon and blue-winged teals, gadwalls, pied-billed grebes and occasionally Western grebes. American coots are year-round residents (breeding and over-wintering) of Lake Umatilla.

Shorebird activity is largely limited to the breeding season, when killdeer, black-necked slilt, American avocet, and spotted sandpiper are common breeders at Umatilla NWR and surrounding areas. Additional species are commonly observed during the spring and fall migration, but which do not over winter in Lake Umatilla, include sandhill cranes, long-billed dowitcher, semipalmated plover, least plover, Western plover, solitary sandpiper, Wilson's snipe, Wilson's and red-naped phalarope, and greater yellowlegs.

PASSERINES

Passerines which are commonly observed nesting at Umatilla NWR include the Western wood pewee, Western and Eastern kingbirds, Northern rough-winged, tree, violet-green, bank, barn, and cliff swallows. Other breeding species include black-capped chickadee, red- and white-breasted nuthatches breed in the Lake Umatilla study area, as well as house, Bewick's and marsh wrens. Yellow warblers are common during the summer breeding season in riparian areas, while yellow-rumped warblers are commonly observed during the spring and fall migratory seasons, as well as over-winter. American crow, common raven and black-billed magpie are year-round resident corvids, and Stellar's and California scrub jays are frequently observed throughout the river reach between John Day and McNary. Other year-round resident passerines include American robin and American goldfinch, as well as song sparrows, yellow-headed, red-winged and Brewer's black birds, Western meadowlark.

Bullock's oriole, brown-headed cowbirds, black-headed grosbeaks, Western tanager, lazuli buntings are common breeding birds observed in Lake Umatilla reach of the Columbia River where suitable habitat conditions exist in riparian and upland areas. Dark-eyed junco, white- and golden-crowned sparrows, savannah sparrow and spotted towhee are frequently observed during the winter and migratory seasons. Mixed upland grasslands are important for long-billed curlew (*Numenius americanus*) and sage sparrow (*Amphispiza belli*), both of which are state-listed sensitive species for Oregon.

GALLINACEOUS BIRDS

Similar to other species present along John Day pool, upland gamebirds are also more abundant in the upper reaches of the pool, particularly in the Umatilla NWR. This is a reflection of suitable

habitat occurrence. Quail and pheasants are frequently seen in the summertime, along with mourning doves feeding on the wheat harvests surrounding the Umatilla NWR. Mountain quail have been observed along the tributaries of the John Day River. California quail have been seen in Irrigon and Willow Creek wildlife areas. Chukar are ground-loving, harvested upland game-birds. Chukar's are common permanent residents of eastern Oregon along the steppe habitats along the Columbia River. Ring-necked pheasants were introduced as an exotic game birds and inhabits grasslands and agricultural fields in the study area (ODFW 2016).

Mourning doves and rock pigeons are frequently observed in multiple habitat types throughout the study area. Belted kingfishers and downy woodpeckers are common breeders at Umatilla NWR, and Northern flickers are commonly observed year-round. Lewis' and hairy woodpecker occur at Mary Hill State Park, as well as common nighthawks. Anna's and rufous hummingbirds also occur within the Lake Umatilla study area.

2.9.2.8 Mammals

TERRESTRIAL

Lake Umatilla provides year-round habitat for food, cover, mating and nesting or denning for a wide variety of mammalian species. In the Columbia Basin Wildlife Area Management Plan, ODFW describes 32 species of mammals using shrub-steppe, forested and scrub-shrub wetlands and emergent herbaceous wetland habitats in the John Day and Lake Umatilla region, including small mammals to large ungulates (ODFW 2008). Predators common in shrub-steppe and forested and scrub-shrub wetland habitats include raccoon (*Procyon lotor*), coyote, striped skunk (*Mephitus mephitus*) and badgers (*Taxidea taxus*). Comprehensive surveys of small rodent distribution, abundance and diversity are lacking, but known species include deer mice, pocket mice, shrews, northern pocket gopher (*Thomomys talpoides*), montane voles, long-tailed voles, and sagebrush voles (ODFW 2008).

Large ungulate populations near John Day and Lake Umatilla are dominated by mule deer, and smaller upland mammals include blacktailed jackrabbit and mountain cottontail (*Sylvilagus nuttallii*). Shrub-steppe habitat is the most important habitat for mule deer in the Lake Umatilla area, although woody and herbaceous wetland habitats provide important habitat resources for deer. Additional, island habitats, particularly those on Umatilla NWR, provide important fawning areas for mule deer due to the lack of predators (Tubor 1976).

The most abundant upland terrestrial invasive animal is the feral swine (*Sus scrofa*). John Day is located within Sherman County, OR, of which feral swine have been reported there and in neighboring counties (ODFW 2013). Swine have destructive rooting activities which damage agricultural crops and sensitive fish and wildlife habitat. House Bill 2221 passed in 2009 requires landowners to notify ODFW if swine are roaming their property (OISC 2007).

Limited data for bat populations exists on the Umatilla NWR or ODFW-managed wildlife areas. However, suitable roost habitat and prey availability exists on Umatilla NWR and the Willow Creek and Irrigon Wildlife Areas to suggest several species of bats, such as Townsend's big-

eared bat (*Corynorinus townsendii*), long-eared myotis (*Myotis evotis*), long-legged myotis (*M. volans*), pallid bat (*Antrozous pallidus*), silver-haired bat (*Lasionycteris noctivagans*), small-footed myotis (*M. ciliolabrum*), and Yuma myotis (*M. yumanensis*) could be present (USFWS 2008 and ODFW 2016). ODFW notes that spring and summer invertebrate populations and suitable roosting habitats are available in forested and scrub-shrub wetland areas, but inventories and surveys are needed to confirm presence and identify potential bat species that may be present in the study area (ODFW 2008).

AQUATIC

Aquatic mammals are more prevalent upstream of RM 252 where woody and herbaceous wetlands are more common. Between RM 252 and John Day (at RM 216), there are fewer wetland habitats, which are important in supporting aquatic mammals, including many small rodents. Beaver (*Castor canadensis*) and river otters (*Lutra canadensis*) are also common in wetland habitats, and muskrats are often associated with cattail-bulrush wetlands in the John Day study area (Tubor 1976).

Nutria (*Myocastor coypus*) are semi-aquatic rodents found in lakes, wetlands, sloughs, drainage ditches, and irrigation canals along the Columbia River. Nutria burrows and tunnels can damage the integrity of flood control levees, man-made canals, and stream banks resulting in erosion and instability. These giant rodents primarily feed upon succulent plant stalks and roots transforming contiguous wetlands into open water habitat. The nutria is considered an invasive species and classified as a Prohibited Species which can be trapped year round (USFWS 2013).

2.9.2.9 Reptiles and Amphibians

Most amphibian and reptile species that typically inhabit arid habitats in the John Day and Lake Umatilla study area are confined to shrub-steppe habitats and the adjacent fringe of forested and scrub-shrub wetlands and emergent herbaceous wetlands. The abundance of woody and herbaceous wetland habitat in the Umatilla NWR, Willow Creek and Irrigon Wildlife Areas provide essential habitat for all life stages of aquatic-dependent species. Terrestrial and aquatic invertebrate populations associated with shrub-steppe and wetland habitats provide an ample prey base for foraging, and the soils, vegetation and habitat structure (logs or other large wood structures) provide opportunity for nesting, egg laying, basking, escape from predators and refugia. ODFW notes that 13 species of amphibians and reptiles are known to occur across the Columbia Basin Wildlife Area habitats, 10 of which are commonly occurring species (ODFW 2008).

Amphibian species include tree frog (*Hyla regilla*), northern leopard frog (*Rana pipiens*), and Oregon spotted frog (*Rana pretiosa*) (ODFW 2008). The Great Basin spadefoot toad (*Spea intermontana*), Western toad (*Anaxyrus boreas*) and Woodhouse's toad (*A. woodhousii*) are also associated with shrub-steppe and wetland habitats in the John Day study area (Tubor 1976).

Reptile species in the John Day and Lake Umatilla study area include northern sagebrush lizard (*Sceloporus graciosus graciosus*) and short-horned lizard (*Phrynosoma douglasii*). Western painted turtles (*Chrysemys picta belli*), an Oregon Conservation Strategy species is common at Willow Creek and Irrigon Wildlife Areas, where populations are thought to be stable or increasing (ODFW 2008). ODFW has observed six species of snake at the Willow Creek and Irrigon Wildlife areas, including common and Western terrestrial garter snakes (*Thamnophis sirtalis* and *T. elegans*), gopher snake (*Pituophis catenifer*), Western rattlesnake (*Crotalus oreganus*), racer (*Coluber constrictor*) and rubber boa (*Charina bottae*) (ODFW 2008). Species status is unclear, although observations indicate individuals are widespread throughout the study area.

A common widespread invasive that thrives in wetlands and open waters, including the warm waters of ponds, lakes, marshes, sloughs, irrigation ditches and streams, is the bullfrog (Lithobates catesbeianus). Bullfrogs eat fish, reptiles, small mammals, birds, amphibians and insects, so vigorously as to adversely affect native populations. They also aid in the spread of Ranavirosis, as well as the chytrid fungus which are major contributors of the global population decline of native frogs (OSU 2018). Two invasive turtle species are known in Oregon and Washington: the red-eared slider (*Trachemy scripta elegans*) and common snapping turtle (*Chelydra serpentina*). These species outcompete western painted turtles for food resources and basking sites.

2.9.2.10 Invertebrates

Historically, the Columbia River may have supported a rich benthoinvertebrate fauna consisting of caddisfly and chironomid larvae; however, today the river is considered to have low species diversity. A baseline sampling survey due to a scheduled drawdown was conducted in 1994-1995. Invertebrates and zooplankton were collected and processed. Cladoceran, branchiopod crustacean) and rotifer (wheel animals) species were found in the upper reservoir of Lake Umatilla. Most taxa both occurred at low densities and occurred infrequently (PSU 2007).

Aquatic invasive species (AIS) common to lakes and reservoirs of Oregon include the Chinese mystery snails (*Cipangopaludina chinensis malleata*), Chinese mitten crab (*Eriocheir sinensis*), Louisiana red swamp crayfish (*Procambrus clarkia*), New Zealand mud snail, zebra (*Dreissena polymorpha*) and quagga mussels (*D. bugensis*) (USFWS 2013). These species outcompete their native counterparts for resources, like food, nesting and cover habitat, often spreading disease and parasites and degrading water quality. AIS threaten the diversity and abundance of native species, the stability and water quality of infested waters, and the commercial and recreational activities dependent on the waters. Species continue to invade primarily by transoceanic shipping, but also through aquaculture, aquarium trade, the bait industry, research, and even environmental restoration projects (CDFG 2008).

Most research on invertebrates has been on the invasive species in the reservoirs and open water habitat. Aquatic invasives common in the waterways of Oregon and Washington include Asian clams, New Zealand mud snails, zebra and quagga mussels, and red-swamp crayfish. There are indications of large beds of *Corbicula fluminea* based on shorelines with dense layers

of shells on the beach and observations of diving duck concentrations. Threatened and endangered invertebrates are discussed in Section 3.

2.10 THE DALLES DAM AND LAKE CELILO

2.10.1 Study Area

The study area used to described the existing conditions and assess the range of potential impacts to wildlife and habitat features includes land associated with The Dalles, Lake Celilo, and the mouths of its primary tributaries, Deschutes River and Fifteenmile Creek (Figure 2-11).

Similar to John Day and Lake Umatilla study area, the upland habitats in the The Dalles Dam and Lake Celilo stuay area are entirely within the Columbia Plateau ecoregion. The river reach between John Day and The Dalles are one of the driest and warmest portions of the Columbia River Basin where winds can exceed 20 miles per hour and temperatures can exceed 100° at the height of the summer.

The Deschutes River and Fifteenmile Creek are the primary tributaries that persistently flow into Lake Celilo from Oregon. No tributaries flow persistently into Lake Celilo from Washington. Between John Day and The Dalles, the Yakama Indian Nation has Trust lands along the Washington shore and the Confederated Tribes of the Warm Springs have Trust lands along the Oregon shore. In addition to grain producing agricultural lands in the uplands, there are numerous wineries and vineyards in this river reach.

Unlike the river reaches upstream of John Day, there are no USFWS-administered wildlife lands in the vicinity of Lake Celilo. ODFW manages 8,526 acres of wildlife habitat along the Deschutes River along the Oregon shoreline, the Lower Deschutes Wildlife Area, where the Deschutes River empties into the Columbia at RM 204. The wildlife area was initially established to provide access to the water for anglers, and acreage was subsequently enhanced to support fish and wildlife habitat (ODFW 2009). Table 1-2 identifies the land cover, vegetation, and habitat of the study area.

Figure 2-11. The Dalles Dam and Lake Celilo Study Area

2.10.2 Land Cover

2.10.2.1 Uplands

Much of the upland habitat adjacent to The Dalles and Lake Celilo study area is similar to other reaches in the Columbia Plateau ecoregion, which consists largely of shrub-steppe vegetation, mixed grasslands, agricultural areas and vineyards. Conifers, where present, consist mostly of Western juniper (*Juniperus occidentalis*) and ponderosa pine. Sagebrush is the dominant native shrub, with bitterbrush present in isolated pockets (ODFW 2009). Grasslands surrounding the Deschutes River confluence consist of bluebunch wheatgrass, sheep fescue (*Festuca ovina*), Sherman big bluegrass (*Poa ampla*), small burnet (*Sanguisorba minor*), and alfalfa (*Medicago sativa*) (ODFW 2009).

Trees are relatively uncommon in shrub-steppe habitats and may occur as isolated individuals, in irrigated park settings, or in woodland clusters. There are a few, relatively isolated pockets of irrigated park settings and upland habitats with cottonwood trees, including Columbia Hills State Park, which includes Horsethief and Little Spearfish Lakes, and Maryhill State Park in

Washington state at RM 194 and 209, respectively. Avery Park is located further downstream on the Washington shoreline near RM 198 and also provides some irrigated forested habitat along the shoreline. Additionally, the Rufus Landing Recreation Area and Giles French Park are administered by the Corps on the Oregon shore immediately downstream from John Day Dam at RM 214 and 215, respectively, and provide trees with limited irrigated upland grasses. Some tree habitat also occurs at the Deschutes River State Recreation Area on the Oregon shore where the Deschutes River flows into Lake Celilo.

Tree profiles in upland habitats consist of Oregon white oak and ponderosa pines. Similar to the John Day study area, understory species in upland habitats along Lake Celilo consist of sagebrush, bitterbrush, and both green and gray rabbitbrush, in addition to various grasses, sedges and forbs, including sunflowers, buckwheat and asters. Upland grasslands consist of a combination of native and non-native species. Native species include bluebunch wheatgrass, sheep fescue (*Festuca ovina*), Sherman big bluegrass (*Poa ampla*), small burnet (*Sanguisorba minor*), and alfalfa (*Medicago sativa*) (ODFW 2009). Non-native, invasive species include medusahead (*Taeniatherum caput-medusae*) and cheatgrass brome (*Bromus tectorum*) (ODFW 2009).

2.10.2.2 Barren Zone (Drawdown Zone)

There are no drawdown areas in the study area between John Day and The Dalles because The Dalles Dam is managed as a run-of-river project. Water elevations in Lake Celilo fluctuate less than five feet in elevation over a normal water year (Corps 2004). Consequently, there are few areas along the shoreline where habitat is exposed for prolonged periods of time. Similar to the John Day study area, typical substrates along the Oregon and Washington shorelines of Lake Celilo are comprised predominantly of basalt bedrock, sand, gravel and silts with limited or no vegetation (Camp et al. 2017 and ODFW 2008). Sand and silt deposits along the shoreline are most evident in backwaters, inlets, and embayments or at the mouths of rivers like the Deschutes River.

Where upland shrub-steppe habitats transition abruptly to the river's edge and no riparian habitat exists, the shorelines are largely formed by a continuous band of basalt bedrock extending from prehistoric lava flows in upstream portions of the river. Similar to the John Day study area, landslides and erosions in the The Dalles study area are uncommon due to the bedrock foundation dominating both the Oregon and Washington shorelines along Lake Celilo. Some plants inhabit the rocky, cliff habitat adjacent to the river including Columbia goldenweed (*Ericameria resinosa*).

2.10.2.3 Wetlands – Forested and Scrub-Shrub

There are 972 acres of Forested and Scrub-Shrub wetlands in The Dalles study area. Forested and scrub-shrub wetlands growth and development is limited between The Dalles and John Day study areas due to the immediate juxtaposition of highways and railroads to the river's shorelines. However, forested and scrub-shrub wetland plant communities occur where tributaries empty into the Columbia River and consists of narrow bands of trees, shrubs, and

herbaceous vegetation, similar to Lake Umatilla upstream of John Day Dam. In addition, due to the presence of dryland farming and vinticulture in the uplands, there are areas where irrigation supports a hydrologic regime and the development of wetland habitats that would otherwise be arid without the presence of irrigation and runoff from farming or agriculture.

Where state and federal parks occur, they are comprised largely of non-native grasses irrigated for recreation. For example, Mary Hill and Columbia Hills State Parks provides a mixture of native and non-native wetland plant communities in the immediate vicinity of the shoreline. Forested habitat consists of native hardwood trees, such as big leaf maples, Oregon ash, black cottonwood and red alders, while the shrubby undergrowth often consists of Pacific willow, common snowberry, golden and red-flowering current, serviceberry, oceanspray and pioneer roses, Douglas spirea, and Oregon grape. Additional scrub-shrub wetland plant species common to the The Dalles study area include sedges, grasses and forbs, including bulrush, blue-bunch wheatgrass and broad-leafed lupine.

There are few forested and scrub-shrub wetland habitats in the Lake Celilo study area that are federally managed or maintained by the states of Oregon or Washington specifically for terrestrial wildlife. ODFW manages the Lower Deschutes Wildlife Area, immediately upstream from the Deschutes River State Recreation Area at on the Columbia River, to improve and maintain habitats for native fish and wildlife species. Mary Hill State Park provides a narrow band of forested wetland vegetation along approximately two miles of shoreline which is adjoining a similarly narrow band of riparian vegetation adjacent to the Waving Tree Winery and Vineyard from RM 210 to 211.

Other forested and scrub-shrub wetland habitats occur in small pockets along both the Oregon and Washington shorelines.

Near the ODFW-managed Lower Deschutes Wildlife Area wetland plant communities are comprised mainly of red alder, cottonwood, spirea, common chokecherry (*Prunus viginiana*), and Lewis' mock orange (*Spiraea* spp.).

2.10.2.4 Wetland – Emergent Herbaceous

There are approximately 700 acres of Emergent Herbaceous wetland habitats in and adjacent to Lake Celilo occurs in isolated pockets along the length of the Oregon and Washington shorelines. Similar to upriver reaches, herbaceous wetlands are a result of altered landscapes associated with modern agricultural and irrigation practices, in addition to operation of The Dalles Dam (ODFW 2009). Emergent wetlands, both forested/scrub and herbaceous, occupy sites where seepage from irrigation or natural waterways maintains the hydric soils necessary to support the establishment and growth of wetland plants. Unlike the John Day study area, there are few slackwater areas which support the development of wetland plant communities.

There are no formal wetland delineations of the The Dalles study area, but summary estimates of USFWS NWI herbaceous wetland classifications are provided in Table 1-2. Similar to the John Day study area, common plants present in freshwater wetlands in Lake Celilo include cattails

and other rushes, a variety of sedges and many of the herbareous species found in forested and scrub-shrub wetland areas discussed above. Trees and shrubs are present in low densities, where they occur in patches along margins. Although aquatic plants are considered important wetland features, they are discussed in greater detail in the following section: *Water*.

2.10.2.5 Water

Open and slack water sites in Lake Celilo are present along both the Oregon and Washington shorelines, as well as around island and lake habitats. As noted above, the location of highways and railroad embankments immediately adjacent to the river channel impounds water in low areas between upland habitats and the river channel throughout the study area. These areas provide 6,776 acres of valuable habitat for birds and wildlife, even though direct connectivity to the Columbia River channel may be limited or non-existent. Slack water is present near Rufus, OR at RM 211 to 2013 where low elevation islands along the Oregon shoreline reduce water velocities. Open water habitat around Miller and Browns Islands provide open water and wetland habitat supporting submerged aquatic vegetation. An additional of open water and backwater channels are present near Bob's Point at RM 207. Horsethief Lake and Spearfish Lake provide larger areas of open water, aquatic habitat sheltered from the main Columbia River channel at RM 193 and 195, respectively.

The location, extent, and nature of aquatic plant beds in Lake Celilo is unknown, however there are few areas of shallow-water, low velocity areas which would support aquatic plant communities important to fish and wildlife. Similar to Lake Umatilla and the John Day study area, there is a narrow band of aquatic vegetation evident in aerial photography in some locations of The Dalles study area, but the species and distribution of aquatic vegetation has been been formally documented.

Similar to the John Day study area, Lake Celilo supports a wide diversity of aquatic plant species, including yellow pond lily, pondweed, duckweed, smartweed, wild millet, goosefoot, and swamp timothy (Corps 2004). Eurasian water-milfoil, purple loosestrife and curley-leaf pondweed, are common aquatic invasive plants in Lake Celilo (USGS 2018b).

2.10.2.6 Islands

There are few notable island habitats in The Dalles study area and the acreage of the islands varies substantially. Immediately downstream from John Day Dam on the Oregon shore across from Mary Hill State Park at RM 212 near Rufus, there are several small low elevation, bedrock islands that are exposed during the late summer months. These islands support scrub-shrub wetlands in ponded embayments and grassy upland habitats.

Miller Island, at RM 203 to 207, is a large island near the confluence of the Deschutes River. The island is owned by the U.S. Forest Service and the main navigation channel for the Columbia River is south of the island. Much of the upland area is other exposed basalt rock with some cliff habitat or open shrub-steppe habitat. The island's periphery is mostly a narrow band of shrubs, low stature vegetation or barren rock. There are some rocky outcrops immediately upriver of

the island which have a subsurface connection to Miller Island but which are isolated from the main portion of the island during normal water years. These rocky outcrops provide nesting habitat for approximately 20 pairs of colonial nesting birds, including Caspian terns and numberous gull species, which forage at The Dalles and John Day Dams, as well as throughout the Columbia River Basin.

Browns Island is a smaller basalt island of upland dry scrub-shrub and forested scrub-shrub wetland habitat at RM 196. There are some trees and scattered wetland shrubs on Browns Island where seasonal hydrology supports the establishment and growth of wetland habitat. Other portions of the island are bare, open ground with some grass and shrub habitat.

2.10.3 Wildlife

2.10.3.1 Birds

RAPTORS

Raptors common in The Dalles study area year-round include bald and golden eagles, osprey, red-tailed hawks and American kestrals. Peregrine falcons are common visitors to the upland cliff habitats adjacent to The Dalles study area and Deschutes River corridor, while prairie falcons are less common visitors to upland habitats. Turkey vultures are commonly found throughout The Dalles study area in the spring and summer months.

The Corps annually hosts an Eagle Watch at The Dalles Dam Visitor Center for visitors to learn about bald eagles and watch the birds congregate along the Columbia River to feed during the winter and roost overnight. In 2017, upwards of 50 bald eagles were present in the vicinity of The Dalles Dam during the winter months (Tilton and Cordie, 2019, pers. communication).

WATERBIRDS, SHOREBIRDS AND WATERFOWL

Many of the water and shorebirds occurring in The Dalles study area are migratory and occur primarily during the spring and fall migration periods. However, there are several colonies of nesting seabirds, including Caspian terns, ring-billed and California gulls which breed in Lake Celilo on low elevation rocky outcrops upriver from Miller Island. Double-crested cormorants, great blue herons, Canada geese, mallards and common mergansers (*Mergus merganser*) are common breeders in The Dalles study area. Migrating waterfowl that are commonly observed in Lake Celilo include American widgeon, ring-necked duck, redhead, and bufflehead, and lesser scaup. Common shorebirds include killdeer and spotted sandpipers, both of which breed in wetland habitats found throughout Lake Celilo (www.ebird.org).

Waterfowl use in Lake Celilo is primarily associated with open and slack water habitats adjacent ot the highways and wetland habitats adjacent to the shorelines. There is limited suitable habitat to support nesting ducks and geese, however some nest habitat occurs on Browns Island at RM 198 and in the Rufus Ponds at RM 211. The presence of shallow water habitat near

Rufus Ponds, as well as gravel bars and low elevation islands, provides protection from high velocities and winds for overwintering habitat and breeding habitat in the summer months.

PASSERINES

Common nighthawk, belted kingfisher, Northern flicker, Western kingbird, Common corvids include black-billed magpie, common raven, and Amercian crow. Smaller passerines which commonly occur in the study area include horned lark, swallows, black-capped chickadee and bushtits. Several wrens are common breeders in The Dalles study area, including, Bewick's, house and canyon wrens. Canyon wrens are associated with canyon habitats within The Dalles study area where cliff habitats occur in closer proximity to wetland and shoreline habitats. Other common birds include American robins and introduced European starlings, yellow and yellow-rumped warblers, spotted towhee, house and song sparrows, dark eyed juncos, Bullock's oriole, Western meadowlark, house and American goldfinches, and several blackbirds, including Brewer's, red-winged and brown headed cowbirds.

GALLINACEOUS BIRDS

According to ODFW, several non-native upland game bird species occur in upland grassy habitats of the Lower Deschutes Wildlife Area, including chukar partridge (*Alectoris chukar*), Hungarian (gray) partridge (*Perdix perdix*) ring-necked pheasant (*Phasianus colchicus*), and California quail (*Callipepla californica*). It is reasonable to assume that these species occur through The Dalles study area, in addition to wild turkeys, and native mourning doves (*Zenaida macroura*).

2.10.3.2 Mammals

TERRESTRIAL

ODFW has documented numerous mammalian species in The Dalles study area, the most abundant of which include mule deer (*Odocoileus hemionus hemionus*), California bighorn sheep (*Ovis canadensis californicus*) and Rocky Mountain elk (*Cervus elaphus nelsoni*) (ODFW 2009). California bighorn sheep can be found in upland canyon habitats in the Deschutes River basin, a portion of which is found within the study area. Other common species include mountain lion and bobcat, coyote, raccoon, striped skunks, squirrels and white-tailed jackrabbit (*Lepus townsendii*) and mountain conttontail (*Sylvilagus nuttallii*). Badgers, long-tailed weasel (*Mustela frenata*) and mink are also known to occur in The Dalles study area.

There has been no systematic survey for smaller mammals or bats within The Dalles study area. However, many species are noted to occur in the Lower Deschutes Wildlife Area and it is reasonable to assume many, if not all, of these species occur elsewhere in The Dalles study area due to proximity and similarity of habitat types adjacent to the Columbia River. ODFW has documented the following bat species at the Lower Deschutes Wildlife Area: little brown myotis *(Myotis lucifugus),* Townsend's big-eared bat *(Plecotus townsendii)*, and pallid bat *(Antrozous pallidus).* Other small mammals documented in the Lower Deschutes Wildlife Area include

California ground squirrel *(Spermophilus beecheyi),* Northern pocket gopher *(Thomomys talpoides)*, vagrant Shrew *(Sorex vagrans)*, Great Basin pocket mouse *(Perognathus parvus)*, deer mouse *(Peromyscus maniculatus)*, house mouse *(Mus musculus)*, bushy-tailed woodrat *(Neotoma cinerea)*, montane vole *(Microtus montanus)*, long-tailed vole *(Microtus longicaudus),* sagebrush vole *(Lagurus curtatus)* and muskrat *(Ondatra zibethicus)* (ODFW 2009).

AQUATIC

River otters and beaver are present where suitable habitat occurs, primarily near island habitats and where wetlands occur along the shorelines.

2.10.3.3 Reptiles and Amphibians

Amphibian and reptiles occur where suitable habitat exists, which differs substantial throughout The Dalles study area. Snakes and lizards common in the dry, upland shrub-steppe habitats include gopher snakes (*Pituophis catenifer*), common garter snake (*Thamnophis sirtalis*), Western rattlesnake (*Crotalus viridis*), northern sagebrush lizard (*Sceloporus graciosus*), and Western fence lizard (*Sceloporus occidentails*). Conversely, common amphibians occur in forested, scrub-shrub and emergent herbaceous wetland habitats include rough-skinned newt (*Taricha granulosa*), Western toad (*Bufo boreas*), and Pacific treefrog (*Pseudacris regilla*).

2.11 BONNEVILLE DAM AND LAKE TO THE COLUMBIA RIVER ESTUARY

2.11.1 Study Area

The study area used to described the existing conditions and assess the range of potential impacts to wildlife and habitat features includes land associated with Bonneville Dam, Bonneville Lake, and the Columbia River to the estuary (River Mile 0 to River Mile 145) (Figure 2-12). The area below Bonneville dam is a free-flowing river influenced by tidal fluctuations, which intensifies closer to the mouth of the Columbia.

Riverine habitat include sloughs, backwaters, islands, shorelines, mudflats and riparian zones. Railroads and highways parallel the river through much of this reach on both sides and prevents riparian expansion here. Human development is also prevalent in the study area. Agricultural areas encompass a substantial amount of the floodplain.

Figure 2-12. Bonneville Dam and Lake Study Area

2.11.2 Land Cover

2.11.2.1 Uplands

There are approximately 165,800 acres of upland habitat, mostly Westside Lowland Conifer-Hardwood Forest, in the study area. There are also approximately 76,000 acres of agricultural lands. Upland areas exhibit a considerable variation in plant communities from west to east. This is attributable to a graduation from a mild, wet marine west coast climate to a dry, cold winter-hot summer continental climate. Pool levels typically only influence a very narrow region immediately abutting the reservoir and river. This zone of influence includes riparian habitat but does not extend into the upland habitats. Thus, the upland zone is not considered an area subject to impacts from implementation of various operational strategies.

2.11.2.2 Barren Zone (Drawdown Zone)

There are no drawdown areas in the study area because Bonneville is operated as a run-of-river project. There are few areas along the shoreline where habitat is exposed for prolonged periods

of time. A substantial delta formed from silts exists at the mouth of the Klickitat River in Bonneville pool. Sand/silt deposits are also evident just downstream of the Deschutes River mouth. Sand and silt deposits along the shoreline are most evident in backwaters, inlets, and embayments or at the mouths of rivers like the Deschutes River.

Where upland shrub-steppe habitats transition abruptly to the river's edge and no riparian habitat exists, the shorelines are largely formed by a continuous band of basalt bedrock extending from prehistoric lava flows in upstream portions of the river.

2.11.2.3 Wetlands – Forested and Scrub-Shrub

There are approximately 76,100 acres of Forested and Scrub-Shrub wetlands in the Bonneville study area. Forested and scrub-shrub wetlands growth and development is limited through much of the area by the immediate juxtaposition of highways and railroads to the river's shorelines. However, forested and scrub-shrub wetland plant communities occur where tributaries empty into the Columbia River and consists of narrow bands of trees, shrubs, and herbaceous vegetation.

Black cottonwood and various species of willows are the dominant tree species for riparian areas in this reach of the Columbia River. Mature black cottonwoods are the dominant tree species in terms of height. Willows range in size from invasive stands on sand bars and beaches to mature stands comprising a major component of the overstory vegetation. Tree species comprising lesser components of the riparian zone include Oregon ash and black hawthorn.

Shrub willows, red osier dogwood, young cottonwoods and Himalayan blackberry are predominant shrub components. A dense shrub layer is often present. Reed canarygrass, nightshade, trailing blackberry, and stinging nettles are common groundcover components of the vegetation. Reed canary grass can dominate ground cover in many locations.

Mature riparian forests provide perch and nesting habitat for bald eagles and osprey in this reach. Many species of passerines, including yellow warblers and Swainson's thrushes, use the riparian forest and shrub habitat for foraging and nesting. Decadent trees, either a result of maturity or from wind/ice snappage provide opportunities for cavity nesters such as downy woodpeckers. Great blue herons also use the riparian stands for nesting. Canada geese will nest within the riparian forest, generally along the edge, on islands. Beaver use shrub willow and cottonwood stands for foraging; denning occurs in the bankline.

Invasive species include Russian olive, rush-skeleton weed, reed canary grass, pepperweed, and purple loosestrife.

2.11.2.4 Wetland – Emergent Herbaceous

There are approximately 42,400 acres of Emergent Herbaceous wetland habitats in the Bonneville study area along the length of the Oregon and Washington shorelines. Similar to upriver reaches, herbaceous wetlands are a result of altered landscapes associated with

modern agricultural and irrigation practices. Emergent wetlands, both forested/scrub and herbaceous, occupy sites where seepage from irrigation or natural waterways maintains the hydric soils necessary to support the establishment and growth of wetland plants.

Emergent wetlands below Bonneville Dam are primarily limited to backwater sloughs and ponded areas away from the main Columbia River. Franz Lake at Franz NWR contains an extensive stand of wapato. Old slough channels, embayments and ponded areas on Government Island, Sandy River Delta, Steigerwald Lake, Ainsworth State Park (RM 138 to 139) and other riverine areas support emergent wetlands. Often, these areas are dominated by reed canarygrass.

These habitats provide forage, loafing, and night roost locations for waterfowl. The extensive wapato stand at Franz Lake supports a substantial (1,000 plus) population of wintering tundra swan in addition to other waterfowl species. These sites also provide foraging areas for various species of waterfowl, great blue herons, rails, passerines such as re-winged blackbirds, swallows, and marsh wrens, and other species of birds, mammals and amphibians.

2.11.2.5 Water

The study area has approximately 181,700 acres of open and slack water. Shallow water habitat occurs along the shoreline of the Columbia River and around islands within the various pools. Typically the substrate for Bonneville is comprised of rock, gravel, sand, and silt with rocky shorelines predominating in many locations. Shallow water areas can be very productive of submergent, emergent and aquatic vegetation in addition to benthic invertebrate populations. However, this productivity is somewhat tempered in Bonneville by fluctuating pool levels. Still, aquatic plant beds are evident in some locations; their areal extent and species composition have not been formally documented, however. Neither has areas of importance for benthic invertebrates nor detailed work on their density and species composition been determinedAquatic plant beds are present in the pool and are expected to be most prevalent below 73.5 msl. Location, extent and nature of these aquatic plant beds is unknown.

Embayments, adjacent ponds, and associated tributaries provide an important habitat feature for fish and wildlife resources on these projects. These embayments are relatively unique to the three projects and provide special wildlife values. They provide protected loafing and roosting areas for waterfowl and other waterbirds, in addition to food resources. Embayments are considered bodies of water cut off from the main river by highway or railroad causeways, or other features and are typically connected to the Columbia River via culverts or small channels. Associated tributaries reflect slack water conditions that extend up tributaries. Adjacent ponds encompass bodies of water adjacent to the river; the source of the water in these sites may arise from subirrigation and/or drainage from adjoining lands.

2.11.2.6 Islands

This reach of the Columbia River is dominated by a number of large islands. Hayden Island occurs just upstream of the mouth of the Willamette River. This island is heavily developed on

its upstream end while the lower half contains riparian forest and grass/forb uplands. Interstate 5 and the railroad bisect Hayden Island. Lemon, Sand, McGuire and Government Islands form a large island complex at RM 112 to 117. Government Island is bisected by Interstate 205. These islands contain grass-forb uplands, riparian forest, sloughs, and small lake habitats. Gary and Flagg Islands are riparian forest dominated islands off the Sandy River delta. Reed Island at RM 124 to 127 is comprised of riparian forest and grass-forb upland. Another Sand Island occurs at RM 131 to 132. Riparian forest and a large, erosive sand bluff on the northeast shoreline dominate this island.

Other notable islands in the study area include Puget, Whites and Tenasillahe islands. These islands cover large areas and provide a diverse array of mixed habitat types supporting numerous wildlife species and populations. Tenasillahe Island is notable because it provides complex forested wetlands and oak savannahs which support the federally threatened Columbian white-tailed deer. Other islands support large breeding colonies of waterbirds, including Miller Sands Island and East Sand Island in the estuary near the Mouth of the Columbia River. Several thousand Caspian terns and double-crested cormorants nest at East Sand Island, along with smaller populations of Brandt's cormorants, and ring-billed gulls. Several hundred American white pelicans nest at Miller Sands Island and Rice Island in the lower river.

2.11.3 Wildlife

2.11.3.1 Birds

RAPTORS

Red-tailed hawks and osprey are probably the most abundant nesting raptors in this reach. Osprey are very dependent on the river for foraging and associated riparian and coniferous forest habitats for nest sites. Two bald eagle nests and two peregrine eyries are associated with the area below Bonneville Dam. Wintering bald eagles are also present.

WATERBIRDS, SHOREBIRDS AND WATERFOWL

Wintering waterfowl account for the majority of waterfowl use in this reach. Steigeiwald and Franz National Wildlife Refuges along with the Government Island area represent the major wintering waterfowl sites. The dense stand of wapato at Franz NWR supports 1,000-plus tundra swans at peak periods during the winter.

Nesting by Canada geese along this reach is not as significant as for Bonneville pool or for the Columbia River downstream of Portland. Production of ducks is minor and generally associated with sloughs, ponds and backwater areas.

PASSERINES

The riparian forest supports numerous passerine species including Swainson's thrushes, song sparrows, western wood peewees and robins. Barn, tree, violet-green and cliff swallows are abundant in this reach.

GALLINACEOUS BIRDS

Gallinaceous and Columbine birds, or ground feeding birds, in the study area include several species of grouse, wild turkey, ring-necked pheasant , Eurasian collared dove, mourning dove, Hungarian partridge, California quail, and band-tailed pigeon. Agricultural lands near the rivers support ring-necked pheasants and mourning doves. Gallinaceous birds eat a variety of seeds, agricultural grasses (i.e wheat, oats, and corn) and insects. The pheasant and quail are found most commonly near agricultural lands. Chukars use a wide variety of habitats including riversides, shrublands, talus areas and uplands.

2.11.3.2 Mammals

TERRESTRIAL

The array of mammals present along this reach of the Columbia River is typical for western Oregon and Washington, including mule deer, mountain lion, coyote, racoon, striped skunks, squirrels, and fox are abundant. Tabor (1976) recorded 16 species of small mammals along this reach of the Columbia River. He noted that riparian habitat - specifically ash/cottonwood/ willow - had the highest diversity of small mammals. Deer mice, vagrant shrew, and Townsend's vole are the most abundant small mammal in his study for this reach.

AQUATIC

River otters and beaver are present where suitable habitat occurs, primarily near island habitats and where wetlands occur along the shorelines. Muskrat would be expected to occur in backwaters, sloughs and ponded areas which support emergent marsh habitat.

2.11.3.3 Reptiles and Amphibians

Amphibian and reptiles occur where suitable habitat exists, which differs substantial throughout Bonneville study area. Western painted turtles occur in Columbia Slough, a former attached side channel of the Columbia River in the Portland area of this reach.

2.11.3.4 Invertebrates

Invertebrates found in the study are are those common to the overall CRSO study area.

CHAPTER 3 - SPECIAL STATUS SPECIES

The following list of threatened, endangered, and sensitive species are species that are listed or candidates for listing under the Endangered Species Act (ESA) of 1973, as amended, and/or protected under the Marine Mammal Protection Act (MMPA) of 1972, as amended and includes species that may occur within the study area or be impacted by any of the alternatives (Table 3-1). The USFWS ECOS database and USFWS Field Office website's were accessed to determine if species should be considered given their range and habitat where they are known to occur.

Table 3-1. Candidate (C), Endangered (E), and Threatened (T) Species located within the Vicinity of the Study Area.

Species, Critical Habitat, and Status				State			
Species	**ESA Status**	**Critical Habitat**	**MMPA**	**ID**	**MT**	**OR**	**WA**
Mammals							
Canada lynx	T	Y	N	X	X	X	X
Gray wolf	E	N	N				X
Grizzly Bear	T	N	N	X	X		X
Pygmy rabbit	E	N	N				X
Columbia White Tailed Deer	T	N	N			X	X
Red Tree Vole	C	N/A	N			X	
Northern Idaho Ground Squirrel							
Selkirk Mountain Woodland carabou							
Birds							
Marbled murrelet	T	Y	N			X	X
Northern spotted owl	T	Y	N			X	X
Short-tailed albatross	E	N	N			X	X
Streaked-horned lark	T	N	N			X	X
Western snowy plover	T	Y	N			X	X
Western Yellow-billed cuckoo	T	N	N	X	X	X	X
Amphibians							
Oregon spotted frog	T	Y	N			X	
Plants							
Ute ladies' tresses	T	N	N	X	X		X
Water howelia	T	N	N	X		X	X
Nelson's checker-mallow	T	N	N			X	X
Spalding's Catchfly	T	N	N	X	X	X	X
Macfarlane's four o'clock							
White bluffs bladderpod	T	Y	N				X

Species, Critical Habitat, and Status				State			
Species	**ESA Status**	**Critical Habitat**	**MMPA**	**ID**	**MT**	**OR**	**WA**
Marine Mammals							
Southern resident killer whales DPS	E	Y	Y			X	X
California sea lion	N	N	Y			X	X
Stellar sea lion	N	N	Y			X	X

C: Candidate
E: Endangered
T: Threatened

3.1 CANADA LYNX

The lynx is a medium-sized cat with long legs, large, well-furred paws, long tufts on the ears, and a short, black-tipped tail. The Canada lynx has long legs and large feet make it highly adapted for hunting in deep snow. The distribution of lynx in North America is closely associated with the distribution of North American boreal forest. Critical habitat for the contiguous United States DPS of the Canada lynx was revised on September 12, 2014 (79 FR 54781). Critical habitat surrounds the western and eastern shores of Lake Koocanusa and extends south from the U.S. – Canada border to the Kootenai River near the town of Troy, Montana. Critical habitat encompasses the Hungry Horse project area including the Hungry Horse Reservoir, the North and South Fork of the Flathead River, and Flathead Lake.

The distribution and population cycles of lynx are strongly associated with their primary prey, the snowshoe hare. Landscapes with high prey densities consist of moist, cool boreal spruce-fir forests. Hares are most abundant in young regenerating or mature multi-storied forests with dense understory vegetation that provides food and cover from predators. In the contiguous U.S., boreal forest habitat is patchy and fragmented. Lynx incorporate these small fragments into their home ranges and use them for traveling between expansive northern forests in Canada with dense snowshoe hare populations. Lynx are highly mobile and disperse in times of low prey availability, often over 60 miles within their home ranges which have been reported as large as 83 square miles (USFWS 2014a). Lynx populations generally occur where continuous snow cover lasts four months or longer. This dynamic habitat is present in higher elevations forests within the Northern Rockies Ecoregion.

3.2 GRAY WOLF

Wolves are listed as endangered in parts of western Oregon and western Washington (https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=A00D, accessed on November 12, 2018), but have been recovered and delisted in Idaho, Montana, and some counties in eastern Oregon and eastern Washington. A keystone predator and habitat generalist, gray wolves utilize a broad spectrum of habitats with three key components: 1) sufficient, year-round prey base of ungulates and secondary prey; 2) suitable and secluded denning sites; and 3) sufficient space with minimal exposure to humans. Wolf den and rendezvous sites can be characterized by having adjacent forested cover and distant from human activity (USFWS 1987).

On May 5, 2011, the Northern Rocky Mountain (NRM) DPS gray wolf population was delisted from ESA protection and management reverted to the state plans (76 FR 25590). The NRM DPS gray wolf population met its biological recovery goals first in 2002, when wolves began dispersing freely between Wyoming, Montana, and Idaho into Canada and Alaska (MFWP 2018, IDFG 2017)). Wolves in Montana and Idaho are not federally listed or protected by federal ESA. The eastern side of Washington and Oregon in within the range for the NRM DPS population, while the western and central parts of the state contain wolves that are fully protected by ESA (43 FR 9607).

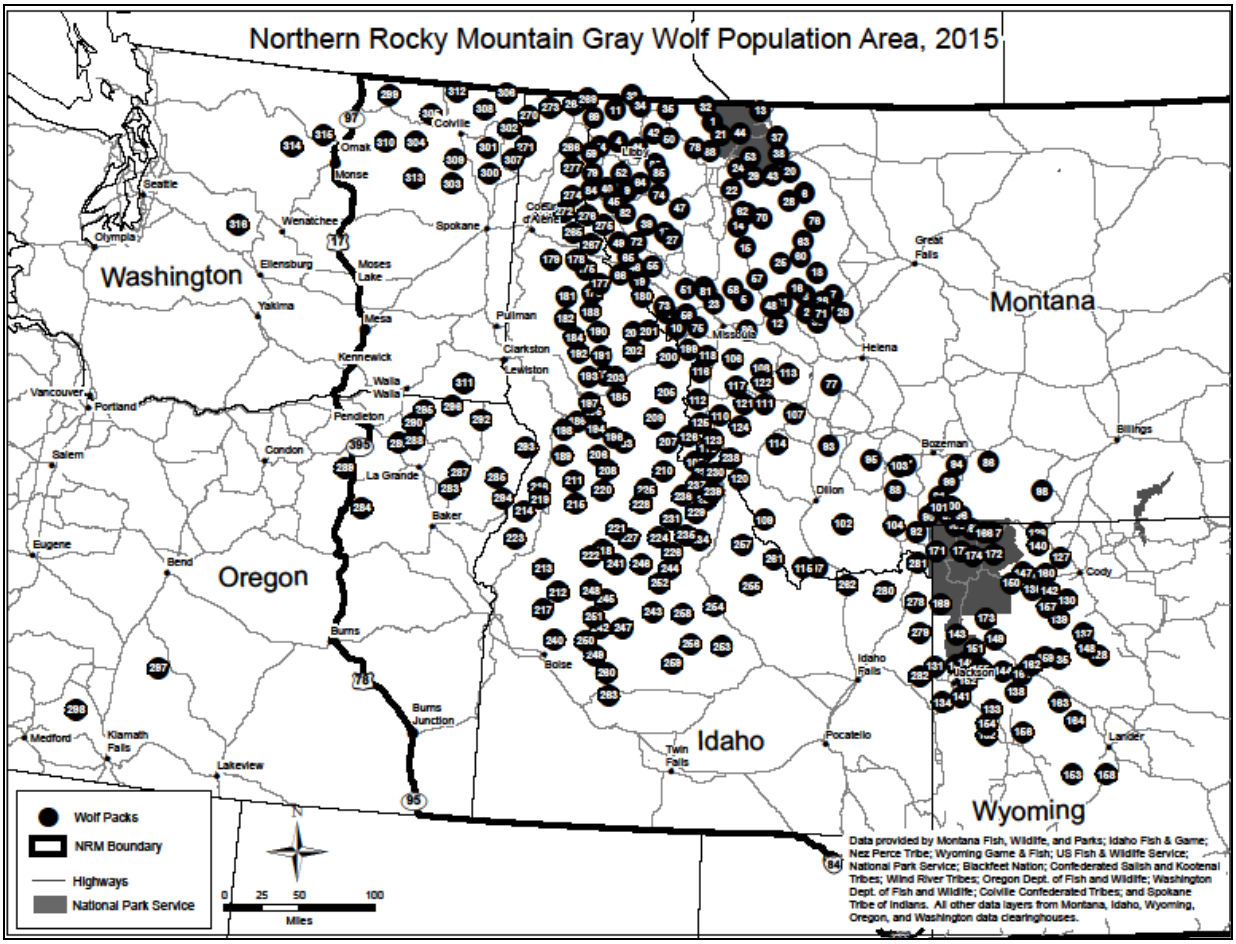

Figure 3-1. Northern Rocky Mountain Gray Wolf Population in Washington, Oregon, Montana, Idaho and Wyoming.

Despite the vast majority of wolves occurring in the delisted zones of Washington and Oregon, a handful of wolf pack and groups are living in the endangered zone near the Columbia and Snake Rivers (Figure 3-1). In 2017 in Washington alone it was recorded that wolf 48f of the Dirty Shirt Pack dispersed 300 miles in eight days. A wolf of the Smackout pack, 65m, traveled a minimum of 1,700 miles from December 2016 and spring of 2017 entering into Yellowstone National Park. A female wolf, 71f, of the Loup Loup pack (near Chief Joseph Dam) dispersed 542 miles from April to July 2017 (WDFW 2018). The wide range of habitats in which wolves can thrive reflects their adaptability as a species and in the study area includes temperate forests,

mountains, and sage-brush steppe. Gray wolves have been known to follow ungulate herds (like deer and elk) from their lowland wintering grounds to their high summer pastures.

3.3 GRIZZLY BEAR

The grizzly bear is listed as threatened throughout the conterminous States, except where listed as an experimental population or delisted. The Bitterroot Ecosystem Recovery Zone Population is an experimental population (65 FR 69624) and the Greater Yellowstone Ecosystem DPS has been delisted due to recovery (40 FR 31734). However, there are several other ecosystems that the grizzly bear occupies in Washington, Idaho and Montana. The current range for grizzly bears overlaps with areas in the Columbia River study area in Montana near Libby and Hungry Horse reservoirs, in Idaho near Orofino and Dworshak Dam (the experimental population), and in Washington near Wenatchee. Habitat use within the Columbia River Basin is varied throughout the year and may include open-canopied upland forests, meadows, riparian and riverine areas, and shrub lands.

The Northern Cascades Ecosystem (NCE) in north-central Washington and south-central British Columbia is the most at-risk population in the U.S. today. The recovery zone encompasses 9,800 square miles and includes all of the North Cascades National Park, and most of the Mount Baker-Snoqualmie, Wenatchee and Okanogan National Forests (USFWS 1997). Despite the NCE being the largest ecosystem also encompassing an additional 3,800 square miles across the international border and providing rugged, remote habitat, the population in Washington is estimated to be fewer than 20 animals. The population is under review to determine a potential up-listing from threatened to endangered status. The eastern border of the NCE parallels State Route 20 and nearly reaches Chief Joseph Dam.

The Northern Continental Divide Ecosystem (NCDE) in northwestern Montana includes Glacier National Park and adjacent areas in Canada, and the Bob Marshall Wilderness Complex, including the Flathead, Kootenai, Helena-Lewis and Clark, and Lolo National Forests contained within 8,900 square miles. This population has approximately 1,000 animals and continues to grow. This ecosystem encompasses the Hungry Horse Dam study area including the Hungry Horse Reservoir and all forks of the Flathead River.

The Cabinet-Yaak Ecosystem (CYE) is located in northern Idaho and northwest Montana with an estimated 50 grizzly bears. The CYE is bisected by the Kootenai River, with the Cabinet Mountains to the south and the Yaak River area to the north. Most of the 2,600 square miles are within the Kootenai and Panhandle National Forests (USFWS 2017).

3.4 COLUMBIA BASIN PYGMY RABBIT

Columbia Basin pygmy rabbits occur in the Columbia Plateau Ecoregion consistent with semiarid shrub steppe habitat and adjacent intermountain regions of the west. Pygmy rabbits are highly dependent upon tall, dense stands of sagebrush (*Artemisia* spp.) for food and shelter. As one of only two native rabbit species in North America that digs its own burrows, pygmy rabbits are generally found in areas of deep, loose soils associated with sagebrush.

Historically, dense vegetation along permanent and intermittent stream channels, alluvial fans, and sagebrush plains provided travel corridors and dispersal habitats for the rabbits. Farming practices on the shrub steppe have provided man-made areas of dense vegetation including fence rows and abandoned fields which may also provide dispersal habitat between local populations. The majority of pygmy rabbit habitats is considered the big sagebrush (*Artemisia tridentate*) – bluebunch wheatgrass (*Agropyron spicatum*) zonal habitat type. The less dominant habitat types includes the threetip sagebrush (*Artemisia tripartite*) – Idaho fescue (*Festruca idahoensis*) zone (USFWS 2012).

Columbia Basin pygmy rabbit may occupy sagebrush dominated land due south of Grand Coulee and Chief Joseph Dam towards the confluence of the Snake River into the Columbia River. Federal lands which contain suitable habitat include the Hanford Reach National Monument and Saddle Mountain National Wildlife Refuge near Mattawa, WA, both of which are adjacent to the Columbia River. They are known to occur, or may occur, in Adams, Benton, Douglas, Franklin, Grant and Lincoln counties in Washington.

3.5 COLUMBIA WHITE-TAILED DEER

The Columbia River DPS Columbia white-tailed deer (CWTD) has maintained its threatened status since listing in March 11, 1967 (32 FR 4001). The Columbia River population occurs along the lower Columbia River in Oregon and Washington from Wallace Island RM 50 downstream to Karlson Island RM 32. There are four main subpopulations (Washington mainland, Tenasillahe Island, Puget Island, Wallace Island-Westport) of CWTD and one minor one (Karlson Island) that are geographically separated by a main river channel or patches of unfavorable habitat. Julia Butler Hansen National Wildlife Refuge, located in the estuary, was established by USFWS for the recovery and maintenance of the CWTD.

These islands and bottomlands within an 18-mile stretch of the lower Columbia contain most of the CWTD range. The white-tailed deer are restricted to the flatlands which have an elevation of about 3 meters above sea level. Vegetation cover preferred by CWTD includes forested communities with plant heights reaching at least two feet. Studies completed in the seventies identified the primary plant communities used by CWTD as park-forest, open canopy forest, sparse rush, and dense thistle (Suring 1974), and some subpopulations used “tidal spruce” communities (Davison 1979).

While degradation of riparian habitat from logging and brush removal remains the largest threat to CWTD, flooding of the lowlands also poses a threat to their survival. Some islands in the lower Columbia River remain undiked and high water restricts woody vegetation survival, therefore decreasing available white-tailed deer habitat. High water can also lead to disease and rot killing the open canopy trees and reducing cover and forage available (USFWS 1976).

3.6 RED TREE VOLE

The red tree vole is a candidate for listing under the ESA. It is a small, endemic vole native to the humid coniferous forests in western Oregon. The red tree vole occurs in western Oregon

from the Cascade crest to the Pacific coast, with a geographic range covering approximately 16.3 million acres across multiple land ownerships (https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=A0J3, accessed on November 13, 2018).

3.7 NORTHERN IDAHO GROUND SQUIRREL

Northern Idaho ground squirrel was listed in April 2000 under the Endangered Species Act as a threatened species. They occuy dry mountain meadoes, such as open areas of grasses and forbs surrounded by ponderosa pine (Pinus ponderosa) or Douglas-fir (Pseuduotsuga menziesii) forest. Unitl 2005, all known Northern Idaho ground squirrel sites were within the elevation range of 3,400 to 5,000 feet. Since then, Northern Idaho ground squirrels have been discovered at higher elevations, including Lick Creek Lookout and Smith Moutnain Lookout at 7,500 feet (Evans Mack 2006).

Populations of this subspecies can only be found in Adams and Valleu Counties of western Idaho. It is estimate that the population has declined by 80% from initial surveys conducted in 1985. Important travel corridor has been fragmented, leaving the gound squirrels to survive in isolated islands of non-connected habitat. As of 2011, recovery status remained unclear, through range wide monitoring shows the opuopulations are stable to slightly increing ove time. Biologists have recorded several new puplation sites, and the animal seems to be responding positively to habiat restoration at certain locations, especially on the Payette National forest (IDFG 2008)

3.8 SELKIRK MOUNTAIN WOODLAND CARIBOU

Selkirk Mountains Wood Caribou were listed under the Endangered Species Act as endangered in 1983 and are proposed to be delisted. The population is generally found aboce approximately 4,000 feet elevation in the Selkirk Mountains. Habitat consists of Englemann spruce/subalpine fir and western red cedar/western hemlock forest types. The population is threatened by habitat fragmentation and loss, predation, and disease.

Historically, the population consisted of approximately 100 animals. However, by the early 1980s this population had dwindled to 25 to 30 individuals whos distribution centered around Stagleap Provincial park, Britsh Columbia. Recovery area for caribou in the Selkirk Mountains is comprised of approximately 5,700 km2 in northern Idaho, notrteaster Washingt, and southern B.C.

3.9 MARBLED MURRELET

The marbled murrelet is a small chubby seabird that has a very short neck that inhabits western Oregon and Washington. It was listed as threatened in 1992 and critical habitat extends from the western slopes of the Cascade Mountains in northwest Washington to the Puget Sound and the Pacific Ocean and from the coast range west to the Pacific Ocean in western Oregon.. Marbled murrelets use forests that primarily include typical old-growth forests (characterized by large trees, a multistoried stand, and moderate to high canopy closure), but also use mature

forests with an old-growth component (USFWS 1997b) Because marbled murrelets feed primarily on fish and invertebrates in nearshore marine waters, they require nearshore marine habitats with sufficient prey resources (USFWS 1997b).

3.10 NORTHERN SPOTTED OWL

The northern spotted owl is a medium-sized, dark brown owl with a barred tail, white spots on the head and breast, and dark brown eyes surrounded by prominent facial disks. Scientific research and monitoring indicate spotted owls generally rely on mature and old-growth forests because these habitats contain the structures and characteristics required for nesting, roosting, and foraging (USFWS 2011). Although spotted owls can disperse through highly fragmented forested areas, the stand-level and landscape-level attributes of forests needed to facilitate successful dispersal have not been thoroughly evaluated or described (USFWS 2011).

3.11 SHORT-TAILED ALBATROSS

Short-tailed albatross are pelagic seabirds that was federally listed as endangered throughout its range, including the United States, on July 31, 2000 (65 FR 147:46643-46654). In 2014, USFWS estimated the total population of short-tailed albatross to approximate 4,350 individuals, of which approximately 1,900 breeding-age birds nest on remote islands in the western Pacific near Japan and Taiwan (USFWS 2014b). Like all albatross species, short-tailed albatross forage at sea where they are frequent visitors to territorial waters of U.S. and productive foraging areas in the Gulf of Alaska, the Aleutian Islands and the Bering Sea, as well as marine waters around Hawaii. Within the Columbia River study area, both Clatsop County in Oregon and Pacific County in Washington are considered part of the species' marine range, but it is unknown to what extent the birds use open ocean areas of the North Pacific Ocean near northern California, Oregon, and Washington. There have been few confirmed sightings of short-tailed albatross off the Oregon Coast. The closest sighting to the study area occurred 20 miles southwest of the Mouth of the Columbia River (Marshall et al., 2003).

3.12 STREAKED HORNED LARK

The streaked horned lark was listed as threatened in October 2013. The streaked horned lark is endemic to the Pacific Northwest and is a subspecies of the wide-ranging horned lark. Streaked horned larks are small, ground-dwelling birds, approximately 16−20 centimeters (6−8 inches) in length. The combination of small size, dark brown back, and yellow on the underparts distinguishes this subspecies from all adjacent forms. The current range of the streaked horned lark can be divided in to three regions: (1) the Puget lowlands in Washington, (2) the Washington coast and lower Columbia River islands (including dredge spoil deposition sites near the Columbia River in Portland, Oregon), and (3) the Willamette Valley in Oregon (https://www.fws.gov/oregonfwo/articles.cfm?id=149489450, accessed on November 12, 2018).

Horned larks are birds of wide open spaces with no trees and few or no shrubs. They nest in the ground in sparsely vegetated sites. They utilize prairies, coastal dunes, sandy beaches, and

grasslands. The habitat adjacent to the Columbia River from Corbet, Oregon west is designated critical habitat.

3.13 WESTERN SNOWY PLOVER

The western snowy plover was listed as threatened in March 1993. It is a small shorebird (about 6 inches long) that nest adjacent to tidal waters along the Pacific Coast from Washington to Mexico (https://www.fws.gov/arcata/es/birds/wsp/plover.html, accessed on November 12, 2018). The western snowy plover winters mainly in coastal areas from southern Washington to Central America.

The Pacific coast population of the western snowy plover breeds primarily above the high tide line on coastal beaches, sand spits, dune-backed beaches, sparsely-vegetated dunes, beaches at creek and river mouths, and salt pans at lagoons and estuaries (USFWS 2007). Less common nesting habitats include bluff-backed beaches, dredged material disposal sites, salt pond levees, dry salt ponds, and river bars (USFWS 2007). In winter, western snowy plovers are found on many of the beaches used for nesting as well as on beaches where they do not nest, in man-made salt ponds, and on estuarine sand and mud flats (USFWS 2007). Within the Columbia River study area, the Pacific Coast population of Western snowy plovers are known to occur on coastal beaches near the mouth of the Columbia River. While Western snowy plovers historically nested in the vicinity of Clatsop Spit in Clatsop County, Oregon, no nests were detected in 2012 even though two individuals were observed near Clatsop Spit (Lauten et al. 2016). A small population of Western snowy plovers occurs on beaches at Leadbetter Point, in Pacific County, Washington, which is outside of the study area; in Oregon, Western snowy plovers nest at Bayocean Spit in Tillamook County, which is also outside of the study area. Although snowy plovers are not currently nesting in the study area, the Oregon Parks and Recreation Department (OPRD) has identified Clatsop Spit in its 2010 Habitat Conservation Plan for the species, which is the western-most portion of the study area (ICF 2010).

3.14 WESTERN YELLOW BILLED CUCKOO

Yellow Billed Cuckoo was listed as threatened in November 2014. While critical habitat has been proposed by the USFWS, no portion of the study area was identified for designation. However, suitable habitat for yellow-billed cuckoos occurs throughout the Columbia River Basin where large remnant stands of forested wetland habitat occurs near Flathead Lake and along the Columbia and Snake Rivers in Washington state. Yellow-billed Cuckoos breed throughout much of the eastern and central U.S., winter almost entirely in South America east of the Andes, and migrate through Central America (https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=B06R#lifeHistory, accessed on November 12, 2018). *Western yellow-billed cuckoos require large contiguous stands of riparian vegetation with optimal home ranges of 200+ acres, of widths of 2000 feet (USFWS 2013).*

Yellow-billed Cuckoos use wooded habitat with dense cover and water nearby, including woodlands with low, scrubby, vegetation, overgrown orchards, abandoned farmland, and dense thickets along streams and marshes. In the western United States cuckoos nests are

often placed in willows along streams and rivers, with nearby cottonwoods serving as foraging sites (https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=B06R#lifeHistory, accessed on November 12, 2018).

3.15 OREGON SPOTTED FROG

Oregon spotted frog was listed as threatened in September 2014. Critical habitat has been designated in Washington and Oregon but the study area does not overlap with critical habitat. Spotted frogs may occur near the confluence of the Washougal and Columbia rivers near Camas, Washington. This species is the most aquatic native frog in the Pacific Northwest. It is almost always found in or near a perennial body of water that includes zones of shallow water and abundant emergent or floating aquatic plants (https://www.fws.gov/oregonfwo/articles.cfm?id=149489458, accessed on November 12, 2018). Large concentrations of Oregon spotted frogs have been found in areas with the following characteristics: (1) the presence of good breeding and overwintering sites connected by year-round water; (2) reliable water levels that maintain depth throughout the period between oviposition and metamorphosis; and (3) the absence of introduced predators, especially warm-water game fish and bullfrogs (https://www.fws.gov/oregonfwo/articles.cfm?id=149489458, accessed on November 12, 2018).

In Oregon, this frog species is only known to occur in Wasco, Deschutes, Klamath, Jackson and Lane counties, although historically they were also found in Multnomah, Clackamas, Marion, Linn, and Benton, counties. In Washington, the frogs currently occur in Whatcom, Skagit, Thurston, Skamania and Klickitat counties.

3.16 UTE LADIES'-TRESSES

A proposal to list Ute ladies'-tresses as threatened was filed with USFWS in November 1990 (55 FR 47347), and the species was listed as threatened in January 1992 (57 FR 2048). No critical habitat is designated for the species and although a revocery plan was prepared, it was never finalized (USFWS 1995). The species usually occurs in small scattered groups and occupies relatively small areas iwhtin the riparian systems. Early to mid-seral riparian habitats created and maintained by stream activity within the floodplain appear to be essential to the orchid. Flowering is generally from mid-July through August; however, based on location it might flower slightly earlier or later.

The primary threats to Ute ladies'-tresses are competition from exotic weeds, vegetation succession, habitat loss through development and modification, mowing during flowering, grazing by livetock, over collection, and vulnerability to stochastic events due to a slow reproductive rate and scattered distribution of populations (57 FR 2048). Additional threats include loss of pollinators, natural herbivory, and changes in hydrology and conflicting management iwht other rare species (Fertig et al. 2005).

Potentially suitable habitat occurs on stabilized gravel bars and/or shoreline areas along the Columbia Rivers that are mosit thorugout the growing season and inundated early in the

growing season. While the species has a wide range across the western United States; within the action area, the plant is currently documented in Washington State, occurring along the Rocky Reach Reservior on gravel bars adjacent ot the Columbia River in Chelan County, Washington (Fertig et al. 2005).

Natural flooding cycles are important for creating new alluvial habitat and for reducing cover of competing plant species for Ute's ladies' tresses throughout their range, including along the Columbia River (Fertig et al. 2005). While discharge from Chief Joseph Dam obviously inflences downstream flows, the water surface elevation in Rocky Reach reseriovr is primarily controlled by the operation of Rocky Reach Dam, which is owned and managed by Chelan County Public Utility District.

3.17 WATER HOWELLIA

Water howellia was listed as threatened in July 1994. It is a winter annual aquatic plants that grows 4 to 24 inches high. The plant grows in areas that were once associated with glacial potholes and former river oxbows that flood in the spring, but usually at least partially dry in late summer (https://www.fws.gov/mountain-prairie/es/uteLadiestress.php, accessed on November 13, 2018). It is associated with deciduous trees such as black cottonwood and aspen. The range that overlaps with the study area includes portions of Clark County in Washington and Columbia and Multnomah counties in Oregon.

3.18 NELSON'S CHECKER-MALLOW

Nelson's checker-mallow was listed as threatened in 1993. Critical habitat has not been designated. The range includes counties that overlap with the study area including Clatsop, Columbia, and Multnomah counties in Oregon, and Cowlitz County in Washington. Nelson's checker-mallow is a perennial herb in the mallow family (Malvaceae). It has tall, lavender to deep pink flowers. The plant can reproduce vegetatively, by rhizomes, and by seeds, which drop near the parent plant (https://www.fws.gov/oregonfwo/Species/Data/NelsonsCheckerMallow/, accessed on November 13, 2018).

The majority of sites where the species occurs is in the Willamette Valley of Oregon; the plant is also found at several sites in the Coast Range of Oregon and at two sites in the Puget Trough of southwestern Washington (https://www.fws.gov/oregonfwo/Species/Data/Nelsons CheckerMallow/, accessed on November 13, 2018). Thus, the range of the plant extends from southern Benton County, Oregon, north to Cowlitz County, Washington, and from central Linn County, Oregon, west to the crest of the Coast Range (https://www.fws.gov/oregonfwo/ Species/Data/NelsonsCheckerMallow/, accessed on November 13, 2018). The species is known to occur in 62 patches within 5 relict population centers in Oregon, and at 2 sites in Washington (https://www.fws.gov/oregonfwo/Species/Data/NelsonsCheckerMallow/, accessed on November 13, 2018).

3.19 SPALDING'S CATCHFLY

Spalding's Catchfly was listed as threatened in October 2001. Critical habitat has not been designated. It is found in Idaho, Montana, Oregon and Washington, primarily in grasslands, but may also be found in sagebrush step and coniferous forests. Its flowers, which bloom July-September, are light green, and lance-shaped. Its leaves and flowers are very sticky. The plant height ranges from 8-24 inches but can grow to three feet. (www.fws.gov/pacific/news/2006/Silene_drft.pdf, accessed on November 30, 2018).

3.20 MACFARLANE'S FOUR-O'CLOCK

Macfarlane's four o'clock was listed as endangered on November 29, 1979. At that time only three pouplations were known, with a total of 20 to 25 individual plants. Ti was downlisted to threatened on March 15, 1996 (61 FR 52) when additional populations were discovered in the Hell's Canyon Recreational Area. USFWS completed the recovery plan in 2000. No critical habitat has been designated.

Macfarlane's four o'clock is only found in northeast Oregon and Northern Idaho. Populations have been found downstream of the Hells Canyon dam and a few sites in the Imnah River and Salmon River Bbasins (61 FR 52). Its habitat is steep river canyon grassland habitats composed of gravelly to loamy and sandy substrates that are characterized by regionally warm and dry conditions. It prefers steep, sunny slope ranging form 1,000 to 3,000 feet in elevation and will grow on rockslides, canyon walls, and sandy to gravelly talus slopes.

Actions that are known to affect this species include instream flow regulation, conversion of native plant communities to agricultural, ranching, or residential use, trespass grazing, and construction, maintiennace, and traffic on roads and trails.

3.21 WHITE BLUFFS BLADDERPOD

White bluffs bladderpod was listed as threatened in May 2013. White Bluffs bladderpod occurs in a single population in a 33 foot wide, 10.6 mile long band along the top of the White Bluffs of the Columbia River, and appears to be restricted to the weathered alkaline paeosols and mixed soils overlying the Ringold Formation. The species habitat is along the top of the bluffs and does not interact with or toerhwise exposed to water management activities associated with the management of the CRS. Southern Resident Killer Whale DPS

The Southern Resident killer whale (SRKW) DPS is a single population totaling 75 individuals as of July 2018 (https://www.whaleresearch.com/orca-population, accessed on November 12, 2018). The population ranges from central California to Southeast Alaska. During the period from July to September, the DPS inhabit the Salish Sea and the waters near the entrance of the Strait of Juan de Fuca. Winter habitat frequently includes the Washington coast and less often the coastal waters of Central California (NMFS 2014). There is no critical habitat designated within the Columbia River study area; however, National Marine Fisheries Service (NMFS) is

presently working through the process of determining whether or not including Pacific Ocean marine water along the West Coast is appropriate for the southern resident DPS.

NMFS has analyzed Chinook salmon stocks based on their estimated importance to the whales and found that the most crucial stocks are those returning to the Fraser River in British Columbia, other rivers draining into Puget Sound and the Salish Sea, and the Columbia, Snake, Klamath, and Sacramento rivers. NMFS' analysis showed that Puget Sound Chinook salmon stocks are one of the most important salmon stocks for Southern Resident killer whales since, the whales have access to them for a greater part of the year than fish from the Columbia, Snake, and Fraser rivers. In the Columbia River basin, different stocks vary in overall importance for the diet of SRKW. For example, Snake River spring-summer Chinook salmon are mainly available to SRKW when the fish gather off the mouth of the Columbia, whereas Snake River fall Chinook remain closer to the coast and would be available for a longer period before migrating upriver in the fall. (NMFS and WDFW 2018; NMFS 2014; NMFS 2018).At times or locations of low Chinook abundance, whales also select other species such as chum salmon, smaller salmonids, or other non-salmonid prey (herring or rockfish).

3.22 STELLER SEA LION

The Eastern Distinct Population Segment (DPS) of the Steller sea lion occurs along the West Coast between Washington and California. Steller sea lions are the largest member of the family Otariidae, the "eared seals". Steller sea lions are opportunistic predators, foraging and feeding near shore and in open waters on a wide variety of fishes and cephalopods (NOAA 2014). The Steller sea lions was previously listed under the ESA and the eastern DPS was delisted in 2014 because it had met its recovery goals (NOAA 2013). In 2010, NMFS' status assessment estimated the population included approximately 70,000 individuals and had maintained a positive growth rate for several years; the western DPS (Steller sea lions born west of Cape Suckling, Alaska at 144º west longitude) is still listed as endangered under the ESA (NOAA 2013). The eastern DPS is still protected under the MMPA in all areas where individuals occur.

In the Columbia River, Steller sea lions use the South Jetty on the Oregon shore at the Mouth of the Columbia River as a haul out area, but no reproductive activity has been documented there; Steller sea lions have not been observed using the North Jetty on the Washington shore as a haul out area. The closest breeding rookery to the Columbia River is on the coast of southern Oregon at Rogue Reef. Use of the South Jetty by Steller sea lions occurs year round, but is heaviest from April through October when as many as 200-300 individuals can be present. Steller sea lions typically forage at river mouths and coastal nearshore areas, however some individuals are regularly observed foraging on white sturgeon and migrating adult salmon as far as upstream as Bonneville Dam on the Columbia River and Willamette Falls on the Willamette River. Between 2002 and 2017, the number of Steller sea lions foraging at Bonneville dam has increased from 0 individuals in 2002 to a high of approximately 69 in 2015 (Tidwell 2017).

3.23 CALIFORNIA SEA LION

Like Steller sea lions, California sea lions are "eared seals" native to the West Coast of North America where they live in coastal waters and on beaches, docks, buoys, and jetties. California sea lions are distributed from the southern tip of Baja California to southeast Alaska, where they are protected under the Marine Mammal Protection Act in all areas. California sea lions breed in rookeries in southern California and Baja California and individuals move north after the breeding season to forage in productive nearshore areas along the Pacific Coast. In 2007, the minimum population estimate for California sea lions was estimated to include approximately 150,000 individuals and the population has experienced a positive growth rate since the 1970s (NOAA 2015b). The primary diet of California sea lions consists of a variety of fish and shellfish, including salmon, steelhead, Pacific whiting, herring, mackerel, eulachon, lamprey, codfish, walleye Pollock, spiny dogfish and squid.

In the Columbia River, California sea lions can be found on the South Jetty, piers and docks in Astoria, Oregon. Since the mid-1980s, increasing numbers of California sea lions have been observed foraging on white sturgeon and migrating adult salmon at Bonneville Dam, 146 miles from the mouth of the river. Scat samples collected in coastal waters and in the Columbia River estuary indicate that salmon comprise 10-30% of the animals' diet (ODFW 2017). Between 2002 and 2017, the number of individual California sea lions observed foraging at Bonneville dam has increased from 30 animals in 2002 to a high of 195 in 2015 (Tidwell 2017).

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Columbia River System Operations
Environmental Impact Statement

Appendix G
Air Quality and Greenhouse Gases

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The following appendix contains four sections related to the evaluation of air quality and Greenhouse Gas (GHG) for the Columbia River Systems Operations (CRSO) EIS. Chapter 1 provides information regarding pollutant emissions management in the Pacific Northwest. Chapter 2 provides a detailed evaluation of methane emissions related to hydroelectric project reservoirs. Chapter 3 describes society's willingness to pay to avoid climate-related impacts associated with an additional unit of a GHG in the atmosphere, also known as the Social Cost of Carbon (SCC). Chapter 4 describes regional haze, Class I Areas and wind speed trends. Chapter 5 evaluates the Columbia River Basin as a source of emissions of methane to the atmosphere.

CHAPTER 1 - AIR QUALITY STANDARDS AND GREENHOUSE GAS TARGETS

Table 1-1 characterizes the human health and environmental concerns related to each of the six criteria pollutants.

Table 1-1. Criteria Air Pollutants: Adverse Health and Environmental Effects

Pollutant	Description and Sources	Health and Environmental Effects
Carbon Monoxide (CO)	CO is formed by the incomplete combustion of fossil fuels and by atmospheric photochemical reactions. CO emissions primarily come from incomplete combustion in mobile sources.	CO exposure reduces blood's ability to carry oxygen to body tissues (hypoxia). Reduced oxygen availability can cause cardiovascular events; exposure is especially dangerous for people with impaired cardiovascular systems. CO exposure may adversely affect other key body functions.
Lead (Pb)	Lead is primarily emitted from industrial processes such as iron and steel processing and from combustion of leaded aviation gasoline.	Lead exposure has neurotoxic effects, especially in young children. Multiple studies show an inverse relationship between blood lead levels and children's IQ even at low blood lead levels. Lead contaminates surface soils and harms plants and other organisms.
Nitrogen Dioxide (NO_2)	NO_2 is primarily emitted from combustion processes such as electric utility fuel combustion and industrial fuel combustion as well as from highway and off-highway vehicles.	NO_2 exposure can cause respiratory symptoms including airway inflammation and decreased lung function. Ecologically, NO_2 deposition results in acidification, excess nutrient enrichment, low dissolved oxygen, harmful algal blooms, and loss of aquatic vegetation. NO_2 also degrades visibility.
Ozone (O_3)	Ground-level ozone is formed through reactions of volatile organic compounds (VOCs) with pollutants such as nitrogen oxides (NO_x) and CO in the presence of sunlight.	Ozone exposure is associated with respiratory symptoms such as asthma exacerbation. Ozone is also harmful to plants, causing cellular damage and plant death. Ozone directly contributes to global climate change.
Particle Pollution $PM_{2.5}$-PM_{10}[1]	Primary PM is directly emitted from sources, such as vehicles and construction sites. Secondary PM is formed from chemical reactions with gases (e.g. organic carbon, sulfates) emitted from power plants, industrial facilities, and vehicles.	Exposure to $PM_{2.5}$ can cause respiratory symptoms such as asthma exacerbation, as well as cardiovascular events. Environmental effects include visibility impairment and deposition of particulate matter which can result in toxic pollutants accumulating in organisms and ecosystems via vegetation, soils, and surface water.
Sulfur Dioxide (SO_2)	SO_2 is primarily emitted from fossil fuel combustion at electric utilities and other industrial facilities. Other sources of emissions include large ships, non-road diesel equipment that burns sulfur-containing fuels, and wildfires in the Pacific Northwest.	SO_2 exposure causes adverse respiratory effects such as bronchoconstriction and decreased lung function. Asthmatics in particular are sensitive to SO_2 exposure. SO_2 deposition on ecosystems results in acidification, excess nutrient enrichment, and increased mercury methylation and ultimate mercury contamination. SO_2 also degrades visibility.

Note: 1PM2.5 includes particles with an aerodynamic diameter less than or equal to 2.5 microns, and PM10 includes particles with an aerodynamic diameter less than or equal to 10 microns.
Sources: CO: USEPA 2010a Pb: USEPA 2006; USEPA 2008 NO2: USEPA 2010b O3: USEPA 2015 PM: USEPA 2012 SO2: USEPA 2010c

Table 1-2 provides the current National Ambient Air Quality Standards (NAAQS) and state-level ambient air quality standards (AAQS).

Table 1-2. National and State Ambient Air Quality Standards

Pollutant	Primary[1] / Secondary[2]	Averaging Period	NAAQS	OR AAQS	WA AAQS	ID AAQS	MT AAQS	Notes
Carbon Monoxide (CO)	Primary	1 hour	35 ppm	35 ppm	35 ppm	35 ppm	23 ppm	3
		8 hours	9 ppm	9 ppm	9 ppm	9 ppm	9 ppm	3
Lead (Pb)	Both	Rolling 3-mo. avg.	0.15 µg/m^3	0.15 µg/m^3	0.15 µg/m^3	0.15 µg/m^3	0.15 µg/m^3	5
	--	Quarterly	1.5 µg/m^3	1.5 µg/m^3	--	--	1.5 µg/m^3	6
Nitrogen Dioxide (NO_2)	Primary	1 hour	100 ppb	100 ppb	100 ppb	100 ppb	0.30 ppm	7
	Both	1 year	53 ppb	53 ppb	53 ppb	53 ppb	0.05 ppm	8
Ozone (O_3)	--	1 hour	--	--	--	--	0.10 ppm	4
	Both	8 hours	0.070 ppm	0.075 ppm	0.070 ppm	0.070 ppm	--	9
Particle Pollution $PM_{2.5}$	Primary	1 year	12.0 µg/m^3	12.0 µg/m^3	12.0 µg/m^3	12.0 µg/m^3	--	10
	Secondary	1 year	15.0 µg/m^3	15.0 µg/m^3	--	15.0 µg/m^3	--	10
	Both	24 hours	35 µg/m^3	35 µg/m^3	35 µg/m^3	35 µg/m^3	--	11
Particle Pollution PM_{10}	Both	24 hours	150 µg/m^3	150 µg/m^3	150 µg/m^3	150 µg/m^3	150 µg/m^3	12
	Both	Annual	--	--	--	--	50 µg/m^3	13
Sulfur Dioxide (SO_2)	Primary	1 hour	75 ppb	75 ppb	75 ppb	75 ppb	0.50 ppm	14
	Secondary	3 hours	0.5 ppm	0.5 ppm	0.5 ppm	0.5 ppm	--	3
	Primary	24 hours	0.14 ppm	0.10 ppm	0.14 ppm	0.14 ppm	0.10 ppm	3, 15
	Primary	Annual	0.030 ppm	0.020 ppm	0.020 ppm	0.030 ppm	0.02 ppm	15

Notes:
1- Primary Standards: provide public health protection, including sensitive populations such as asthmatics, children, and the elderly
2-Secondary Standards: provide public welfare protection, including protecting against decreased visibility and damage to animals, crops, vegetation, and buildings
3- Not to be exceeded more than once per year
4- State violation when exceeded more than once over any 12-month period
5- Not to be exceeded
6- Non-attainment areas subject to previous standards
7- 98th percentile of 1-hour daily maximum concentration, averaged over 3 years
8- Annual average
9- Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
10- Annual mean, averaged over 3 years
11- 98th percentile, averaged over 3 years
12- Not to be exceeded more than once per year on average over 3 years
13- State violation when 3-year average exceeded
14- 99th percentile of 1-hour daily maximum concentration, averaged over 3 years
15- Previous SO2 standards in effect for certain areas; no longer applicable for areas in attainment status for 1 year
16- State violation when average over four consecutive quarters exceeds standard
Sources: USEPA 2016; USEPA 2018 (SIPS); MT DEQ 2007.

Table 1-3 lists GHG emissions reductions targets for identified counties and municipalities that have plans either announced or passed in the Pacific Northwest. The Affected Environment presents the state specific targets.

107 **Table 1-3. Emissions Reduction Targets for Pacific Northwest Municipalities**

County/ Municipality	Targets?	Plan?	Rule & Rule Year	Method[a]	Targeted Industries	Type	Base-line Year	Targets	Source
WASHINGTON									
Bellingham, WA	Yes	Yes	City Council approved the Climate Protection Action Plan, 2007	production	Municipal; Residential; Commercial; Industrial; Transportation; Waste	GHG	2002	7% by 2012 28% by 2020 85% by 2050	Climate Protection Action Plan, 2018
King County, WA	Yes	Yes	Ordinance 17270, Council Motion 14349, May, 2015	consumption & production	Transportation; Industrial; Residential; Commercial; Electric Power & Gas; Agriculture; Waste	MT CO2e	2007	25% by 2020 50% by 2030 80% by 2050	King County Strategic Climate Action Plan, 2015
Seattle, WA	Yes	Yes	Resolution 31312, October 3, 2011 and Resolution 31447, June 17, 2013	production	Building Energy; Land Use; Waste	GHG	n/a	0 net GHG by 2050	Seattle Climate Action Plan, 2013
Olympia, WA	No	Yes	City council votes to create the Climate Action Plan, May 10, 1990	production	Buildings; Vehicle Fleet; Street Lighting; Water/ Sewer; Waste	CO2e	2005		City of Olympia Greenhouse Gas Emissions Inventory, 2008
OREGON									
Beaverton, OR	Yes	Yes	Sustainable Beaverton Strategy (SBS) developed in 2014	consumption & production	Fleet; Natural Gas; Electricity; Commute; Supply Chain; Water	CO2e	2008	75% by 2050	Sustainable Beaverton Strategy, 2014
City of Portland and Multnomah County, OR	Yes	Yes	2009 Climate Action Plan updated in 2015	production	Residential; Commercial; Industrial; Transportation; Waste	GHG	1990	14% by 2013 40% by 2030 80% by 2050	Climate Action Plan Progress Report, 2017

County/ Municipality	Targets?	Plan?	Rule & Rule Year	Method[a]	Targeted Industries	Type	Base-line Year	Targets	Source
Corvallis, OR	Yes	Yes	Climate Action Plan adopted by the Corvallis City Council, December 2016	production	Supply Chain; Commute; Watershed; Waste; Fleet; Electricity; Natural Gas	GHG	1990	75% by 2050	Climate Action Plan Goals, 2015
Eugene, OR	Yes	Yes	Counsel Ordinance 20567 Bill 151, July27, 2016	production	Energy; Agriculture; Land Use; Waste; Health; Urban; Natural Resources	GHG	1990	10% by 2020	Strategic Climate Action Plan, 2015
Lake Oswego, OR	No	No	City Council Voted to Draft Climate Action Plan, 2017	production	Materials; Energy; Transportation	CO2e	2008	60% by 2040	Sustainability Action Plan for City Operations, 2014
Milwaukie, OR	No	No	Draft of Climate Action Plan Committee Charter, February 7, 2018	no inventory	--	--	--	--	Climate Action Plan Committee Charter, 2018
West Linn, OR	Yes	Yes	Sustainable West Linn Strategic Plan – Update 2015	production	City Facilities City Fleet	CO2	2008	80% by 2040[b]	Sustainable West Linn, 2015
MONTANA									
Bozeman, MT	Yes	Yes	Bozeman City Commission in adopted the Community Climate Action Plan in 2011	production	Residential; Commercial; Transportation	CO2e	2008	10% by 2025	Bozeman Climate Action Report, 2010
Missoula, MT	Yes	Yes	Resolution 8174, June 26, 2017	production	Municipal	CO2e	2008	30% by 2017 50% by 2020 100% by 2025	No Report Missoula Greenhouse Emissions Inventory, 2010

County/ Municipality	Targets?	Plan?	Rule & Rule Year	Method[a]	Targeted Industries	Type	Base-line Year	Targets	Source
Whitefish, MT	Yes	Yes	Climate Action Plan approved following a public hearing, April 16, 2018	production	Municipal	GHG	2005	26% by 2025	City of Whitefish Climate Action Plan, 2018
IDAHO									
Boise, ID	No	Yes	Resolution #21500, Blueprint Boise Comprehensive Plan, November 29, 2011.	no inventory	--	--	--	--	Boise's Comprehensive Plan, 2018
Ketchum, ID	Yes	No	Resolution 15-012, March 12, 2015	production	No inventory	GHG	2007	75% by 2030	National Mayors Group Committed to Protecting Climate, 2017

Notes:

[a]Production–based inventory measures GHG produced from activities within administrative boundaries whereas consumption–based emissions inventory measures GHG emitted in the production of goods (both within and outside of the administrative boundary) consumed within administrative boundaries.

[b]Target is only to reduce West Linn City operations emissions, not city-wide emissions.

CHAPTER 2 - ENERGY SECTOR GHG EMISSIONS MODELLING

AURORA is the primary model used in the CRSO GHG emissions analysis. AURORA is a power production cost model, described in the Appendix J - Hydropower. The quantitative emissions analysis focuses specifically on carbon dioxide (CO_2) emissions. CO_2 is the primary source of GHG emissions from power generation, accounting for over 80 percent of energy-related carbon emissions (EIA 2018). Additionally, the AURORA model emissions reporting is limited to CO_2. This analysis notes that quantifying only the CO_2 emissions may understate total GHG emissions and this point is considered in assessing the intensity of the GHG emissions effects of the action alternatives.

Table 2-1 presents the regional nodes or zones used in the AURORA model. Each of these zones contains a set of power resources from which power is "dispatched" to meet demand for electricity. This analysis focused on emissions from power generation from zones in the Pacific Northwest and across the broader Western Interconnection (as defined in Section 3.8.2), excluding sources in Northern Mexico and Canada.

Table 2-2 presents the detailed emissions outputs of AURORA for each action alternative by month and by region in million metric tons (MMT) CO_2. The analysis relies on 3,200 iterations of the AURORA model (drawn from 80 water years and 40 climate scenarios) to estimate the average dispatch of power resources and thus emissions for the regional power system. The values in the table reflect averages across all 3,200 iterations and represent emissions expected in 2022. The AURORA outputs take into consideration the change in modelled hydropower generation and the resource replacement portfolios of either zero-carbon or conventional least-cost resources. Even under a "zero-carbon" portfolio there is the potential for emissions to increase as other coal or natural gas power plant generation increases to meet load under MO3 and MO4.

Note that the emissions estimates from AURORA in Table 2-2 are for the base case scenario (described below) and that the Pacific Northwest totals presented in this table do not include Jim Bridger and North Valmy power plants, which are included in the "Other Western US" region in the AURORA model instead.

The AURORA CO_2 emissions output is the basis for forecasting emissions from 2022 to 2041. This analysis considers a base case scenario for the mix of resources generating power in the Pacific Northwest over time, as well as two additional scenarios that assess the sensitivity of emissions estimates to alternative assumptions regarding potential future coal plant retirements that have been announced and are described in the NW Council 7th Power Plan Midterm Assessment (2019). The sensitivity analysis scenarios developed by Bonneville for power system reliability analysis (and described in Section 3.8) are as follows:

- The "limited coal retirement" scenario assumes an additional reduction of 2,505 MW of coal power capacity compared to the No Action base case by 2022 (see Table 2-3). This scenario includes potential future coal plant retirements and only limited coal capacity remaining (including Colstrip unit 4 and Jim Bridger units 3 and 4).

- The "no coal" scenario assumes the retirement of all coal plants operating in the Northwest or serving Northwest loads by 2022.

Table 2-3 compares emissions forecasts for 2022 across the base case under the zero-carbon resource replacement portfolios (as described in Section 3.8).

Table 2-4 displays the full 2022 to 2041 emissions projections for the base case, including both the conventional least-cost and zero-carbon resource replacement portfolios.

The emissions projections for 2022 for the base case analysis rely on the CO_2 emissions from power generation reported by the AURORA model runs with the addition of emissions from Jim Bridger and North Valmy power plants (estimated as the average annual emissions from 2012, 2014, and 2016) as these coal plants are not within the AURORA Pacific Northwest estimate.[1] Emissions projections between 2023 and 2035 rely on average annual decreases in coal generation and increases in natural gas generation observed in dispatch forecasts from the NW Council over the same timeframe based on the NW Council's Regional Portfolio Model (RPM) for the Existing Policy scenario of the 7th Power Plan (NW Council 2016b). The NW Council dispatch data do not extend beyond 2035, therefore emissions between 2036 and 2041 are held constant at 2035 levels (NW Council 2016b).

Table 2-1. AURORA Zones and Regions

AURORA Zone	Region
Avista	Pacific Northwest
Bonneville, ID and MT	Pacific Northwest
Bonneville, OR	Pacific Northwest
Bonneville, WA	Pacific Northwest
Chelan County PUD	Pacific Northwest
Douglas County PUD	Pacific Northwest
Grant County PUD	Pacific Northwest
Idaho Power FE	Pacific Northwest
Idaho Power MV	Pacific Northwest
Idaho Power TV	Pacific Northwest
Northwestern, MT	Pacific Northwest
Olympia	Pacific Northwest
Pacificorp East ID	Pacific Northwest

[1] A considerable fraction of the emissions are associated with generation from two coal plants, Jim Bridger in Wyoming and half of the generation of North Valmy in Nevada. Both lie outside the Pacific Northwest region; however, the NW Council considers them regional resources (NW Council 2016; 2019). All generation from Jim Bridger serves Pacific Northwest customers as does half of North Valmy. While this consumption-based approach contrasts with AURORA production-based emissions estimates, these emissions are included to ensure generation and emissions are consistent with historical NW Council data and forecasts relied on in this analysis (NW Council 2016b; 2019). Over the last three years of available data, the EPA estimated Jim Bridger emitted an average of 14.2 MMT CO2, and 900,000 tons of CO2 for half of North Valmy. However, the analysis considers that by 2022 North Valmy 1 will retire and therefore includes only 474,000 tons of CO2. (USEPA 2018; NW Council 2019).

AURORA Zone	Region
PACW South	Pacific Northwest
Portland General	Pacific Northwest
Puget Sound Central	Pacific Northwest
Puget Sound North	Pacific Northwest
Seattle CL	Pacific Northwest
Tacoma Power	Pacific Northwest
Balancing Authority of Northern California	California
Imperial Irrigation District	California
Los Angeles Water & Power	California
PG&E Bay Area	California
PG&E North	California
PG&E ZP26	California
Southern California Edison	California
San Diego Gas and Electric	California
Turlock Irrigation District	California
Arizona Public Service	Other Western United States
El Paso Electric	Other Western United States
Nevada North	Other Western United States
Nevada South	Other Western United States
Pacificorp East, UT	Other Western United States
Pacificorp East, WY	Other Western United States
Public Service, CO	Other Western United States
Public Service, NM	Other Western United States
Salt River Project	Other Western United States
Tucson Electric	Other Western United States
Valley Electric Association	Other Western United States
Western Area Power Administration (WAPA), CO	Other Western United States
WAPA, Lower CO	Other Western United States
WAPA, Upper MO	Other Western United States
WAPA, WY	Other Western United States

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169 **Table 2-2. Emissions by Region and Month for each CRSO Scenario in Million Metric Tons CO2, Base Case**

AURORA Average Monthly Emissions by Region, Month and Scenario, MMT CO_2												
Scenario and Region	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
NAA												
Pacific Northwest	2.2	1.9	1.8	1.4	0.95	0.81	1.6	2.1	2.3	2.2	2.2	2.6
California	3.9	3.2	2.8	2.5	2.5	2.9	4.2	4.5	4.2	4.1	4.0	4.4
Other Western US	8.5	7.4	7.1	6.2	6.5	7.0	10	10	8.9	7.7	7.9	9.4
MO1 Conventional Least-Cost (Difference from No Action)												
Pacific Northwest	-0.024	-0.0047	0.018	0.071	0.087	0.041	0.018	0.051	0.0024	0.016	0.012	0.048
California	-0.015	-0.00082	0.0046	0.023	0.034	0.0051	0.016	0.036	-0.012	0.0012	-0.0035	0.0081
Other Western US	-0.036	-0.006	0.0088	0.041	0.044	0.0093	0.052	0.11	-0.021	0.0051	-0.0046	0.021
MO1 Zero-Carbon (Difference from No Action)												
Pacific Northwest	-0.064	-0.06	-0.034	0.0098	0.025	-0.0051	-0.1	-0.1	-0.11	-0.021	-0.019	0.00033
California	-0.014	-0.0012	-0.002	0.015	0.035	0.016	0.014	0.044	-0.008	-0.025	-0.015	0.0071
Other Western US	-0.03	0.0093	0.018	0.057	0.093	0.051	0.09	0.15	-0.021	-0.06	-0.024	0.025
MO2 (Difference from No Action)												
Pacific Northwest	-0.11	-0.088	0.038	-0.0083	-0.13	-0.068	-0.17	-0.30	-0.11	-0.027	-0.046	-0.085
California	-0.025	-0.016	0.025	-0.013	-0.097	-0.051	-0.048	-0.069	0.02	0.00062	-0.017	-0.024
Other Western US	-0.054	-0.037	0.048	-0.028	-0.12	0.0097	-0.019	-0.16	0.035	0.037	-0.0016	-0.044
MO3 Conventional Least-Cost (Difference from No Action)												
Pacific Northwest	0.27	0.30	0.32	0.41	0.43	0.28	0.37	0.12	0.23	0.21	0.13	0.15
California	0.022	0.020	0.019	0.065	0.14	0.11	-0.007	-0.15	-0.038	-0.017	-0.027	-0.021
Other Western US	0.012	0.036	0.045	0.13	0.19	0.088	-0.13	-0.39	-0.093	-0.09	-0.13	-0.12
MO3 Zero-Carbon (Difference from No Action)												
Pacific Northwest	0.14	0.14	0.15	0.21	0.25	0.15	0.079	-0.15	-0.013	0.044	0.0065	0.0092
California	0.063	0.061	0.055	0.086	0.14	0.1	0.025	-0.1	0.0088	-0.013	-0.007	0.015
Other Western US	0.11	0.13	0.14	0.23	0.32	0.19	0.029	-0.27	-0.0024	-0.066	-0.049	0.0024
MO4 Conventional Least-Cost (Difference from No Action)												
Pacific Northwest	-0.00065	0.028	0.58	0.53	0.40	0.28	0.35	0.39	0.18	0.14	0.081	0.12
California	-0.018	-0.0053	0.18	0.12	0.17	0.16	0.07	0.0013	-0.053	0.0037	-0.0064	0.011
Other Western US	-0.070	-0.022	0.35	0.19	0.24	0.19	0.0053	-0.0018	-0.096	-0.034	-0.072	-0.018

AURORA Average Monthly Emissions by Region, Month and Scenario, MMT CO_2												
Scenario and Region	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
MO4 Zero-Carbon (Difference from No Action)												
Pacific Northwest	-0.14	-0.16	0.34	0.24	0.15	0.12	0.045	0.020	-0.12	-0.09	-0.075	-0.036
California	-0.027	-0.014	0.16	0.088	0.11	0.095	0.0094	-0.008	-0.045	-0.052	-0.032	0.0042
Other Western US	-0.10	-0.044	0.35	0.21	0.29	0.19	-0.048	-0.084	-0.21	-0.18	-0.11	-0.033
Preferred Alternative (Difference from No Action)												
Pacific Northwest	-0.045	-0.042	0.0098	0.14	0.18	0.084	0.017	-0.049	-0.03	-0.031	0.0077	0.0059
California	-0.013	-0.0098	0.0074	0.062	0.086	0.031	-0.0059	-0.023	-0.0073	-0.0079	0.0041	-0.00078
Other Western US	-0.031	-0.016	0.029	0.12	0.14	0.053	-0.01	-0.068	-0.022	-0.035	0.0077	-0.0045

Note: Emissions associated with Jim Bridger and North Valmy generation are associated to the "Other Western US" region in the AURORA. Model. All values for MOs reflect the difference relative to the No Action Alternative in MMT CO_2 and are rounded to two significant figures.

Source: AURORA model outputs

Table 2-3. Emissions Forecast for 2022, Base Case

Alternative (Resource Replacement Portfolio)	**Base Case without additional coal retirements**	
	2022 Emissions (MMT CO_2)	**Change in Emissions Relative to Base Case NAA**
NAA	36.7	--
MO1 (Zero-Carbon)	36.2	-0.76%
MO2	35.6	-3.0%
MO3 (Zero-Carbon)	37.7	2.7%
MO4 (Zero-Carbon)	37.0	0.83%
PA	36.9	0.70%

174 **Table 2-4. Total Annual Emissions from 2022 to 2041, Base Case**

Total Annual Emissions Estimates for Each Alternative, MMT CO_2									
Year	No Action	MO1 (Conventional Least-Cost Replacement)	MO1 (Zero-Carbon Replacement)	MO2	MO3 (Conventional Least-Cost Replacement)	MO3 (Zero-Carbon Replacement)	MO4 (Conventional Least-Cost Replacement)	MO4 (Zero-Carbon Replacement)	PA
2022	36.7	37.0	36.2	35.6	39.9	37.7	39.8	37.0	36.9
2023	36.8	37.1	36.3	35.7	40.8	38.0	40.2	37.2	36.8
2024	36.7	37.1	36.3	35.7	40.8	38.0	40.2	37.2	36.8
2025	36.7	37.1	36.3	35.6	40.8	37.9	40.2	37.1	36.8
2026	36.7	37.0	36.2	35.6	40.8	37.9	40.1	37.1	36.7
2027	36.6	37.0	36.2	35.6	40.8	37.9	40.1	37.0	36.7
2028	36.6	37.0	36.2	35.5	40.8	37.8	40.1	37.0	36.7
2029	36.6	37.0	36.1	35.5	40.8	37.8	40.1	37.0	36.6
2030	36.6	36.9	36.1	35.5	40.8	37.8	40.1	36.9	36.6
2031	36.5	36.9	36.1	35.4	40.8	37.7	40.1	36.9	36.6
2032	36.5	36.9	36.0	35.4	40.8	37.7	40.1	36.9	36.6
2033	36.5	36.9	36.0	35.4	40.8	37.7	40.1	36.8	36.6
2034	36.5	36.9	36.0	35.4	40.8	37.7	40.1	36.8	36.5
2035	36.5	36.8	36.0	35.3	40.8	37.7	40.1	36.8	36.5
2036	36.5	36.8	36.0	35.3	40.8	37.7	40.1	36.8	36.5
2037	36.5	36.8	36.0	35.3	40.8	37.7	40.1	36.8	36.5
2038	36.5	36.8	36.0	35.3	40.8	37.7	40.1	36.8	36.5
2039	36.5	36.8	36.0	35.3	40.8	37.7	40.1	36.8	36.5
2040	36.5	36.8	36.0	35.3	40.8	37.7	40.1	36.8	36.5
2041	36.5	36.8	36.0	35.3	40.8	37.7	40.1	36.8	36.5

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CHAPTER 3 - SOCIAL COST OF CARBON

GHG emissions influence a variety of socioeconomic outcomes related to climate change, including agricultural productivity, human health, flood risk, and infrastructure and fishery damages. The value of reducing levels of GHGs in the atmosphere is the avoided damages that would be generated by a unit of GHG if it were present. Economists express this value in monetary terms representing society's willingness to pay to avoid climate-related impacts associated with an additional unit of a GHG in the atmosphere. This value is defined as the "social cost" of GHGs. The more common term, "social cost of carbon" (SCC), generally pertains to CO2 emissions.

The academic literature and Federal agency guidance on these measures is actively evolving. A Federal Interagency Working Group (IWG) on the Social Cost of GHGs formerly issued guidelines that were updated over time (the most recent was in August 2016) to help agencies assess the climate change-related benefits of reducing carbon emissions and integrate these estimates into their assessments of regulatory impacts in cost-benefit analyses (Interagency Working Group 2016). The Interagency guidance provided a SCC dollar value based on the average of three integrated assessment models (IAMs). The socioeconomic effects of changes in emissions are calculated by multiplying the change in emissions in a given year by that year's SCC value. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across affected years.

The literature identifies an average social cost per ton of carbon dioxide of $42 for the year 2020 (2007 dollars, assuming a discount rate of 3 percent), though the value varies between $12/ton and $123 dollars per ton depending on the carbon distribution scenario and discount rate assumption (Marten et al. 2015). There are differences in the social cost measures for different GHGs due to differences in the "global damage potential" of the GHGs. While global warming potential of GHGs account for the differences in radiative forcing of the gases as compared with CO_2, global damage potential captures the differences across gases in terms of climate-related damages.

Table 3-1 presents the full schedule of SCC estimates for the years 2010 to 2050 from the August 2016 IWG update. The table lists estimates for three discount rates: 5 percent, 3 percent and 2.5 percent as well as an estimate of low-probability high impact outcomes at the 3 percent discount rate. As per best practices the 3 percent discount rate is considered the central estimate. The schedule comes from the August 2016 update to the Social Cost of Carbon. Dollars values are in 2019 US dollars adjusted using the BEA Implicit Price Deflator. The totals are the discounted present values as well as annualized values, each in an independent table.

Table 3-2 presents the total present value estimates of the SCC for each action alternative under the varying discount rate assumptions by multiplying the SCC value estimate from Table 3-1 by the emissions estimate for that specific year. The present values reflect the value of the changes in GHG emissions under each alternative relative to the No Action Alternative in

the base case (i.e., these values do not reflect the limited coal or no coal retirement scenarios described above). Table 3-3 annualizes these estimates. All values are presented in millions of 2019 US dollars, rounded to two significant digits.

Table 3-1. Social Cost of Carbon Estimates per Metric Ton CO_2 in 2019 US dollars

	Annual Social Cost per Metric Ton CO_2 Emissions, 2019 Dollars			
Discount Rate Year	**5% Average**	**3% Average**	**2.5% Average**	**3% High Impact (95th)**
2010	$12.04	$37.31	$60.18	$103.52
2011	$13.24	$38.52	$61.39	$108.33
2012	$13.24	$39.72	$63.80	$111.94
2013	$13.24	$40.93	$65.00	$116.76
2014	$13.24	$42.13	$66.20	$121.57
2015	$13.24	$43.33	$67.41	$126.39
2016	$13.24	$45.74	$68.61	$130.00
2017	$13.24	$46.94	$71.02	$134.81
2018	$14.44	$48.15	$72.22	$139.63
2019	$14.44	$49.35	$73.43	$144.44
2020	$14.44	$50.56	$74.63	$148.05
2021	$14.44	$50.56	$75.83	$151.67
2022	$15.65	$51.76	$77.04	$155.28
2023	$15.65	$52.96	$78.24	$158.89
2024	$15.65	$54.17	$79.44	$162.50
2025	$16.85	$55.37	$81.85	$166.11
2026	$16.85	$56.57	$83.06	$169.72
2027	$18.06	$57.78	$84.26	$172.13
2028	$18.06	$58.98	$85.46	$175.74
2029	$18.06	$58.98	$86.67	$179.35
2030	$19.26	$60.18	$87.87	$182.96
2031	$19.26	$61.39	$89.07	$186.57
2032	$20.46	$62.59	$90.28	$190.18
2033	$20.46	$63.80	$91.48	$193.80
2034	$21.67	$65.00	$92.68	$197.41
2035	$21.67	$66.20	$93.89	$202.22
2036	$22.87	$67.41	$95.09	$205.83
2037	$22.87	$68.61	$97.50	$209.44
2038	$24.07	$69.81	$98.70	$213.05
2039	$24.07	$71.02	$99.91	$216.67
2040	$25.28	$72.22	$101.11	$220.28
2041	$25.28	$73.43	$102.31	$223.89
2042	$26.48	$73.43	$103.52	$227.50
2043	$26.48	$74.63	$104.72	$231.11
2044	$27.69	$75.83	$105.93	$233.52
2045	$27.69	$77.04	$107.13	$237.13
2046	$28.89	$78.24	$108.33	$240.74

Discount Rate Year	Annual Social Cost per Metric Ton CO_2 Emissions, 2019 Dollars			
	5% Average	3% Average	2.5% Average	3% High Impact (95th)
2047	$28.89	$79.44	$110.74	$244.35
2048	$30.09	$80.65	$111.94	$247.96
2049	$30.09	$81.85	$113.15	$251.57
2050	$31.30	$83.06	$114.35	$255.18

Table 3-2. Total Discounted SCC Estimates (Present Value) for Each Alternative and Discount Rate, Millions of 2019 US Dollars (2022-2041)

Alternative (Resource Replacement Scenario)	Total Discounted SCC Estimates (PV), Million 2019 US Dollars			
	Present Value 5% Average	Present Value 3% Average	Present Value 2.5% Average	Present Value 3% 95th
No Action	$8,000	$31,000	$48,000	$95,000
Difference from No Action				
MO1 (Conventional Least-Cost)	$82	$320	$500	$980
MO1 (Zero-Carbon)	-$100	-$400	-$610	-$1,200
MO2	-$240	-$950	-$1,500	-$2,900
MO3 (Conventional Least-Cost)	$910	$3,600	$5,500	$11,000
MO3 (Zero-Carbon)	$260	$1,000	$1,600	$3,100
MO4 (Conventional Least-Cost)	$760	$3,000	$4,600	$9,100
MO4 (Zero-Carbon)	$78	$310	$470	$930
Preferred Alternative	$16	$62	$94	$190

Note: Values for all action alternatives are relative to No Action, they represent the difference in the total discounted SCC estimates in 2019 USD. The values are rounded to two significant digits.

Table 3-3. Annualized SCC Estimates for Each Alternative and Discount Rate, Millions of 2019 US Dollars (2022-2041)

Alternative (Resource Replacement Scenario)	Total Annualized SCC Estimate, Million 2019 US Dollars			
	Present Value 5% Average	Present Value 3% Average	Present Value 2.5% Average	Present Value 3% 95th
No Action	$610	$2,100	$3,000	$6,200
Difference from No Action				
MO1 (Conventional Least-Cost)	$6.3	$21	$31	$64
MO1 (Zero-Carbon)	-$7.7	-$26	-$38	-$79
MO2	-$18	-$62	-$91	-$190
MO3 (Conventional Least-Cost)	$69	$230	$340	$710
MO3 (Zero-Carbon)	$20	$68	$99	$200
MO4 (Conventional Least-Cost)	$58	$200	$290	$600
MO4 (Zero-Carbon)	$6	$20	$30	$61
Preferred Alternative	$1.2	$4.0	$5.9	$12

Note: Values for all action alternatives are relative to No Action, they represent the annualized estimates in 2019 USD. The values are rounded to two significant digits.

CHAPTER 4 - REGIONAL HAZE AND WIND SPEED DATA

Section 3.7.1 discusses EPA permitting and regulatory requirements related to air quality and criteria air pollutants. The 1999 Regional Haze Rule call for states to establish goals for improving visibility in national parks and wilderness areas and to develop long-term strategies for reducing emissions of air pollutants that cause visibility impairment (EPA 2019a). The rule provides protection to 156 "Class I Areas" across the country (EPA 2019a). These Class I areas are defined as having special natural, scenic, recreational, or historic value in a national or regional context. The management and improvement of visibility conditions is organized by regional planning organizations, with the Western Regional Air Partnership (WRAP) managing the Western United States. In the Pacific Northwest there are 37 Class I Areas. These include large national parks, including Glacier National Park in Montana (covering over 1 million acres) and Mount Rainier. In addition, the Columbia River Gorge Scenic Area is within the Columbia River Basin. The Gorge is not a Class I Area but has protection as a National Scenic Area and, as such, receives protection along with Class I Areas (OR DEQ 2020).

Haze may be formed by natural air pollutants or air pollutant emissions from anthropogenic sources. Fugitive dust and other small airborne particles generate haze as well as a variety of other particles react with sunlight in the atmosphere to form haze and impair visibility and air quality related values (AQVRs). AQRVs include visibility as well as any other resource that could be adversely affected by changes in air quality including but not limited to cultural, biological or physical resources identified by a Federal land manager in a Class 1 Area. Air pollutant emissions from major sources, such as power plants, may contribute to haze even if they are operating within the requirements of their Prevention of Significant Deterioration (PSD) permits. Near a source of air pollutants, such as a city or power plant, haze is typically a mixture of aerosols (a dispersion of microscopic solid or liquid particles in gaseous media such as smoke or fog) and gases, such as sulfur dioxides and nitrogen dioxides from fossil fuel power plants (EPA 1999).

The EPA and other state agencies that regulate these areas examine haze in terms of a "haze-index," based on the unit of measurement "deciview." The higher the deciview, the lower the visibility. Generally, visibility at Class I Areas in the Pacific Northwest has improved since 2000, however some monitors have identified increasing index scores (i.e., worsening visibility) in recent years (OR DEQ 2020). As multiple factors contribute to haze, including wildfires, variations may occur year to year.

Table 4-1 presents the number of Class I areas and the number acres they cover by state. Figure 4-1 presents a map of Class I Areas in the Pacific Northwest and the CRSO Regions.

Table 4-1. Class I Areas in the Pacific Northwest by State

State	Number of Class 1 Areas	Total Acres
Idaho	5	1,363,684
Montana	12	3,040,568
Oregon	12	1,111,372
Washington	8	3,019,420
Total[/1]	**34**	**8,535,044**

1/ The total number of Class 1 Areas does not sum because some Class 1 Areas cross state borders, for example Yellowstone National Park is Montana, Wyoming and a small part of Idaho. For Class 1 Areas in multiple states, the area is included in the state specific count but not counted multiple times in the total.

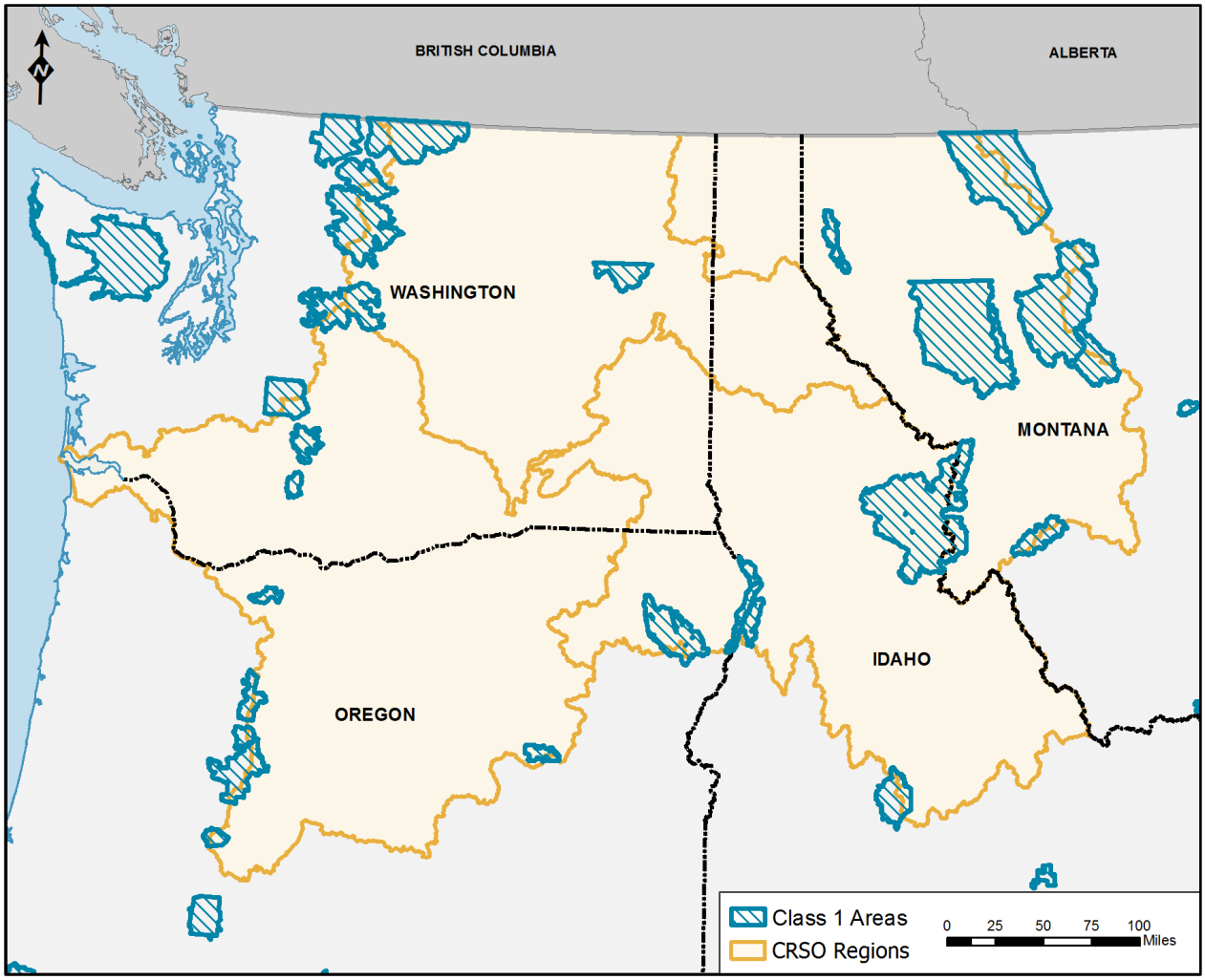

Figure 4-1. Class 1 Areas in the Pacific Northwest and CRSO Regions

The Air Quality analysis also considers regional wind speeds at a variety of meteorological monitors in the Pacific Northwest to evaluate potential windblown fugitive dust effects. This analysis considers the EPA guidance on high-wind events (25 miles per hour) as well as the fugitive dust guidance from the AP-42 emissions factors (potential for wind erosion occurring at 12 miles per hour) to assess the potential for fugitive dust effects due to changes in water

elevation as well as other sources of potential dust (e.g., unpaved roads or construction activities).

Table 4-2 presents the list of relevant monitoring stations. Stations were selected based on proximity to CRSO projects and the availability of data. The data on wind speed is from the Midwest Regional climate data portal. The data presented in Tables 4-3 and 4-4 reflect multiple years of wind data from the Midwestern Regional Climate Center cli-MATE program. All records missing either a speed or direction record were excluded. Table 4-3 presents median and mean wind speeds, as well as the 5th and 95th percentiles for the relevant monitoring stations, as well as the percentage of time for "calm" hours (below 1.3 mph), wind speeds above the AP-42 threshold of 12 mph, and wind speeds above the high-wind event threshold of 25 mph.

Table 4-4 presents the monthly breakdown by station. Generally speaking, the results indicate relatively low median and average wind speeds across the region, below both the high-wind event threshold and the lower AP-42 threshold. All the stations do experience occasional speeds above 25 miles per hour; however, occurrences are infrequent, accounting for less than 1 percent of the recorded hourly data analyzed with the exception of at the Dalles. Walla Walla, the Dalles, and Pullman Moscow experience the highest percentage of hours with speeds above 12 miles per hour indicating a higher likelihood for the potential of wind erosion and suspension of sediment at sites near those monitors.

Table 4-2. Meteorological Monitoring Stations Analyzed

Station Name	County and State	Closest CRSO Project(s) and Relative Direction
Dalles	Klickitat, WA	Dalles and John Day
Hermiston	Umatilla, OR	McNary and Ice Harbor
Lewiston	Nez Perce, ID	SE of Lower Granite and W of Dworshak
Kalispell	Flathead, MT	East of Libby and West of Hungry Horse
Pasco Tri-Cities	Franklin, WA	NW of Ice Harbor and N of McNary
Pullman Moscow	Whitman, WA	NE Lower Granite and NW of Dworshak
Lowell/Three Rivers	Idaho, ID	SE of Dworshak
Walla Walla	Walla Walla, WA	Lower Snake

Table 4-3. Mean, Median, 5th and 9th Percentile Wind Speeds for Regional Monitors, Miles per Hour

	Monitoring Station Location							
Percentile	Walla Walla	Dalles	Hermiston	Lewiston	Tri-Cities	Pullman Moscow	Lowell/ Three Rivers	Kalispell
5th	0	0	0	0	0	0	0	0
Median	7	6	6	5	6	7	0	5
95th	17	21	18	15	17	18	6	15
Calm Periods (% of all records below 1.3 mph)	12%	27%	18%	25%	24%	25%	69%	38%

	Monitoring Station Location							
Percentile	**Walla Walla**	**Dalles**	**Hermiston**	**Lewiston**	**Tri-Cities**	**Pullman Moscow**	**Lowell/ Three Rivers**	**Kalispell**
Above 12 mph	19%	29%	18%	9%	15%	23%	0.16%	12%
Above 25 mph	0.80%	1.6%	0.86%	0.42%	0.92%	0.81%	0%	0.31%
Mean Wind Speed (excluding calm periods)	9.0	10.9	8.8	7.3	8.5	10.0	4.4	8.1
Maximum Wind Speed	48	40	41	47	47	49	23	44

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294 **Table 4-4. Monthly Median, 5th and 9th Percentile Wind Speeds for Regional Monitors, Miles per Hour**

Station	Percentile	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Walla Walla	5th	0	0	0	0	0	0	0	0	0	0	0	0
Walla Walla	Median	6	7	8	8	8	8	8	8	7	7	6	6
Walla Walla	95th	19	18	20	18	16	16	15	15	15	16	20	21
Dalles	5th	0	0	0	0	0	0	0	0	0	0	0	0
Dalles	Median	3	3	6	9	10	13	14	11	7	5	3	3
Dalles	95th	14	17	21	22	23	24	23	23	21	18	15	14
Hermiston	5th	0	0	0	0	0	0	0	0	0	0	0	0
Hermiston	Median	5	5	7	8	8	8	8	7	6	5	5	5
Hermiston	95th	16	18	21	21	19	20	18	17	16	16	17	16
Lewiston	5th	0	0	0	0	0	0	0	0	0	0	0	0
Lewiston	Median	5	5	6	6	6	6	5	5	5	5	5	5
Lewiston	95th	17	15	16	15	14	14	14	13	13	13	16	16
Tri-Cities	5th	3	3	3	3	3	3	3	3	3	3	3	3
Tri-Cities	Median	6	7	8	8	8	8	7	7	6	6	6	6
Tri-Cities	95th	21	21	22	21	18	18	16	16	16	18	20	18
Pullman Moscow	5th	0	0	0	0	0	0	0	0	0	0	0	0
Pullman Moscow	Median	9	8	9	8	7	6	5	5	6	7	9	9
Pullman Moscow	95th	21	20	20.85	20	17	16	15	15	16	17	20	20
Lowell/Three Rivers	5th	0	0	0	0	0	0	0	0	0	0	0	0
Lowell/ Three Rivers	Median	0	0	0	0	0	0	0	0	0	0	0	0
Lowell/ Three Rivers	95th	6	6	6	6	7	7	6	5	5	5	6	6
Kalispell	5th	0	0	0	0	0	0	0	0	0	0	0	0
Kalispell	Median	0	3	6	7	6	6	5	5	3	3	3	0
Kalispell	95th	15	15	16	17	16	14	15	15	14	14	15	15

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CHAPTER 5 - METHANE EVALUATION COLUMBIA RIVER BASIN

5.1 METHANE EVALUATION COLUMBIA RIVER BASIN

5.1.1 Introduction

The greenhouse gas (GHG) methane (CH_4) produced from anthropogenic activities accounts for roughly 40% of global climate forcing (Stocker et al. 2013). An estimate of global methane sources shows that roughly 71% of methane emissions stem from anthropogenic activities, namely the burning of fossil fuels (Figure 5-1). Inland water bodies, including freshwater lakes and manmade reservoirs, can be net emitters of CH_4 and the less potent GHG carbon dioxide (CO_2), particularly in tropical and mid-latitude locations (Demarty and Bastien 2011). Hydroelectric dams can prevent the downstream transport of organic and inorganic carbon (C) as the riverine system conditions are converted into lacustrine systems (Wetzel 2001). It has recently been suggested that the drawdown of reservoirs behind dams is perhaps an important anthropogenic source of GHG emissions to the atmosphere, and thus should be included in global budget estimates (Deemer et al. 2016). A recent synopsis of GHG research studies has concluded that worldwide CH_4 emissions are responsible for 80% of the radiative forcing from reservoir surfaces over a 100-year span and 90% over a 20-year span (Deemer et al. 2016). CH_4 is 25 times more potent than CO_2 at trapping heat per 100 years (Stocker et al. 2013). This report will therefore focus on CH_4 emissions because it is a much more potent GHG than CO_2, however it is important to not discount the production of CO_2 via oxidation, described below.

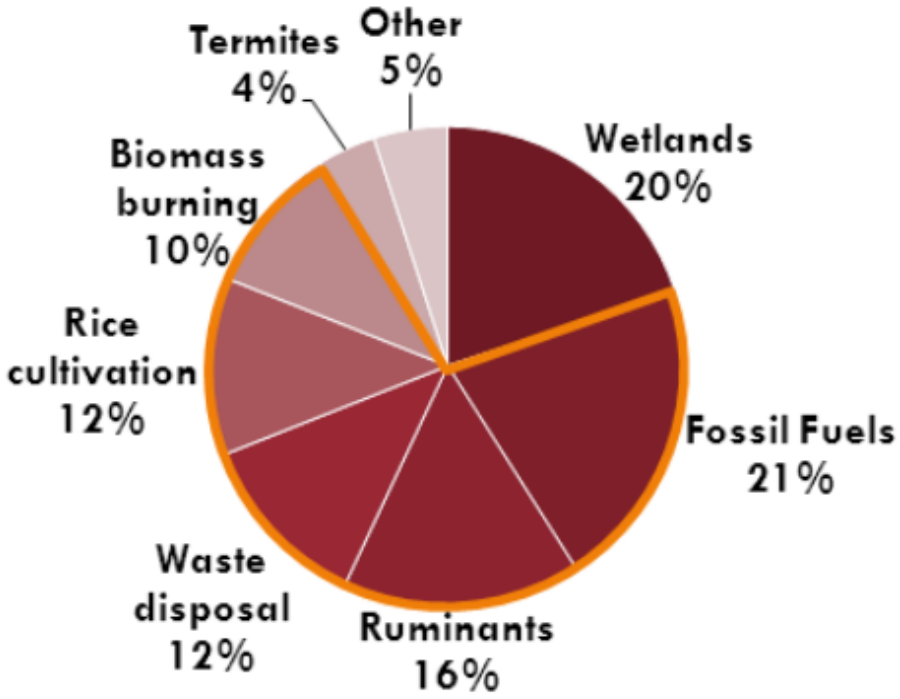


Figure 5-1. Estimates of global sources of methane with anthropogenic sources outlined in orange (Wuebbles and Hayhoe 2002).

To more fully comprehend the environmental conditions that affect CH_4 production, it is helpful to have a fundamental understanding of the underlying chemistry, namely reduction-oxidation (redox) potential and the ensuing reactions. Oxidation involves the loss of electrons from a species and reduction involves the gain of electrons. Oxidation always occurs in conjunction with reduction because the net exchange of electrons must balance - the number of electrons lost by one species must equal the number gained by the other, therefore, in any redox reaction one species is always oxidized and another is reduced.

A general redox reaction is as follows:

$$\text{Oxidized species} + e^- + H^+ \leftrightarrow \text{reduced species}$$

Redox potential is the tendency of an environment to receive or supply electrons. A solution with a higher (more positive) reduction potential than the new species will have a tendency to gain electrons from the new species (i.e., to be reduced by oxidizing the new species) and a solution with a lower (more negative) reduction potential will have a tendency to lose electrons to the new species (i.e., to be oxidized by reducing the new species). Figure 5-2 shows standard reduction potentials.

An oxic environment has high redox potential because O_2 is available as an electron acceptor. For example, Fe (iron) oxidizes to rust in the presence of O_2 because the iron shares its electrons with the O_2:

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

By contrast, an anoxic environment has low redox potential because of the relative absence of O_2.

The net reaction for aerobic oxidation of organic matter (OM) is:

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

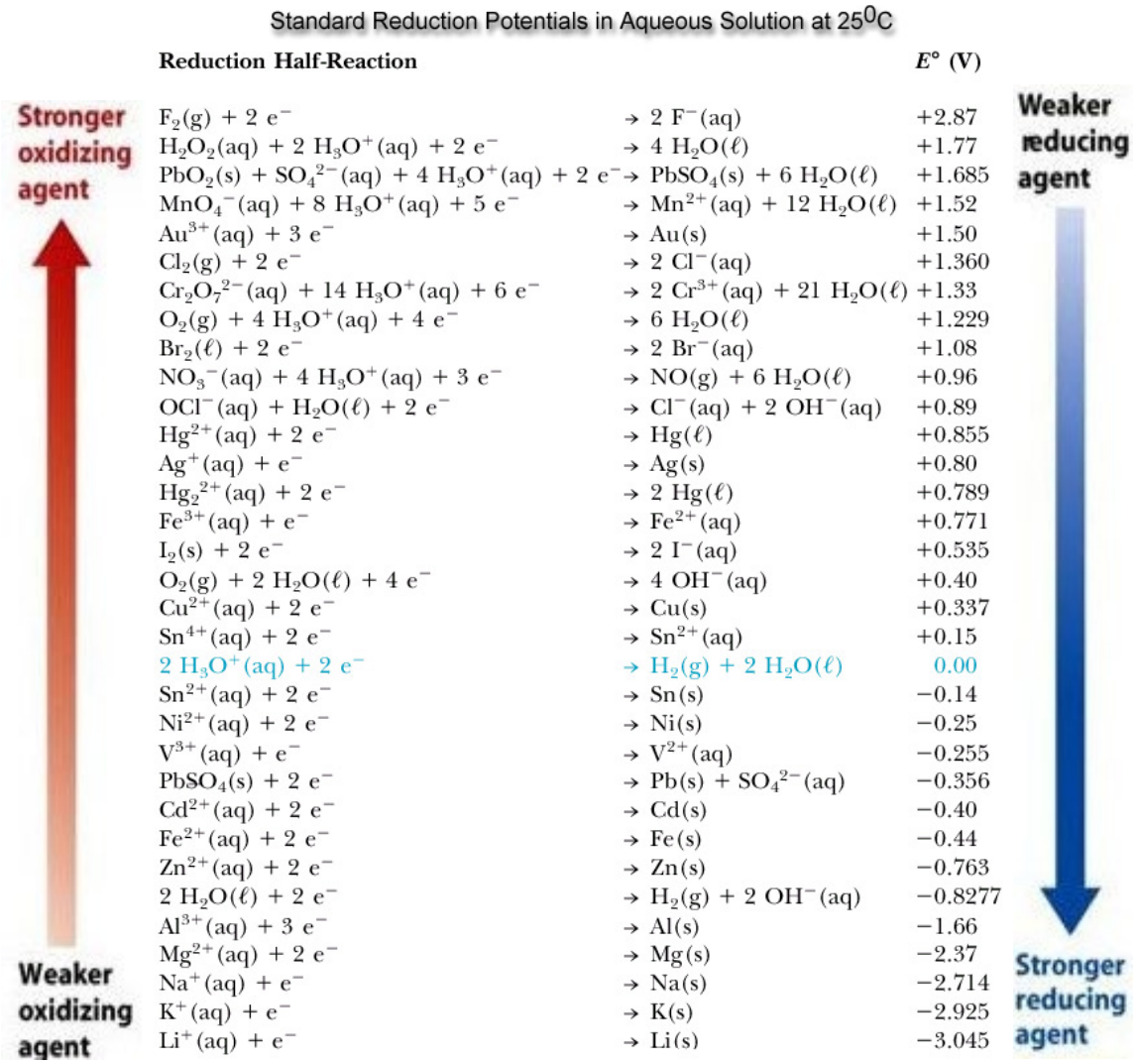
In this case, oxygen is the electron acceptor; the reduction half-reaction is:

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$$

CH_4 is produced primarily under anoxic conditions from the degradation of organic matter (OM) by microbes within lake or reservoir sediments. This process, called methanogenesis, is a form of anaerobic respiration and uses C in the form of CO_2 or acetic acid instead of oxygen, as demonstrated in the following reactions:

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

$$CH_3COOH \rightarrow CH_4 + CO_2$$



Reduction Half-Reaction		$E°$ (V)
$F_2(g) + 2\ e^-$	$\rightarrow 2\ F^-(aq)$	+2.87
$H_2O_2(aq) + 2\ H_3O^+(aq) + 2\ e^-$	$\rightarrow 4\ H_2O(\ell)$	+1.77
$PbO_2(s) + SO_4^{2-}(aq) + 4\ H_3O^+(aq) + 2\ e^-$	$\rightarrow PbSO_4(s) + 6\ H_2O(\ell)$	+1.685
$MnO_4^-(aq) + 8\ H_3O^+(aq) + 5\ e^-$	$\rightarrow Mn^{2+}(aq) + 12\ H_2O(\ell)$	+1.52
$Au^{3+}(aq) + 3\ e^-$	$\rightarrow Au(s)$	+1.50
$Cl_2(g) + 2\ e^-$	$\rightarrow 2\ Cl^-(aq)$	+1.360
$Cr_2O_7^{2-}(aq) + 14\ H_3O^+(aq) + 6\ e^-$	$\rightarrow 2\ Cr^{3+}(aq) + 21\ H_2O(\ell)$	+1.33
$O_2(g) + 4\ H_3O^+(aq) + 4\ e^-$	$\rightarrow 6\ H_2O(\ell)$	+1.229
$Br_2(\ell) + 2\ e^-$	$\rightarrow 2\ Br^-(aq)$	+1.08
$NO_3^-(aq) + 4\ H_3O^+(aq) + 3\ e^-$	$\rightarrow NO(g) + 6\ H_2O(\ell)$	+0.96
$OCl^-(aq) + H_2O(\ell) + 2\ e^-$	$\rightarrow Cl^-(aq) + 2\ OH^-(aq)$	+0.89
$Hg^{2+}(aq) + 2\ e^-$	$\rightarrow Hg(\ell)$	+0.855
$Ag^+(aq) + e^-$	$\rightarrow Ag(s)$	+0.80
$Hg_2^{2+}(aq) + 2\ e^-$	$\rightarrow 2\ Hg(\ell)$	+0.789
$Fe^{3+}(aq) + e^-$	$\rightarrow Fe^{2+}(aq)$	+0.771
$I_2(s) + 2\ e^-$	$\rightarrow 2\ I^-(aq)$	+0.535
$O_2(g) + 2\ H_2O(\ell) + 4\ e^-$	$\rightarrow 4\ OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2\ e^-$	$\rightarrow Cu(s)$	+0.337
$Sn^{4+}(aq) + 2\ e^-$	$\rightarrow Sn^{2+}(aq)$	+0.15
$2\ H_3O^+(aq) + 2\ e^-$	$\rightarrow H_2(g) + 2\ H_2O(\ell)$	0.00
$Sn^{2+}(aq) + 2\ e^-$	$\rightarrow Sn(s)$	−0.14
$Ni^{2+}(aq) + 2\ e^-$	$\rightarrow Ni(s)$	−0.25
$V^{3+}(aq) + e^-$	$\rightarrow V^{2+}(aq)$	−0.255
$PbSO_4(s) + 2\ e^-$	$\rightarrow Pb(s) + SO_4^{2-}(aq)$	−0.356
$Cd^{2+}(aq) + 2\ e^-$	$\rightarrow Cd(s)$	−0.40
$Fe^{2+}(aq) + 2\ e^-$	$\rightarrow Fe(s)$	−0.44
$Zn^{2+}(aq) + 2\ e^-$	$\rightarrow Zn(s)$	−0.763
$2\ H_2O(\ell) + 2\ e^-$	$\rightarrow H_2(g) + 2\ OH^-(aq)$	−0.8277
$Al^{3+}(aq) + 3\ e^-$	$\rightarrow Al(s)$	−1.66
$Mg^{2+}(aq) + 2\ e^-$	$\rightarrow Mg(s)$	−2.37
$Na^+(aq) + e^-$	$\rightarrow Na(s)$	−2.714
$K^+(aq) + e^-$	$\rightarrow K(s)$	−2.925
$Li^+(aq) + e^-$	$\rightarrow Li(s)$	−3.045

Figure 5-2. Standard reduction potentials at 25°C, where E° (v) = electrode potential at standard state: solutes concentration = 1 mol/L; gases pressure = 1 atm (Wilbraham et al. 2008).

However, a sequence of redox reactions must occur before methanogenesis is possible. Each of these half-reactions involves oxidants, or electron acceptors, which exhibit low redox potentials. In aquatic environments, OM is oxidized as follows, and as summarized in Table 5-1 below, which also denotes the standard reduction potentials of each half-reaction (Schlesinger and Bernhardt 2013):

1) O_2 reduction (aerobic oxidation): availability of O_2 in water is limited by the amount of organic matter present any by how much circulation there is in the water column.
2) NO_3 reduction (denitrification): NO_3 availability typically quickly runs out.
3) Mn reduction and Fe reduction: dependent on soil composition.
4) SO_4 reduction: usually minor in fresh water and more important in marine environments

5) CO_2 reduction (methanogenesis): usually highly available and thus very important in freshwater systems, particularly those rich in OM.

Table 5-1. Sequence of Organic Matter Oxidation Preceding Methanogenesis in Aquatic Environments.

Organic Matter Oxidation Reactions (Reducing Half-Reactions)		
Sequence	**Reaction**	**E° (v)**
1. Reduction of O_2	$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	+0.812
2. Reduction of NO_3	$2NO_3^- + 6H^+ + 6e^- \rightarrow N_2 + 3H_2O$	+0.747
3. Reduction of Mn^{4+}	$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$	+0.526
4. Reduction of Fe^{3+}	$Fe(OH)_3 + 3H^+ + e^- \rightarrow Fe^{2+} + 3H_2O$	-0.047
5. Reduction of SO_4^{2-}	$SO_4^{2-} + 10H^+ + 8e^- \rightarrow H_2S + 4H_2O$	-0.221
6. Reduction of CO_2	$CO_2 + 8H^+ + 8e^- \rightarrow CH_4 + 2H_2O$ -or- $CH_3COOH \rightarrow CH_4 + CO_2$	-0.244

CH_4 produced by microbial anaerobic respiration in benthic substrates can be converted to CO_2 in the overlying water column, as represented by the following reaction:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

CH_4 can undergo reverse methanogenesis within anoxic freshwater or low salinity estuarine sediments, whereby it is anaerobically oxidized via coupling to nitrate and nitrite reduction, thus reducing the emission of CH_4 (Tremblay et al. 2005). This results in a CH_4 sink instead of source, although CO_2 is still produced. However, as stated previously CH_4 is the more potent GHG as it is 25 times better at trapping heat than CO_2.

Anaerobic oxidation occurs via the following reactions:

$$CH_4 + 4NO_3^- \rightarrow CO_2 + 4NO_2^- + 2H_2O$$

$$3CH_4 + 8NO_2^- + 8H^+ \rightarrow 3CO_2 + 4N_2 + 10H_2O$$

The decomposition of organic C by microbes in reservoirs can be a significant source of CH_4 to the atmosphere, but can range substantially depending on water temperature, reservoir age, sediment deposition rates, redox conditions, and the quantity and quality of C delivered to the sediments (Barros et al. 2011; Nguyen et al. 2010; Sobek et al. 2012; West et al. 2012; Falter 2017). Generally, systems that are more nutrient-enriched exhibit higher rates of CH_4 emission, and autochthonous C has been correlated to higher rates of methanogenesis than allochthonous C (Bastviken et al. 2008; West et al. 2012). A key characteristic of reservoirs that emit high levels of CH_4 is the presence of large amounts of flooded OM, particularly under anoxic conditions, and CH_4 production is further increased from continued high inputs of OM and the nutrients nitrogen and phosphorus (Nguyen et al. 2010; Sobek et al. 2012; Harrison et al. 2016).

As mentioned previously, methanogenesis depends on the availability of OM, in the form of either particulate organic matter (POM) and/or dissolved organic matter (DOM), which is then reduced under anaerobic conditions. Recent studies have associated CH_4 production with shallow depth systems, shallow (littoral) areas of reservoir systems, marshlands, embayments (coves), and stream deltas, which provide concentration points for OM and can positively influence methanogenesis (Bastviken et al. 2004; Demarty and Bastien 2011; West et al. 2012; Arntzen et al. 2013; Deemer et al. 2016; Falter 2017). These conditions, particular to each reservoir, result in extensive variability in CH_4 production both between and even within reservoirs. In run-of-river reservoirs, as on the mid-Columbia River, a littoral aquatic macrophyte (AM) bed may have CH_4 production rates per unit area 3 or 4 orders of magnitude greater than in the adjacent deep-water column (Falter 2017). The following table shows principal controllers of CH_4 emissions for reservoirs in general, demonstrating the extensive variables that drive CH_4 emissions (Table 5-2).

Table 5-2. Controllers of CH_4 Emissions to Atmosphere from Reservoirs (Falter 2017).

Controllers of CH_4 Production and Release[1/]	Relationship to CH_4 Production and Release
Reservoir age	CH_4 production sharply drops after 3 years; release of soluble OM and nutrients from flooded terrestrial vegetation tails out to near zero after 30-50 years
Reservoir surface area[b] (size)	CH_4 production (mg CH_4 m^{-2} day^{-1}) higher in small lakes/reservoirs; Dramatically increased in water bodies less than 1 – 2 km^2 (0.3 – 0.7 mi^2).
Lake length	Greater length provides greater shoreline length and potential for littoral development.
Shoreline development (SDL): compares shoreline length to a same area circle	Higher SDL related to potentially higher littoral thus potential sites of CH_4 production and release
Lake orientation	Wind fetch strongly correlated to mixing, thus sediment entrainment and gas diffusion at S/W and A/W interfaces
Hydraulic Retention Time (HRT)	CH_4 production directly correlated w/ HRT; Low HRT water bodies have very low CH_4 emission rates in pelagic waters.
Lake level fluctuation – Load following	CH_4 release from shallow sediments positively correlated with fluctuation frequency magnitude, and rapidity of water surface change.
Year-round top-to-bottom water circulation	Precludes development of anoxia, hence CH_4 production in water column and surficial sediments year-round; anaerobic conditions with accompanying methanogenesis may occur in deeper sediments. Thicker sediment deposits may store more CH_4, subject to release at S/W interface with sufficient currents.
Winter ice cover	Winter ice cover in a water body can provide a months-long seal of the A/W interface leading to lower under-ice oxygen levels and increased CH_4 accumulation both in the water column and sediments due to anoxic conditions. Large volumes of CH_4 releases can then occur at Spring overturn.

[b] Per Holgerson and Raymond (2016): Small lakes have a high perimeter-to-surface-area ratio and accumulate a higher relative amount of terrestrial carbon. Small lakes also tend to be shallow, which means their terrestrial carbon loads are highly concentrated compared to larger lakes. Lastly, gases produced at the bottom of these lakes are able to surface more so than in larger lakes, due to greater water mixing and shallower waters.

Controllers of CH_4 Production and Release[1/]	**Relationship to CH_4 Production and Release**
Vertical water stratification	Stratification permits vertical layering and isolation from atmosphere of deeper areas of water column and sediments. Anoxia is enhanced with subsequent CH_4 production.
Near-bottom velocity	CH_4 production in, and release from sediments at S/W interface negatively correlated with near-bottom velocity.
Fine sediment accumulation	CH_4 production is inversely correlated with sediment particle size, i.e., finer sediments can have higher rates of methanogenesis.
Littoral fine, organic-rich sediment	Strongly correlated with near-shore band of OM accumulation, potential CH_4 production, and AM, then release via either: 1) direct diffusion to water [least important], ebullition; or 2) the AM pathway to water. Relative areal coverage determines total CH_4 release of the total reservoir.
Organic content of watershed soils	Aquatic CH_4 production is positively correlated with allochthonous (loading from terrestrial sources) OM inputs to reservoir.
Organic content and nutrients of lake sediments	High CH_4 production is correlated with OM and nutrients of sediments. Drowned timber and terrestrial vegetation extremely important drivers of methanogenesis in early life of reservoir.
Littoral sediment development	Littoral fine sediments tend to be rich in OM and nutrients, correlating with methanogenesis and CH_4 release to water via diffusion, ebullition, or AM piping, yielding the highest rates of CH_4 production in a reservoir per unit area.
Nutrient loading from watershed to reservoirs	CH_4 production increases with non-point watershed nutrient supply (irrigated agriculture, forest practices, and urban runoff).
Nutrient loading to reservoirs	Higher nutrient loading usually leads to higher lake productivity, organic sediments, and CH_4 production.
In-Reservoir (autochthonous) production	Higher autotrophic production provides more OM to sediments for anaerobic decomposition in sediment, thus higher CH_4 production. Autotrophic OM production from within the water body is more efficient at CH_4 production.
Water temperature	Higher water temperatures correlate very strongly with higher CH_4 production
Water transparency	Clearer waters indicate lower plankton but higher potential littoral AM production; balance of resulting OM accrual is dependent on physical characteristics, e.g., steep shorelines limit littoral area, greatly reducing CH_4 production rates.
Rooted aquatic macrophyte (AM) development	Shore bands of AM reduce water velocity which forms, traps, and builds OM- and nutrient-rich benthic sediments. By reducing velocity in thick beds, deeper anoxic sediments conducive to methanogenesis develop.
CH_4 Ebullition to surface	Generally a large factor in CH_4 release to atmosphere in littoral waters < 3 m for several reasons: 1) drawdown-enhanced release of CH_4 from sediments occurs mostly in the drawdown band; 2) OM deposits form there from settling in quiescent water along with high OM production from ABA and AM; 3) AM release bubbles in the shallow littoral ensuring that more CH_4 reaches the surface; and 4) AM piping of gaseous CH_4 to the A/W. In deeper water columns, most of CH_4 bubbles are absorbed and/or oxidized to CO_2 before reaching the A/W interface.
ABA = attached benthic algae	AM = aquatic macrophytes
S/W = sediment/water interface	A/W = air/water interface
OM = organic matter	WS = Watershed of reservoir

403 1/ Bold type = major forcing factor

CH_4 can be released into the water column via diffusion, bubbling (ebullition), or by plant-mediated transport in the presence of emergent vegetation (Bastviken et al. 2004; Harrison et al. 2016). CH_4 can also be emitted from reservoirs during drawdown periods via degassing at turbines and spillways (Deemer et al. 2016). The graphic below depicts CO_2 and CH_4 pathways in a freshwater reservoir with an anoxic stratum (Figure 5-3):

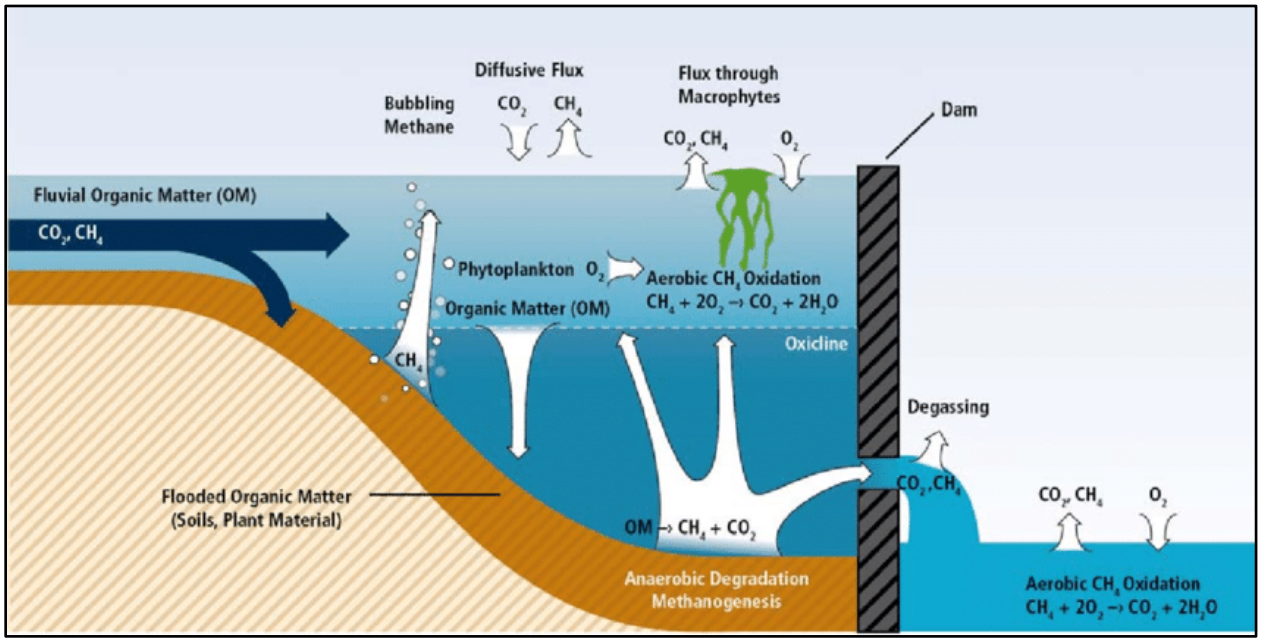


Figure 5-3. Pathways of CO_2 and CH_4 in a freshwater reservoir with an anoxic stratum (Kumar et al. 2012).

Ebullition occurs when CH_4 gas is formed when the partial pressure of all dissolved gases in the pore-water exceeds the ambient pressure and surface tension of the overlying water (Boudreau et al. 2005; Boudreau 2012). Bubbles then develop and enlarge under continued production of CH_4, causing fissures or spaces to form inside the sediment (Boudreau 2012; Johnson et al. 2002). As CH_4 production within the sediment continues, the gas bubbles can grow, combine with other bubbles, and travel upwards through the sediment until they are released into the water column and ultimately into the atmosphere. Figure 5-4 depicts the general pathway of CH_4 production in lakes and reservoirs in forming CH_4 bubbles. Reservoir drawdowns decrease the hydrostatic pressure upon the sediment, which can enable bubbles to move more easily and quickly upward through the sediment, allowing CH_4 ebullition rates to temporarily increase (Maeck et al. 2014). Conversely, in areas where the water is deeper and less disturbed, less CH_4 ebullition occurs because most of CH_4 bubbles are absorbed and/or oxidized to CO_2 before reaching the air. (Beaulieu et al. 2016, Falter 2017).

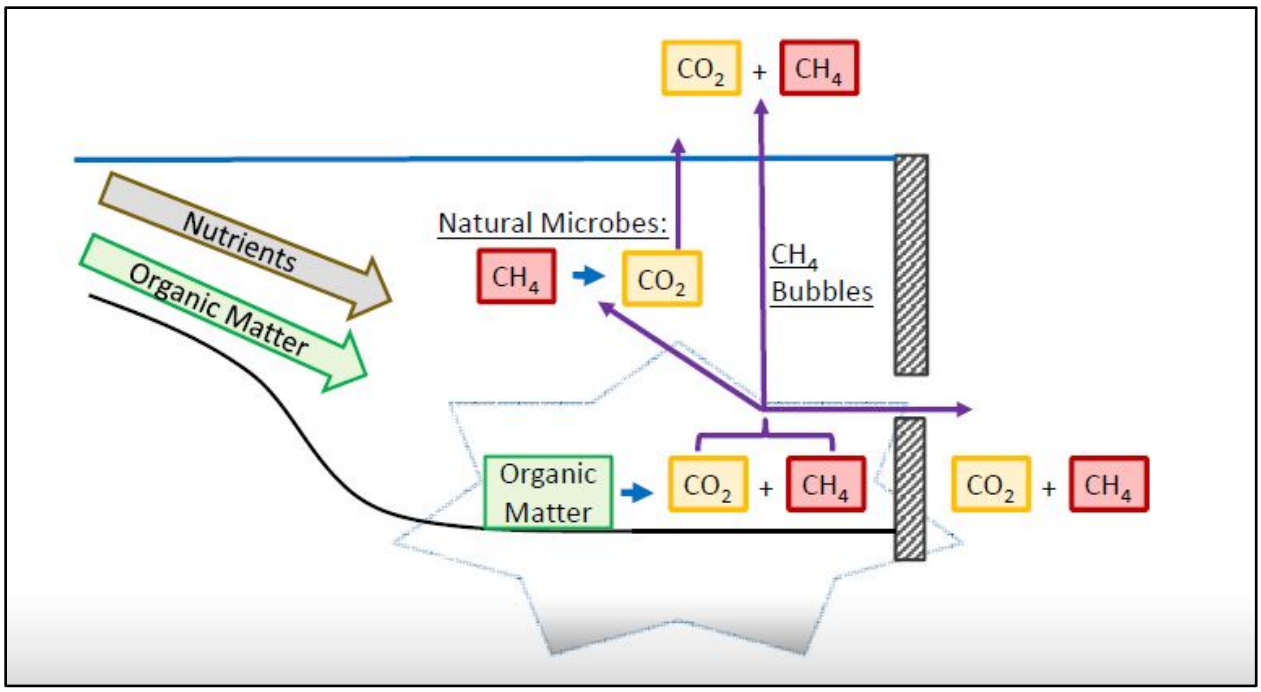


Figure 5-4. Diagram of anaerobic GHG production in lake sediments and resulting formation of CH_4 bubbles within the water column (Northwest Power and Conservation Council 2017).

5.1.2 Methane (CH_4) Emissions Evaluation Framework

The purpose of this report is to provide a preliminary assessment of the potential impacts affecting CH_4 emissions from hydroelectric dam operations within the Columbia River basin. While little research currently exists for this particular geographical area, this is a burgeoning topic of interest and ongoing research initiatives are hoping to capture more information regarding CH_4 emissions from hydroelectric projects in the Pacific Northwest to better inform regional decision makers and dam owner/operators on potential impacts resulting from hydropower operations. In light of the limited data available and time and resource constraints, this report relies on a collection of representative and/or relevant research findings within the field of GHG emission analyses, and as mentioned previously will focus primarily on CH_4 emissions as this is the more potent GHG compared to CO_2.

5.2 LEVEL 1 EVALUATION

5.2.1 River Basin Description

This assessment of GHG emissions encompasses the entire Columbia River basin located south of the U.S.-Canada border, including the mainstem Columbia River and its tributaries, such as the Kootenai and Snake Rivers, located within the Pacific Northwest region (parts of Montana, Idaho, Washington and Oregon). The headwaters of the Columbia and Kootenai Rivers are excluded as these reside in Canada. Figure 2-1 shows the basin and major hydropower projects.

The Columbia River is the fourth largest river in North America as measured by average annual flow and the single largest freshwater source on the west coast. It originates in British Columbia and flows 1,954 km (1,214 mi) through Canada and the United States to the Pacific Ocean. Although only 15 percent of the river's basin lies in Canada, 38 percent of the average annual flow volume originates in Canada. In addition, up to 50 percent of the peak flood waters in the lower Columbia River between Oregon and Washington originate from snowmelt in the Canadian portion of the Columbia River basin. Seasonal unregulated discharge ranges widely from 36,000 cfs to 1,240,000 cfs with an annual mean of 275,000 cfs. The estuarine portion of this immense river, as defined by salt intrusion, ranges from 20 km to 50 km (12 mi to 31 mi) long and the river is tidally influenced all the way upstream to the first hydroelectric project, Bonneville Dam, located 235 km (146 mi) from the estuary mouth (Figure 5-5). Average water depth is 7 m (23 ft), with narrow channels that are dredged to 20–30 m (65–98 ft) deep (Pfeiffer-Herbert et al. 2015).

Within the basin over 60 large hydroelectric projects and their reservoirs are owned and operated by many different entities for multiple purposes (Figure 5-5). The hydroelectric projects located in Eastern Washington, the mid-Columbia mainstem reach, on the Kootenai and Flathead Rivers in Montana, and on the Snake River in Idaho are all within xeric terrain. Many of these reservoirs, along with those located in hydric Western Oregon, have agricultural inputs and are generally not nutrient-limited (Arntzen et al. 2013). However, compared to other U.S. regions, most Pacific Northwest rivers are colder, swifter, and more oxygenated, and thus generally have better water quality with modest levels of nutrient inflow impacts (Arntzen et al. 2013; Falter 2017). Nonetheless, some parts of the basin have substantial drainage areas with significant nutrient loading from agricultural uses, urban/suburban runoff, and treated wastewater, boosting productivity particularly in the mid- and lower-Columbia segments. Conversely, some sections of the basin host ultra-oligotrophic reservoirs (Falter 2017). Overall, most of the reservoirs in the basin are generally oxic although some are known to be anoxic seasonally, such as the Brownlee complex on the Snake River (Arntzen et al. 2013; Nürnberg 2004); anoxic conditions are required for CH_4 production, as noted earlier.

Many Pacific Northwest hydropower complexes employ spring spill operations to aid migratory juvenile fish in accordance with the operative biological opinions and the Clean Water Act. Fish spill operations are conducted at the four lower Snake River and four lower Columbia River dams for the benefit of juvenile fish passage. Fish passage spill is also conducted at Dworshak Dam to provide additional water for flow augmentation and to moderate temperature in the lower Snake River. Such spill operations have the potential to enhance CH_4 outgassing in the tailrace.

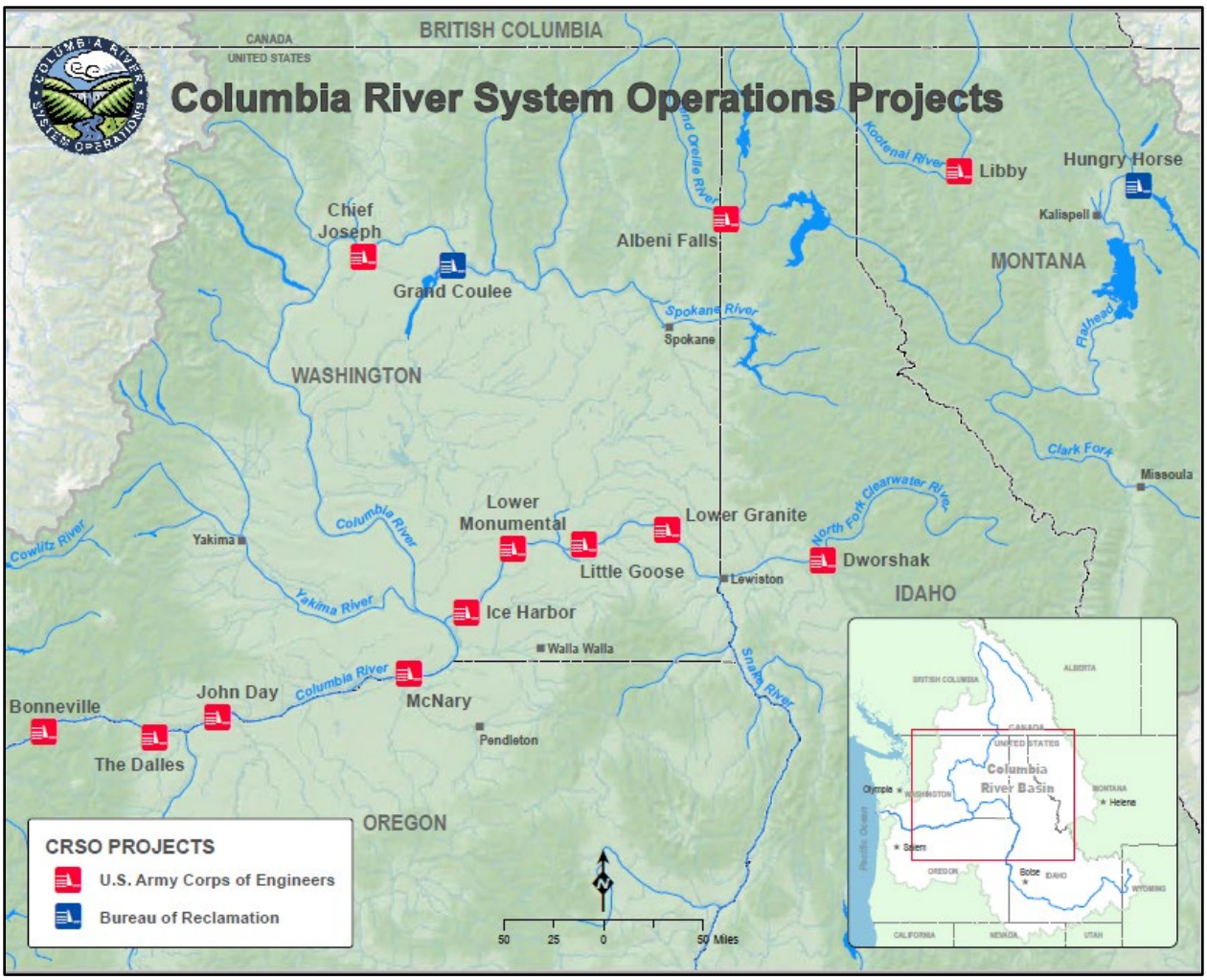


Figure 5-5. Columbia River basin showing major federal hydroelectric projects.

Specifically, high CH_4 emission rates may occur if gas levels increase within slow moving river reaches and then is rapidly released downstream at turbulent sites (Lilley et al. 1996; Nürnberg 2004). Drafting reservoirs can also lead to ebullition of CH_4 because the hydrostatic pressure on littoral sediments becomes reduced, enabling CH_4 bubbling directly into the water column instead of undergoing oxidation (Falter 2017). Fluctuating reservoir levels can also contribute to releases of CH_4 from the littoral zone, although most of the drawdown zone typically encompasses the surface waters which do not contain adequate OM and fine sediments necessary for CH_4 production (Falter 2017). This is especially true for projects located in Eastern Washington and Western Idaho (i.e. the Snake River Complex and Dworshak dam).

5.2.2 Summary of Existing Data

While very little data is available for Columbia River hydropower project reservoirs, recent findings show that CH_4 emissions from hydroelectric reservoirs in the basin are relatively low compared to other hydroelectric reservoirs, likely because of the well-oxygenated conditions typically found in the basin, particularly in the mainstem of the river (Kumar et al. 2012; Falter

2017). Soumis et al. (2004) found a range of emissions between 3.2 – 9.0 mg CH_4 m^{-2} day^{-1} for F.D. Roosevelt Lake, behind Grand Coulee Dam in the upper portion of the basin. Priest Rapids Reservoir, located on the mid-Columbia reach, was found to have very low surface estimates of CH_4: Falter (2017) reported a mean of 0.004 mg CH_4 m^{-2} day^{-1} from the pelagic zone and Arntzen et al. (2013) reported a mean close to zero. The Lower Monumental Reservoir on the Snake River was also found to have comparable mean flux rates (Arntzen et al. 2013; Falter 2017). By comparison, the free-flowing Hanford reach of the Columbia was found to have a mean surface flux of 0.08 mg CH_4 m^{-2} day^{-1} during the fall (Arntzen et al. 2013). These amounts are quite low compared to a global synthesis, whereby Deemer et al. (2016) calculated a mean range of CH_4 emissions from hydroelectric reservoirs worldwide of 24 – 112 mg CH_4 m^{-2} day^{-1} and a mean of 120 mg CH_4 m^{-2} day^{-1} for all reservoirs worldwide.

Conversely, CH_4 production in the littoral zone of the Priest Rapids Reservoir was found to be much higher, with a mean of 362 mg CH_4 m^{-2} day^{-1} (Falter 2017). This large difference between the two reservoir zones is likely due to underestimating CH_4 flux by current gas diffusion methodologies as it is difficult to accurately quantify and thus extrapolate. The high potential for CH_4 production in littoral zones of a water body that is only moderately productive, like Priest Rapids reservoir, is another factor influencing this measurement (Falter 2017). It is important to note that the high ratio of pelagic:littoral area resulted in relatively low overall reservoir-wide mean CH_4 emissions compared to general estimates for reservoirs on a national scale (Falter 2017).

Given evidence from Falter (2017), littoral areas in the Columbia River Basin are expected to be confined to the mid-Columbia River area, an area in which the CRS project reservoirs do not experience considerable changes in under any of the MOs or the Preferred Alternative. While MO3 would result in breaching the four lower Snake River projects, which would result in the loss of the reservoirs behind these projects, the information provide in Falter (2017) indicates that littoral areas are less likely at these sites.

Chapter 3 of the EIS details some of the characteristics of regions through the CRSO study area, including the mid-Columbia region (Region B) where littoral zones are abundant. For example, Table 5-2 profiles the hydrology of reaches in the region, noting that many of these areas are characterized by flat pools at particular times of year, while Section 3.3 describes sediment supply and transport in the same region. More information about the aquatic vegetation and shoreline development that that contributes to CH_4 production in the littoral zones abundant in the mid-Columbia River, is described in detail in Section 3.6 of the EIS.

The Priest Rapids reservoir has very comparable limnology to the Rock Island and Rocky Reach reservoirs directly upstream (Falter 2017). The data for Priest Rapids can be applied toward these reservoirs, thus it is expected that there are very low CH_4 emissions from pelagic waters and sporadic distribution of moderately high CH_4 emission pockets within the littoral sediment accumulation zones and along aquatic macrophyte beds (Falter 2017). By applying the controllers of CH_4 production and emission described previously in Table 1-2 and within other global research results, pelagic methanogenesis is believed to be very low in the Rock Island

and Rocky Reach reservoirs and exceptionally low in oligotrophic water bodies such as nearby Lake Chelan, whose river flows into the Columbia (Deemer et al. 2016; Falter 2017). Given this, there are likely also amplified areas of CH_4 production near sediment deposition zones (i.e., stream deltas, backwater embayment areas, and nearshore deposition areas of organic sediment deposition) and areas with highly productive aquatic macrophyte beds and attached benthic algae populations. These amplified areas likely have high rates of local methanogenesis and may produce greater emissions of CH_4 within the water column and into the atmosphere (Falter 2017). As noted above, both reservoirs' morphometry and hydrology indicate that these potentially high CH_4 emission rates that are expected to occur within the littoral zones are a small portion of the overall reservoir area, suggesting that the CH_4 emissions per reservoir are likely to be low on the regional scale and extremely low on the national and worldwide scales of CH_4 emissions from hydropower project reservoirs (Falter 2017).

For the lower river section, studies have found higher CH_4 oxidation in the lower Columbia River estuary compared to the mainstem and tributaries because of the prevailing saltwater conditions, which results in a net uptake of riverine CH_4 by the estuarine sediment, creating a CH_4 sink (Lilley et al. 1996; Tremblay et al. 2005). Pfeiffer-Herbert et al. (2015) found that nearly a quarter of the riverine CH_4 supply was consumed by methantrophic bacteria within the Columbia River estuary, greatly reducing the potential for CH_4 emissions. Additionally, the estuary experiences rapid flushing due to the sheer volume of discharge from the Columbia River and also tidal action, which both minimize CH_4 production (Pfeiffer-Herbert et al. 2015).

Degassing of CH_4 at hydroelectric projects' forebays and tailraces from water passing through the turbines or spillways is highly variable between each project and appears to also be dependent on the season (Arntzen et al. 2013). Overall, system concentrations of CH_4 in March across Columbia River hydroelectric projects were lower in the tailrace than in the forebay, indicating that the system was a source, with a mean degassing flux of 3.1×10^{-6} t CH_4 d^{-1} (Arntzen et al. 2013). During September, the system was a sink for CH_4, with a mean degassing flux of -5.6×10^{-4} t CH_4 d^{-1} (Arntzen et al. 2013). This also supports Falter's (2017) findings that Lower Monumental and Priest Rapids were sinks for CH_4 at the hydropower projects' outflows.

Ebullition as measured in littoral embayment zones for the mid-Columbia and Snake River hydropower complexes were high in September (mean concentrations of CH_4 were over 7,000 mg L^{-1}) and were roughly an order of magnitude lower in March (Arntzen et al. 2013). These results are to be expected, as higher CH_4 flux coincides with increased temperatures in the summer (DelSontro et al. 2010). Increased summer temperatures also moderately affect hyporheic flux of CH_4 within sediment pore-water in littoral embayments – the system had mean fluxes of 4.2 mg m^{-2} day^{-1} in March and 8.1 mg m^{-2} day^{-1} in September (Arntzen et al. 2013). CH_4 efflux from ebullition was more pronounced in embayment areas within reservoirs than embayments located in the free-flowing Hanford reach segment of the River, as was CH_4 pore-water flux, although the differences in the sediment pore-water values were minor and remained relatively constant seasonally (Arntzen et al. 2013).

There can be wide variation between projects' estimated CH_4 emissions from ebullition: the mean flux for the embayments of the Lower Monumental reservoir on the Snake River ranged from roughly 10.5 – 533 mg CH_4 m^{-2} day^{-1}, and Priest Rapids reservoir embayments had a range of about 176 – 1039 mg CH_4 m^{-2} day^{-1} (Arntzen et al. 2013). Again, it is difficult to accurately estimate and extrapolate CH_4 ebullition flux for a given area using current gas diffusion methodologies and given the extensive range of small-scale site-specific variables that control CH_4 emissions (Falter 2017).

5.3 RECOMMENDATIONS AND CONCLUSIONS

5.3.1 Methane (CH_4) Emissions Summary

The available data presented in this report on surface fluxes of CH_4 emissions from diffusion for the Columbia River hydroelectric project reservoirs, particularly those located on the mainstem or in more arid terrain, demonstrate that the basin's overall contributions to global CH_4 emissions are very small compared to other studies of comparable systems (Table 5-3), although they can be quite high locally. The Columbia basin reservoirs produce CH_4 in the range of one or two orders of magnitude less than current global estimates of surface emissions from reservoirs, even when only including hydroelectric reservoirs (Table 3-1). As discussed previously, relatively cold water temperatures and OM input coupled with well-oxygenated conditions and low water residence times prevalent throughout the basin contribute to low levels of CH_4 emissions in the region (St. Louis et al. 2000; Barros et al. 2011; Kumar et al. 2012; Arntzen et al. 2013; Falter 2017). The emission values seen thus far for the Columbia River system are quite low; indeed, during the fall the system tends to act as a CH_4 sink (Arntzen et al. 2013; Falter 2017). Slightly higher rates of CH_4 emissions from diffusion have been identified at other reservoir settings in the United States, including both run-of-river projects and lakes **(**Beaulieu et al. 2016, 2018; Bevelhimer et al. 2016).

Table 5-3. Compiled synopsis of CH_4 emissions from diffusion from recent literature.

Literature Synopsis of CH_4 Emissions from Diffusion		
Surface flux amount	**Sample Site Information**	**Source Cited**
120 mg CH_4 m^{-2} d^{-1}	Global reservoirs (all)	Deemer et al. 2016
1.0×10^{11} g CH_4 y^{-1}	Global temperate reservoirs	Barros et al. 2011
24 – 112 mg CH_4 m^{-2} d^{-1}	Global hydroelectric reservoirs	Deemer et al. 2016
1.5 – 12.0 mg CH_4 m^{-2} d^{-1}	Temperate run-of-river reservoir, Switzerland	DelSontro et al. 2010
3.0 – 11.0 mg CH_4 m^{-2} d^{-1}	Wisconsin recreational reservoirs (flooded peatlands)	St. Louis et al. 2000
3.2 – 9.0 mg CH_4 m^{-2} d^{-1}	F.D. Roosevelt Lake, Columbia River (behind Grand Coulee Dam)	Soumis et al. 2004
4×10^{-3} mg CH_4 m^{-2} d^{-1}	Priest Rapids Reservoir	Falter 2017
0 mg CH_4 m^{-2} d^{-1} (350 g CH_4 y^{-1})	Priest Rapids complex	Arntzen et al. 2013
0 mg CH_4 m^{-2} d^{-1} (-0.5 g CH_4 y^{-1})	Lower Monumental complex, Snake River	Arntzen et al. 2013
0.08 mg CH_4 m^{-2} d^{-1}	Hanford Reach, Columbia River (September)	Arntzen et al. 2013

Literature Synopsis of CH_4 Emissions from Diffusion		
Surface flux amount	**Sample Site Information**	**Source Cited**
0.07–6.18 mg CH_4 m^{-2} h^{-1} in tributary areas 0.03–2.18 mg CH_4 m^{-2} h^{-1} in in open water areas	Harsha Lake, Ohio	Beaulieu et al. 2016
2.0 mg CH_4 m^{-2} h^{-1}	Harsha Lake, Ohio	Beaulieu et al. 2018
251-5151 kg CH_4 day^{-1}	Six hydropower reservoirs in the southeastern United States	Bevelhimer et al. 2016

For contributions of CH_4 emissions to the atmosphere via degassing at hydroelectric projects, Arntzen et al. (2013) found that the tailrace acted as a sink seasonally in the fall with an overall net flux of -4.2×10^{-4} t CH_4 d^{-1}, which supports Falter's (2017) finding that the tailraces of hydroelectric complexes along the mainstem were sinks for CH_4. Soumis et al. (2004) also found low emissions of CH_4 emissions via degassing, with values ranging from 0.003 – 0.815 t CH_4 d^{-1} for hydropower project reservoirs in the upper basin (F. D. Roosevelt) and on the Clearwater River (Dworshak), a tributary to the Snake River.

Table 5-4 describes the flux of CH4 emissions from ebullition recorded across recent studies, again comparing other sites to estimates from select CRSO sites. As previously described, ebullition can account for the most significant source of CH_4 emissions from reservoirs. Arntzen et al. (2013) recorded high and extremely variable efflux of CH_4 via ebullition within littoral embayments, ranging from 10.5 to 533 mg CH_4 m^{-2} d^{-1} within Lower Monumental Dam reservoir embayments (mean flux of 324 mg CH_4 m^{-2} d^{-1}) and ranging from 176 to 1039 mg CH_4 $m^{-2}d^{-1}$ within Priest Rapids Dam reservoir (mean flux of 482 mg CH_4 m^{-2} d^{-1}). Arntzen et al. (2013) were careful to note that their study was not designed to estimate reservoir-wide ebullition emissions; as mentioned previously it is very difficult to accurately estimate and extrapolate CH_4 ebullition flux for an entire reservoir, let alone a complete river system, especially one the size of the Columbia River basin. These areas are characterized by water velocity near zero, abundance of aquatic macrophytes, oxic conditions, and high nutrient inputs, which all contribute to CH_4 production. Related research in the CRSO context by Miller et al. (2017) found that ebullition comprises more than 97 percent of emissions from these two hydropower reservoirs. Combined, these estimates from CRS projects suggest considerable variability across sites.

Unlike the diffusion citations, these CRS projects can produce methane from ebullition at levels more consistent with other temperate reservoirs recently studied. Beaulieu et al. (2016) identify ranges of 0 to 136.1 mg CH4 m^2 h^{-1} in the open-water areas and 0 to 186.1 mg CH_4 m^2 h^{-1} in the tributary-areas of Harsha Lake in Ohio. In a more recent study at the same site, Beaulieu et al. (2018) report rates they characterize as among the highest ever reported at a reservoir (mean of 32.3 mg CH4 m^{-2} h^{-1}), however this site (a lake) is very dissimilar to the reservoirs within the CRSO system. At six hydropower reservoirs in the southeastern United States, ebullition rates ranged considerably from 0 to 3834 kg day^{-1}. In similarly temperate European settings, DelSontro et al. (2010) found ebullition values for a Swiss reservoir to be substantially higher at roughly 1,000 mg CH_4 m^{-2} day^{-1}. For reservoirs in France and Germany, Decloux et al.

(2017) extrapolate their findings to estimate total annual ebullition flux of 2.7±2.3 $MgCH^4$ while Maeck et al. (2013) identify emissions ranges of 0 to 4235 mg m^{-2} d^{-1} across ten sites, respectively. Across studies that measure both types of emissions, CH_4 emissions from ebullition are more significant contributors to total emissions than diffusion.

Table 5-4. Compiled synopsis of CH_4 emissions from ebullition from recent literature.

Literature Synopsis of CH_4 Emissions from Ebullition		
Surface flux amount	**Sample Site Information**	**Source Cited**
324 mg CH_4 m^{-2} d^{-1}	Lower Monumental Dam, Snake River, Washington	Arntzen et al. 2013
482 mg CH_4 m^{-2} d^{-1}	Priest Rapids Dam reservoir, Columbia River, Washington	Arntzen et al. 2013
0–136.1 mg CH_4 m^2 h^{-1} in the open-water areas 0–186.1 mg CH_4 m^2 h^{-1} in the tributary-areas	Harsha Lake, Ohio	Beaulieu et al. 2016
32.3 mg CH_4 $m^{-2}h^{-1}$	Harsha Lake, Ohio	Beaulieu et al. 2018
0-3834 kg CH_4 day^{-1}	Six hydropower reservoirs in the southeastern United States	Bevelhimer et al. 2016
1,000 mg CH_4 m^{-2} day^{-1}	Swiss reservoir	Del Sontro et al. 2010
2.7±2.3 mg CH_4 annually	French reservoir	Descloux et al. 2017
0-4235 mg CH_4 m^{-2} d^{-1}	Ten German reservoirs	Maeck et al. 2013

Reservoir drawdown can influence rates of CH_4 ebullition due to a reduction in the hydrostatic pressure on littoral sediments. The magnitude of effects of fluctuating reservoir levels on CH_4 emissions from the littoral zone and riverine areas depends on specific localized site characteristics (Falter 2017); the projects that are typically drafted more deeply during seasonal operations are located in more arid regions of the basin (i.e. the Snake River Complex and Dworshak dam), and thus are less likely to experience large increases in CH_4 emissions during drawdown periods. For these reservoirs that undergo a wider operating range, the fluctuation of the reservoir levels and the age of the projects prevent sufficient amounts of impounded OM needed for increased CH_4 production. These hydroelectric projects are all at least 40 years old, and several studies have found that GHG production is severely reduced or mirrors emissions from natural lakes after ten years (St. Louis et al 2000; Tremblay et al 2004; IPCC 2006; Barros et al 2011). Arntzen et al. (2013) found hyporheic flux of CH_4 within sediment pore-water in littoral embayments to range from approximately 4 – 8 mg m^{-2} day^{-1}, while DelSontro et al. (2010) found peak flux from sediments to be about 40 mg m^{-2} day^{-1} for a temperate hydropower project reservoir in Switzerland. Despite this seemingly high value, DelSontro et al. (2010) estimated the system-wide sediment flux to be only about 15 mg m^{-2} day^{-1}.

5.3.2 Recommendations

Ideally, more data is required to fully assess and verify contributions of CH_4 emissions via the various pathways from hydroelectric reservoirs within the Columbia River basin. Unfortunately, due to time and resource constraints, a full suite of scientific data collection and analyses is simply not feasible at this time. Data and knowledge gaps imperative to quantifying CH_4

emissions from hydroelectric reservoirs in the Columbia River basin and determining their contribution to the global carbon budget are detailed below.

It is critical to incorporate both short and long-term temporal and spatial variability in research efforts, which can be quite difficult to capture due to resource constraints and logistical feasibility. As discussed previously, the amount of CH_4 emitted varies widely among reservoirs (depending on basin-specific characteristics, reservoir morphology, latitude, and climate), within reservoirs (nearshore vs. water column, sample site proximity to dam and location within the water column), and over time (land use changes, reservoir aging, seasonal and daily biological and physical changes such as precipitation, photosynthesis, methanogenesis, and temperature). In addition, individual dam operation should also be considered; operations vary, depending on energy demand, reservoir level, and runoff/precipitation amounts. Average CH_4 diffusive emission values can vary by an order of magnitude in temperate regions, highlighting the need for comprehensive assessments (IPCC 2006).

Despite the difficulties of such an endeavor, quantifying CH_4 emissions from reservoirs is essential because reservoirs can be of substantial size, e.g., Franklin D. Roosevelt Lake, behind Grand Coulee Dam, is considerable at 125 mi^2 (324 km^2). Furthermore, the extensive total surface area of all reservoirs regionally and globally necessitates studying these systems at larger spatial and temporal scales to capture all of the variability in order to establish realistic estimates of CH_4 contributions to the regional and global carbon budgets.

Arguably the most important aspect towards broadening the knowledge base of mechanisms contributing to CH_4 emissions is to conduct comprehensive assessments of site-specific characteristics for each reservoir, notably climate (wind, precipitation, temperature) and drainage basin characteristics (residence time, OM inputs). Climate affects OM inputs and CH_4 production and oxidation (Nguyen et al. 2010; Barros et al. 2011; Sobek et al. 2012; West et al. 2012; Falter 2017); wind, precipitation and temperature likely affect gas exchange rates at the water-atmosphere interface (Bastviken et al. 2008), and it has also been thoroughly demonstrated that warmer temperatures are associated with greater CH_4 emissions (Barros et al. 2011; Demarty and Bastien 2011; Deemer et al. 2016).

Additionally, since increased GHG emissions is positively correlated with warmer temperatures, there will be an ongoing need to study the impacts of climate change on CH_4 processes within temperate hydroelectric reservoirs (IPCC 2006). The IPCC notes that temperature is the main driver affecting reservoirs as a result of climate change, which impacts oxygenation levels, redox potentials, lake stratification mixing rates, growth of biota, and methanogenesis rates (IPCC 2006). Warming trends are likely to prolong and intensify summer thermal stratification which leads to anoxic conditions aiding increased methanogenesis, leading to increased CH_4 production (IPCC 2006; Barros et al. 2011; Demarty and Bastien 2011; Deemer et al. 2016).

Run-of-river hydroelectric projects are regularly used in densely populated areas with poor water quality to improve oxygen conditions or selectively draft cooler water from deeper within the reservoir (Kumar et al. 2012). This strategy could be useful in mitigating against the effects of increased GHG emissions from global climate change impacts. Building new structures that

promote degassing, such as stilling basins or aeration weirs, may also help prevent GHG supersaturation at project tailraces (Kumar et al. 2012). The IPCC (2006) recommends proactive risk management as an adaptive measure to address extreme climate events; as precipitation events become more unpredictable, reservoir operations may become more limited in range, particularly for run-of-river projects. Climate change is imperative to consider when assessing GHG production and future mitigation measures.

Wind stress can create turbulence and waves, affect vertical circulation (and contribute to down- or up-welling), and influence transport of OM or dissolved compounds involved in methanogenesis or oxidation, all of which is also dependent on the specific characteristics of the body of water (shape, depth, size) and its surrounding terrain (Bastviken et al. 2004; Falter 2017). Wind direction is particularly important in influencing downwelling or upwelling, which can directly affect CH_4 production. Downwelling favors CH_4 oxidation, as CH_4 is converted into CO_2 due to the heightened availability of oxygen coupled with a decreased supply of OM within the water column, thus reducing CH_4 emissions (Capelle and Tortell 2016). Conversely, upwelling can lead to increased CH_4 emissions as CH_4 from the deeper oxic regions is shuttled to the reservoir surface (Capelle and Tortell 2016). Indeed, coastal upwelling and downwelling were found to be the dominant transport mechanism for CH_4 across the continental shelf of southern British Columbia (Capelle and Tortell 2016). CH_4 measurements at varying water depths, under different weather conditions and in multiple seasons are necessary to determine the role upwelling and downwelling may play for any particular reservoir. These measurements can be difficult to obtain as the data collection must encompass broad spatial and temporal scales in order to capture upwelling or downwelling events, as evidenced by the extremely limited number of studies addressing the role of upwelling and downwelling in CH_4 production.

Land use, type and amount of vegetation cover, along with intensity and frequency of precipitation events can alter OM loading and water residence time, thus affecting CH_4 production and emissions (Bastviken et al. 2004). Reservoirs often have shorter residence times than natural lakes and have more complex in-situ variability because they typically have one or more major inlets compared to naturally occurring lakes (Falter 2017). The reservoir inlets also play into the dynamics of how OM is incorporated into the reservoir, e.g. if it is quickly carried to the deeper anoxic layers, the OM will more readily undergo methanogenesis (Capelle and Tortell 2016). These examples illustrate a need for measuring site-specific residence time and variability around OM inputs.

Another crucial element in understanding and quantifying CH_4 emissions is the adoption of standardized methods. There is a remarkable lack of consistent, standardized methods or protocol for measuring CH_4 emissions. Granted, this is a relatively new field of research - the first IPCC Assessment Report considering GHG contributions to global climate change was published in 1990. Yet after nearly 30 years there is still no standard methodology for measuring CH_4 emissions from reservoirs, particularly ebullition (Lilley et al. 1996; St. Louis et al. 2000; Johnson et al. 2002; Boudreau 2012; Harrison et al. 2016). The suite of environmental variables that contribute to ebullition is not fully understood, and as discussed earlier, emphasis should be placed on comprehensive assessments of site-specific characteristics to capture all

variables influencing CH_4 emissions. For instance, in deep reservoirs, CH_4 bubbles typically dissolve in the water column before reaching the surface, unlike in shallow reservoirs (Delsontro et al. 2010). This highlights the idea that estimating CH_4 diffusive emissions should be done on a case-by-case basis until additional knowledge on the dynamics of CH_4 emissions is available.

However significant and promising advancements in monitoring techniques that could be employed to generate emissions estimates have been made in recent years (e.g., Beaulieu et al. 2016). A recent study by Miller et al. (2017) provides an overview of the methods used to measure methane flux at temperate hydropower reservoirs, including the bubble trap, optical detector, echosounder, inverted tunnel, and automated bubble trap.

It is also important to understand the effects of stratification. Methanogenesis is prevalent in persistently stratified tropical reservoirs (Demarty and Bastien 2011), but because of oxidation by methantrophic bacteria in the oxygenated layer of the water column, most of the CH_4 produced in a tropical reservoir is instead emitted to the atmosphere as the less potent GHG CO_2 (Guerin and Abril 2007). While not strictly acting as a CH_4 sink, oxidation does ultimately reduce CH_4 emissions, although GHG is still being produced. Deep tropical reservoirs also allow greater methanotrophic activity in the water column compared to shallow reservoirs, resulting more efficient oxidation of CH_4 and less emission directly to the atmosphere (Lima 2005). Again, measurements should be conducted long- and short-term and across multiple depths and locations to capture temporal and spatial variability.

Turning to the role of hydroelectric projects themselves, more information is needed to fully understand and measure degassing from turbines. CH_4 degassing can occur at the project from turbulence as water passes through the turbines or can occur further downstream. When passing through the turbines, CH_4 gas is exposed to low pressure and high temperature conditions which enables rapid degassing in tropical reservoirs (Kemenes et al. 2007). However, high amounts of CH_4 can remain in the outflow after passing through the turbines; GHG has been measured up to 25 mi (40 km) downstream of a tropical dam (Guerin et al. 2006). These findings point to the need to better understand and quantify degassing that occurs at the turbines and downstream of hydroelectric dams, particularly in temperate regions for which such data is still lacking.

Another consideration that should be included in CH_4 emissions estimates is the concept that age matters: reservoirs produce more GHG in the first ten to twenty years after impoundment (IPCC 2006; Barros et al 2011). Studies of Canadian systems demonstrated that CO_2 emissions from reservoirs over ten years old were on par with emissions from natural lakes and rivers (Tremblay et al 2004). Temperate reservoirs had a significant negative relationship between age and GHG emissions, meaning with increasing age GHG diminished over time (St. Louis et al 2000). Therefore, it is important to incorporate the age of the reservoir in calculations of GHG emissions.

To more accurately estimate CH_4 contributions to the global carbon budget, future research efforts should continue to focus on tropical reservoirs due to the relationship between

temperature and high OM with CH_4 emissions and because this is the region with the most potential for future hydroelectric development. It would be very informative and beneficial to the scientific community at large to assess whether reservoirs are net CH_4 sinks or sources by evaluating pre- and post-impoundment values to compare carbon burial in the reservoir versus under pre-impoundment conditions (i.e., carbon burial in the ocean). However, as hydroelectric power is already very highly developed in temperate regions, many hydroelectric dams are nearing the end of their lifespans; consequently, the effects of dam decommissioning on the global carbon budget will be important to study. The major knowledge gaps listed above need to be filled by future research to better understand CH_4 production overall and to better estimate regional and global carbon budgets.

5.3.3 Conclusions

Primary contributing controllers of CH_4 emissions from hydroelectric project reservoirs are geographically and sample site-specific, and include availability of OM, condition of reservoir sediments, reservoir trophic status (dependent upon nutrient inputs, primary productivity, and water temperature), presence of rooted aquatic macrophyte and algal populations, and factors that affect CH_4 ebullition to the reservoir surface, including hydrostatic pressure changes and benthic sediment conditions (Falter 2017). Strong correlations have been identified between reservoir CH_4 emissions and OM and nutrient accumulation in nearshore sediments, nutrient loading in reservoirs (eutrophic conditions), increased water temperatures, and presence of aquatic macrophytes (Bastviken et al. 2004; Demarty and Bastien 2011; West et al. 2012; Arntzen et al. 2013; Deemer et al. 2016; Falter 2017). The available data and comparisons presented in this report support the likelihood that CH_4 emissions are very low from pelagic waters within Columbia River basin hydroelectric project reservoirs. The sporadic distribution of moderately high CH_4 emissions for some reservoirs results from 'hot spots' of littoral sediment accumulation and robust aquatic macrophyte beds. The high ratios of pelagic:littoral area, particularly for Eastern Washington reservoirs, in all probability means overall reservoir-wide CH_4 emissions are low in comparison to reservoirs on a regional or national scale.

Even though the surface flux measurements of Columbia River hydroelectric project reservoirs presented in this report indicate that CH_4 emissions are lower compared to other studies conducted in temperate regions, it's been shown that CH_4 ebullition and pore-water flux in littoral embayments can potentially produce substantial emissions, particularly in the summer. The values reported here may be high relative to surface flux values, but are on par with ebullition and pore-water flux results from recent comparable studies of temperate reservoirs and are much lower than global estimates (DelSontro et al. 2010; Arntzen et al. 2013; Deemer et al. 2016). The implication of these results is that temperate hydroelectric project reservoirs provide a modest source of CH_4 to the atmosphere. Indeed, several studies have found that, in particular, temperate estuarine and river contributions of CH_4 to the global budget are likely minor because of their small footprint (De Angelis and Lilley 1987; Middelburg et al. 2002; Borges and Abril 2012; Pfeiffer-Herbert et al. 2015). This realization coupled with the knowledge that the primary controllers affecting CH_4 emissions are inconsistently present within Columbia River basin reservoirs supports the conclusion that GHG emissions from

hydroelectric projects in the Columbia River basin play a relatively minor role in contributing to the global CH_4 and overall GHG emissions budgets.

Indeed, CH_4 emissions from reservoirs compared to total global sources are quite small. In mean estimates of data from the 2000s, global reservoirs, including tropical locations, contributed about 4–5% of CH_4 from anthropogenic sources, and of these, hydroelectric reservoirs contributed about 3–6% of CH_4 emissions (Deemer et al. 2016). However, non-tropical reservoirs have been shown to emit far less CH_4 due to local regional features such as geology, climate, type of flooded soils and vegetation, and hydrologic regime (Figure 5-6; St. Louis et al. 2000); CH_4 emissions from hydroelectric reservoirs in the western United States were reported to be the lowest of those on the continent, compared to eastern Canada and Central/South America (Soumis et al. 2004).

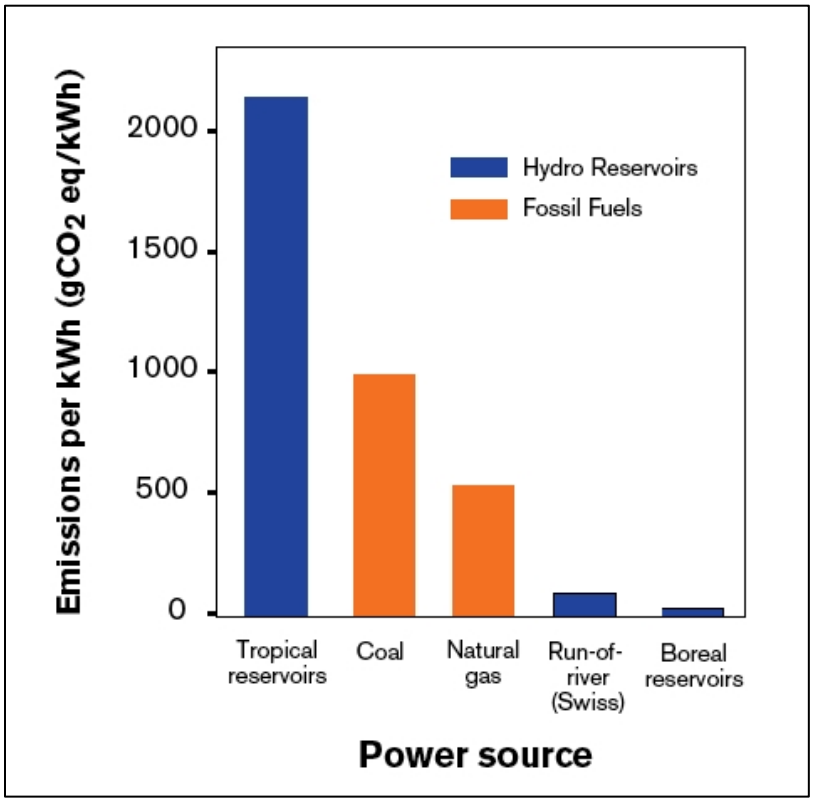


Figure 5-6 Comparison of CO_2 and CH_4 emissions per kilowatt-hour for various power sources

Note: based on one year of data; tropical reservoirs bar represents net average emissions from three Brazilian reservoirs, boreal reservoirs bar represents gross average emissions from five Canadian reservoirs, run-of-river bar represents gross emissions (without degassing) from the Wohlensee reservoir in Switzerland (International Rivers, 2008).

In the United States, ruminant digestion is the largest anthropogenic source of CH_4 (Figure 5-7; EPA 2018). Within the category of electric power production, hydroelectric dams account for a very small portion, second only to petroleum-based generation (gasoline or diesel generators, for example); the value is so small that hydroelectric GHG emissions are not accounted for separately in the EPA's 1990–2016 Draft Inventory of US Greenhouse Gas Emissions and Sinks,

but are included with renewable-based generation (Figure 5-8; EPA 2018). Again, CH_4 emissions are specific to the local characteristics of the reservoir and its operation, and those in the western United States, particularly the Columbia River basin, have been shown to be a minor player in contributing to the global budgets of GHG and especially CH_4 emissions compared to worldwide or even solely U.S. sources (Lilley et al. 1996; Soumis et al. 2004; Arntzen et al. 2013; Falter 2017).

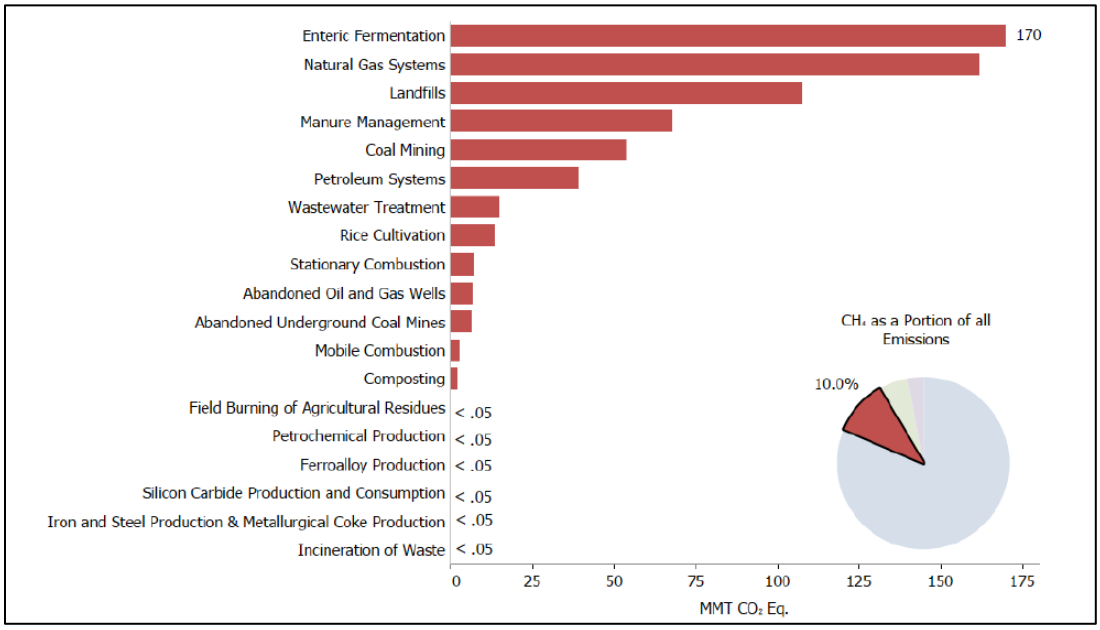


Figure 5-7. Anthropogenic sources of CH_4 emissions (million metric tons of CO2 equivalent) in 2016 (EPA 2018).

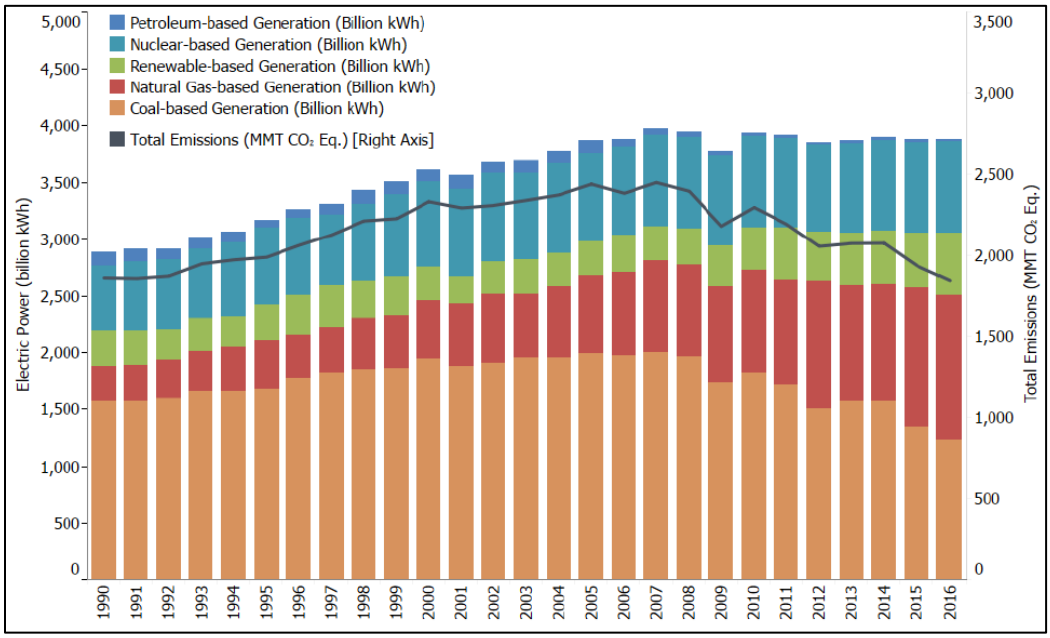


Figure 5-8. Emissions (million metric tons of CO_2 equivalent) from electric power generation; hydroelectric power is included in renewable-based generation, colored green (EPA 2018).

CHAPTER 6 - REFERENCES

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Appendix H
Power and Transmission

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ADS	Anchor dataset
aMW	Average Megawatts
Bonneville	Bonneville Power Administration
BP-20	Bonneville FY 2020-2021 rate proceeding
BP-22	Bonneville FY 2022-2023 rate proceeding
BP-28	Bonneville FY 2028-2029 rate proceeding
COI	California-Oregon Intertie
Corps	U.S. Army Corps of Engineers
CRS	Columbia River System
CRSO	Columbia River System Operations
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EIS	Environmental Impact Statement
FCRPS	Federal Columbia River Power System
FERC	Federal Energy Regulatory Commission
FY	Fiscal year
GENESYS	NW Council's GENeration Evaluation SYStem Model
GIS	Geographic Information System
GW	Gigawatt
GWh	Gigawatt-hour
HYDSIM	Hydrologic Simulator Model
ID	Idaho
IMPLAN	IMPact Analysis for PLANning Model
IOU	Investor-owned Utility
IRP	Integrated Resource Plan
LOLP	Loss-of-Load Probability
LSR	Lower Snake River
kW	Kilowatt
kWh	Kilowatt-hour
Mid-C	Mid-Columbia market hub
MMBTU	Million British Thermal Units
MOs	Multiple Objective Alternatives
MO1	Multiple Objective Alternative 1
MO2	Multiple Objective Alternative 2
MO3	Multiple Objective Alternative 3
MO4	Multiple Objective Alternative 4
MT	Montana

MW	Megawatt
MWh	Megawatt-hour
NAA	No Action Alternative
NAICS	North American Industry Classification System
NED	National Economic Development
NEPA	National Environmental Policy Act
NREL	National Renewable Energy Laboratory
NW Council	Northwest Power and Conservation Council
NWEC	Northwest Energy Coalition
OR	Oregon
PA	Preferred Alternative
PDCI	Pacific DC Intertie
PF	Priority Firm
PUD	Public Utility District
RAM2020	Rates Analysis Model
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RUC	Rural-Urban Continuum
Tri-Cities	Region consisting of three neighboring cities (Kennewick, Pasco and Richland)
TRM	Tiered Rate Methodology
U.S.C.	United States Code
WA	Washington
WECC	Western Electricity Coordination Council
WTP	Willingness-to-pay

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CHAPTER 1 - INTRODUCTION

1.1 FRAMEWORK FOR THE ANALYSIS

This appendix details the analysis of the effects of the CRSO alternatives on power and transmission, including the models, methods, and data sources employed, and a stepwise presentation of the results for each alternative. Figure 1-1 presents the framework for the analysis.

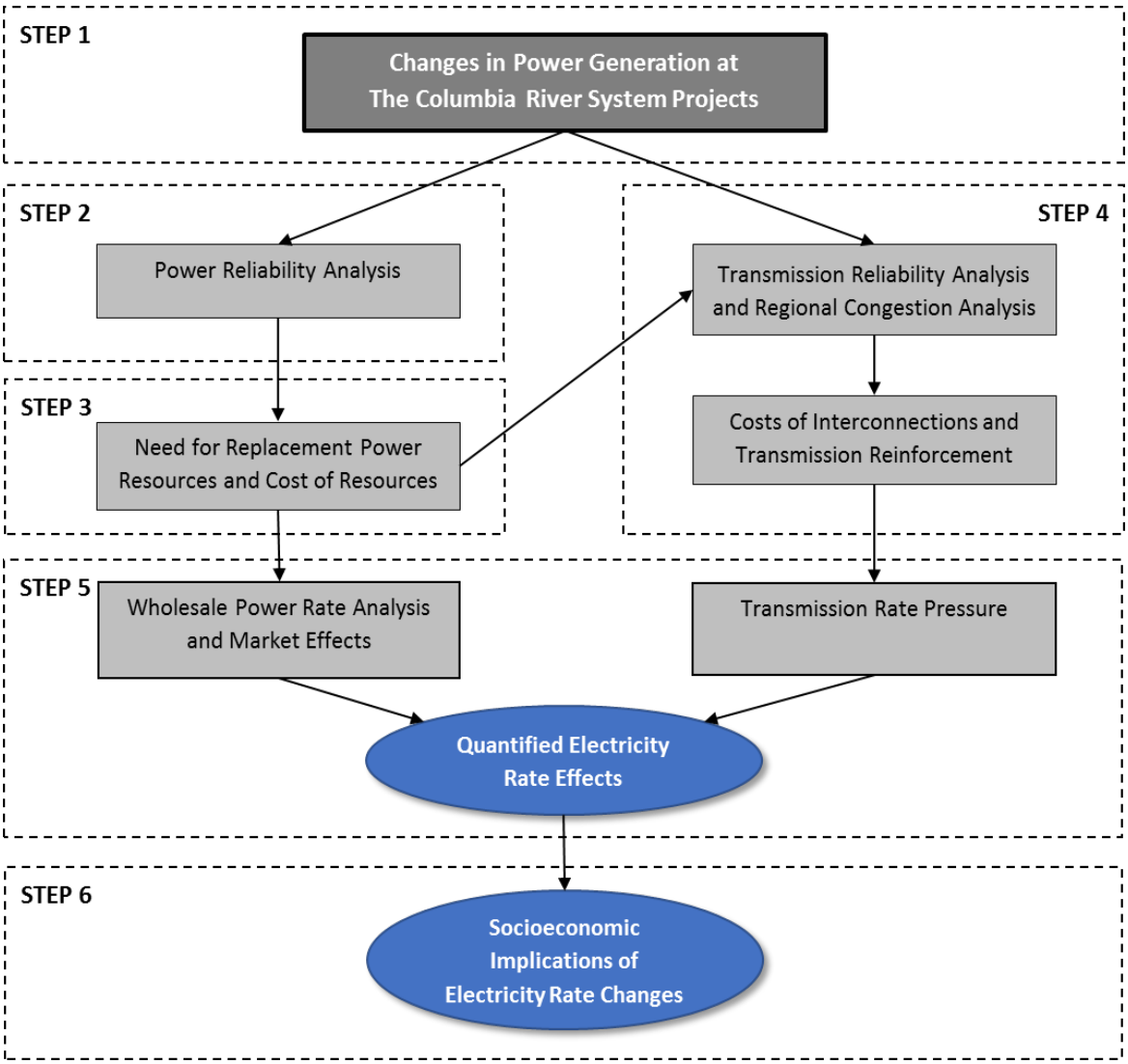

Figure 1-1 Analytical Approach for Evaluating Power and Transmission Effects of the CRSO Action Alternatives

Note: Additional power and transmission analysis occurs within each of the step boxes depicted.

The analysis first assesses the effects of the CRSO alternatives on power generation based on average historical water conditions and for critical water conditions.[1] The amount of power generated by the system under each of the alternatives determines whether additional changes to or investments in the system may be required to maintain Bonneville's ability to supply adequate and reliable power (both energy and capacity) to its firm power customers under 20-year contracts. The analysis then evaluates the extent to which the alternatives would result in the need for Bonneville or other regional entities to acquire power from other resources (e.g., new generating plants) and construct new transmission infrastructure to replace the lost capability at Federal hydropower projects. To the extent this analysis identifies a potential need to acquire resources or transmission infrastructure, and if Bonneville proposes to take such action in the future, Bonneville would do so consistent with the Northwest Power Act and would complete additional site-specific planning, analysis, and compliance with environmental laws, including the National Environmental Policy Act (NEPA).

Based on the need for additional investments under each alternative, the analysis considers the rate pressure resulting from the increased costs of providing power. The wholesale rate pressure analysis considers potential effects of alternatives on the price Bonneville charges to its power customers. The retail rate pressure analysis considers how wholesale rate pressure may affect the cost of living and doing business for electricity end-users (households, businesses, and industry) across the Pacific Northwest.

The areas of analysis for the power and transmission resources differ as a function of Bonneville's products and services. Both the power and transmission analyses focus on Bonneville's service area (Figure 1-2)**.** The Bonneville Service Area is defined by the Northwest Power Act as the Pacific Northwest, which includes Oregon, Washington, Idaho, the portion of Montana west of the Continental Divide, and the portions of Nevada, Utah, and Wyoming within the Columbia River drainage basin. However, because Bonneville regularly markets its surplus power both within and outside the Pacific Northwest, the power analysis additionally considers potential effects on power markets within the larger Western Interconnection (Figure 1-3). Similarly, because the power system of the Western Interconnection reacts to changes in Pacific Northwest generation (e.g., changes in generation from the CRS projects), the social welfare effects analysis considers changes in generation and costs for the entire Western Interconnection.

1 The "critical water year" or "critical water conditions" represent the historic water year when the capability of the hydro system produces the least amount of dependable generation while considering power and non-power operating constraints.

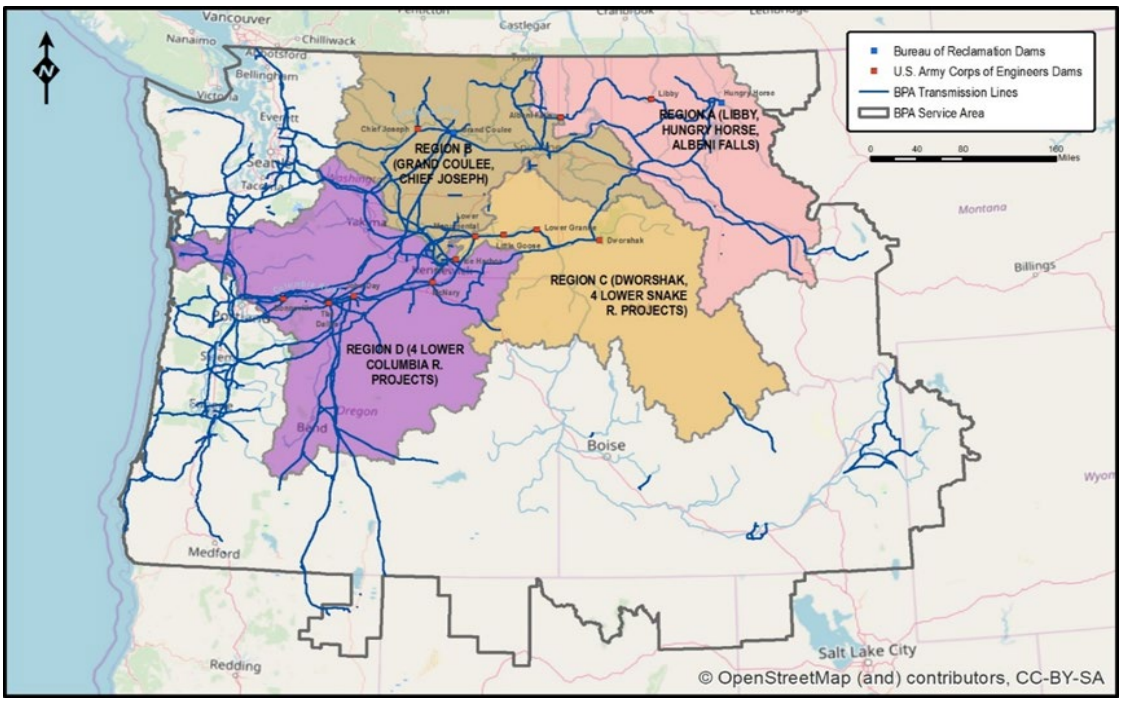

Figure 1-2. Transmission Area of Analysis – the Bonneville Service Area and Transmission Lines

Note: The dark blue lines are Bonneville transmission lines

Source: Bonneville GIS 2018

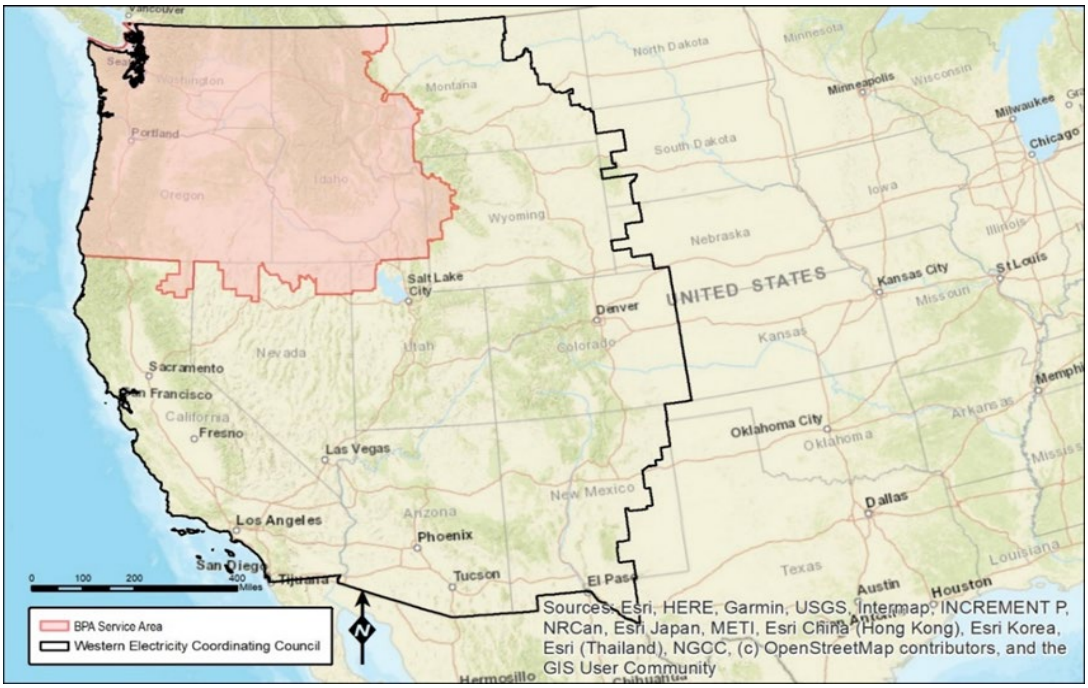

Figure 1-3. Power Area of Analysis – the U.S. Portion of the Western Interconnection and the Bonneville Service Area

Source: WECC 2018, Bonneville GIS 2018

The power and transmission analysis considers the effects of the alternatives over a 50-year timeframe. However, the quantitative analysis is limited to the period for which information is available to reasonably predict potential effects. The social welfare effects are average annual values of changes in the marginal cost of producing power. These average annual estimates are subject to increasing uncertainty over the 50-year analysis timeframe. The retail rate pressure analysis evaluates potential changes in the cost of electricity for residential, commercial, and industrial ratepayers over a 20-year timeframe (2022-2041), based on the best available information.[2] Quantifying effects beyond 20 years introduces uncertainty regarding how the electricity sector will evolve in response to policy and technological developments.

1.2 ORGANIZATION OF THE APPENDIX

A detailed discussion of Step 1 of this analysis—evaluating effects of the Multiple Objective Alternatives (MOs) on power generation at the 14 CRS projects—appears in Appendix J, *Hydropower*.[3] The remainder of this appendix is organized as follows:

- **Chapter 2 - Power Supply and Replacement** Resources**:** Chapter 2 focuses on Steps 2 and 3 (Figure 1-1), describing the approach to modeling changes in power generation at the CRS projects, impacts on power supply (expressed in terms of loss of load probability [LOLP]), and costs associated with maintaining an adequate and reliable supply of electricity.[4] This chapter also considers how the uncertainty regarding potential future coal plant retirements could influence the results of this analysis.
- **Chapter 3 - Transmission System Reliability and** Congestion**:** Chapter 3 describes Step 4 (Figure 1-1), linking changes in how and where power is generated to effects on the transmission system reliability and congestion.
- **Chapter 4 - Wholesale Power and Transmission** Rates**:** Chapter 4 describes Step 5 (Figure 1-1), evaluating how changes in the cost of power generation and transmission affect Bonneville's wholesale power and transmission rate pressure.
- **Chapter 5 - Social and Economic Effects of Changes in Power and** Transmission**:** Chapter 5 details Step 6 (Figure 1-1), describing effects of the alternatives on residential, commercial, and industrial ratepayers across the Pacific Northwest. Specifically, this chapter evaluates

[2] The power analysis model generation for a single year (2022) using 80 historical water years under the operations, maintenance and configuration regime for the CRS projects defined by the alternatives. The transmission power-flow analysis relies on the 2023 and 2028 Western Electricity Coordinating Council (WECC) base cases to inform the transmission system reliability assessment and the 2028 WECC base case is used to inform the regional transmission congestion forecasts. The transmission rate analysis models the cumulative rate pressure differences through the 2028 rate period (FY 2028 – 2029). The socioeconomic analysis then relies on the rate forecast from the NW Council to project the rate pressure effects over the 20-year timeframe.

[3] The 14 CRS projects are Libby, Hungry Horse, Albeni Falls, Grand Coulee, Dworshak, Chief Joseph, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and Bonneville.

[4] Loss of Load Probability under the No Action Alternative is 6.6%. The NW Council target for LOLP is 5%. *See NW* Council Document Number 2011-14, Page 4, available at: https://www.nwcouncil.org/sites/default/files/2011_14_1.pdf.

how the changes in the costs of generating and delivering power affect the cost of living and doing business in the region.

1.3 SUMMARY OF RESULTS OF THE POWER AND TRANSMISSION ANALYSIS

Table 1-1 presents the summary of results for all alternatives. The following paragraphs describe results by topic for the MOs relative to the No Action Alternative.

1.3.1 Regional Hydropower Generation

Under MO1, hydropower generation from the CRS projects would decrease by 130 average megawatts (aMW) (roughly the amount of power used by 100,000 Northwest homes or a city about the size of Everett, Washington consumes) relative to the No Action Alternative.[5] Under MO3 and MO4, the generation from the CRS projects would decrease by 1,100 and 1,300 aMW (more than the amount of power used by the city of Seattle and about two cities the size of Portland), respectively. Under MO2, however, generation would increase by 450 aMW (about half the amount of power used by the city of Seattle). Under the Preferred Alternative hydropower generation would decrease by 160 aMW (roughly the amount of power used by 130,000 Northwest homes).

Under MO1, the Federal Columbia River Power System (FCRPS) would lose 290 aMW of firm power,[6] which is used to serve Bonneville's long-term, firm power sales to preference customers. Firm power would decrease by 730 aMW under MO3 and 870 aMW under MO4. Firm power would increase by 370 aMW under MO2. Firm power would decrease by 300 aMW under the Preferred Alternative.

1.3.2 Regional Power Supply – Loss of Load Probability (LOLP)[7]

Under the No Action Alternative, regional LOLP is currently 6.6 percent. Without replacement resources, regional LOLP would increase under MO1 (+4.6 percentage points), MO3 (+7.3 percentage points) and MO4 (+23 percentage points). LOLP would decrease under MO2 (-1.6 percentage points) and the Preferred Alternative (-0.1 percent) relative to the No Action Alternative. If Bonneville and/or its power customers did not acquire additional resources to replace the reduction in hydropower generation under MO1, M03, and MO4, then there would be an increased risk of power shortages. Replacement resources would be required not only to replace the energy lost but also to replace some peaking capability of the hydropower system.

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[5] An average megawatt is one million watts delivered continuously 24 hours a day for one year.

[6] Firm power is the amount of power that can be reliably produced by the FRCPS assuming the most adverse water year on record (critical water).

[7] LOLP is expressed as a percentage that reflects the probability that the system will not be able to meet the demand for electricity in a particular year. Higher LOLPs reflect the increased likelihood that the power system would be unable to meet demand, and therefore, will result in power shortages or blackouts. A high LOLP is an indication of a less reliable power system. A low LOLP reflects a low likelihood that the power system will experience a power shortage. The LOLP is a measure of the frequency of outages but not a measure of their duration or magnitude.

Replacing lost peaking capability would result in a need for replacement resources (e.g. 560 MW natural gas generation or 1,800 MW of new zero-carbon resources under MO1) that would exceed the average power lost (-130 aMW) and would increase transmission rate pressure and wholesale power costs. Under MO3, 1,120 MW of natural gas or 3,150 MW of zero-carbon resources would be required. Under MO4, 3,240 MW of natural gas or 5,600 MW of zero-carbon resources would be required. MO2 and the Preferred Alternative reduce LOLP and therefore do not require additional replacement resources.

1.3.3 Wholesale Power and Transmission Rate Pressure

Under the No Action Alternative, the average cost of Bonneville's firm power for regional public customers is $34.56 per megawatt hour (MWh). Reductions in the generating capability of the CRS projects would require replacement resources to meet Bonneville's current firm power load obligation. The cost to Bonneville of replacing these resources is affected by (1) the type of resource replacing the lost generation (zero-carbon or conventional least-cost); and (2) whether Bonneville acquires the replacement resources or other regional utilities acquire the resources. Bonneville's cost of power would go up under MO1, MO3, and MO4, and decrease slightly under MO2.

- Under MO1, Bonneville wholesale power rates experience upward rate pressure ranging from 4.5% (potentially leading to wholesale rates of $36.14/MWh) to 8.6% (potentially leading to wholesale rates of $37.53/MWh) under the conventional least-cost portfolio financed by entities other than Bonneville and the zero-carbon portfolio financed by Bonneville, respectively.
- Under MO2, Bonneville wholesale power rates experience downward rate pressure of 0.8% (potentially leading to wholesale rates of $34.28/MWh).
- Under MO3, Bonneville wholesale power rates experience upward rate pressure ranging from 8.2% (potentially leading to wholesale rates of $37.41/MWh) to 19.3% (potentially leading to wholesale rates of $41.23/MWh) under the conventional least-cost portfolio financed by entities other than Bonneville and the zero-carbon portfolio financed by Bonneville, respectively.
- Under MO4, Bonneville wholesale power rates experience upward rate pressure ranging from 15.3% (potentially leading to wholesale rates of $39.87/MWh) to 25.3% (potentially leading to wholesale rates of $43.32/MWh) under the conventional least-cost portfolio financed by entities other than Bonneville and the zero-carbon portfolio financed by Bonneville, respectively.
- Under the Preferred Alternative, experience upward rate pressure of 2.7% (potentially leading to wholesale rates of $35.47/MWh).

All of the alternatives would result in some degree of upward transmission rate pressure for the 2020 to 2028 analysis period relative to the No Action Alternative.

- Under MO1: The upward transmission rate pressure would be 0.74 percent annualized (6.1 percent over an 8-year period [BP-22 to BP-28]) relative to the No Action Alternative under the conventional least-cost replacement portfolio, and 0.62 percent annualized increase (5.1 percent over an 8-year period) under the zero-carbon replacement portfolio.
- Under MO2: The upward transmission rate pressure would be 0.11 percent annualized (0.89 percent over an 8-year period [BP-22 to BP-28]) relative to the No Action Alternative.
- Under MO3: The upward transmission rate pressure would be 1.3 percent annualized (11 percent over an 8-year period [BP-22 to BP-28]) for the conventional least-cost portfolio and 1.5 percent annually (13 percent over an 8-year period) under the zero-carbon portfolio, relative to the No Action Alternative.
- Under MO4: The upward transmission rate pressure would be 1.6 percent annualized (14 percent over an 8-year period [BP-22 to BP-28]) for the conventional least-cost portfolio, and 1.9 percent (17 percent over an 8-year period) under the zero-carbon portfolio, relative to the No Action Alternative.
- Under the Preferred Alternative: The upward transmission rate pressure would be 0.09 percent annualized (0.70 percent over an 8-year period [BP-22 to BP-28]) relative to the No Action Alternative.

1.3.4 Socioeconomic Effects

Socioeconomic effects measure the impact of the MOs on regional retail ratepayers. Overall, the MOs have differing effects on regional ratepayers. Regional utilities that purchase most or all of their power supply from Bonneville would experience larger effects than entities that do not currently purchase firm power from Bonneville, such as the region's Investor-owned Utilities (IOUs) and certain public utility districts (PUDs). A summary of the potential regional retail rate pressure impacts of the MOs is provided below:

- Under MO1, depending on the types of power resources and transmission infrastructure acquired or built to replace the services of the reduced hydropower generation, households in the region could experience an increased cost of electricity of 0.62 percent to 0.74 percent. However, this increase is not evenly distributed; customers of utilities that receive power from Bonneville would generally experience larger increases, up to 7.6 percent for some households. The increased cost of electricity may change household and business spending patterns on other regional goods and services, resulting in a reduction in annual regional economic output (i.e., reductions in sales from businesses across the region) of $120 million to $140 million and cost 790 to 910 jobs.
- Under MO2, households in the region could experience a decreased cost of electricity of 0.39 percent. Customers of utilities that receive power from Bonneville would generally experience larger decreases, up to 1.3 percent. This potential decrease in the cost of power could result in an increase in regional economic output of $82 million and 560 jobs.

- Under MO3, depending on the types of power resources and transmission infrastructure acquired or built to replace the services of the reduced hydropower capacity and generation, households in the region could experience an increased cost of electricity of 1.6 to 3.6 percent. However, this increase is not evenly distributed; customers of utilities that receive power from Bonneville would generally experience larger rate increases, up to 15 percent for some households, compared to customers of utilities who do not receive power from Bonneville. The increased cost of electricity may change household and business spending patterns on other regional goods and services, resulting in a reduction in annual regional economic output (i.e., sales) of $320 million to $740 million and cost 2,100 to 4,900 jobs.
- Under MO4, depending on the types of power resources and transmission infrastructure acquired or built to replace the services of the reduced hydropower generation under MO4, households across the region could experience an increased cost of electricity of 2.8 to 3.2 percent on average. However, this increase is not evenly distributed; customers of utilities that receive power from Bonneville would generally experience larger increases, up to 18 percent for some households, compared to customers of utilities who do not receive power from Bonneville. The increased cost of electricity may result in a reduction in annual regional economic output (i.e., sales) of $560 million to $630 million and cost 3,600 to 4,100 jobs.
- Under the Preferred Alternative, households in the region could experience an increased cost of electricity of 0.33 percent. Customers of utilities that receive power from Bonneville would generally experience larger increases, up to 1.1 percent, compared to customers of utilities who do not receive power from Bonneville. This potential increase in the cost of power may result in a reduction in regional economic output (i.e., sales) of $68 million and cost 440 jobs.

1.3.5 Additional Power Rate Sensitivity Analysis

The analysis of replacement resources and associated costs for each alternative relies on assumptions, for example about the future resources that would be available to serve the region under the No Action Alternative baseline. Accordingly, the quantitative results of the analysis are sensitive to these assumptions. The base case power rate analysis described in this appendix relies on a number of assumptions regarding resource availability, resource costs, coal-plant retirements, carbon policies, and other factors that affect the resulting power rate pressure effects. Some of these assumptions have changed or have been updated since the power rate analysis for the base case was developed. Chapter 3 of the main body of the EIS *Power and Transmission*, Section 3.7.3.1 *Base Case Methodology and Cost Sensitivities Analysis,* describes these effects and provides estimates where practicable.

The specific rate sensitivities addressed include the following:

- Fish and Wildlife Costs
- Integration Services (Hydro Flexibility)

- Resource Financing Assumptions
- Resource Cost Uncertainties (Contingencies)
- Demand Response
- Oversupply

The results are included in the summary table, Table 1-1, but not described in detail.

1.3.6 Other Regional Cost Pressure Analysis including Availability of Coal Resources

In addition to the base case analysis and the six rate sensitivities discussed above, analysis was performed to assess the impacts of other regional cost pressures, including the potential incremental costs to the region associated with (1) "Regional Cost of Carbon Compliance" and (2) accelerated "coal retirement" (capital costs and other costs).

Energy economics and state and local de-carbonization policies are changing the generation scenario in the region and across the Western Interconnection into the 2020s and beyond. The analysis used for the results summarized above reflects assumptions about the future of the power system as of 2017. These assumptions include the retirement of only a few coal-fired power plants serving Northwest loads. Since this analysis was performed, regional utilities have announced additional coal-plant retirements and have accelerated the plans for retiring other coal plants. The loss of generation from these coal resources would affect the reliability of the regional power system. As a result, this analysis considered how a range of potential coal-plant retirements could affect the LOLP and the amount of replacement resources needed to restore the LOLPs to the No Action Alternative levels. In general terms, the results of the coal retirement sensitivity analyses suggest that the impacts to MO2 would likely be a reduction in rate pressure, MO3 would see a further upward rate pressure, and MO1, MO4, and the Preferred Alternative would show a similar or slightly smaller upward rate pressure compared to the base case without the additional coal-plant retirements. When considering all cost pressure sensitivities (i.e., not only coal retirements but other regional cost pressures, such as replacement resource financing assumptions or renewable integration services mentioned above), the analysis generally finds that potential upward rate pressure effects are understated.

Table 1-1. Summary of Power and Transmission Effects for All Alternatives

Effect[1/]	No Action Alternative[2/]	MO1 Relative to No Action[1/]	MO2 Relative to No Action	MO3 Relative to No Action[1/]	MO4 Relative to No Action[1/]	Preferred Alterative Relative to No Action
CRS Hydropower Generation (aMW)	8,300	-130	+450	-1,100	-1,300	-160
Firm power of FCRPS (aMW)	7,100	-290	+370	-730	-870	-300
LOLP	6.6%	+4.6 LOLP %	-1.6 LOLP %	+7.3 LOLP %	+23 LOLP %	-0.1 LOLP %
Replacement Resources to return LOLP to No Action Alternative level	——[2/]	560 MW of Gas or 1,200 MW Solar plus 600 MW demand response	Avoided build of 440 MW of Gas or 250 MW solar, 660 MW MT wind, and 600 MW demand response[2/]	1,120 MW natural gas or 2,550 MW solar, 1,150 MW of battery storage and 600 MW demand response	3,240 MW natural gas or 5,000 MW solar and 600 MW demand response	------[7/]
Replacement Resource Cost to return LOLP to No Action Alternative level (annual cost)	——[2/]	+$43 million or +$162 million	-$19 million to -$140 million[3/]	+$250 million or +$420 million	+$241 million or +$577 million	$0
Transmission Infrastructure to return LOLP and/or transmission system reliability to No Action Alternative level (annualized reinforcement and/or interconnection cost)	——[2/]	$3.8 million to $3.9 million	——[4/]	$9.1 million to $13 million	$12 million to $19 million	——[7/]
Average Bonneville Wholesale Priority Firm (PF) Power Rate pressure (base analysis) Potential Range of Bonneville wholesale power rate ($/MWh) Potential Range of Bonneville wholesale power rate pressure including rate sensitivities	$34.56	+4.5% to +8.6% $36.14/MWh to $37.53/MWh +6.0% to +14.4%	-0.8%[/3] $34.28/MWh -0.7% to +1.9%	+8.2% to +19.3% $37.41/MWh to $41.23/MWh +4.1% to +50.3%	+15.3% to +25.3% $39.87/MWh to $43.32/MW +17.9% to +40.8%	+2.7% $35.47 +0.4% to +2.7%

Effect[1/]	**No Action Alternative[2/]**	**MO1 Relative to No Action[1/]**	**MO2 Relative to No Action**	**MO3 Relative to No Action[1/]**	**MO4 Relative to No Action[1/]**	**Preferred Alterative Relative to No Action**
Annualized Transmission Rate Pressure relative to No Action Alternative (%)	——[2/]	+0.62% to +0.74%[/5]	+0.11%	+1.5% to +1.5%	+1.6% to +1.9%	+0.09%
Average Annual Social Welfare Effects ($): Market Price Method Estimate	——[2/]	-$25 million	+$75 million[3/]	-$150 million	-$180 million	-$6.7 million
Average Annual Social Welfare Effects ($): Production Cost Method Estimate	——[6/]	-$64 million to -$170 million	+$82 (up to +$170 million) million[4/]	-$270 million to -$540 million	-$380 million to -$650 million	-$25 million
Residential Rate, weighted average and range across all scenarios (cents/kWh and % change from the No Action Alternative)	10.21	+0.62% to +0.74%% (-0.48% to +7.6%)	-0.39% (-1.3% to +0.46%)	+1.6% to +3.6% (+0.062% to +15%)	+2.8% to +3.2% (+0.041% to +18%)	+0.33% (less than +0.01% to +1.1%)
Commercial Rate, weighted average and range across all scenarios (cents/kWh and % change from the No Action Alternative)	8.89	+0.66% to +0.77% (-0.62% to +8.2%)	-0.48 % (-2.0% to +0.46%)	+1.7% to +4.1% (+0.070% to +15%)	+3.0% to +3.4% (+0.042% to +18%)	+0.36% (less than +0.01% to +1.3%
Industrial Rate, weighted average and range across all scenarios (cents/kWh and % change from the No Action Alternative)	7.25	+0.86% to +1.0% (-1.1% to +12%)	-0.58% (-2.4% to +0.57%)	+2.2% to +5.2% (+0.10% to +29%)	+4.0% to +4.5% (+0.51% to +36%)	+0.47% (less than +0.01% to +1.9%)
Regional Economic Productivity Effects: Change in Output	——[2/]	-120 million to -$140 million	+$82 million	-320 million to -$740 million	-560 million to -$630 million	-$68 million
Regional Economic Productivity Effects: Change in Employment	——[2/]	-790 jobs to -910 jobs	+560 jobs	-2,100 jobs to -4,900 jobs	-3,600 jobs to -4,100 jobs	-440 jobs

Effect[1/]	No Action Alternative[2/]	MO1 Relative to No Action[1/]	MO2 Relative to No Action	MO3 Relative to No Action[1/]	MO4 Relative to No Action[1/]	Preferred Alterative Relative to No Action
Share of households experiencing >5% increase in rates relative to NAA, highest across portfolios	——[2/]	1.2%	0%	21%	26%	0%
Share of businesses with >5% increase in rates relative to NAA, highest across portfolios	——[2/]	2.1%	0%	26%	26%	0%
Regional Cost of Carbon Compliance	——[2/]	-$16 to +$88 million/year	-$37 to -$194 million/year	+$34 to +$623 million/year	+$10 to +$561 million/year	+$9 to +$47 million/year

Notes: The estimated LOLP effect, and resulting social welfare and rate impacts, rely on the best available information regarding planned coal plant retirements as of 2017 when the modeling efforts began for this analysis. Based on regional energy policy developments and expected coal-plant closures as of 2019, Section 2.3 of this appendix, *2.3 Sensitivity of LOLP to Assumptions About Coal* Capacity, discusses how these results could change if the expected coal-plant closure assumptions change.

1/ The ranges in some entries on this table represent different scenarios, such as whether Bonneville acquires replacement resources or other entities acquire the resource and whether the conventional least-cost or zero-carbon resources are built.

2/ The analysis of the No Action Alternative for these effect categories provides a baseline against which the MOs are compared. Thus, the No Action Alternative results presented in this table describe the baseline magnitude of power and transmission values (e.g., for LOLP and rates) and the MO1 through MO4 results describe the change relative to No Action. A "——" indicates an effect category that is not relevant to the No Action Alternative because it only occurs as a result of implementing the MOs (e.g., the need for new generation and transmission infrastructure and associated costs).

3/ This value would be -4% without the new fish collection structure at McNary Dam. That is, without the structure, wholesale rates under MO2 would be 4% lower than under the No Action Alternative.

4/ MO2 is assumed to result in avoidance of a need to build additional resources that would have been anticipated under the No Action Alternative. As such, replacement resource costs are negative, and social welfare effects are positive.

5/ Under MO1, transmission rate pressure is lower under the zero-carbon portfolio (0.64 percent) than under the conventional least-cost portfolio (0.75 percent). For the other alternatives the low end of the transmission rate pressure range is the conventional least-cost portfolio.

6/ The production cost method for valuing social welfare effects of the MOs relies on information on the fixed and variable costs of replacement generation resources. These costs are not relevant to the No Action Alternative.

7/ The LOLP of the Preferred Alternative is essentially the same as the No Action Alternative, so no resources are needed to return power system reliability to the same level as the No Action Alternative. Conversely, the Preferred Alternative does not materially contribute to avoiding building new resources.

CHAPTER 2 - POWER SUPPLY AND REPLACEMENT RESOURCES

The operation, configuration, and maintenance changes described in the CRSO MOs would affect the magnitude of power generated from the 14 CRS projects, as detailed in the Appendix J, *Hydropower*. The CRS projects are a subset of the FCRPS (31 Federal dams), and the associated transmission infrastructure. The FCRPS and other resources acquired by Bonneville to meet its firm power supply obligations constitute what is known as the Federal Base System. Fluctuations in power generation at the CRS projects would therefore trigger adjustments in not only the Federal Base System but also the larger regional system of aggregated resources (e.g., incorporating additional generating capacity) to ensure the system is capable of supplying the demand for power, which fluctuates over the course of minutes, hours, days, months, and years.

This chapter first describes the methods employed to identify how changes in generation at the CRS projects under the MOs would affect the adequacy and reliability of Bonneville's power supply absent any adjustments (i.e., the ability of the system to meet the demand for power). It then describes the approach used to identify and quantify the costs of "replacement resources," which are investments that would be needed to add capacity to maintain power system reliability at a level consistent with the No Action Alternative.

This stage of the analysis is scenario based. It evaluates the sensitivity of the results to assumptions regarding how the system would respond to changes stemming from the CRSO MOs (changes in generation at the CRS projects) in conjunction with other potential changes in regional power generation (e.g., coal plant retirements).

2.1 REGIONAL POWER SYSTEM RELIABILITY ANALYSIS

This analysis relies on the power system reliability metric referred to as Loss of Load Probability (LOLP). LOLP is expressed as a percentage that reflects the probability that the CRS and the larger regional power supply is adequate to meet the region's expected load demand for electricity in a year. Higher LOLPs reflect the increased likelihood that the power system would be unable to meet demand and lower LOLPs reflect a decreased likelihood that the power system would be unable to meet demand. The LOLP is a measure of the frequency of outages but not a measure of their duration or magnitude. While LOLP reflects the adequacy of the aggregated regional power supply, individual utilities within the Pacific Northwest, such as Bonneville, face a wide range of future resource needs that are unique to them which trigger actions and/or decisions to develop, add, or acquire resources to meet their obligations.

Achieving a higher level of power system reliability (a lower LOLP) requires the development of resources to meet either load growth or as replacement for losses in existing resources. Resources are developed by either individual utilities to meet their load serving obligations or by commercial/independent power producers that assume the risk of building resources to meet forecasted supply needs.

In 2011, the NW Council set a regional standard for LOLP to be no higher than 5 percent. That is, in roughly one of every 20 years, the region would experience one or more energy shortages (potentially blackouts). The NW Council recommends investments in the power and transmission systems until the LOLP reaches 5 percent.

The analysis applies the NW Council's GENeration Evaluation SYStem (GENESYS) model to determine LOLP for the No Action Alternative and each MO. The GENESYS model relies on datasets containing plant-specific parameters and constraints for hydropower resources, thermal generation plants, and wind and solar power plants. Additional inputs to the model include power demand (i.e., "loads") produced by the NW Council and assumptions regarding the availability of independent power producers and imports from outside the region.[8]

The GENESYS model relies on Monte Carlo simulations of the system to estimate LOLP based on weather-related load uncertainty, in addition to uncertainties in streamflows, wind, solar, and forced outages for thermal generation.[9] The model performs a detailed dispatch of the regulated hydropower projects in the watershed of the Columbia River, Pacific Northwest regional thermal plants, wind, solar, along with other renewable energy resources, to determine the power imports that would be necessary to meet the load (demand) of the Pacific Northwest. The full results of hydropower generation effects are included in Chapter 3 of Appendix J, *Hydropower*.

Table 2-1 presents the LOLP results for each MO. Based on the modeled changes in power generation, existing load forecasts, and coal plant retirements anticipated as of 2017, the No Action Alternative would result in an LOLP of 6.6 percent in 2022. This would exceed the current NW Council target of 5 percent.[10] However, because the NW Council's target is useful regional guidance, and 6.6 percent is within the range of LOLP in recent years, this analysis considers the 6.6 percent LOLP a reasonable benchmark level during the timeframe of this analysis.

Changes in power generation anticipated from structural and operational changes specified by the MOs would affect the LOLP of the regional power system. As identified in Table 2-1, MO1, MO3, and MO4 are anticipated to increase LOLP. That is, these alternatives would increase the risk that regional power supplies will not be able to meet regional demands for energy, resulting in blackouts or periods of power shortage because of the loss of power supplied by the CRS. These alternatives would reduce power supply adequacy and system reliability, for example, by increasing spill levels or directly removing hydropower from the system due to

[8] Details for load descriptions are provided in NW Council's Pacific Northwest Power Supply Adequacy Assessment for 2022, Document 2017-5 (July 11, 2017), available at https://www.nwcouncil.org/sites/default/files/2017-5.pdf.
[9] In general, Monte Carlo simulation is a statistical technique that uses random events, or probability analysis, to simulate an outcome. Bonneville uses it to forecast potential regional load growth.
[10] Note that LOLP is a probabilistic estimate and does not indicate magnitude or scale of potential power system outages and it is also not linear in effects, however, it is a useful metric of overall system reliability and stability. *See* NW Council Document Number 2011-14, Page 4, available at: https://www.nwcouncil.org/sites/default/files/2011_14_1.pdf.

dam breach. MO2 and the Preferred Alternative would increase anticipated hydropower from the CRS projects and therefore would reduce LOLP relative to the No Action Alternative. That is, the region would experience a reduced risk of blackouts under MO2.

Table 2-1. LOLP Results for CRSO Alternative

Alternative	LOLP (%)	Change from No Action	Blackout(s) / Power Shortage(s) Every x Years
No Action	6.6	-	1 year in every 15 years
MO1	11	+4.4	1 year in every 9 years
MO2	5.0	-1.6	1 year in every 20 years
MO3	14	+7.4	1 year in every 7 years
MO4	30	+23	1 year in every 3 years
PA	6.5	-0.1	1 year in every 15 years

2.2 REPLACEMENT RESOURCES TO MAINTAIN REGIONAL POWER SYSTEM RELIABILITY

For each of the alternatives where the LOLP would be higher than the No Action Alternative, the analysis identifies replacement resources that would add sufficient capacity to restore power system reliability (LOLP) to the No Action Alternative level of 6.6 percent. The following data sources informed the assessment of potential replacement resources and associated costs:

- NW Council Resource Adequacy Advisory Committee
- NW Council 6th and 7th Power Plans
- NW Council 7th Power Plan Mid-Term Assessment
- Regional Integrated Resource Plans (IRP)

Based on these sources, the analysis assumes that only resources that would be commercially available at large scale would be viable replacement resources as identified in the NW Council's 7th Power Plan. Specifically, the resources evaluated to replace capacity in the larger regional power system include natural gas fired-resources (single and combined cycle), solar, wind (in both Montana and the Columbia Gorge), demand response, and energy storage.[11] In addition, the replacement resource analysis includes the NW Council target of 600 MW of demand response for all alternatives that would reduce power system reliability, although more capacity from demand-response may be feasible. All cost-effective conservation from the NW Council's 7th Plan is included in the load forecast.

[11] Neither demand response nor batteries are resources as defined in the Northwest Power Act; however, Bonneville considers them actions/tools that could be used (i.e., demand response) or property that could be procured (i.e., batteries).

2.2.1 Replacement Resource Portfolio Assumptions

The specific resources that would be developed to maintain a sufficient and reliable supply of power are uncertain. Costs, technical feasibility, and regional greenhouse gas emissions policies and targets, among other factors, all influence resource availability in the future.

To determine the optimal mix of resources under each portfolio, this analysis assesses the cost-effectiveness of specific power resources by dividing the total costs by the LOLP benefit. The most cost-effective resources were then added into the GENESYS model until the resulting LOLP reached the No Action Alternative LOLP (6.6 percent). Given uncertainties regarding what projects would be developed to restore power system reliability under the MOs, the analysis considers two alternative potential resource-replacement portfolios:

- **"Zero-carbon" portfolio:** Under this portfolio, only carbon-free resources (e.g., solar, wind, non-power generating tools such as demand response, or storage technologies for those resources such as batteries and pumped storage) are used. While they are the lowest-cost option among carbon-free resources, the portfolios that reduce the LOLP to the No Action Alternative level may have higher costs than the natural gas resources selected in the "conventional least-cost" portfolios. The EIS assesses the MOs with the zero-carbon replacement resources on the assumption that *new* resources would be carbon-free. However, existing resources (other than coal-plants slated for retirement) continue to operate and may decrease or increase generation in response to changes in hydropower generation from the CRS projects and non-Federal hydropower projects in the Columbia River basin.
- **"Conventional least-cost" portfolio:** Under this portfolio, the potential cost of the replacement resources would drive replacement resource selection, using gas-fired power generation as the lowest cost resource historically.

This analysis considers the zero-carbon and conventional least-cost replacement resource portfolio analysis for MO1, MO3, and MO4. Table 2-2 describes resources prioritized for each replacement resource portfolio. Ultimately, the conventional least-cost portfolio consists of natural gas resources whereas the zero-carbon portfolio reflects a mixture of demand response and solar power. To provide a sense of scale, the region currently has about 900 MW of solar (roughly 55,500 acres or 8.5 square miles of land).

As previously described, MO2 would result in improved adequacy of power system supply relative to the No Action Alternative, avoiding the need for replacement resources. To provide perspective on the benefit of this additional power system reliability, the analysis considers the extent to which resources would need to be added to the No Action Alternative to achieve the same level of reliability as MO2 (5 percent LOLP). In effect, this is a measure of the potential "avoided build" (and associated avoided costs) under MO2 relative to the No Action Alternative. The analysis identifies avoided build of new resources using the GENESYS model in the same manner as described previously to identify replacement resources needed for the other MOs. This analysis finds that the avoided build under MO2 relative to the No Action

Alternative would be 440 MW of natural gas for the conventional least-cost resource portfolio or 660 MW of Montana wind, 250 MW of solar, and 600 MW of demand-response for the zero-carbon resource portfolio.

To maintain power system reliability in the Northwest with MO3, additional generation resources would be needed. For the previous analysis, Bonneville considered two scenarios for replacement portfolios. The first scenario adds resources to restore the LOLP to the same level as the No Action Alternative for the base scenario without additional coal-plant retirements. This approach replaces only the generation produced in dry water conditions (in the water years when power shortages are most likely), but does not replace the full capability that would be lost in MO3. It also relies more on generation from non-CRSO projects (i.e. leans on the rest of the regional power system) to meet load in the region, primarily by operating thermal resources.

In the future condition with additional coal-plant retirements, this option would not be sufficient to return the LOLP to the No Action level, because without coal, more of the capability or replacement capability of the Lower Snake River (LSR) projects would be needed for power system reliability. The third scenario developed designed a portfolio of replacement resources that replaces all of the generation capabilities currently supplied by the LSR projects. In the short-term, this portfolio may replace some of the generation capability that may be considered surplus (though it does contribute to reducing fossil-fuel-based generation and GHG emissions). However, as more coal plants retire, replacing the full capability of the LSR projects becomes more essential to maintain the reliability of the power system. For example, the ability of the projects to ramp generation up and down quickly is very valuable to integrating new renewable generation.

For the rate analysis (scenario 2), Bonneville chose to design a portfolio that is in-between the two scenarios described above, in other words, more than replacing the minimum generation needed just for power system reliability under the current system before coal plants retire but less than a full replacement of all capabilities. Additionally, base rates for this scenario included a reduction in assumed generation inputs revenues to serve as a proxy for lost hydropower flexibility; sensitivity analysis fine-tuned this estimated change in flexibility benefits.

The PA has an LOLP of 6.5 percent, which is very close to that of the No Action Alternative. Therefore, the PA would neither require additional resources nor avoid the need to build new resources to match the power system reliability under the No Action Alternative.

The costs of the potential replacement portfolios (and the avoided cost in the case of MO2) are based on the best available information from the NW Council's 7th Power Plan, Midterm Assessment, and consultation between Bonneville and staff experts at the NW Council (NW Council 2018).

Table 2-2. Potential Replacement Resource Portfolios by Scenario

Resource Portfolio	MO1	MO2[1/]	MO3	MO4
Zero-Carbon	600 MW demand-response and 1,200 MW solar	Avoided build of 440 MW of simple cycle natural gas or 250 MW solar, 660 MW MT wind, and 600 MW demand response[1/]	600 MW demand-response, 2,550 MW solar, and 1,250 MW of battery storage	600 MW demand-response and 5,000 MW solar
Conventional Least-Cost	560 MW simple cycle natural gas		1,120 MW combined cycle natural gas	3,240 MW simple cycle natural gas

1/ MO2 would improve power system reliability relative to the No Action Alternative; therefore, the analysis identifies potential "avoided builds" of replacement resources.

Table 2-3 provides the per unit capital costs ($/kW) of the replacement resources identified for each alternative and portfolio. The analysis used the midpoint of the costs for the resource replacement selection. The NW Council's 2022 load forecast that was used for the LOLP reliability modeling include all cost-effective conservation. According to the 7th Power Plan, by 2022 there is 1,871 aMW of conservation available to the region price at $80 per MWh or below. There is an additional 148 aMW of conservation price at over $80 dollars per MW and half of it is price at over $140 dollars per MWh. This conservation has a higher cost than the other resources that were developed for the MOs, and therefore were not included.

Table 2-3. Capital Costs of Replacement Resources (2019$)

Resource Type	Cost ($/kW)
Solar	$1,350 to $1,500
Wind	$1,500 to $1,700
Combined Cycle Gas	$1,100 to $1,300
Simple Cycle Gas	$500 to $650
Reciprocating Engine	$1,250 to $1,450
Solar Co-Located with DC-Coupled Battery[1/]	$2,568

Source: Cost based on the NW Council Midterm Assessment, 2018; energy storage costs sourced from three recent IRPs https://www.nwcouncil.org/sites/default/files/2018-10%20-%20Final%20Draft%20for%20PC%20-%207th%20Plan%20Mid-Term%20Assessment.pdf

Note: The costs have not been scaled up or down for changes in costs for resources that are ten or more times larger than projects contemplated in the Midterm Assessment.

1/Cost from NW Council 'Battery Storage Reference Plan for 2021 Power Plan' presentation by Mike Starrett.

2.2.2 Cost Assumptions for Replacements: Bonneville Finances vs. Region Finances

Uncertainty related to how replacement resources would be acquired, and the cost associated with replacement portfolios has implications for the relative effect of alternatives on ratepayers across the Pacific Northwest. To account for this uncertainty, the analysis considers two scenarios for financing the development of new resources with different implications on ownership or rights to capacity. One scenario ("Bonneville Finances Scenario") assumes Bonneville would acquire output from the replacement resources (costs recovered from Bonneville's customers and their retail ratepayers). The second scenario assumes regional

public utilities would finance the construction of resources, and their costs would be recovered directly from the retail ratepayers of those utilities ("Region Finances Scenario").

While this analysis requires some simplification to evaluate potential outcomes for financing replacement resources, it highlights the need to address the practical and technical ramifications of developing additional resources. For example, Bonneville does not have statutory authority to own or construct replacement resources; thus Bonneville's role would be limited to contracting for the output of replacement resources acquired or developed by another entity.[12] In addition, developing new resources, whether purchased by Bonneville or regional entities, can require long lead times for the planning, permitting, land acquisition, and physical construction.

To quantify the full cost of a replacement resource under each portfolio and alternative, the analysis undertakes the following:

- amortizes the capital cost of the resources over their expected life span at the tax-exempt financing rate from the FY 2019 Common Agency Assumptions;
- estimates variable costs of the resources (e.g., fuel costs) using the AURORA dispatch under each alternative; and
- estimates variable cost of other changes in the power system (e.g., adding solar into the power system reduced the need to burn gas and coal, and all portfolios create changes in power purchases and export sales).

Table 2-4 presents the estimated costs for replacement resources under each financing scenario and resource replacement portfolio. These costs would be slightly higher in all alternatives when Bonneville would finance the replacement resources because the analysis assumes that the interest rates available to the regional consortium of public utilities would be lower than those available to Bonneville.

Table 2-4. Annual Replacement Resource Costs by Financing Scenario and Replacement Portfolio (thousands, 2019$)

Financing Scenario	Resource Portfolio	Average Annual Costs	MO1	MO2	MO3	MO4	PA
Region	Conventional Least-Cost	Capital Costs	$27,000	Avoided build of 440 MW of Gas or 250 MW solar, 660 MW MT wind, and 600	$138,000	$156,000	Neither replace-ment resources nor
		Variable Costs[1/]	$7,000		$96,000	$42,000	
	Zero-Carbon	Capital Costs Demand Response	$131,000 $30,000		$389,000 $30,000	$547,000 $30,000	

[12] The term "acquire" and "acquisition" as used in the Northwest Power Act expressly excludes authorization for the Bonneville Administrator to construct or have ownership of any electric generating facility. *See* 16 U.S.C. §389a(1).

Financing Scenario	Resource Portfolio	Average Annual Costs	MO1	MO2	MO3	MO4	PA
Bonneville	Conventional Least-Cost	Capital Costs	$27,000	MW demand response[/2]	$138,000	$156,000	avoided build
		Variable Costs[1/ and 3/]	$16,000		$112,000	$91,000	
	Zero-Carbon	Capital Costs Demand Response	$131,000 $20,000		$389,000 $20,000	$547,000 $20,000	

Notes: Estimates are rounded to two significant digits. These estimates are the post-processing results from the rates analysis which including financing assumptions, and, as such, do not represent the direct GENESYS results from the LOLP modelling. The costs do not include transmission costs discussed in Chapter 3. Demand response costs under Bonneville finances scenario exclude assumed Demand Response program in Portland area ($10 million, which is included in the Region finance).

1/ The variable costs are the fuel costs and operations and maintenances associated with the replacement resources (including fuel transmission in MO3 or storage tank backups in MO1 and MO4); other costs such as import and export effects and changes to operations at other power plants (e.g., increased generation from existing regional natural gas resources) are not included in this total. Chapter 5 describes the system-wide variable cost effects.

2/ The analysis of avoided builds for MO2 was not implemented in the rates analysis and therefore no costs were estimated.

3/ Due to Bonneville ratemaking procedures, these estimates of the Bonneville variable costs reflect critical water year replacement resource generation (i.e., more gas-fired generation). The region-replace scenario is for an average water year.

2.3 SENSITIVITY OF LOLP TO ASSUMPTIONS ABOUT COAL CAPACITY

The No Action Alternative assumes 1,675 MW of coal capacity would be retired and 4,246 MW of coal capacity would continue to exist in the Pacific Northwest. However, energy economics in addition to state and local de-carbonization policies are changing the generation portfolio in the region and across the Western Interconnection into the 2020s and beyond. For example, regional IOUs have recently announced additional and accelerated coal-plant retirements.[13] In light of this, a sensitivity analysis considers how a range of potential coal-plant retirements under the No Action Alternative could affect the LOLP. This sensitivity analysis additionally assumes that no new natural gas power plants would be constructed to serve northwest loads; therefore, the sensitivity analysis applies only to the zero-carbon replacement options. Specifically, the sensitivity analysis focuses on the following scenarios:

- **Limited Coal Retirement Scenario**. This scenario assumes that an additional 2,505 MW of coal generation would be retired compared to the No Action Alternative baseline. Under

13 Both the Oregon Coal to Clean Energy Act (2016) and the Washington Clean Energy Transformation Act (2019) mandate the elimination of coal-fired resources in retail rates by 2025 (WA) and 2030 (OR). In 2017, the CRSO power analysis selected the NW Council's Resource Adequacy dataset for 2022 as the basis to prepare LOLP analysis for the CRSO EIS. The NW Council's 2022 data set was prepared in 2017, and included 407 MW of utility solar (updated to 550 MW for the CRSO) in the region, and 4,246 MW of coal, dedicated to serving regional IOU load. This plan, which is utilized for the No Action Alternative, does not incorporate TransAlta's plan to close their last unit at Centralia in 2025, nor Washington State's New Energy Transition Act which would render nearly all coal uneconomical by 2025.

this scenario, Colstrip Unit 4 and Jim Bridger Units 1 and 2 would continue operating. Under this scenario, 1,741 MW of coal capacity would continue to operate in the Pacific Northwest.

- **No Coal Scenario**. This scenario assumes that all coal plants operating in the Pacific Northwest or serving Pacific Northwest loads would be retired. As such, no coal capacity would exist under this scenario.

Table 2-5 presents assumptions about the capacity of coal generation that would serve Northwest loads under the No Action Alternative (base case) and the study of coal generation scenarios.[14]

Table 2-5. Coal Power Plants Retirement Assumptions

Coal Plant	No Action Alternative (Base Case) (MW)	Limited Coal Retirement Scenario (MW)	No Coal Scenario (MW)
Centralia 2 (WA)	670	0	0
Colstrip 3 (MT)	518	0	0
Colstrip 4 (MT)	681	681	0
Hardin (MT)	119	0	0
Jim Bridger 1 (WY)	530	0	0
Jim Bridger 2 (WY)	530	0	0
Jim Bridger 3 (WY)	530	530	0
Jim Bridger 4 (WY)	530	530	0
Montana 1 (MT)	4	0	0
North Valmy 2 (NV)	134	0	0
Total	**4,246**	**1,741**	**0**

Table 2-6 and Figure 2-1 present the LOLP associated with No Action Alternative, and alternative coal plant closure scenarios. As shown, the alternative scenarios where additional coal is assumed to retire would substantially increase LOLP. For context, a 50 percent LOLP indicates blackouts or emergency measures in about every other year. The LOLP for the No Action Alternative where all coal is retired would be 63 percent. To reduce this LOLP to the base-case LOLP (6.6 percent) under the zero-carbon portfolio, the analysis assumes that 600 MW of demand response (the NW Council target) and 1,696 MW of Montana wind (the effective transmission transfer capability following the Colstrip closure 1-4). The addition of these resources would lower the LOLP to 53 percent and are represented by the first blue diamond in Figure 2-2. [15] Subsequently, the analysis added as much solar as required to lower the LOLP to the No Action Alternative level of 6.6 percent.

[14] These analyses focus on the LOLP and the impacts to the fixed costs of the Pacific Northwest power system that would result; therefore, a full analysis was not prepared.

[15] Figure 2-2 does include 1,696 MW of Montana wind (the amount of currently available transfer capability with Washington's state share of freed up Colstrip 3&4 Transmission) and 600 MW of demand response.

778 **Table 2-6. Coal Capacity Assumptions Zero-Carbon Replacement Resources**

Alternative	Base Case Coal Capacity Assumption in EIS (4,246 MW)			More Limited Coal Capacity (1,741 MW)			No Coal Capacity (0 MW)		
	Pre-Resource Build LOLP	Zero-Carbon Resource Build (MW)	Resource Build Relative to No Action (MW)	Pre-Resource Build LOLP	Zero-Carbon Resource Build (MW)	Incremental Resource Build as Impacted by Additional Coal Retirement (MW)	Pre-Resource Build LOLP	Zero-Carbon Resource Build (MW)	Incremental Resource Build as Impacted by Additional Coal Retirement (MW)
No Action	6.6%	0	0	27%	8,800	0	63%	28,000	0
MO1	11%	1,800	+1,800	39%	9,300	0	69%	27,000	0
MO2	5.0%	0	0	16%	5,900	0	49%	22,000	0
MO3	14%	3,150	+3,150	43%	13,000	1,350	79%	35,000	+4,150
MO4	30%	5,600	+5,600	55%	12,000	0	81%	30,000	0
PA	6.5%	0	0	24%	8,600	0	59%	27,000	0

779 *Notes*: The replacement resources for No Action include demand-response, wind, and solar; for MO1 and MO3, the analysis additionally includes storage (e.g.,
780 batteries, pumped storage). The incremental resource builds under the More Limited Coal Capacity or No Coal Capacity are additive with the resource builds
781 under the base case.

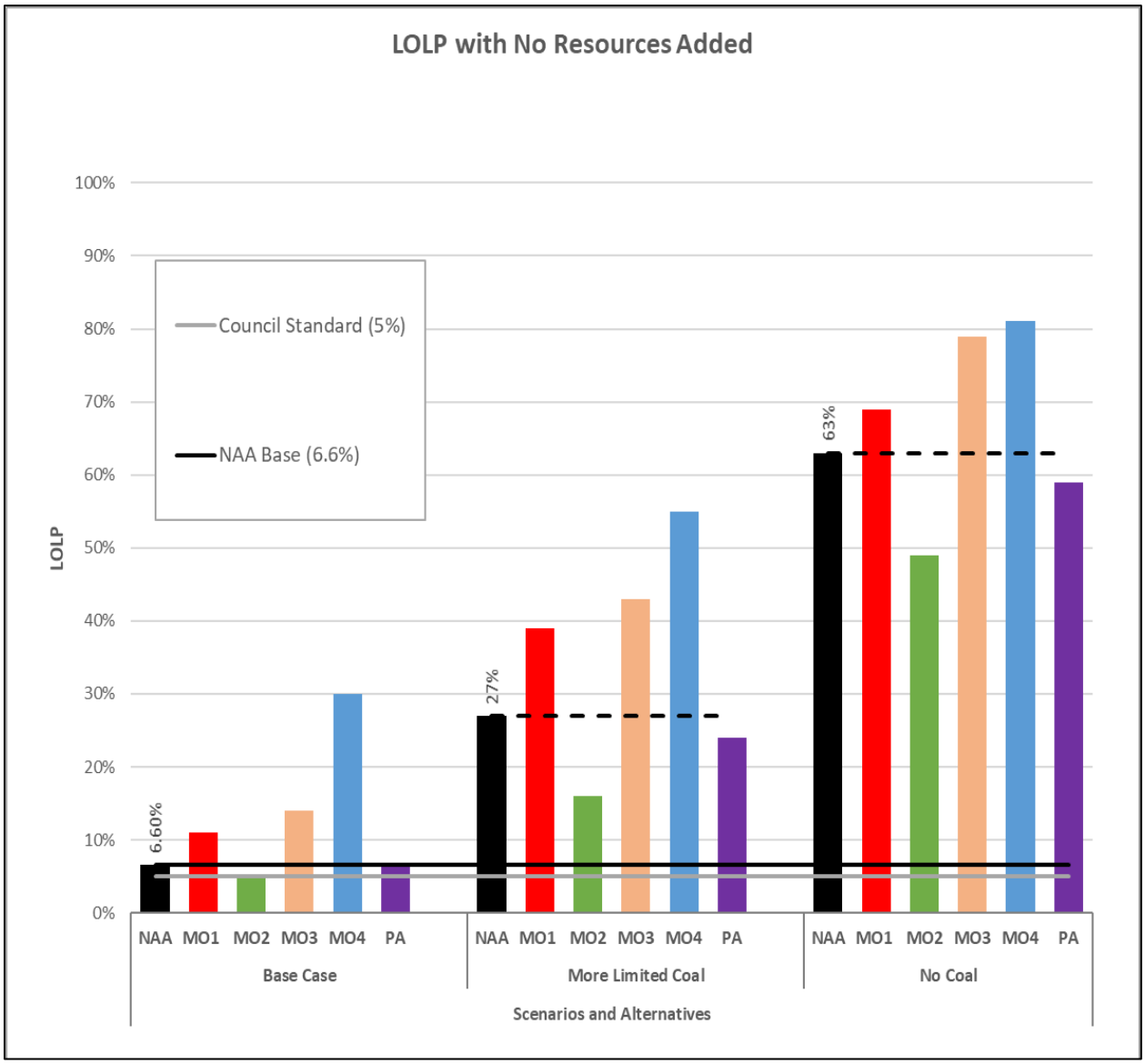

Figure 2-1. LOLP for Coal Capacity Scenarios Before Potential Replacement Resources Are Evaluated

Under the zero-carbon portfolio, MOs are assumed to utilize up to 5,000 MW of solar replacement power, which would be the most cost-effective way to serve load. However, the effectiveness of solar to serve load rapidly becomes less effective in reducing LOLP for requirements that exceed 5,000 MW. As shown in Figure 2-2, the first 5,000 MW of solar to replace the coal plants is relatively effective in reducing anticipated LOLP, but the curve flattens out at this point and additional solar becomes less effective in reducing LOLP.[16] Because of the declining effectiveness of solar as a regional replacement for coal plant closures, energy storage is assumed to be utilized in MOs to lower the costs of the replacement portfolios (the red

[16] The base assumption is that the No Action Alternative includes 550 MW of solar, so this represents an additive amount of solar in addition to that base amount.

squares in Figure 2-2 include 4 gigawatts (GW) of energy storage, which is almost twice the amount of utility-scale battery-storage capacity that the EIA projects for the United States nationwide for 2023[17]).

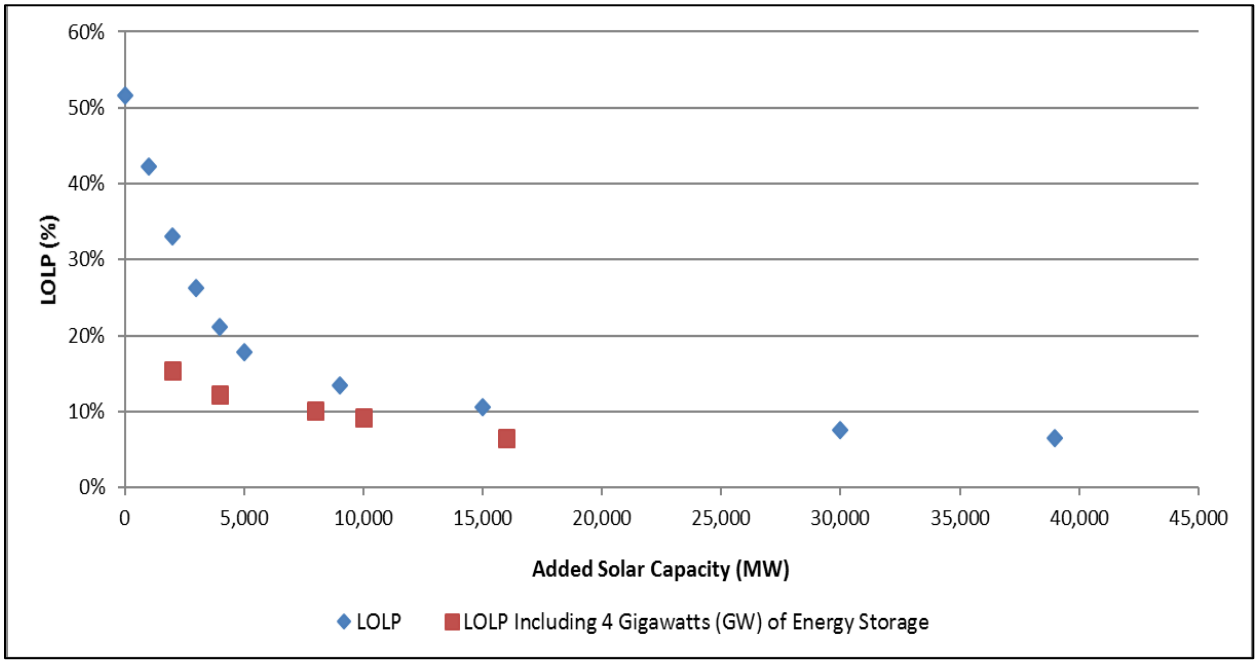

Figure 2-2. Effectiveness of Solar at Reducing LOLP under the No Coal Scenario, Including 600 MW of Demand Response and 1,696 MW of Montana Wind

All of the LOLP studies include 4,905 MW of existing wind generating facilities located near the Columbia River Gorge dedicated to serve Pacific Northwest loads. For the CRSO analysis, additional wind in the Gorge was not selected as a zero-carbon replacement resource primarily due to the fact that additional Gorge wind provides very little incremental benefit in reducing the LOLP. Figure 2-3 presents the No Action Alternative (no coal scenario) case where the LOLP is 63 percent with no resource additions. Even after the addition of 25,000 MW of new gorge wind the LOLP remains at 37.1 percent, a reduction of approximately 26 percent. In contrast, the addition of 25,000 MW of solar capacity would reduce LOLP to below 10 percent (a reduction of approximately 40 percent).

[17] U.S. Energy Information Administration, "U.S. utility scale battery storage power capacity to grow substantially by 2023" (July 10, 2019), available at: https://www.eia.gov/todayinenergy/detail.php?id=40072.

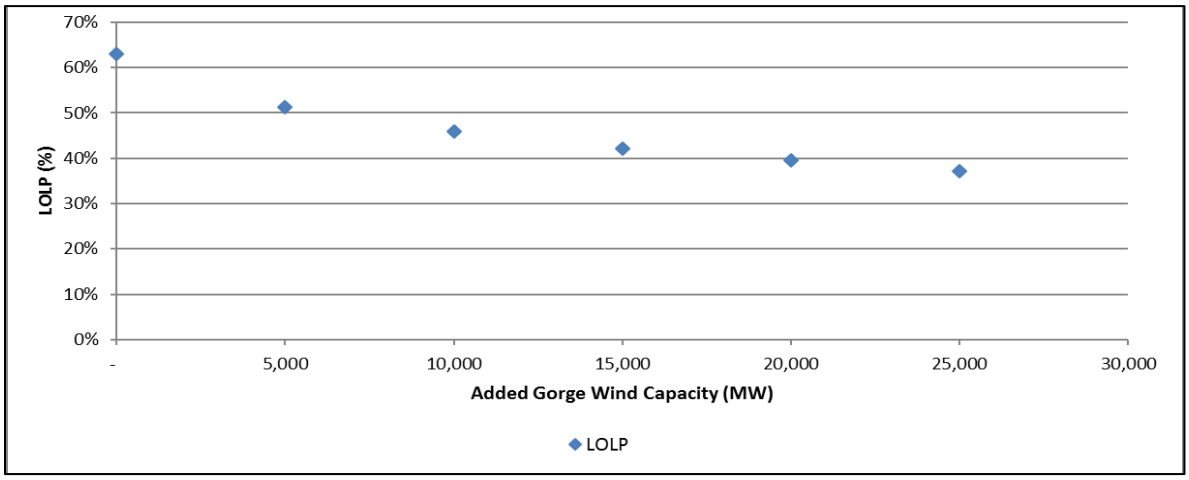

Figure 2-3. Summary of LOLP under the No Action Alternative in the No Coal Scenario with Additional MWs of Gorge Wind

2.3.1 Other Potential Solutions to Replace Coal and Hydropower

Without coal and with less hydropower, the capital investment costs of the zero-carbon portfolio to maintain regional power system reliability would be in the tens of billions of dollars. Facing a replacement portfolio cost of this magnitude could prompt other actions to replace lost generation such as further development of demand-response programs, pursuit of geothermal energy, or Montana and coastal wind that have generation profiles more closely aligned with Pacific Northwest area loads (see Figure 2-4) as well as new technologies not yet available at utility scale.

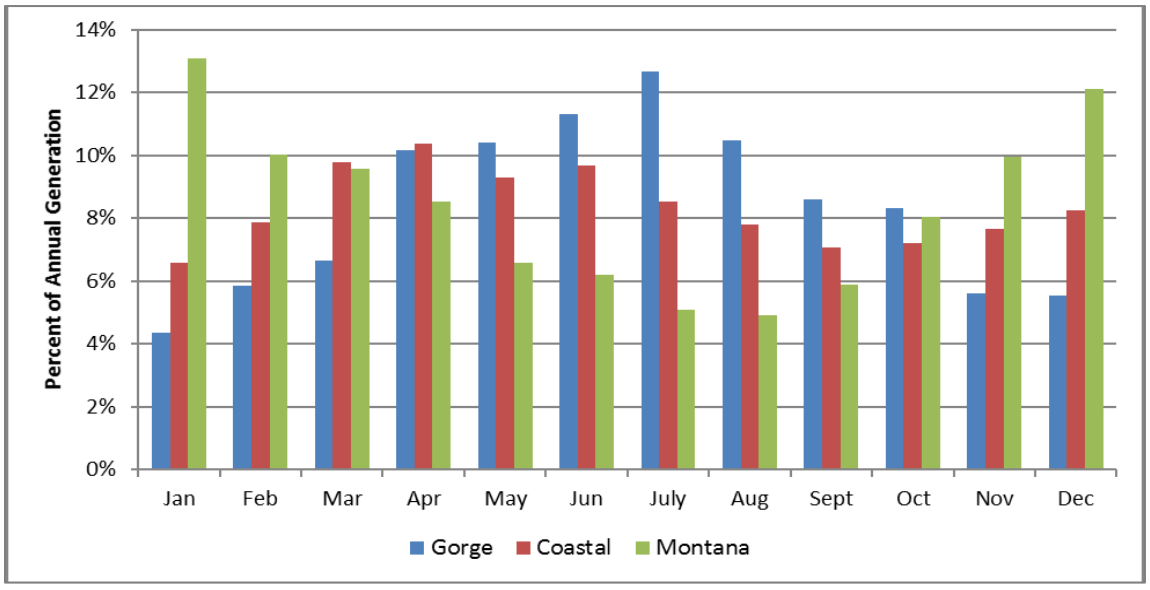

Figure 2-4. Wind Energy Distribution by Region

Note: Monthly generation profiles are the average monthly generation since 2011. Gorge is the Milner Dam Wind Park in Idaho; Coastal is the Coastal Energy project in Washington; and Montana is the Judith Gap Wind Energy Center.

Source: EIA 2019

2.3.2 Summary Results: Meeting Load

In summary, the amount of zero-carbon replacement resources required to return the region to the No Action Alternative target of 6.6 percent LOLP are substantial under a limited coal or no coal scenario. To meet that level, MO3 would require between 4,000 MW and 7,000 MW of zero-carbon replacement resources over the No Action Alternative alone (requiring around 60,000 to 110,000 acres). Table 2-7 below shows the replacement resources that would be required (in MW of capacity) for each alternative to meet the No Action Alternative LOLP.

This analysis does not include the additional amount of generation reserves needed to integrate new renewable resources under a zero-carbon replacement resource portfolio. Generation reserves allow grid operators to increase or decrease generation in response to changes in load and generation. In this analysis, the generation reserves needed for the No Action Alternative are included in all modeling. However, additional reserves needed under a zero-carbon replacement resource portfolio have not been included. Currently, generation reserves are generally supplied through the flexibility of hydropower or gas-fired generators in the region. With further technological advances, other options may be available in the future. MO3 and MO4 reduce the flexibility of the hydropower system to supply these generation reserves.

Table 2-7. Potential Renewable Resources Required to Meet 6.6 Percent LOLP, Total and Difference from No Action (MW)

Alternative	Demand Response (MW)	Montana Wind (MW)	Solar (MW)	Energy Storage (MW)[/4]
Base Case				
No Action	0	0	0	0
MO1	0 + 600	0+0	0 +1,200	0+0
MO2[1/]	0 + 0[1/]	0+0[1/]	0+0[1/]	0+0
MO3	0 + 600	0+0	0 +2,550	0+0
MO4	0 + 600	0+0	0 +5,000	0+0
PA	0 + 0[2/]	0 + 0[2/]	0 + 0[2/]	0 + 0[2/]
Limited Coal[3/]				
No Action	600	1,696	4,000	2,500
MO1	600 + 0	1,696 + 0	4,000 + 500	2,500 + 0
MO2	600 + 0	1,696 + 0	4,000 - 2,900	2,500 + 0
MO3[5/]	600 + 0	1,696 + 0	4,000 + 3,200	2,500 + 1,000
MO4	600 + 0	1,696 + 0	4,000 + 3,200	2,500 + 0
PA	600 + 0	1696 + 0	4,000 – 200	2,500 + 0
No Coal[3/]				
No Action	600	1,696	22,000	4,000
MO1	600 + 0	1,696 + 0	22,000 - 1,000	4,000 + 0
MO2	600 + 0	1,696 + 0	22,000 - 6,100	4,000 + 0
MO3	600 + 0	1,696 + 0	22,000 + 6,000	4,000 + 1,000
MO4	600 + 0	1,696 + 0	22,000 + 1,400	4,000 + 0
PA	600 + 0	1,696 + 0	22,000 - 1,000	4,000 + 0

Note: In each cell, the first number refers to the amount of renewable energy capacity needed to replace the retired coal plants and the second number is the additional capacity needed to replace lost hydropower generation

from the MOs. In a few cases, the MOs reduce the amount of new resources needed compared to the No Action Alternative in the scenarios with limited or no coal.

1/ MO2 under all coal scenarios would create a reliability benefit. Therefore, the amount of resources relative to the No Action Alternative is negative representing a potential avoided build of replacement resources. The avoided build in the base case would be 600 MW of demand response, 660MW of Montana wind and 250 MW of solar.

2/ The PA, under the base analysis, results in approximately the same LOLP as the No Action Alternative and would not require the addition of new resources.

3/ The limited coal scenario includes 1,741 MW of remaining coal capacity and the no coal scenario has 0 remaining coal capacity.

4/ Some scenarios more than double the EIA projected U.S. battery storage capacity projected for 2023.

5/ Returning MO3 to a LOLP of 6.6% does not replace the LSR sustained ramping or reserve capabilities.

Figure 2-5 depicts the marginal resource build required under the MOs relative to the No Action Alternative considering the limited or no coal scenario to restore the LOLP. With less coal in the Pacific Northwest, MO3 replacement resources would require more additional renewable resources because solar is less effective at replacing the winter loss of power from the LSR dams than the summer power losses. For MO3 it may be cost-effective to add battery storage for peak demand.

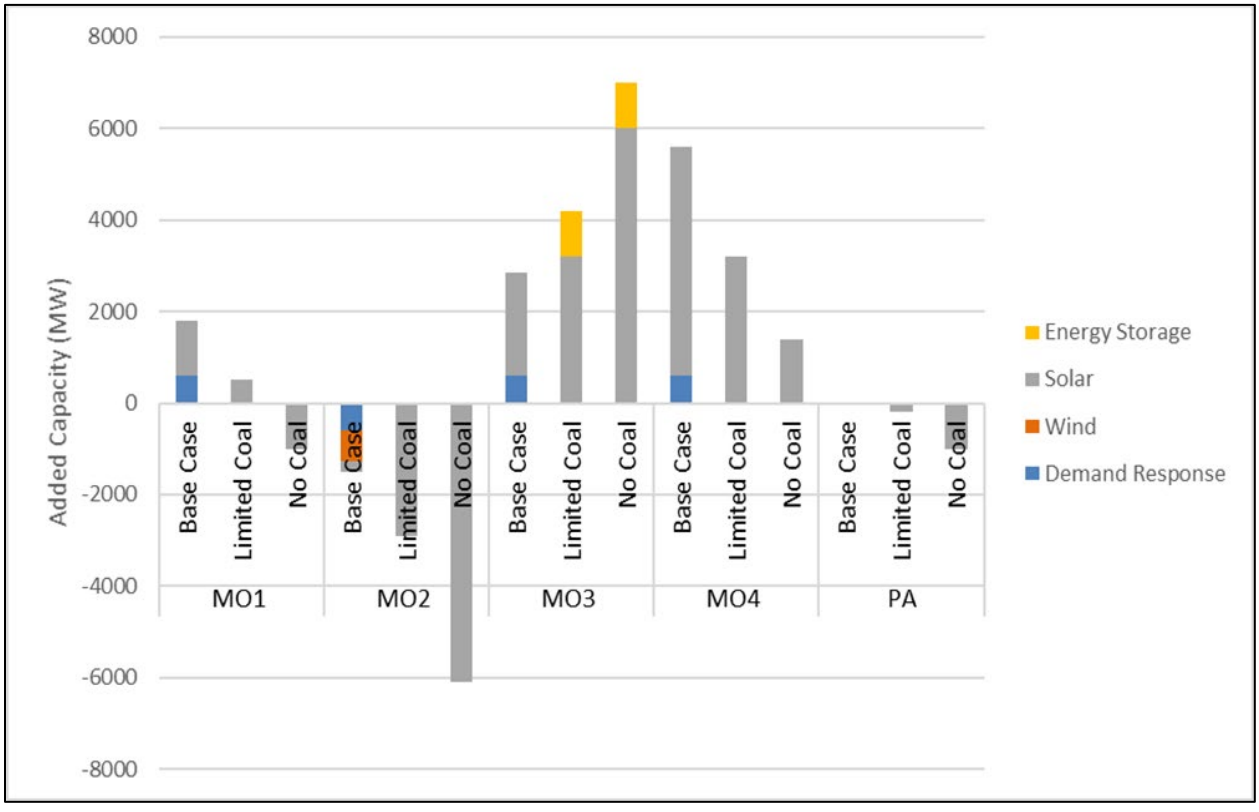

Figure 2-5. Marginal Resource Build Above No Action for the Base Case, Limited Coal and No Coal in MW

Note: For the no coal scenario, the total solar is -1,000 MW for MO1 and the PA, -6,100 MW for MO2, 6,000 for MO3 and +1,400 MW for MO4. See Table 2-6 for the full coal scenario resource results.

2.4 COMPARISON OF THE NWEC STUDY WITH THE MO3 ALL-GAS ALTERNATIVE

2.4.1 Scenarios

The MO3 replacement resource portfolios were designed to include enough new generating resources so that power system reliability was equal to that of the No Action Alternative (i.e., LOLP would equal 6.6 percent). The Northwest Energy Coalition (NWEC) study, by contrast, does not target a specific LOLP nor does it include enough information to extrapolate the cost of its all-gas alternative with an LOLP equal to that of the reference scenario (i.e., the NWEC equivalent of the No Action Alternative). However, every portfolio considered in the NWEC study has an LOLP below the 5 percent LOLP standard after including replacement resources. In total, NWEC examined nine portfolios including combinations of demand response, energy efficiency, renewables and non-generating resources, and natural gas. This comparison focuses on the natural gas scenarios.

2.4.2 Natural Gas Replacement Resource Portfolio

Examining the NWEC all-gas alternative and the MO3 conventional least-cost portfolio, the two portfolios are similar in their conclusions about the amount of replacement resource capacity that would be required. However, there is a difference in the type of natural gas replacement resources, as the NWEC studies use some level of reciprocating engines instead of combined cycle natural gas turbines. Table 2-8 below compares the portfolios.

Table 2-8. Comparison of NWEC and MO3 Portfolios (Installed MW)

Resource	NWEC All Gas	MO3 Conventional Least-Cost
Combined Cycle	500	1,120
Reciprocating Engines	450	--
Total	950	1,120

2.4.3 Variable Costs

The following tables outline the differences in total variable costs between the NWEC and MO3 portfolios. The difference is substantial, amounting to approximately a factor of three. Variable costs in the CRSO are derived from the changes in fuel consumption and other variable costs using the AURORA model. The NWEC study used GENESYS to estimate the total production costs as changes in fuel consumption and regional imports and exports. NWEC concludes that annual production costs would be $335 million (Table 2-9). That amount consists of $253 million in fuel-related costs and $82 million from loss of exports.

Table 2-9. Comparison of Variable Costs

Costs	NWEC All Gas	MO3 Conventional Least-Cost	NWEC All Gas (Low Cost)
Variable Costs	$335 million	$137 million	$198 million

The large difference in fuel-related costs between the two studies results from a difference in gas price forecasts. For the NWEC study, the average gas price at all hubs is $4.97 per million British thermal units (MMBTU), while the MO3 uses a figure of $2.20/MMBTU at Stanfield. For the M03 study, even the highest 5 percent of simulations had a lower gas price ($4.13/MMBTU) than the NWEC study. The differences in gas prices make up 90 percent of the fuel costs differences that drive the $253 million discrepancy in production costs. Table 2-10 below presents the gas prices and the estimate of MO3 fuel costs using the 5th and 95th percentile fuel costs.

Table 2-10. Fuel Prices and Total Production Costs

	Gas Prices/Costs		
Measure	**Lowest 5%**	**Average**	**Highest 5%**
Fuel Prices ($/MMBTU)			
MO3 Average Fuel Price	1.13	2.20	4.13
NWEC Hub Fuel Price (Average Only)	4.97	4.97	4.97
Production Costs			
MO3 Production Costs	$73 million	$137 million	$227 million
NWEC Production Costs (Average Only)	$253 million	$253 million	$253 million
MO3 as a Percentage of NWEC Costs	28.9%	54.2%	89.7%

To calculate regional energy imports and exports, the NWEC study only examined the Pacific Northwest, where M03 looks WECC-wide. The NWEC methodology concludes that the all-gas scenario would result in a lowering of net exports out of the region by $82 million The MO3 methodology, by contrast, is not set up to account for such a loss. A more precise analysis under MO3 would be required in order to estimate any potential loss of revenue from power exports. AURORA does estimate changes in total production costs for California and the rest of the Western United States. These are not directly comparable to changes in regional imports and exports, but they do provide an estimate of changes in regional power generation.

2.4.4 Fixed Costs

Under the NWEC study, the fixed costs are approximately 42 percent higher than the fixed gas costs of M03. One of the major drivers of this difference is the drop in estimated fixed gas transmission costs between the 7th Power Plan and the latest estimates from the 8th Power Plan. These cost estimates are partially dependent on the fuel efficiency of the gas plant, but in general these fixed costs have dropped from $62.60/kW in the 7th Power Plan to $41.40/kW for the 8th Power Plan.

Table 2-11 presents the annualized replacement resource fixed costs.

Table 2-11. Total Fixed Costs

Costs	NWEC All Gas	MO3 Conventional Least-Cost	NWEC All Gas (Low Cost)
Fixed Costs	$200 million	$140 million	$60 million

Note: The fixed costs include the annualized capital costs, transmission and gas pipeline costs.

2.4.5 Summary

The differences in overall results between NWEC and MO3 conventional least-cost is largely explained by the differences in fuel price forecasts. The higher price per MMBTU in the NWEC study generates a total variable cost nearly three times higher than that of the MO3 conventional least-cost portfolio. The fixed costs are comparable between the two studies, with discrepancies coming from the use of more recent data in MO3.

In December 2019, Northwest RiverPartners released a report prepared by EnergyGPS Consulting, LLC (EGPSC) (2019), reviewing the above NWEC study. The review points out that the NWEC study relied on load and resource forecasts that are now over three years old and now out-of-date, in large part due to changing regional energy and climate policies. Many more coal-plants are slated for retirement since the NWEC study, and the authors expect that all cost-effective demand response and energy efficiency resources will be used to replace the lost coal generation. Further, the reliance on imports was noted as being too high, the cost of transmission too low, and no penalty associated with increasing reliance on fossil-fuel-based generation. The review paper used updated load, resource, and policy information to propose a replacement portfolio for the lower Snake generation using new renewable resources with battery storage, an adder for transmission costs to integrate the new resources, and an adder for the compliance cost of incremental carbon emissions. This portfolio would cost about $860 million per year or $96/MWh.

CHAPTER 3 - TRANSMISSION SYSTEM RELIABILITY AND CONGESTION

The following sections present the results of analyses for regional congestion and the reliability of the Bonneville transmission system. These analyses build on the power generation results as discussed in Appendix J, *Hydropower* and the power system reliability results discussed in Chapter 2 of this appendix, *Power Supply and Replacement Resources*. The regional transmission congestion forecasting was a standalone result of the transmission modeling while the Bonneville transmission system reliability analysis was an input to the Bonneville transmission rate pressure analysis (as described in Chapter 4 of this appendix, *Wholesale Power and Transmission Rates*). The following sections describe the methodology, data, and results of the regional congestion forecasting and Bonneville transmission system reliability analyses that supports the transmission discussion in Chapter 3, Section 3.7*, Power and Transmission* of the main body of the EIS.

Based on the power system reliability analysis described in Chapter 2 of this appendix, the resource mix and general geographic location of replacement resources for each alternative and for each resource replacement portfolio were identified to maintain the LOLP under each of the alternatives (see Chapter 2). The resource mix and general locations were then considered with past Bonneville interconnection requests and existing infrastructure to identify reasonable locations for siting replacement resources as shown in Table 3-1 through Table 3-3 below.

Table 3-1. Conventional Least-Cost Replacement Resources and Assumed Locations

Alternative	Total Amount (MW) and Assumed Location
MO1	560 MW, gas-fired simple-cycle combustion turbines in north central Oregon near McNary Substation.
MO2	N/A (LOLP under this alternative is lower than under No Action Alternative).
MO3	1,120 MW of gas-fired combined-cycle turbines in north central Oregon near McNary Substation.
MO4	3,240 MW of gas-fired simple-cycle combustion turbines in north central Oregon and southeast Washington.
PA	N/A (LOLP under this alternative is lower than under No Action Alternative).

Table 3-2. Zero-Carbon Replacement Resources and Assumed Locations

Alternative	Location
MO1	1,200 MW of solar generation in south central Oregon, and 600 MW of demand response in Spokane, Portland, and Seattle.
MO2	N/A (LOLP under this alternative is lower than under No Action Alternative).
MO3	2,550 MW of solar generation in north central Oregon, south central Oregon and 600 MW of demand response in Spokane, Portland, and Seattle.
MO4	5,000 MW of solar generation in south central Oregon, north central Oregon, central Washington, south central Idaho, and 600 MW of demand response in Spokane, Portland, and Seattle.
PA	N/A (LOLP under this alternative is lower than under No Action Alternative).

962 **Table 3-3. Detailed Zero-Carbon Replacement Resources and Assumed Locations**

Approximate Replacement Resource Location	Replacement Resource Amount				
	MO1	MO2	MO3	MO4	PA
Demand Response					
Spokane	300 MW	--	300 MW	300 MW	--
Portland	200 MW	--	200 MW	200 MW	--
Seattle	100 MW	--	100 MW	100 MW	--
Solar					
Captain Jack Substation	--	--	1,250 MW	1,250 MW	--
Grizzly Substation	1,200 MW	--	1,250 MW	1,250 MW	--
Slatt Substation	--	--	50 MW	1,250 MW	--
Wautoma Substation	--	--	--	625 MW	--
Midpoint Substation	--	--	--	625 MW	--

963 *Note*: The substations listed are the assumed interconnection points and do not represent the location of the
964 replacement resource itself.

965 ## 3.1 REGIONAL CONGESTION FORECASTING

966 The regional transmission congestion analysis relies on a production cost modeling analysis to
967 evaluate how changes in the operation of the CRS projects and the replacement resources
968 under each alternative would alter the utilization of the transmission system in the Pacific
969 Northwest. This section provides an overview of the production cost modeling analyses for the
970 MOs.

971 Production cost modeling allocates the available generating resources to the required load in a
972 way that minimizes the overall cost of operation. The allocation of available generating units
973 conforms to the operating constraints of the generators and the transmission system. The
974 regional transmission congestion analysis used the GridView modeling package (which is
975 developed by ABB, Inc.) for the production cost modeling. GridView simulates the conventional
976 least-cost (i.e. most economic) operation of a power system in hourly intervals for periods
977 ranging from one day to many years. For the CRSO EIS congestion analysis, a one-year window
978 with an hourly time step was used to produce a forecast of the utilization of generating
979 resources and power flow patterns across the transmission system.[18] Gridview incorporates
980 detailed hourly generation and load modeling, and a nodal transmission system representation
981 of the Western Interconnection derived from powerflow modeling.

982 WECC's 2028 Anchor Data Set (ADS) case (Version 2.2 released 1/25/2019) provides the basis
983 for development of the base case used in the congestion forecast studies. This ADS case is the

[18] All values produced using GridView are averages over hourly intervals. Values cited as maximums and minimums are calculated from these hourly averages. Maximums and minimums based on values averaged over shorter time intervals or on values taken instantaneously (e.g. SCADA) may be higher and lower respectively. Any references to instantaneous engineering units (e.g. MW) used in all tables and charts are implicitly suffixed with "averaged over the hour."

best publicly available utility-provided modeling information forecasted for 2028 for generating resources, customer loads, and transmission expansion plans for the Western Interconnection.

As discussed in Appendix J, *Hydropower,* the operating restrictions and limitations for each hydropower project along with its historical water run-off data produces forecasted monthly values for average energy production at each project. Monthly maximum and minimum generation limits were also provided for several Federal hydropower projects in the Pacific Northwest. The congestion analysis uses the monthly values as inputs to determine the individual project's hourly generation for each month. To assess the operation of the hydropower system over the range of future water run-off scenarios, the congestion analysis uses the hydropower generation results for historical run-off for three years representing median (1960), high (1997), and low (1931) flows. A description of the hydropower generation results that serve as inputs to the transmission analysis are available in Appendix J, *Hydropower*.

GridView was run for the two resource replacement scenarios (conventional least-cost and zero-carbon), for each CRSO alternative.[19] Resource replacement portfolios were not run for the No Action Alternative, MO2, or the Preferred Alternative because neither alternative would result in changes in power system operations and generation that would require resource replacement. A total of 36 GridView case runs are included in the transmission congestion analysis.

The structural and operational measures with the studied alternatives and their resource replacement portfolios would result in shifts in generation across the Pacific Northwest and the entire Western Interconnection. Shifts in the pattern of generation can alter the ranges of power flows expected across transmission interfaces.[20] Power flow changes that approach transmission interface limits indicate the risk that changes to generation dispatch may be needed. In certain cases, this may also indicate increased reliability risk to the regional transmission system.[21] This analysis assumes that implementation of the studied alternatives and their resource replacement portfolios would not require changes in any transmission interface definitions or limits.[22] The assumed system operating limits were not changed

[19] GridView was also run for a no resource replacement scenario. These results are not used in this analysis.
[20] A transmission interface in this context refers to a collection of one or more transmission facilities for which the aggregate power flow is monitored in GridView. Transmission interface definitions generally correspond to the flow on one or more WECC-rated paths, Bonneville internal flowgates, or other similar sets of related transmission facilities.
[21] The modeled limit in GridView for an interface could represent a system operating limit, total transfer capability, or WECC Path Rating.
[22] The transmission path transfer capabilities are established based on what is the most limiting element (the amount power that transmission equipment or line(s) can accommodate). Removing generation from one location and replacing it in another location can change the limiting element. In some cases, even the path limits need to be changed. The congestion forecast is likely conservative because it estimates a highly optimized power system and does not account for unplanned outages, maintenance, or other circumstances that affect the transmission system and may result in congestion. Thus, if an unplanned outage, routine maintenance, or other circumstances occurred, the impacts to congestion would be greater than those identified in the congestion analysis.

because there is not enough certainty about the possible replacement resources to have confidence that changing the limit assumptions would increase accuracy when the GridView studies that were performed. Transmission interface limits are assumed to reflect "all lines in service" conditions throughout the entire year, so the potential impact of planned maintenance or forced outages on congestion is excluded. A map of regional transmission lines and flowgates that generally correspond to the transmission interfaces used in the GridView analysis is provided in Figure 3-1.

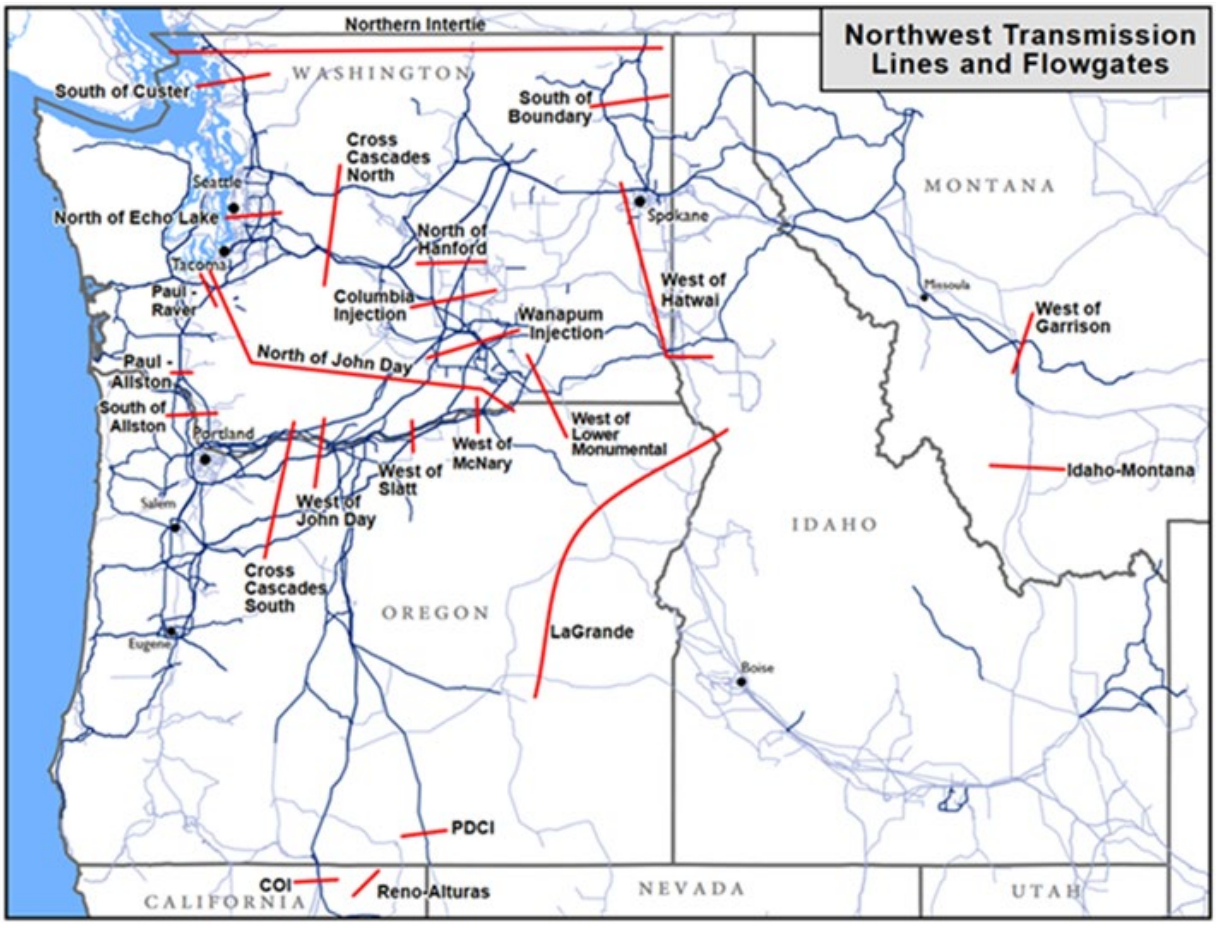

Figure 3-1. Northwest Transmission Lines and Flowgates

In this analysis, transmission interfaces experiencing flows within 0.1 percent of its current transfer limit are said to be "congested." The change in the number of congested hours is one measure of the impact that the alternatives and their resource replacement portfolios have on the regional transmission system. Transmission interfaces that are congested can, therefore, restrict the dispatch of lower cost generating plants and instead require the dispatch of higher cost generating plants, which increases the overall cost of serving customer loads.

While the WECC ADS is the primary dataset used in the GridView analysis, transmission interface limits were updated with Bonneville's most current information at the time of the study. For transmission interfaces in which limit information was only available in one direction, the limit for the opposite direction was assumed to be of equal magnitude. Table 3-4 shows the

transmission interface limits based on the WECC ADS on the regional transmission system and also on certain key interfaces in Canada, Montana and Idaho. Table 3-5 shows the updates to the transmission interface limits based on Bonneville's current information.

Table 3-4. Pacific Northwest Transmission Interfaces and Limits

Interface Name	Direction 1 Limit (MW and Direction)		Direction 2 Limit (MW and Direction)	
P01 ALBERTA-BRITISH COLUMBIA	1,000	East-to-West	1,200	West-to-East
P03 NORTHWEST-BRITISH COLUMBIA	3,000	South-to-North	3,150	North-to-South
P03EAST SIDE NW-BC	400	South-to-North	400	North-to-South
P03WEST SIDE NW-BC	2,750	South-to-North	2,850	North-to-South
P04 WEST OF CASCADES-NORTH	10,250	East-to-West	10,250	West-to-East
P05 WEST OF CASCADES-SOUTH	7,500	East-to-West	7,500	West-to-East
P06 WEST OF HATWAI	4,277	East-to-West	4,250	West-to-East
P08 MONTANA TO NORTHWEST	2,200	East-to-West	1,350	West-to-East
P14 IDAHO TO NORTHWEST	2,400	East-to-West	1,200	West-to-East
P16 IDAHO-SIERRA	500	North-to-South	360	South-to-North
P17 BORAH WEST	4,450	East-to-West	4,450	West-to-East
P18 MONTANA-IDAHO	383	North-to-South	256	South-to-North
P19 BRIDGER WEST	4,100	East-to-West	2,300	West-to-East
P20 PATH C	2,250	West-to-East	2,250	East-to-West
P25 PACIFICORP/PG&E 115 KV INTER	100	North-to-South	45	South-to-North
P65 PACIFIC DC INTERTIE (PDCI)	3,220	North-to-South	3,100	South-to-North
P66 COI	4,800	North-to-South	3,675	South-to-North
P71 SOUTH OF ALLSTON	3,100	North-to-South	1,480	South-to-North
P73 NORTH OF JOHN DAY	8,800	North-to-South	8,800	South-to-North
P75 HEMINGWAY-SUMMER LAKE	1,500	East-to-West	550	West-to-East
P80 MONTANA SOUTHEAST	600	East-to-West	600	West-to-East
P83 MONTANA ALBERTA TIE LINE	325	South-to-North	300	North-to-South
BPA 01 TRICITIES	1,050	Import	--	Export
COLUMBIA INJECTION	1,300	Import	--	Export
NORTH OF ECHO LAKE	2,800	South-to-North	--	North-to-South
NORTH OF HANFORD	4,450	North-to-South	4,450	South-to-North
PAUL-ALLSTON	2,400	North-to-South	2,400	South-to-North
RAVER-PAUL	1,450	North-to-South	1,450	South-to-North
SOUTH OF BOUNDARY	1,400	North-to-South	--	South-to-North
SOUTH OF CUSTER	1,850	North-to-South	--	South-to-North
WEST OF JOHN DAY	4,530	East-to-West	4,530	West-to-East
WEST OF LOWER MONUMENTAL	4,200	East-to-West	4,200	West-to-East
WEST OF MCNARY	5,230	East-to-West	5,230	West-to-East
WEST OF SLATT	4,670	East-to-West	4,670	West-to-East

Table 3-5. Bonneville Transmission Interface Limit Changes

Interface Name	Direction	Limit in ADS Case (MW)	New Bonneville Limit (MW)
TRICITIES AREA IMPORT	Import	--	1,050
P04 WEST OF CASCADES-NORTH	East-to-West	10,700	10,250
P05 WEST OF CASCADES-SOUTH	East-to-West	7,605	7,500

Interface Name	Direction	Limit in ADS Case (MW)	New Bonneville Limit (MW)
P14 IDAHO TO NORTHWEST	East-to-West	3,400	2,400
P14 IDAHO TO NORTHWEST	West-to-East	2,250	1,200
P73 NORTH OF JOHN DAY	North-to-South	8,000	8,800
NORTH OF ECHO LAKE	North-to-South	2,636	2,800
NORTH OF HANFORD	North-to-South	5,100	4,450
RAVER-PAUL	North-to-South	1,800	1,450
SOUTH OF CUSTER	North-to-South	2,832	1,850
WEST OF JOHN DAY	East-to-West	3,750	4,530
WEST OF MCNARY	East-to-West	5,000	5,230
WEST OF SLATT	East-to-West	4,200	4,670
Z CG PDCI SOUTH	North-to-South	2,800	Removed

Note: The interface Z CG PDCI South was duplicative of the PDCI Interface and was removed from the ADS case.

3.1.1 Transmission Interface Utilization Results

Given the hydropower generation levels under each CRSO alternative, the gas-fueled replacement generation resources added for the conventional least-cost resource replacement portfolio were regularly called on as part of GridView's hourly least-cost generating dispatch process.[23] When the zero-carbon resource replacements were added with the hydropower generation levels under each alternative, additional solar generation was assumed to be non-dispatchable with a fixed hourly output and zero variable cost. It had an approximately 23 percent capacity factor. About 274 aMW, 583 aMW, and 1,152 aMW of the solar resource replacements for MO1, MO3, and MO4 respectively were called upon. Although Demand Response would be necessary to meet power resource adequacy standards under both resource replacement portfolios, because it was assumed to be a high variable cost dispatch resource, it was never called upon in the transmission congestion modeling.

Figure 3-2 identifies the regional transmission interfaces that became congested for at least one hour during the GridView simulations for any of the studied alternatives. The middle (darker) dot is the number of congested hours for median run-off cases (without portfolios) for each alternative. The outer (lighter) dots are the maximum and minimum number of hours for all cases run for that alternative (i.e. three runs for No Action Alternative, MO2, and the Preferred Alternative; nine runs for MO1, MO3, and MO4).

The changes in the patterns of generation under the MO alternatives and their resource replacement portfolios would have measurable impacts on loading and congestion for many regional transmission interfaces. The changes in the numbers of congested hours on most transmission interfaces, however, are small in comparison to the changes related to variations in hydropower generation related to different run-off conditions.

[23] Conventional least-cost use was predicted on gas hub price forecasts, as described above in Chapter 2, *Power Supply and Replacement Resources.*.

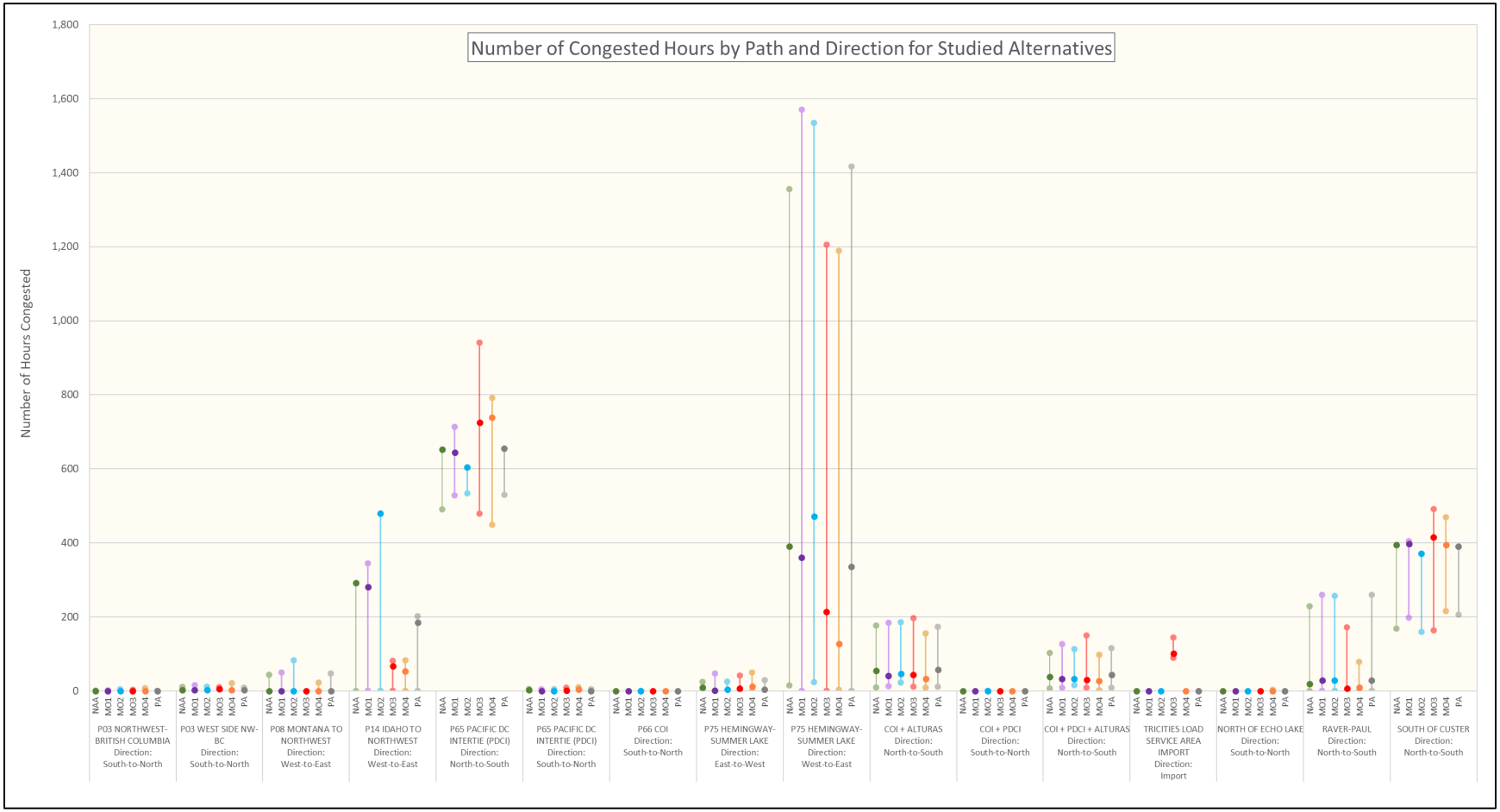

Figure 3-2. Number of Congested Hours by Interface and Direction for Studied Alternatives Without Additional Coal Retirements

Congested transmission interfaces can restrict the use of lower cost generating plants in the region and in the WECC and end up requiring the dispatch of higher cost generating plants. Using the higher cost generating plants increases the overall cost of serving customer loads. Congestion constraints on the transmission system as a result of hydropower generation or resource replacement portfolios under the alternatives can also lead to the restriction or curtailment of renewable resource generation, such as wind and solar, as part of the conventional least-cost (i.e. economic) dispatch. This shift in the use of generating resources may result in the use of resources that produce higher levels of greenhouse gases (see Chapter 3.8 of the main body of the EIS, *Air Quality and Greenhouse Gases* for more discussion).

The GridView simulation assumes that if available zero variable cost generation in a given hour exceeds the amount that can be delivered to load due to transmission interface limits, then the excess generation must be "curtailed." Under normal conditions, generation from the hydropower projects would be reduced to allow for the excess generation and water would be spilled or stored for later use rather than run through the generating turbines. However, during times of increased hydropower run-off, additional spill or storage is no longer practicable, and the curtailment of both solar and wind generation is necessary.

Under MO1, the solar generation added for the zero-carbon resource replacement portfolio increases combined system-wide solar and wind curtailment by 461 gigawatt hours (GWh) in a heavy run-off years, which is 18.4 percent of the 2,504 GWh produced by the added solar generation. Under MO2, increased hydropower generation increases combined solar and wind curtailment by 721 GWh in a heavy run-off year, which is 15 percent of the 4,811 GWh of higher hydropower generation under MO2. Under MO3, the solar generation added for the zero-carbon portfolio increases combined system-wide solar and curtailment by 763 GWh in a heavy run-off year, which is 14.1 percent of the 5,124 GWh produced by the added solar generation. UnderMO4, solar generation added for the zero-carbon portfolio increases combined system wide solar and wind curtailment by 1,371 GWh in a heavy run-off year, which is 14.2 percent of the 9,659 GWh produced by the added solar generation. Finally, under the Preferred Alternative, changes to hydropower generation change combined system-wide solar and wind curtailment by between 9 GWh and -288 GWh depending on the level of water run-off, which is 1.0% to -15% of the system-wide combined curtailment. These shifts in renewable resource generation and curtailments are modeled at the regional and Western Interconnection-wide scale and allocated based on the security-constrained economic dispatch. These results do not estimate curtailments based on specific Bonneville or other utility oversupply policies.

There can be instances when the generating resources are located within the load service area where transmission congestion could prevent load from being fully served by other generating resources without reinforcing the transmission system to increase capacity. The regional congestion analysis suggested that this may occur under MO3 in the Tri-Cities area due to the location of Ice Harbor Dam within the load service area.

The Tri-Cities transmission interface consists of transmission lines and transformers used to provide service to serve Kennewick, Pasco, and Richland. The Ice Harbor project is also located

inside this area, and its output reduces the need for bringing in (importing) power from outside the load area and the need for power to flow across the Tri-Cities transmission interface. When needed imports across the Tri-Cities transmission interface approach 1,050 MW to meet load, there is potential to require reductions to customer loads. The risk increases further when imports exceed 1,160 MW.

Under MO3, flows across the Tri-Cities transmission interface increase substantially compared to any other MOs and the Preferred Alternative due to its removal of all Ice Harbor generation. Table 3-6 shows that there are hours where flows across the Tri-Cities transmission interface would exceed the 1,050 MW and 1,160 MW levels for each hydropower run-off scenario and resource replacement portfolio.

The simulation results indicate that new transmission reinforcements or net load reductions in the Tri-Cities area would likely be needed under MO3 to allow for uninterrupted load service to end users because there are very limited options for managing congestion across the Tri-Cities transmission interface.[24] For transmission interfaces other than the Tri-Cities, any increased congestion identified for the CRSO EIS alternatives would restrict the dispatch of lower cost generating plants. Therefore, the overall cost of serving customer loads increases, but would not prevent customer loads from being served.

Table 3-6. Tri-Cities Import Limit Violations under MO3 Without Additional Coal Retirements

	Import Limit: 1,050 MW			Import Limit: 1,160 MW		
Run-Off	**MO3**	**MO3 Conventional Least-Cost**	**MO3 Zero-Carbon**	**MO3**	**MO3 Conventional Least-Cost**	**MO3 Zero-Carbon**
Low Water Run-Off						
Hours Above Limit	124	142	131	16	21	17
Maximum Amount about Limit (MW)	202	213	202	92	103	92
Total of Energy above Limit (MWh)	7,203	8,370	7,359	611	776	642
Median Water Run-Off						
Hours Above Limit	99	109	98	12	15	12
Maximum Amount about Limit (MW)	194	199	196	84	89	86
Total of Energy above Limit (MWh)	5,644	6,330	5,734	474	535	474
High Water Run-Off						
Hours Above Limit	87	98	88	12	16	13
Maximum Amount about Limit (MW)	195	208	195	85	98	85
Total of Energy above Limit (MWh)	5,101	5,792	5,013	410	560	401

[24] For this reason, flows across the Tri-Cities transmission interface were monitored but not used to constrain the economic dispatch

These findings are consistent with the Bonneville system reliability assessment as described in Section 3.2, 3-143.2 Bonneville Transmission System Reliability and Network Interconnections. Section 3.2 contains additional powerflow results and identifies any needed reinforcements as a result of changes in hydropower generation under the CRSO alternatives.

3.1.2 GridView Congestion Results by Transmission Interface

The following sections detail the congestion results by transmission interface for only those interfaces experiencing congestion as presented in Figure 3-2 above. These transmission interfaces include Bonneville Network flowgates, WECC-rated paths, load service areas, and combinations of flows on multiple parallel interfaces. Some transmission lines are therefore part of more than one congested transmission interface grouping that was modeled. Although many interfaces are bidirectional many interfaces only show congestion occurring for flows in one direction.

Tables 3-7 through 3-14 present the total annual congested hours estimated by GridView for low, median and high run-off years for those interfaces and directions that show at least one hour of congestion over one of the scenarios.

3.4.1.1 P03 West Side Northwest to British Columbia

The limit on this interface is 2,750 MW and it is a bidirectional interface that experiences congestion in the south to north direction. Annual congestion is highest in low run-off years with minimal to no congestion occurring during high run-off across all resource replacement portfolios. The largest increases relative to the No Action Alternative occur under MO4 during low-run off conditions under the conventional least-cost resource replacement portfolio.

Table 3-7. Annual Congested Hours for Low, Medium, and High Runoff Years, West Side Northwest to British Columbia, under the No Action and Relative to No Action for all MOs Without Additional Coal Plant Retirements (GridView Output)

Interface	Run Off	No Action	MO1 Conv. Least-Cost	MO1 Zero-Carbon	MO2	MO3 Conv. Least-Cost	MO3 Zero-Carbon	MO4 Conv. Least-Cost	MO4 Zero-Carbon	PA
P03 WEST SIDE NW-BC	Low	11	-1	-3	+1	-1	-6	+10	-2	-3
	Median	3	-2	2	-1	+7	-1	-1	-1	-1
	High	0	0	0	+1	0	0	0	0	0

3.4.1.2 P08 Montana to Northwest

This bidirectional interface has a limit of -1,350 MW and experiences congestion in the west to east direction only. This interface shows congestion under high run-off conditions in alternatives with lower hydropower generation relative to the No Action Alternative (specifically MO3 and MO4). Relative to the No Action Alternative, the changes in congestion hours are highest under MO2, MO3, and MO4 during high-runoff years.

Table 3-8. Annual Congested Hours for Low, Medium, and High Runoff Years, P08 Montana to Northwest, under the No Action and Relative to No Action for all MOs Without Additional Coal Plant Retirements (GridView Output)

Interface	Run Off	No Action	MO1 Conv. Least-Cost	MO1 Zero-Carbon	MO2	MO3 Conv. Least-Cost	MO3 Zero-Carbon	MO4 Conv. Least-Cost	MO4 Zero-Carbon	PA
P08 MONTANA TO NORTHWEST	Low	0	0	0	0	0	0	0	0	0
	Median	0	0	0	0	0	0	0	0	0
	High	44	+6	-2	+39	-44	-44	-35	-21	+3

3.4.1.3 P14 Idaho to Northwest

The Idaho to Northwest bidirectional interface has a limit of -1,200 MW and experiences congestion in the west to east direction only. This interface contains multiple transmission lines, including the Hemingway – Summer Lake transmission line, which is both a part of the Idaho to Northwest Interface and is its own interface with one transmission line (see the description for P75 below). It should be noted that Bonneville neither operates nor manages the Idaho to Northwest or Summer Lake-Hemingway transmission paths.

If the Hemingway – Summer Lake Interface flows reach its limit, then GridView limits flows on the Northwest to Idaho Interface even though it may not appear as an Idaho to Northwest Interface congestion hour in Table 3-9. For the Idaho to Northwest Interface, transmission congestion would occur under all alternatives in median and high run-off scenarios. Congestion is greater in median run-off scenarios for the No Action Alternative, MOs, and the Preferred Alternative.

Table 3-9. Annual Congested Hours for Low, Medium, and High Runoff Years, West Side Idaho to Northwest, under the No Action and Relative to No Action for all MOs Without Additional Coal Plant Retirements (GridView Output)

Interface	Run Off	No Action	MO1 Conv. Least-Cost	MO1 Zero-Carbon	MO2	MO3 Conv. Least-Cost	MO3 Zero-Carbon	MO4 Conv. Least-Cost	MO4 Zero-Carbon	PA
P14 IDAHO TO NORTHWEST	Low	0	0	0	0	+1	0	0	0	0
	Median	292	+53	-8	+187	-211	-223	-209	-234	-107
	High	150	+3	-44	+90	-125	-134	-85	-105	+52

3.4.1.4 P65 Pacific DC Intertie (PDCI)

This PDCI intertie interface has a limit 3,220 MW for the north to south direction and 3,100 MW for the south to north direction. Congestion primarily occurs on the north to south direction under all CRSO alternatives. Increases in congestion would occur relative to the No Action Alternative under all CRSO alternatives and all run-off scenarios. The increases in congestion

relative to the No Action Alternative would be highest for MO3 with the conventional least-cost resource replacement portfolio where both the north to south and south to north directions experience increases in the number of congested hours. MO4 with the conventional least-cost resource replacement portfolio would also experience increases in the number of congested hours under both scenarios.

Table 3-10. Annual Congested Hours for Low, Medium, and High Runoff Years, P65 Pacific DC Intertie, under the No Action and Relative to No Action for all MOs Without Additional Coal Plant Retirements (GridView Output)

Interface	Run Off	No Action	MO1 Conv. Least-Cost	MO1 Zero-Carbon	MO2	MO3 Conv. Least-Cost	MO3 Zero-Carbon	MO4 Conv. Least-Cost	MO4 Zero-Carbon	PA
PDCI North-to-South	Low	490	+47	+71	+44	+100	-11	+20	-41	+40
	Median	652	+21	+62	-47	+180	+34	+110	+37	+3
	High	576	+21	+58	+11	+365	+156	+215	+32	-12
PDCI South-to-North	Low	5	0	-2	0	+3	0	+5	+1	-1
	Median	2	-2	-2	-2	0	0	+2	+1	-2
	High	0	0	0	0	0	0	0	0	0

3.4.1.5 P75 Hemingway-Summer Lake

The Hemingway-Summer Lake interface has a limit of 1,500 MW in the east to west direction and limit of 550 MW in the west to east direction. Congested hours are highest in the west to east direction under all of the alternatives. Relative to the No Action Alternative, the number of congestion hours in the west to east direction decrease under MO4 and MO3 for median and high run-off when there would be less hydropower generation available to send in an easterly direction under those alternatives. It should be noted that Bonneville does not operate or manage the Hemingway-Summer Lake transmission path.

Table 3-11. Annual Congested Hours for Low, Medium, and High Runoff Years, P75 Hemingway-Summer Lake, under the No Action and Relative to No Action for all MOs Without Additional Coal Plant Retirements (GridView Output)

Interface	Run Off	No Action	MO1 Conv. Least-Cost	MO1 Zero-Carbon	MO2	MO3 Conv. Least-Cost	MO3 Zero-Carbon	MO4 Conv. Least-Cost	MO4 Zero-Carbon	PA
HEMINGWAY-SUMMER LAKE West-to-East	Low	15	-15	-7	+9	-11	+17	-11	+38	-14
	Median	390	+2	+83	+81	-159	+100	-238	-70	-54
	High	1,356	+82	+214	+179	-528	-498	-526	-167	+61
HEMINGWAY-SUMMER LAKE East-to-West	Low	24	-11	+23	+1	-13	+18	-17	+23	+5
	Median	9	-5	-5	-5	-4	+1	-8	-3	-5
	High	4	-3	+1	-3	-4	-4	-4	-4	+1

3.4.1.6 Raver-Paul

The Raver-Paul interface has a limit of 1,450 MW and has congested hours in the north to south direction. Congestion occurs primarily under the median and high run-off scenarios for MO1 and MO2. Congestion would be decrease under these run-off scenarios under MO3 and MO4, particularly under high run off conditions.

Table 3-12. Annual Congested Hours for Low, Medium, and High Runoff Years, Raver-Paul, under the No Action and Relative to No Action for all MOs Without Additional Coal Plant Retirements (GridView Output)

Interface	Run Off	No Action	MO1 Conv. Least-Cost	MO1 Zero-Carbon	MO2	MO3 Conv. Least-Cost	MO3 Zero-Carbon	MO4 Conv. Least-Cost	MO4 Zero-Carbon	PA
RAVER-PAUL	Low	0	0	0	0	0	0	0	0	0
	Median	19	+6	-1	+10	-10	-11	-10	-17	+10
	High	229	+19	+29	+28	-57	-87	-158	-157	+30

3.4.1.7 South of Custer

The South of Custer interface has a limit of 1,850 MW and had congestion hours in the north to south direction. Congestion occurs under the No Action Alternative for all run-off scenarios. Congestion increases on the South of Custer interface most notably under MO3 and MO4 under high run-off conditions.

Table 3-13. Annual Congested Hours for Low, Medium, and High Runoff Years, West Side South of Custer, under the No Action and Relative to No Action for all MOs Without Additional Coal Plant Retirements (GridView Output)

Interface	Run Off	No Action	MO1 Conv. Least-Cost	MO1 Zero-Carbon	MO2	MO3 Conv. Least-Cost	MO3 Zero-Carbon	MO4 Conv. Least-Cost	MO4 Zero-Carbon	PA
SOUTH OF CUSTER	Low	168	+68	+30	-8	-4	+2	+2	+48	+38
	Median	395	+10	+4	-23	-17	-3	-6	-1	-4
	High	378	+15	+3	-18	+87	+114	+71	+33	-5

3.4.1.8 North of Echo Lake

North of Echo Lake has a limit of 2,800 MW and had three congested hours on the south to north interface under the MO4 zero-carbon resource replacement portfolio. North of Echo Lake and South of Custer make up a complimentary pair of unidirectional interfaces.

3.4.1.9 California Oregon Intertie and Alturas and PDCI (COI + Alturas, COI+PDCI+Alturas)

The interties connecting the Pacific Northwest to systems in the south include multiple lines and interties that experience congestion. The limit for COI and Alturas is 4,800 MW and the limit including the PDCI is 8,020 MW. The north to south interface experiences congested hours. For the three run-off scenarios, all lines in this interface would experience the greatest number of congested hours under MO3 in higher run-off conditions.

Table 3-14. Annual Congested Hours for Low, Medium, and High Runoff Years, California-Oregon Intertie and Alturas and PDCI, under the No Action and Relative to No Action for all MOs Without Additional Coal Plant Retirements (GridView Output)

Interface	Run Off	No Action	MO1 Conv. Least-Cost	MO1 Zero-Carbon	MO2	MO3 Conv. Least-Cost	MO3 Zero-Carbon	MO4 Conv. Least-Cost	MO4 Zero-Carbon	PA
C0I + ALTURAS	Low	9	+4	+7	+13	+12	+10	+5	0	+3
	Median	55	-17	-14	-9	-3	-3	-7	+9	+3
	High	177	-20	+7	+8	+19	-5	-26	-21	-4
C0I + PDCI + ALTURAS	Low	6	+3	+7	-10	+4	+6	+5	-4	+3
	Median	38	-5	-5	-6	0	-5	+1	+8	+5
	High	103	-6	+23	+10	+47	+17	-5	-21	+12

3.2 BONNEVILLE TRANSMISSION SYSTEM RELIABILITY AND NETWORK INTERCONNECTIONS

The purpose of the transmission system reliability powerflow analysis was to evaluate transmission system reliability and interconnection requirements that may be necessary under each of the MOs. The hydropower generation (as discussed in Appendix J, *Hydropower*) and the location of replacement resources without additional coal retirements (as discussed in Section 2.2), were used in the powerflow analysis to assess the impacts of the MOs and the Preferred Alternative to the transmission system. The analysis does not include the additional generation reserves needed to integrate renewable resources because there is not enough certainty about the possible replacement resources to have confidence that changing reserve assumptions would increase accuracy of the simulation. The resource replacement mix and general locations for each of the conventional least-cost and zero-carbon resource replacement portfolios are shown in Tables 3-1 through 3-3 above.

A summer 2023 WECC-derived base case for power demand and loads along with the associated power flow was used to evaluate the CRSO alternatives. As transmission system reliability impacts are largely dictated by the extremes in loading, the most informative scenarios involved seasonal consideration of peak loads within the region. The base case assumed that load demand would be met by the minimum hydropower generation levels for the Lower Snake and Lower Columbia projects, with a corresponding increase in hydropower generation in Upper Columbia (Chief Joseph and Grand Coulee) projects. Next, to reflect full transmission system usage by serving regional loads and providing for export on the Southern

Interties, the analysis included generation output from existing wind resources in the Pacific Northwest. This formed the No Action Alternative that was used as the basis for comparison with MOs.

The powerflow analysis focused on the lower CRS hydropower generation variation by alternative. The powerflow analysis focused on the lower CRS generation dispatch due to the following:

- The transmission system generally evolved with high generation output from the various Columbia River System resources. Operation of the transmission system with reduced generation at the CRS projects generally results in reduced stress to the transmission system.
- Since reduced peak output from the CRS resources was central to all of the MO alternatives (MO2 had increased average output, but, did not result in increased peak output from the CRS resources), the result would be a system that has less capacity or ability to reliably serve the peak loads typical in July and August when there is a reduced availability of hydropower generation.
- The third consideration was the location of the replacement resources. For the conventional least-cost and zero-carbon portfolios, it was important to see how the reduced output from the CRS hydropower projects would interact with the addition of the replacement resources. Again, it is the times when the CRS resources are at their lowest output that are critical to determining whether the transmission system, in concert with the replacement resources, will still be able to reliably serve load within the Region. While the CRS resources would be at a reduced output, the replacement resources would be at or near their expected full output to serve the required load.

For each of the MOs and the Preferred Alternative, the No Action Alternative was adjusted by modifying the generation at the Lower Snake and Lower Columbia River projects to the minimum levels specified in each of the alternatives. The replacement resources were then added to preserve service to loads within the region and to support exports on the Southern Interties.

3.2.1 Powerflow Results

Given seasonal demand for power in the Pacific Northwest and seasonal differences in transmission system capacity, winter and spring/fall demand scenarios were determined not to produce conditions that were limiting. During the summer, however, many areas experience substantial peak loads at the same time that the capability of the transmission system is reduced. The capability of the transmission system is reduced in the summer because higher ambient temperatures limit the ability of the system to transmit energy. Additionally, due to low streamflow conditions and spill requirements, generation and flexibility allowed under the various alternatives for the Columbia and Lower Snake hydropower projects is at the lowest levels, which results in a higher reliance on the replacement resources. The reduction in allowed generation also limits the flexibility of the CRS projects during the limiting summer

season. For these reasons, a summer 2023 base case was used in the powerflow analysis to assess the impact to the transmission system from replacement resources operating in conjunction with output from the Columbia River projects under each of the CRSO alternatives.

Table 3-15 provides the generation levels in MW modeled in the powerflow cases for the significant generating resources in the region, including the CRS projects. For the No Action Alternative and each of the MO alternatives, there is a column labeled "Hydsim" that includes the generation levels prior to the addition of the assumed replacement resources. The generation at the various CRS projects is taken from the HYDSIM output for that alternative (see Appendix J, *Hydropower*). Generation from the replacement resources is listed at the bottom of the table. Table 3-16 provides the corresponding transmission interface flows from the powerflow cases for the major transmission interfaces in the region.

For the Preferred Alternative analysis, the minimum and maximum hydropower generation levels (see Appendix J, *Hydropower*), were analyzed and were found to fall within the range of dispatches previously analyzed through the powerflow modeling for the various MOs and the No Action Alternative. Because the Preferred Alternative analysis found that the generation levels were similar to those previously modeled and found to not require transmission reinforcements, no additional powerflow simulations were completed.

For the Preferred Alternative analysis, the expected monthly maximum and minimum generation outputs from the CRS projects on the Columbia and LSR for the Preferred Alternative and the No Action Alternative were compared. Table 3-17 through Table 3-19 below, list the expected monthly maximum generation for the CRS projects under the No Action Alternative, Preferred Alternative, as well as the difference (Preferred Alternative minus the No Action Alternative), respectively. Similarly, Table 3-20 through Table 3-22 below, list the expected monthly minimum generation for the CRS projects under the No Action Alternative, Preferred Alternative, as well as the difference (PA minus the No Action Alternative), respectively.

For the LSR Projects (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor), the difference tables (Table 3-19 for the maximum generation and Table 3-22 for the minimum generation) show modest shifts (increase for some CRS projects, decrease for others) in expected generation across all the months of the year. The minimum generation levels, in particular show no change for the LSR projects.

For the projects of the Lower Columbia (McNary, John Day, The Dalles, and Bonneville), the difference table for the maximum generation (Table 3-19) does show more substantial increases for the April through September timeframe. The increases in generation could provide for additional units to be on-line and available to support the electrical stability of the larger network.

1319 **Table 3-15. Generation Levels from the Powerflow Cases Without Additional Coal Plant Retirements (MW)**

Plant	NAA Hydsim	MO1			MO2			MO3			MO4		
		Hydsim	Gas	Solar	Hydsim	Gas	Solar	Hydsim	Gas	Solar	Hydsim	Gas	Solar
Bonneville	136	131	131	131	163	163	163	132	132	132	113	113	113
Dalles, The	310	307	307	307	322	322	322	301	301	301	280	280	280
John Day	443	385	385	385	397	397	397	388	388	388	372	372	372
McNary	272	258	258	258	276	276	276	252	252	252	246	246	246
FCRPS Lower Columbia	1,161	1,081	1,081	1,081	1,158	1,158	1,158	1,073	1,073	1,073	1,011	1,011	1,011
Ice Harbor	65	55	55	55	68	68	68	0	0	0	62	62	62
Lower Monumental	84	84	84	84	87	87	87	0	0	0	83	83	83
Little Goose	80	80	80	80	86	86	86	0	0	0	81	81	81
Lower Granite	80	80	80	80	84	84	84	0	0	0	81	81	81
FCRPS Lower Snake	309	299	299	299	325	325	325	0	0	0	307	307	307
Grand Coulee	4,777	4,777	4,777	4,777	4,777	4,777	4,777	4,777	4,777	4,777	4,777	4,778	4,777
Chief Joe	2,038	2,038	2,038	2,038	2,038	2,038	2,038	2,038	2,038	2,038	2,038	2,038	2,038
FCRPS Upper Columbia	6,815	6,815	6,815	6,815	6,815	6,815	6,815	6,815	6,815	6,815	6,815	6,816	6,815
CGS	1,151	1,151	1,151	1,151	1,151	1,151	1,151	1,151	1,151	1,151	1,151	1,152	1,151
Libby	90	90	90	90	90	90	90	90	90	90	90	90	90
Priest Rapids	790	790	790	790	790	790	790	790	790	790	790	790	790
Rock Island	437	437	437	437	437	437	437	437	437	437	437	437	437
Rocky Reach	1,112	1,112	1,112	1,112	1,112	1,112	1,112	1,112	1,112	1,112	1,112	1,113	1,112
Wanapum	853	853	853	853	853	853	853	853	853	853	853	854	853
Wells	800	800	800	800	800	800	800	800	800	800	800	801	800
Mid Columbia (Total)	3,992	3,992	3,992	3,992	3,992	3,992	3,992	3,992	3,992	3,992	3,992	3,995	3,992
NW Thermal Gen	6,374	6,374	6,374	6,374	6,374	6,374	6,374	6,374	6,374	6,374	6,374	6,308	6,374

Plant	NAA Hydsim	MO1			MO2			MO3			MO4		
		Hydsim	Gas	Solar	Hydsim	Gas	Solar	Hydsim	Gas	Solar	Hydsim	Gas	Solar
Wind Power – NW	5,580	5,661	5,071	4,357	5,569	5,110	5,300	6,000	4,823	3,166	5,727	2,384	1,056
Replacement Resources													
MO Gas Central Ferry	--	--	--	--	--	--	--	--	--	--	--	1,060	--
MO Gas McNary	--	--	560	--	--	440	--	--	1,120	--	--	1,120	--
MO Gas Slatt	--	--	--	--	--	--	--	--	--	--	--	1,060	--
MO Solar Captain Jack	--	--	--	--	--	--	--	--	--	1,250	--	--	1,250
MO Solar Grizzly	--	--	--	1,200	--	--	250	--	--	1,250	--	--	1,250
MO Solar Midpoint	--	--	--	--	--	--	--	--	--	--	--	--	625
MO Solar Slatt	--	--	--	--	--	--	--	--	--	50	--	--	1,250
MO Solar Wautoma	--	--	--	--	--	--	--	--	--	--	--	--	625

1320 **Table 3-16. Interface Flows from the Powerflow Cases Without Additional Coal Plant Retirements (MW)**

Path	NAA Hydsim	MO1			MO2			MO3			MO4		
		Hydsim	Gas	Solar	Hydsim	Gas	Solar	Hydsim	Gas	Solar	Hydsim	Gas	Solar
Alston - Keeler	1,245	1,246	1,244	1,214	1,245	1,243	1,239	1,240	1,236	1,161	1,248	1,263	1,176
California-Oregon Intertie (COI)	3,716	3,704	3,706	3,727	3,717	3,721	3,725	3,716	3,720	3,801	3,702	3,690	3,775
Hemingway-Summer Lake	-155	-157	-157	-109	-155	-155	-146	-153	-153	-50	-157	-166	-98
IDAHO - NORTHWEST	-50	-48	-49	-43	-50	-52	-49	-52	-54	-15	-48	-25	-49
Keeler - Pearl	406	406	406	372	409	409	403	401	400	313	405	418	323

Path	NAA Hydsim	MO1			MO2			MO3			MO4		
		Hydsim	Gas	Solar	Hydsim	Gas	Solar	Hydsim	Gas	Solar	Hydsim	Gas	Solar
MONTANA - NORTHWEST	-46	-46	-46	-64	-45	-46	-48	-49	-50	-96	-45	-40	-104
North of Dixonville	-781	-779	-779	-682	-784	-785	-763	-779	-780	-430	-777	-774	-417
North of Echo Lake	-941	-942	-940	-938	-942	-941	-941	-941	-938	-933	-942	-947	-919
North of Grizzly	4,039	4,028	4,029	3,032	4,037	4,040	3,832	4,046	4,048	2,092	4,027	4,014	2,037
North of Grizzly/Marion	6,173	6,159	6,165	5,089	6,172	6,180	5,951	6,172	6,186	3,939	6,158	6,192	3,919
North of Hanford (NOH)	3,910	3,913	3,881	3,838	3,915	3,890	3,896	3,923	3,860	3,785	3,914	3,695	3,513
NORTH OF JOHN DAY	6,141	6,147	6,272	5,958	6,147	6,246	6,102	6,092	6,345	5,696	6,156	6,449	5,874
North of Malin/Captain Jack	3,553	3,546	3,547	3,755	3,551	3,553	3,597	3,559	3,561	3,079	3,548	3,544	3,077
Northwest-British Columbia	-3,139	-3,139	-3,139	-3,139	-3,139	-3,139	-3,139	-3,138	-3,138	-3,139	-3,139	-3,161	-3,138
Northwest-British Columbia (East)	-299	-299	-300	-299	-298	-299	-299	-299	-299	-299	-299	-299	-299
Northwest-British Columbia (West)	-2,840	-2,840	-2,839	-2,840	-2,841	-2,840	-2,840	-2,839	-2,839	-2,840	-2,840	-2,861	-2,839
NWACI	3,716	3,704	3,706	3,727	3,717	3,721	3,725	3,716	3,720	3,801	3,702	3,690	3,775
PACIFIC DC INTERTIE (PDCI)	2,940	2,940	2,940	2,940	2,940	2,940	2,940	2,940	2,940	2,940	2,940	2,940	2,940
Paul - Allston (PA)	2,074	2,076	2,072	2,040	2,072	2,069	2,066	2,070	2,061	1,981	2,081	2,098	2,003

Path	NAA Hydsim	MO1			MO2			MO3			MO4		
		Hydsim	Gas	Solar	Hydsim	Gas	Solar	Hydsim	Gas	Solar	Hydsim	Gas	Solar
Raver - Paul (RP)	1,590	1,592	1,588	1,563	1,588	1,585	1,583	1,586	1,579	1,514	1,596	1,609	1,534
Redmond Area Import	-530	-530	-530	-530	-530	-530	-530	-530	-530	-529	-530	-530	-529
SORE Southern Oregon Import	-456	-456	-456	-455	-456	-456	-456	-456	-456	-440	-456	-455	-440
SOUTH OF ALLSTON	2,248	2,250	2,244	2,207	2,245	2,240	2,237	2,242	2,231	2,137	2,256	2,276	2,163
South of Boundary SOB	1,001	1,001	1,001	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,001	1,001
South of Custer SOC	2,753	2,753	2,752	2,753	2,754	2,753	2,753	2,753	2,752	2,753	2,753	2,774	2,752
South of Grizzly	4,007	3,995	3,997	4,214	4,004	4,008	4,053	4,013	4,016	3,334	3,995	3,985	3,280
South of Summer Lake	3,743	3,734	3,735	3,854	3,742	3,745	3,770	3,746	3,749	2,932	3,733	3,726	2,918
West of Cascades - North (WOCN)	3,821	3,823	3,818	3,777	3,817	3,813	3,810	3,815	3,803	3,703	3,829	3,827	3,731
West of Cascades - South (WOCS)	5,266	5,266	5,272	5,203	5,244	5,249	5,229	5,273	5,285	5,006	5,277	5,251	4,985
WEST OF HATWAI	813	815	809	837	811	807	816	826	813	898	814	756	849
West of John Day	3,407	3,402	3,400	3,458	3,379	3,377	3,391	3,435	3,431	3,481	3,424	3,383	3,423
West of Lower Monumental (WOLM)	1,659	1,669	1,592	1,531	1,669	1,609	1,640	1,504	1,348	1,220	1,677	2,154	1,153
West of McNary (Scheduling)	2,700	2,701	3,006	2,465	2,708	2,947	2,661	2,666	3,274	2,167	2,708	3,109	1,831
West of Slatt	3,650	3,661	3,721	3,290	3,656	3,704	3,581	3,654	3,774	2,933	3,673	4,328	3,453

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Considering the modest shifts in generation under the PA as compared to the No Action Alternative, no additional transmission reinforcements are expected to be needed under the PA. Also, under the PA, there would be an increase in the operational outputs of the plants of the Lower Columbia. The transmission system would realize some operational benefits from having additional generating units on-line in order to support the electrical stability of the larger network.

Where there are modest increases in expected plant output at some of the CRS projects, those outputs would not be expected to exceed the existing transmission capacity or otherwise trigger a need for system reinforcement.

Table 3-17. No Action Alternative, Monthly Maximum Generation by Plant

Plant	October	November	December	January	February	March	April 1	April 2	May	June	July	August 1	August 2	September
Grand Coulee	3,795	3,810	3,817	3,820	4,172	4,087	4,050	3,978	4,092	4,422	4,660	4,580	4,541	4,113
Chief Joseph	1,990	1,984	1,982	2,006	2,214	2,143	2,152	2,153	2,216	2,340	2,444	2,414	2,418	2,163
Lower Granite	503	651	783	721	783	783	691	673	673	673	610	512	512	498
Little Goose	572	769	733	800	790	785	685	663	653	653	590	561	561	565
Lower Monumental	598	736	837	847	842	820	810	800	794	713	694	643	643	583
Ice Harbor	554	571	637	553	647	622	656	643	640	646	490	539	540	591
McNary	593	773	826	860	862	855	729	744	742	685	750	744	746	640
John Day	1,899	2,115	2,105	2,091	2,089	2,097	1,901	1,880	1,910	2,008	1,874	1,962	1,965	2,077
The Dalles	1,387	1,751	1,807	1,922	1,776	1,744	1,389	1,390	1,428	1,393	1,389	1,365	1,368	1,543
Bonneville	819	905	950	971	991	925	788	795	769	719	767	812	823	869

Table 3-18. Preferred Alternative, Monthly Maximum Generation by Plant

Plant	October	November	December	January	February	March	April 1	April 2	May	June	July	August 1	August 2	September
Grand Coulee	3,661	3,668	3,689	3,704	4,048	3,958	4,127	4,062	4,148	4,461	4,717	4,631	4,594	3,996
Chief Joseph	1,989	1,983	1,983	2,006	2,211	2,145	2,264	2,265	2,323	2,437	2,516	2,491	2,497	2,145
Lower Granite	634	651	783	721	783	788	776	756	756	771	688	571	571	624
Little Goose	707	769	733	800	790	785	755	731	721	736	658	619	619	700
Lower Monumental	667	736	837	847	847	820	820	810	804	729	704	653	653	651
Ice Harbor	593	571	637	553	647	622	624	611	608	630	463	518	518	635
McNary	767	773	832	860	861	855	937	950	933	871	957	945	949	808
John Day	2,259	2,236	2,231	2,232	2,234	2,244	2,187	2,172	2,171	2,159	2,156	2,149	2,153	2,226
The Dalles	1,688	1,752	1,808	1,922	1,774	1,744	1,713	1,714	1,755	1,717	1,705	1,681	1,686	1,877
Bonneville	954	905	950	972	986	926	915	921	891	846	890	938	955	1,002

Table 3-19. Difference (Preferred Alternative – No Action Alternative), Monthly Maximum Generation by Plant

Plant	October	November	December	January	February	March	April 1	April 2	May	June	July	August 1	August 2	September
Grand Coulee	-133	-142	-128	-116	-123	-129	78	84	56	40	57	51	53	-117
Chief Joseph	-1	-1	1	0	-2	2	111	111	107	97	72	77	79	-17
Lower Granite	132	0	0	0	0	5	85	83	83	98	78	59	59	127
Little Goose	135	0	0	0	0	0	70	68	68	82	68	58	58	135
Lower Monumental	69	0	0	0	5	0	10	10	10	15	10	10	10	68
Ice Harbor	39	0	0	0	0	0	-33	-32	-32	-16	-27	-22	-22	44
McNary	174	0	6	0	-1	0	208	205	190	186	208	201	203	168
John Day	360	121	126	141	145	147	286	293	260	151	281	187	188	150
The Dalles	301	1	1	0	-2	0	324	324	327	324	316	316	318	334
Bonneville	135	0	0	1	-5	0	126	126	122	126	124	126	132	134

Table 3-20. No Action Alternative, Monthly Minimum Generation by Plant

Plant	October	November	December	January	February	March	April 1	April 2	May	June	July	August 1	August 2	September
Grand Coulee	366	362	359	347	335	322	303	378	280	324	359	451	389	362
Chief Joseph	196	441	435	431	427	193	192	252	189	181	190	241	210	197
Lower Granite	80	82	0	0	0	83	81	78	78	77	80	80	80	80
Little Goose	86	86	0	0	0	86	82	80	80	80	80	80	80	82
Lower Monumental	87	87	0	0	0	83	82	79	79	77	83	84	84	85
Ice Harbor	68	68	0	0	0	63	62	60	60	59	63	66	66	67
McNary	279	272	264	262	260	257	268	240	252	236	263	260	259	284
John Day	482	486	477	474	472	467	469	357	444	419	456	401	448	477
The Dalles	380	378	362	357	353	344	359	262	327	279	350	316	353	382
Bonneville	130	127	113	108	105	103	109	96	97	87	106	120	119	133

Table 3-21. Preferred Alternative, Monthly Minimum Generation by Plant

Plant	October	November	December	January	February	March	April 1	April 2	May	June	July	August 1	August 2	September
Grand Coulee	363	360	354	347	331	320	404	378	374	404	365	369	364	360
Chief Joseph	196	442	435	431	426	192	257	252	252	225	194	197	197	197
Lower Granite	80	82	0	0	0	83	81	78	78	77	80	80	80	80
Little Goose	86	86	0	0	0	86	82	80	80	80	80	80	80	82

Plant	October	November	December	January	February	March	April 1	April 2	May	June	July	August 1	August 2	September
Lower Monumental	87	87	0	0	0	84	82	79	79	77	83	84	84	85
Ice Harbor	68	68	0	0	0	63	62	60	60	59	63	66	66	67
McNary	273	272	264	262	260	258	251	239	238	223	250	260	259	280
John Day	508	508	498	495	493	490	395	377	376	376	479	491	490	505
The Dalles	379	378	362	357	352	347	288	262	261	238	352	371	370	383
Bonneville	128	127	113	108	105	104	110	96	97	87	106	119	119	133

Table 3-22. Difference (Preferred Alternative – No Action Alternative), Monthly Minimum Generation by Plant

Plant	October	November	December	January	February	March	April 1	April 2	May	June	July	August 1	August 2	September
Grand Coulee	-2	-3	-6	0	-4	-3	101	0	94	79	7	-82	-25	-2
Chief Joseph	0	0	0	0	-1	0	65	0	63	44	4	-43	-13	0
Lower Granite	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Goose	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lower Monumental	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ice Harbor	0	0	0	0	0	0	0	0	0	0	0	0	0	0
McNary	-6	0	0	0	0	1	-16	-1	-15	-14	-13	0	0	-4
John Day	26	22	21	21	21	23	-74	20	-68	-42	22	90	43	28
The Dalles	-1	0	0	0	0	3	-71	0	-66	-41	2	55	17	0
Bonneville	-1	0	0	0	0	1	1	0	0	0	0	0	0	0

3.2.2 Bonneville Network Reinforcement Needs

Though the quantity of generation added via the resource replacement portfolios is considerable for some of the alternatives, the addition of these resources would not require network reinforcements in most cases. This is because the displacement of the CRS hydropower generation would tend to relieve congestion on existing monitored interfaces on the transmission system while the replacement resource tend to be located on the unconstrained side of most monitored interfaces.

MO3, which includes the breach of LSR dams, would be the only alternative where the studies indicated a need for system reinforcement. As also discussed in Section 3.1, *3.1 Regional Congestion* Forecasting, generation at Ice Harbor provides load service to the Tri-Cities during peak summer load conditions and during emergencies (e.g., loss of the main grid connection at Sacajawea). An outage of one of the transmission lines connecting the Tri-Cities area to the main transmission grid limits the amount of power that can be delivered to the Tri-Cities load.

During such outages, having generation from the Ice Harbor project supports reliable service to the Tri-Cities load. The generation at Ice Harbor also provides support for transmission operations and maintenance in the Tri-Cities area. In MO3, the inability to take lines out of service for maintenance and to respond to operational constraints, such as the loss of a transmission line, could result in loss of load within the Tri-Cities area.

Prior to evaluating the impacts of potential breach of Ice Harbor Dam, Bonneville had identified the need for a transmission reinforcement project just beyond the 10-year planning horizon to maintain reliable load service to the Tri-Cities area and to support transmission operations and maintenance. The base need for the project would arise independent of removal of the generation at Ice Harbor. The timing of the reinforcement, however, is very dependent upon when Ice Harbor generation might be removed.

Under MO3, the loss of hydropower generation at Ice Harbor would require that the reinforcement project be in place prior to breaching of the dam, which may be sooner than would be required under the No Action Alternative. The scope of the likely reinforcement would include a new substation, a new 20-mile-long transmission line, and the expansion of an existing substation near the Tri-Cities. The reinforcement project would be approximately $94 million in capital costs (direct, unloaded costs) to construct. It should be noted that these types of transmission system reinforcements typically takes many years to plan, permit, and construct.

3.2.3 Bonneville Transmission Interconnections

The developer of the individual generation resources under the resource replacement portfolios would have to develop additional transmission infrastructure, such as lines, that would result in additional costs—attributed to the cost of developing the actual resource—to reach the larger transmission network. Those costs would vary depending on the geographical location of the resource with respect to the transmission network, size of the individual project, and other factors.

Bonneville, for its part of the resource interconnection, would provide additional network facilities at the interconnection substations to complete the interconnection of the new resource to the larger transmission network. The Bonneville interconnection would require equipment such as bulk transformers, circuit breakers, and other substation equipment, which may require the expansion of multiple existing substations. Added transmission substation infrastructure to accommodate interconnections can take several years to plan, permit, and construct, especially at those substations requiring expansion beyond the current footprint.

The expected capital costs (direct, unloaded costs) associated with the interconnection of the resource replacement portfolios under the CRSO alternatives are depicted in Table 3-23 and Table 3-24. Interconnection costs would range from $70 to $357 million, depending on the alternative and resource replacement portfolio. Under MO2, while there is the potential for future avoided costs of individual generation, as discussed above in Chapter 2, the avoided costs are not likely to result in an overall cost reduction because this is not an avoided capital

costs for transmission facilities that would otherwise be required to reliably serve load. Similarly, under the Preferred Alternative, there would not likely be any replacement resources and no associated interconnection costs.

Table 3-23. Interconnection Costs for the Conventional Least-Cost Resource Replacement Scenario

	MO1		MO2		MO3		MO4		PA	
Location	Capacity (MW)	Cost	Capacity (MW)	Cost	Capacity (MW)	Cost	Capacity (MW)	Cost	Capacity (MW)	Cost
McNary	560	$70 million	-	-	1,120	$72 million	1,120	$72 million	-	-
Central Ferry	-	-	-	-	-	-	1,060	$72 million	-	-
Slatt	-	-	-	-	-	-	1,060	$72 million	-	-
Total	560	$70 million	-	-	1,120	$72 million	3,240	$220 million	-	-

Note: Cost estimates are rounded to two significant digits and may not sum to the totals reported due to rounding. This table does not present the costs associated with the potential avoided transmission interconnections required under MO2. The substation expansion needed for interconnection of resources from the No Action Alternative to MO2 levels would cost about $70 million.

Table 3-24. Interconnection Costs for the Zero-Carbon Resource Replacement Scenario

	MO1		MO2		MO3		MO4		PA	
Location	Capacity (MW)	Cost	Capacity (MW)	Cost	Capacity (MW)	Cost	Capacity (MW)	Cost	Capacity (MW)	Cost
Captain Jack	-	-	-	-	1,250	$72 million	1,250	$72 million	-	-
Grizzly	1,200	$72 million	-	-	1,250	$72 million	1,250	$72 million	-	-
Slatt	-	-	-	-	50	$3.2 million	1,250	$72 million	-	-
Wautoma	-	-	-	-	-		625	$70 million	-	-
Midpoint (Idaho)	-	-	-	-	-	-	625	$70 million	-	-
Broadview (Montana)	-	-	-	-	-	-	-	-	-	-
Total	1,200	$72 million	-	-	2,550	$150 million	5,000	$360 million	-	-

Note: Cost estimates are rounded to two significant digits and may not sum to the totals reported due to rounding. This table does not present the costs associated with the potential avoided transmission interconnections required under MO2. The substation expansions needed for interconnection of resources from the No Action Alternative to MO2 levels would interconnect an additional 250MW of resource capacity at Grizzly, at a cost of about $70 million, and an additional 660MW of resource capacity at Broadview (Montana) at a cost of about $72 million.

3.2.4 Bonneville Operational Considerations

Alternatives MO1, MO3, and MO4 all would result in reduced hydropower generation from the Lower Columbia projects (MO3 does have some allowance for increased output from the Lower Columbia CRS projects during August). Though no immediate transmission system reliability issues were identified during the powerflow analysis discussed in Sections 3.2.1, through 3.2.3 , in the future, lost hydropower generation under MO1, MO3, and MO4 may affect voltage and dynamic stability on the transmission system (i.e., the ability of the transmission to get back to a stable configuration following a significant disturbance in the transmission system) due to a reduction of generators that are online during certain times of the year.[25] Without sufficient voltage support, inertia, and frequency response capability, the power system will not be stable. This, in turn, can lead to equipment damage and potentially wide-spread uncontrolled loss of load. Additionally, if too few generation units are on-line, the transmission system may need to operate at a lower transfer level, which could result in congestion and require re-deployment of resources throughout the Western Interconnection to meet the required demands at that time.

The conventional least-cost replacement portfolios assume the location of replacement resources would be in close proximity to the CRS projects where hydropower generation is being displaced and would provide similar voltage and dynamic support for the transmission system. Under the zero-carbon resource replacement portfolio, the replacement resources would be spread in multiple locations in Oregon, Washington, and Idaho. The dispersed location of these replacement resources would benefit voltage support. The analysis does not include adding resources for the generating reserves needed to integrate the increased amount of renewable resources because there is not enough certainty about the possible replacement resources to have confidence that changing reserve assumptions would increase accuracy of the simulation.

Depending on the timing for installation of the solar resources, they may not provide adequate dynamic response to a disturbance in the transmission system (such as a line or equipment outage) compared to what would have been expected from the lost hydropower generation.[26] Unlike hydropower (or other rotating generators), solar resources do not have rotating mass and may not have specialized voltage control capability to assist the transmission system to respond to disturbances. Technology under development may allow solar resources to assist

[25] "Online" generators need to be running within an acceptable operating range based on turbine generator efficiencies and mechanical capabilities.

[26] Gas generators (such as those under the conventional least-cost replacement resource portfolio) provide a similar rotating momentum as hydropower generators and would maintain a proper voltage profile that would support transmission system operation and be responsive to disturbances such as equipment outages or changes in load.

with transmission disturbances in the future. Until such technology is developed, additional transmission system requirements may be needed under a zero-carbon resource portfolio.[27]

Under the Preferred Alternative, for the projects of the Lower Columbia (McNary, John Day, The Dalles, and Bonneville), the difference between the Preferred Alternative and the No Action Alternative for the maximum generation does show substantial increases in generation for the April through September timeframe. The increases in generation could provide for additional units to be on-line and available to support the electrical stability of and operational benefits for the larger transmission network.

3.2.5 Summary of Transmission Infrastructure Costs

The total costs associated with the MO alternatives (MO1, MO3, and MO4) would range from $70.1 million to $357.5 million (Table 3-23 and Table 3-24). The system study identified the need for network reinforcement sooner than currently planned to maintain reliable load service to the Tri-Cities area under MO3. The cost associated with implementing this project on an accelerated timeline would be about $94.5 million under both the conventional least-cost and the zero-carbon resource replacement portfolios. The system study did not identify additional network reinforcements under any of the MO alternatives based on the assumed replacement resource portfolios.

Alternative MO1 would result in the lowest replacement costs under both the conventional least-cost and zero-carbon resource replacement portfolios (about $70.1 million and $72.4 million, respectively). The distinction in cost impacts between the two replacement portfolios would become more pronounced under other MO alternatives. Under MO3, replacement costs under the conventional least-cost resource replacement scenario would be about $166.9 million, and under the zero-carbon resource replacement portfolio would be about $242.6 million. MO4 would result in the highest replacement costs for both resource replacement portfolios (about $217.3 million for conventional least-cost and about $357.5 million for zero-carbon). Since MO2 would result in a reduction in LOLP (5 percent as compared to 6.6 percent for No Action Alternative), the comparison costs for MO2 would represent costs that might be avoided if that alternative were selected. The avoided costs are not likely to produce a reduction in cost because this is not an avoided capital cost of transmission facilities that would otherwise be required to reliably serve load. Under the Preferred Alternative, no replacement resources would likely be needed; therefore, there would be no interconnection costs under this alternative.

[27] Examples of requirements could include: Increased synchronous condensing capability (i.e., a free-spinning motor that adjusts to conditions on the power grid to provide voltage support) at the Lower Columbia projects; Addition of static reactive power devices (electrical devices that provide quick response to maintain voltage stability) at strategic points on the transmission system (voltage support only); An increased requirement for generating units at the Lower Columbia projects to be online in order to provide voltage and dynamic support for requirements of the transmission system.

A qualitative discussion of operational impacts from the various MO alternatives (MO1, MO3, and MO4, primarily) highlighted that since alternatives MO1, MO3, and MO4 would all result in reduced generation from the Lower Columbia River projects, the reduced generation would likely also result in fewer generating resources at the CRS projects being on-line to support (e.g. voltage and dynamic support) the transmission system. Under the Preferred Alternative, there could be some additional flexibility that could provide operational benefits for the transmission system.

CHAPTER 4 - WHOLESALE POWER AND TRANSMISSION RATES

Bonneville's wholesale power and transmission rate setting process (or "rate case") is a public administrative process that is implemented pursuant to requirements established under Section 7(i) of the Pacific Northwest Power Planning and Conservation Act ("Northwest Power Act"). Pursuant to the Northwest Power Act, wholesale power and transmission rates are set to recover the costs associated with the acquisition, conservation and transmission of electric power, including the amortization of the Federal investment in the FCRPS over a reasonable number of years. As described in the previous chapters, the CRSO EIS alternatives would affect the revenue requirements of both power and transmission rates, by affecting the costs to replace resources in addition to the costs to connect those replacement resources to the transmission grid.

This chapter describes how the power and transmission costs described in Chapters 2 and 3 of this appendix affect the rates that power and transmission customers pay for delivered power (i.e., "wholesale power and transmission rates"). Chapter 5 of this appendix, describes how these changes would affect end-users (i.e., "retail rates").

4.1 POWER RATE PRESSURE ANALYSIS

4.1.1 Power Rates Methodology and Assumptions

This analysis relies on the Rates Analysis Model (RAM2020) used to set rates for the FY 2020-2021 period (BP-20 rate proceeding or BP-20) to evaluate the effects of the CRSO EIS alternatives on Bonneville wholesale priority firm (PF) power rates. The Power Rate, Market Price, and Power and Transmission Risk studies from BP-20 detail the ratemaking methodology used, including statutory directives governing cost recovery through rates and assumptions relevant to rate design.[28] The governing methodology for the rate design is the Bonneville Tiered Rate Methodology (TRM).[29]

RAM2020 is then updated for the multiple factors that affect wholesale electricity rates for a given customer for each scenario in the power rates analysis.[30] The key assumptions affecting

28 See the Power Rates Study (BP-20-FS-BPA-01) and associated Power Rates Study Documentation (BP-20-FS-BPA-01A), the Market Price Study and Documentation (BP-20-FS-BPA-04), and the Power and Transmission Risk Study (BP-20-FS-BPA-05) and associated Power and Transmission Risk Study Documentation (BP-20-FS-BPA-05A) from the BP-20 rate case, located externally at https://www.bpa.gov/Finance/RateCases/BP-20/Pages/Final%20Proposal.aspx

29 The TRM, as described in the Chapter 3.7.2, Power and Transmission Affected Environment, established the rate design methodology used to tier the PF power rate that applies to firm power requirements service.

30 Bonneville currently sells and transmits firm power from the CRS projects under long term contracts to regional customers (municipalities, PUDs, cooperatives, Federal agencies, and direct service industries) across the Pacific Northwest. Regional IOUs also have the right to request and buy firm power but currently do not. Bonneville also operates and maintains three-fourths of the high-voltage transmission system within the Pacific Northwest (Bonneville 2018a). This system interconnects and integrates electric power that flows through the regional transmission system throughout the western United States and parts of Canada and Mexico.

rate pressure are included in the following sections: current power sales under long term Regional Dialogue power sales contracts and application of Bonneville's TRM; generation and contract resource forecasts; costs in the revenue requirement (including the Colville Settlement payment, fish and wildlife expenses, and capital costs); transmission expenses for power deliveries; new revenue requirement additions for replacement resource costs; market price forecasts for electricity and gas; and revenue credits (including the revenues associated with the sale of surplus power and the Treasury payment under 4(h)(10)(C) of the Northwest Power Act). Results are then applied customer by customer based on specific product choice of customers and the associated rate design under the TRM. This analysis assumes that Bonneville's customer base and customer product selections would remain constant over the timeframe of this analysis.

As addressed in Section 2.3 resulting rate pressures and socioeconomic effects did not consider the potential for additional coal retirements beyond those anticipated in the NW Council's 7th Power Plan and the Mid-Term update to the 7th Power Plan (published in 2016 and 2019, respectively). Subsequent announcement of earlier and additional retirements of coal-fired power plants than those assumed in this study, and described in Section 2.3 could have material impacts on the results of this analysis. However, the potential rate pressure effects of the Limited or No Coal scenarios are not reflected in the base case analysis that assumes 4,246 MW of coal are dedicated to serving regional load. Information about additional power rate sensitivity analyses and financial analysis are included in detail in Section 3.7.3 of the EIS, *Power and Transmission Environmental Consequences,* and are not repeated herein.

4.1.1.1 Tier 1 Purchases and Load

Customer load forecasts are updated for the BP-22 rate period (2022/2023). Forecasts of each customer's Total Retail Loads and their dedicated non-federal power supply requirements from BP-20 provide the starting point for determining assumed load supplied by Bonneville. However, because the forecasted amount of generation from the Tier 1 System resources affects the amount of firm power Bonneville's customers can purchase at Tier 1 rates, Bonneville's anticipated load is also affected by changes to both:

- hydropower operations, and
- the amount and dispatch of any required replacement resource.

Therefore, for CRSO EIS alternatives, customer loads on Bonneville are calculated after updating the forecasted Tier 1 resource generation changes under each alternative. This accounts for the changes in critical water assumptions from the HYDSIM analysis, any applicable changes to Bonneville system obligations (such as Canadian Entitlement or Reclamation Irrigation loads), and

any replacement power resources. Table 4-1 shows annual average loads for Bonneville's firm power customers and the computed Tier 1 System resources available to meet these loads. [31]

Table 4-1. Net Public Customer Loads and Tier 1 System Loads by Replacement Resource Scenario, by Alternative (aMW)

Scenario	NAA	MO1	MO2	MO3	MO4	PA
Public Utility Customer Loads (aMW)[1/]						
Bonneville Finances Zero-Carbon	6,891	6,880	7,002	6,861	6,977	6,811
Region Finances Zero-Carbon	6,891	6,783	7,002	6,544	6,456	6,811
Bonneville Finances Conventional Least-Cost	6,891	6,812	7,002	6,895	6,651	6,811
Region Finances Conventional Least-Cost	6,891	6,787	7,002	6,548	6,461	6,811
Tier 1 System Resources (aMW)[2/]						
Bonneville Finances Zero-Carbon	7,141	7,111	7,509	7,036	7,561	6,844
Region Finances Zero-Carbon	7,141	6,787	7,509	6,348	6,211	6,844
Bonneville Finances Conventional Least-Cost	7,141	6,847	7,509	7,152	6,537	6,844
Region Finances Conventional Least-Cost	7,141	6,787	7,509	6,348	6,211	6,844

1/ Includes Tier 2 Load Service.
2/ Represents the net Federal system available for load service to public utilities after Federal Base System obligations have been met.

4.1.1.2 Resource Assumptions

Federal hydropower operation and replacement resource assumptions are adjusted for each CRSO EIS alternative. Table 4-2 presents the forecast hydropower generation from the Federal system assuming an average of historical water conditions and critical water conditions (1937 water) over 20 years.

Generation that serves Bonneville load other than the 14 CRS projects—including contracted wind and solar, and thermal resources (which are all unaffected by hydropower operations on the Columbia and Snake River systems)—do not vary across alternatives. This analysis assumes BP-20 forecasts for these resources.

Table 4-2. CRS Hydropower Generation for Average Water and Critical Water (1937), by Alternative (aMW)

	NAA	MO1	MO2	MO3	MO4	PA
CRS Hydropower Generation – 1937 (Critical Water)	6,285	5,987	6,663	5,537	5,396	5,980
CRS Hydropower Generation – Average Water	8,387	8,255	8,832	7,282	7,084	8,624

[31] Bonneville sells firm power to its preference customers, Federal agencies and Direct Service Industry (DSI) customers. Because DSI load is invariant to the size of the Tier 1 System, it is assumed to be constant across all scenarios at BP-20 Proposal levels.

4.1.1.3 Revenue Requirement

Bonneville's proposed spending levels from BP-20 for FY2020-2021 are extrapolated into the CRSO study period accounting for inflation. In addition, several revenue requirement line items vary in response to different hydropower operations under CRSO EIS alternatives. These include:

- Colville Settlement payment;
- Bonneville Fish and Wildlife Program expenses and capital costs;
- transmission expenses for Power; and
- replacement resource costs.

The following sections describe these items in more detail.

COLVILLE AND THE SPOKANE TRIBE OF INDIANS SETTLEMENT PAYMENTS

The annual Colville and the Spokane (likely starting in 2021) settlement payments are a function of Bonneville's revenue from power sales and generation at Grand Coulee. As such, these payments are anticipated to vary across CRSO alternatives when Bonneville's revenue would be affected. The anticipated change in the payments under each CRSO EIS alternative is estimated based on forecast power sales revenues, power sales price, and Grand Coulee generation. Table 4-3 presents the estimated percent change in the Colville and Spokane settlement payments under each CRSO EIS alternative compared to the No Action Alternative.

Table 4-3. Percent Change of the Colville and Spokane Settlement Payment by Alternative Relative to the No Action Alternative

Alternative	Change in Payment
MO1	0 to 1%
MO2	-2%
MO3	+2 to 5%
MO4	+5 to 9%
PA	+1%

BONNEVILLE FISH AND WILDLIFE PROGRAM EXPENSE AND CAPITAL COSTS

This analysis assumes that capital expense levels developed for BP-20 provide the best available starting point to forecast the capital costs across all alternatives.[32] However, Bonneville Fish

[32] Initially, program expense levels for the No Action Alternative were set to FY 2016 levels to reflect the applicable FY when the Notice of Intent to Prepare the EIS was released. Bonneville evaluated the difference in capital costs in FY 2016 from the repayment study run for the BP-20 rate proceeding, and determined that FY 2016

and Wildlife Program expenses and associated costs (both capital and expense) may vary across the CRSO EIS alternatives. Rates were adjusted based on anticipated changes to Bonneville Fish and Wildlife Program expenses under CRSO EIS alternatives. Bonneville Fish and Wildlife Program costs are assumed to be $299 million for MO1, MO2, and MO4. For MO3, $267 million is assumed to be spent, which accounts for removal of the Lower Snake River Compensation Plan expenses from the revenue requirement, given that the LSR dams would no longer be operating to produce power. For each alternative, the change in annualized costs from the No Action Alternative is directly incorporated into rate calculations across power customers (consistent with TRM methodology). Table 4-4 shows the change in structural costs for each alternative.

Table 4-4. Change in Structural Capital Costs for Power Relative to the No Action Alternative by Alternative (thousands, 2019$)

Capital Costs from Structural Measures	NAA	MO1	MO2[1/]	MO3	MO4	PA
Annualized Costs	--	21,000	57,000	17,000	47,000	9,000

Note: Estimates are rounded to two significant digits. Assumes a 50-year useful life and a Bonneville financing rate of 4.22%.

1/ MO2 includes a costly fish collection structure at McNary and MO3 includes reductions in O&M costs from the Lower Snake Dams. If MO2 were implemented, fish collection at McNary could be achieved by a less costly option.

Table 4-5 presents the total power sales by alternative, the wholesale power rate prior to structural costs, and the portion of the total upward wholesale rate pressure that is derived from the changes in structural capital costs in dollars per MWh ($/MWh).

Table 4-5. Effect of Structural Costs on Wholesale Power Rates by Alternative and Scenario (2019$)

Alternative	Scenario	Wholesale Power Rate (without structural costs) ($/MWh)	Tier 1 Power Sales (1,000 MWh)	Cost per Megawatt Hour of Structural Cost Change ($/MWh)
NAA	N/A	$34.56	59,770	N/A
MO1	Bonneville Finances Zero-Carbon	$37.19	59,643	$0.35
	Region Finances Zero-Carbon	$36.48	58,215	$0.36
	Bonneville Finances Conventional Least-Cost	$36.29	58,585	$0.35
	Region Finances Conventional Least-Cost	$35.78	58,250	$0.36
MO2[1/]	N/A	$33.35	60,716	$0.94

and BP-20 fish and wildlife capital costs were nearly identical. Because many other capital costs (such as investment in generating assets, systems, etc.) and debt management programs (such as Regional Cooperation Debt) affect the level of amortization and debt repayment in any given year, it was deemed the BP-20 repayment run (incorporating a number of debt management decisions since the BP-16 rate period) provides a superior forecast for capital costs going forward, and therefore capital expense levels from BP-20 were assumed across all alternatives.

Alternative	Scenario	Wholesale Power Rate (without structural costs) ($/MWh)	Tier 1 Power Sales (1,000 MWh)	Cost per Megawatt Hour of Structural Cost Change ($/MWh)
MO3	Bonneville Finances Zero-Carbon	$40.94	59,357	$0.29
	Region Finances Zero-Carbon	$37.53	55,015	$0.31
	Bonneville Finances Conventional Least-Cost	$37.59	59,804	$0.29
	Region Finances Conventional Least-Cost	$37.10	55,050	$0.31
MO4	Bonneville Finances Zero-Carbon	$42.56	60,789	$0.77
	Region Finances Zero-Carbon	$40.02	53,873	$0.87
	Bonneville Finances Conventional Least-Cost	$41.87	56,537	$0.82
	Region Finances Conventional Least-Cost	$39.00	53,909	$0.87
PA	N/A	$35.31	58,574	$0.16

1/ MO2 includes a costly fish passage at McNary. If MO2 were implemented, fish collection could be achieved by a less costly option. MO3 includes reductions in O&M costs and ongoing capital spend for the Lower Snake Dams.

TRANSMISSION EXPENSES FOR POWER

After meeting Bonneville's firm requirements power sales obligations, Bonneville is authorized to sell the power that is surplus both in and out of the Pacific Northwest region. Because these surplus (or secondary) sales are delivered across Bonneville's transmission system, the Bonneville power revenue requirement includes transmission expenses to deliver such sales. In addition, there are other obligations for which Bonneville's power business line incurs a transmission cost, such as delivering the Canadian Entitlement or delivering power to Reclamation loads, which are recovered in power rates.

The transmission rates are anticipated to be materially different across the MOs. Consequently, these expenses were adjusted for each alternative. For each alternative, the incremental deviation in annualized cost from the No Action Alternative was directly assigned to rate calculations across power customers (consistent with TRM). Table 4-6 shows the end-result transmission expense for power assumptions for each CRSO EIS alternative without additional coal retirements.

Table 4-6. Expenses Incurred by Power for Use of Transmission Services (thousands, 2019$)

Portfolio	NAA	MO1	MO2	MO3	MO4	PA
Discretionary Expenses						
Bonneville Finances Zero-Carbon	72,421	74,582	78,640	64,042	69,444	71,477
Region Finances Zero-Carbon	72,421	71,915	78,640	60,766	59,552	71,477
Bonneville Finances Conventional Least-Cost	72,421	71,723	78,640	61,800	56,039	71,477

Portfolio	NAA	MO1	MO2	MO3	MO4	PA
Region Finances Conventional Least-Cost	72,421	72,089	78,640	60,651	59,288	71,477
Non-Discretionary Expenses						
All scenarios	31,000	31,000	31,000	31,000	32,000	31,000

REPLACEMENT RESOURCE COSTS

This analysis relies on the overarching assumption that increased constraints on the Federal hydropower system and removal of Federal resources affect LOLP. Consequently, if the LOLP for a particular MO is greater than that for the No Action Alternative, replacement power resources are required to return the region to the No Action Alternative level of LOLP (see Section 2.2. Two different replacement resource portfolios are considered in this analysis: (1) "zero-carbon," and (2) "conventional least-cost." Each of these portfolios is described in detail in Chapter 2 of this appendix, *Power Supply and Replacement Resources* and inform the selection of replacement power generation scenarios. Additionally, the power rates analysis considers whether the replacement resources are purchased and financed by Bonneville (Bonneville finances) or by a consortium of public utilities (Region finances). Therefore, for all MOs that would require resource replacement (MO1, MO3, and MO4), four sets of rates are computed across all of Bonneville's customer base:

- Bonneville finances zero-carbon
- Region finances zero-carbon
- Bonneville finances conventional least-cost
- Region finances conventional least-cost

To compute the capital costs that would be required for resource replacement, the analysis uses the same methodology that is used to compute the marginal capacity resource cost for the power demand rate under the TRM, including the NW Council's assumptions (7th Power Plan and the Mid-Term update to the 7th Power Plan) (See Chapter 2, *Power Supply and Replacement* Resources of this appendix). The production cost model, AURORA, provides variable costs (e.g., O&M and fuel, where applicable) using the modeled dispatch under the applicable scenario (Section 3. 3 of Appendix I, *Hydroregulation* and Section 2.3.3 of Appendix J, *Hydropower* provides additional detail on AURORA modeling). Bonneville's FY 2019 Common Agency Assumptions for Bonneville Treasury Financing Rates and Public Financing Rates documents provide financing assumptions for the "Bonneville finance" and "Region finance" options respectively. These rates are used to amortize the total investment costs for any gas-fired generation or solar generation replacements under the CRSO EIS alternatives, then included in the revenue requirement.[33]

[33] See Appendix J, Hydropower, and Section 2.2, *Replacement Resources to Maintain Regional Power System Reliability,* for a discussion of replacement resource selection.

In Bonneville finance scenarios, Bonneville's loads and resources assumptions include power generation associated with these replacement resources from AURORA. In the Region finance scenarios, Bonneville's loads and resources are not adjusted, nor are the costs associated with any replacement resources included in the revenue requirement.

However, resource replacement in the zero-carbon scenarios includes demand response. For these scenarios, the analysis assumes that 600 MW of demand response would be achievable, split across Portland, Seattle, and the rest of Washington. Additionally, the analysis assumes that Bonneville would be the entity acquiring demand response in Seattle and the rest of Washington, regardless of whether the scenario was Bonneville finances or the Region finance, and that a local IOU would acquire demand response in Portland. Just like thermal and solar replacements, AURORA directly provides the dispatch of demand response.

Demand-response costs are sourced from the NW Council's 7th Power Plan and the Mid-Term update to the 7th Power Plan. To avoid double counting, the demand-response costs taken from the plan *do not account for transmission and distribution offsets*, because the Transmission Rate Analysis accounts for those effects. Table 4-7 presents resource replacement cost assumptions for the No Action Alternative and each MO without additional coal retirements.

Table 4-7. Annual Resource Replacement Costs by Alternative and Scenario (thousands, 2019$)

Scenario	NAA	MO1	MO2	MO3	MO4	PA
Bonneville Finances Zero-Carbon	-	151,665	-	407,384	565,223	-
Region Finances Zero-Carbon	-	160,042	-	416,693	574,532	-
Bonneville Finances Conventional Least-Cost	-	42,780	-	249,957	240,346	-
Region Finances Conventional Least-Cost	-	34,118	-	233,764	197,820	-

Note: Given the reliability benefit of MO2, there are avoided resource replacement costs because MO2 has a lower LOLP than the baseline LOLP for No Action Alternative. As an estimate, the value of these avoided resource replacements could range from $20 million to $140 million annually, depending on the least-cost or zero-carbon portfolio. This is incremental value is not accounted for in resulting rates or socioeconomic effects in this analysis. These costs include Demand Response costs in the zero-carbon scenarios ($20 million for Bonneville finances and $30 million for region finances). In the Bonneville finance zero-carbon scenario the other $10 million of demand response costs are paid by a regional IOU.

4.1.2 Market Prices

The production cost model, AURORA, is used to forecast market prices. Specifically, the BP-20 version of AURORA was updated to account for hydropower operations and replacement resources applicable under each CRSO EIS alternative. Table 4-8 presents monthly-diurnal market prices for the No Action Alternative, Preferred Alternative and MOs under average water conditions.

Table 4-8. AURORA Average Market Price by Scenario and Alternative (Mid-C $/MWh, 2019$)

Scenario	NAA	MO1	MO2	MO3	MO4	PA
Zero-Carbon	$19.10	$18.73	$18.25	$19.56	$19.12	$19.30
Conventional Least-Cost	$19.10	$19.28	$18.25	$19.77	$20.72	$19.30

4.1.3 Revenue Credits

For the most part, revenues from sources other than long-term firm power sales are assumed to remain flat at the same levels forecast in BP-20. This includes revenues associated with assigning certain power costs from Federal generating resources that provide capacity or energy for ancillary and control area services provided by Bonneville Transmission, revenues associated with downstream benefits, and any market-sales revenues extending into the FY2022 period. No additional resources above the amount needed for the base analysis were added regardless if additional reserves would be needed to integrate added intermittent renewable generation. Two revenue credits, however, would be affected by different hydropower operations under CRSO EIS alternatives: the secondary energy revenue credit and the revenue credit under section 4(h)(10)(C) of the Northwest Power Act. These credits are described below.

4.1.3.1 Secondary Energy Revenue Credit

This credit accounts for the expectation that Bonneville will have surplus power in an average water year, compared to critical water (1937 water conditions). To forecast the amount of this credit Bonneville relied on the BP-20 methodology for valuing the sale of surplus power. Bonneville's load-resource balance is computed based on expected loads, adding system obligations, less the expected Federal system output with 1937 water conditions.[34] If loads exceed resources, the deficit is made up by System Augmentation—a flat purchase of power assumed in the resource mix. If, on the other hand, resources exceed load, a flat Firm Surplus sale is assumed on the load side so that total loads equal total resources (with 1937 water conditions). Generation in excess of the amount of energy available with 1937 water conditions (i.e., the additional energy expected on average across all 80 water years) is then assumed to be sold into the wholesale power market. Bonneville also assumes purchases of power to cover short term supply needs in a particular monthly-diurnal period. This is known as balancing purchases and is netted against expected surplus sales. The expected value of these *net*

[34] 1937 was a relatively dry year with a very early runoff of winter snowpack. This year is used to compute what is considered "firm" generation. Average water years produce more—and a better shape of—generation, such that if loads are met with 1937 water conditions, in expectation more generation will be available to sell. This excess is then sold into the market producing secondary revenue credits, which are credited to the PF rate, reducing the net revenue requirement collected from Bonneville's long-term firm power customers. In some periods under certain weather or water conditions, Bonneville makes balancing purchases to meet load; these are netted from total secondary sales before the secondary credit is applied against the cost base collected in rates.

secondary revenues is credited against the total revenue requirement to produce a net revenue requirement to be collected from power rates charged to Bonneville's firm power customers.

Under each replacement resource scenario, AURORA is used to calculate: (1) the amount of generation from the replacement resources meeting load with 1937 water conditions to achieve initial load-resource balance, and (2) the average dispatch of the resources under all water conditions. Because the dispatch of gas-fired resources will be higher with low water conditions, and lower with average water conditions, the net effect is to reduce the secondary energy credit slightly for the difference in dispatch. Table 4-9 shows the quantity and value of secondary energy revenue credits anticipated for each CRSO EIS alternative and the replacement resources.

Table 4-9. Secondary Energy Revenue Credit by Alternative and Scenario (aMW and thousands, 2019$)

Scenario	NAA	MO1	MO2	MO3	MO4	PA
Quantity (aMW)						
Bonneville Finances Zero-Carbon	2,310	2,440	2,403	1,980	1,971	2,380
Region Finances Zero-Carbon	2,310	2,406	2,403	1,909	1,831	2,380
Bonneville Finances Conventional Least-Cost	2,310	2,381	2,403	1,807	1,706	2,380
Region Finances Conventional Least-Cost	2,310	2,408	2,403	1,911	1,834	2,380
Value thousands, 2019$)						
Bonneville Finances Zero-Carbon	325,894	328,847	374,083	284,071	360,986	(323,142)
Region Finances Zero-Carbon	325,894	290,170	374,083	252,697	235,893	(323,142)
Bonneville Finances Conventional Least-Cost	325,894	310,305	374,083	299,258	243,748	(323,142)
Region Finances Conventional Least-Cost	325,894	309,921	374,083	254,962	266,294	(323,142)

4.1.3.2 4(h)(10)(C) Credits

The Northwest Power Act requires Bonneville to make expenditures to mitigate fish and wildlife and their habitats in the Columbia River Basin affected by the development and operation of the Columbia River System.[35] Bonneville fulfills this mandate by making expenditures for: (1) direct fish and wildlife program operations and maintenance; (2) direct fish and wildlife program capital projects; and (3) power purchases made to replace the Federal system's firm generating capability lost due to fish mitigation measures. While Bonneville incurs these costs as part of its section 4(h)(10)(A) mitigation duty, the actions funded also offset the impacts of the Columbia River System's non-power purposes such as navigation, irrigation, or flood risk management. Bonneville is responsible for the power share of mitigation costs only, and must therefore recover the non-power share of its fish and wildlife mitigation expenditures in some other way. Section 4(h)(10)(C) provides that vehicle. It requires the Administrator to allocate the expenditures incurred mitigating fish and wildlife and to recoup the non-power share of those expenditures from the U.S. Treasury. The system-wide weighted average of the non-

[35] Section 4(h)(10)(A), 16 U.S.C. § 839b(h)(10)(A).

power cost allocation is 22.3%. Bonneville thus takes a 22.3% credit annually against its obligations to the U.S. Treasury for the non-power share of mitigation it funds.

The annual amount of section 4(h)(10)(C) credit is expected to vary across CRSO EIS alternatives because the hydropower operations undertaken and mitigation expenditures that Bonneville would make to protect fish and wildlife under these alternatives would vary, and, in turn, affect the amount of credit received. The value of the credit was modeled for the MOs using the standard rate case procedure (see Appendix J, *Hydropower*). Table 4-10 below shows the estimated revenue from the 4(h)(10)(C) Treasury credit under each alternative and scenario. The analysis of replacement power costs under these alternatives is in Section 4.2 of Appendix J, *Hydropower*.

Table 4-10. 4(h)(10)(C) Treasury Credit by Scenario (thousands, 2019$)

Scenario	NAA	MO1	MO2	MO3	MO4	PA
Bonneville Finances Zero-Carbon	$93,336	$94,018	$90,096	$111,162	$110,743	$95,090
Region Finances Zero-Carbon	$93,336	$94,018	$90,096	$111,162	$110,743	$95,090
Bonneville Finances Conventional Least-Cost	$93,336	$94,060	$90,096	$110,951	$112,526	$95,090
Region Finances Conventional Least-Cost	$93,336	$94,060	$90,096	$110,951	$112,526	$95,090

4.1.4 Summary of Wholesale Power Rate Pressure by Alternative

This analysis describes how the changes in the cost of power generation and transmission place upward (or downward) pressure on wholesale electricity rates. The term “upward rate pressure” indicates the potential for increases in rates resulting from the added costs of and/or reduced revenue from generating and transmitting power; upward rate pressure could lead to increased rates absent the ability of Bonneville or other entities to balance out the added costs. Likewise, “downward rate pressure” indicates the potential for reductions in rates resulting from decreased costs of generating and transmitting power.

The power generation variables and the total cost adjustments described in the previous sections provide the inputs to the final wholesale power rate pressure calculation. The total costs, including all applicable discounts, divided by total system output defines the rate pressure effect for each MO and replacement resource and financing scenario. Rates may vary by utility depending on utility specific variables such as demand charges and discounts.

Table 4-11 summarizes the potential Tier 1 Average Net Cost by Scenario. The information in Table 4-11 identifies how wholesale rates would be affected if Bonneville or other regional utilities are not able to balance out the increased costs of generating and transmitting power for MO1, MO3, MO4, and the Preferred Alternative. For alternatives with relatively limited added rate pressure (e.g., the Preferred Alternative), if Bonneville is able to balance out the increased costs, wholesale power customers may not experience the increase in wholesale power rates described in Table 4-11.

This analysis did not include the effects of additional coal-plant retirements that were announced regionally after the analysis was initiated. Factoring in the effect of additional coal-

plant retirements would likely increase the upward rate pressure further relative to the No Action Alternative for MO3, and lower the rates further for MO2. For MO1 and MO4, it would likely reduce the upward rate pressure relative to the No Action Alternative. When considering all cost pressure sensitivities (i.e., not only coal retirements but other regional cost pressures, such as replacement resource financing assumptions or renewable integration services), the analysis generally finds that potential upward rate pressure effects are understated.

Table 4-11. Forecast Average Bonneville Wholesale PF Power Rate by Alternative and Scenario ($/MWh, 2019$)

Scenario	NAA	MO1	MO2[1/]	MO3	MO4	PA
Bonneville Finances Zero-Carbon	$34.56	$37.53	$34.28	$41.23	$43.32	$35.47
Region Finances Zero-Carbon		$36.83		$37.84	$40.88	
Bonneville Finances Conventional Least-Cost		$36.64		$37.88	$42.70	
Region Finances Conventional Least-Cost		$36.14		$37.41	$39.87	

1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection could be achieved by a less costly option. Without the structure, wholesale PF rates under MO2 would be 4% lower than under the No Action Alternative as opposed to the less than one percent decrease when including the structure.

4.2 TRANSMISSION RATE PRESSURE ANALYSIS

4.2.1 CRSO Transmission Rate Pressure Methodology and Assumptions

For the transmission rate pressure analysis, a comparative analysis estimated capital costs, potential sales impacts, and the transmission rate pressure for each MO over time compared to the No Action Alternative. The transmission rate pressure analysis did not consider the potential for additional coal retirements beyond those anticipated in the BP-20 Initial Proposal and "base case" forecast. Additional details about impacts of these retirements are described in the Power Reliability Sensitivity Analyses (see Section 2.2).

4.2.1.1 Revenue Requirement

To evaluate the impacts of the MOs, the analysis calculates the estimated incremental change in revenue requirement due to additional transmission capital investments. The incremental revenue requirement approach takes the loaded capital investment and estimates the capital-related costs over time. The transmission rate pressure analysis incorporates the revenue requirement with the updated capital-related costs as described below.

CAPITAL ASSUMPTIONS

The transmission investments required to support the conventional least-cost and zero-carbon resource replacement portfolios under each of the MOs were used to identify the incremental capital costs associated with each of the MOs. Chapter 2 of this appendix, *Power Supply and Replacement* Resources describes the resource-replacement portfolios and selection process. Chapter 3.2 describes the process of determining the costs of new transmission infrastructure.

This analysis uses typical planning estimates for the direct costs, with overhead cost loadings applied.

The overhead cost forecast is a composite rate used to distribute the non-direct capital project costs. The overhead costs are loaded onto the direct capital cost estimates. The cost components include non-direct transmission costs, supply chain support services and contracting costs, and corporate overhead costs. The FY 2019 composite rate is projected through FY 2025 (year of assumed energization) using a forecast of the GDP price deflator. This analysis assumes that capital spending would have a flat distribution between the construction start in FY 2022 and energization in FY 2025 for all capital investments. Table 4-12 below presents the capital costs added by alternative.

Table 4-12. Total Incremental Capital Costs by Portfolio and Alternative (thousands)

Alternative	Portfolios	Direct Costs	Loaded Costs
NAA	N/A	N/A	N/A
MO1	Zero-Carbon	$72,000	$99,000
	Conventional Least-Cost	$70,000	$96,000
MO2[1/]	N/A	N/A	N/A
MO3	Zero-Carbon	$243,000	$331,000
	Conventional Least-Cost	$167,000	$228,000
MO4	Zero-Carbon	$357,000	$489,000
	Conventional Least-Cost	$217,000	$297,000
PA[2/]	N/A	N/A	N/A

1/MO2 does not require additional capital investment. While there is the potential for avoided builds, as described in Chapter 2, the avoided builds are not likely to produce a reduction in the capital portfolio compared to the No Action Alternative.
2/The Preferred Alternative does not require additional capital investment.

4.2.1.2 Expense Assumptions

No changes to transmission expenses are assumed to occur under CRSO EIS alternatives. Both transfer costs and demand response expenses are included in the power revenue requirement.

4.2.1.3 Segmentation Assumptions

As described in Chapter 3.7 of the main body of the EIS, *Power and Transmission*, the costs that make up the transmission revenue requirement are spread across various segments of the transmission system (groups of transmission facilities servicing a particular function or providing a specific service) for ratemaking purposes.[36] The transmission rate pressure analysis treats the capital investments under each MO as additions to the network segment. This

[36] Additional information can be found in Bonneville's Transmission Segmentation Study and Documentation, last published for the BP-18 rate proceeding, and available at: https://www.bpa.gov/Finance/RateCases/BP-18/Pages/BP-18-Final-Proposal.aspx.

treatment is consistent with the standard practice when investments in the system could benefit multiple users.

To incorporate this assumption into the analysis, the segmented investment base is adjusted within the revenue requirement based on when the investments are energized. When the network investment base increases, the network segment's percent share of the capital-related cost allocation increases when holding all else equal. This, in turn, reduces the percent share of costs for all other segments except the ancillary services segment. The costs of the ancillary services segment were assumed to remain constant at the level in the No Action Alternative baseline, consistent with the assumption regarding generation reserves described in Section 2.3 as the costs of which interact with ancillary services. Therefore, when incremental capital-related costs for each alternative were spread across the segments, the ancillary services segment was excluded from incremental cost distribution.

4.2.1.4 Financing Assumptions

The transmission rate pressure analysis is based on the following financing assumptions:

- All investments would be fully Treasury financed, consistent with typical long-term financial modeling. While there is a chance that future investments may be eligible to be part of a large generator interconnection agreement or part of the lease purchase program, those options are not modeled;
- Repayment period would be 30 years, which matches the maximum life of a single bond. This is shorter than the allowable repayment period of 35 years;
- Depreciation period would be 51 years, consistent with the weighted average service life of transmission assets; and
- Given uncertainty around time periods for construction, debt was assumed to be issued when new plant investment is put into service; therefore, there was no inclusion of allowance for funds used during construction in this analysis.

4.2.1.5 Repayment Assumptions

The financial modeling approach used in this analysis differs from a rate case approach, as an incremental revenue requirement methodology replaces the repayment model used in a rate case. Traditional repayment modeling evaluates the entire debt portfolio, aiming to minimize the costs, while considering borrowing authority constraints and financial policies. This analysis instead adds the incremental capital-related costs on top of the underlying debt portfolio, without re-running the repayment model or evaluating the potential impacts of financial policies.

The incremental approach is used to isolate the impacts of the capital additions because adding capital investment on top of the underlying debt portfolio could trigger other impacts if the repayment modeling was used. In reality, the impacts that could be triggered in repayment modeling would not only be attributed to these capital investments, but would also reflect the

impacts of the full capital forecast and the underlying debt portfolio, thus obscuring the true impact of each discrete investment. Therefore, when running a delta analysis, the incremental approach used in this analysis better isolates the capital-related cost impacts of investments. However, this approach has some limitations. For example, the capital-related cost pressures could trigger a borrowing authority or financial policy effect that could increase rate pressures. Additionally, adding investments to the capital portfolio could trigger re-evaluation of the full portfolio, which may cause trade-offs in investments.

4.2.1.6 Rate Pressure Analysis

To analyze each of the CRSO EIS alternatives against the No Action Alternative, the transmission rate pressure analysis used the transmission long-term rates model. The rate levels used for the No Action Alternative were based on an existing long-term model with FY 2020-2021 (BP-20) rates applied and certain long-term financial planning assumptions. The No Action Alternative transmission analysis did not make changes to the segmented revenue requirement, long-term sales, or short-term sales.

To calculate the rate pressure under each MO, the No Action Alternative model was updated based on changes to the segmented revenue requirement, long-term sales, and short-term sales for each alternative. Once the modeling assumptions were updated for each MO, review of the modeling occurred to identify adjustments needed for cost recovery.

4.2.1.7 Short-Term Sales Assumptions

For each CRSO EIS alternative and resource replacement portfolio, the analysis relies on hydropower and market price forecasts to calculate short-term sales. Where changes occur to the hydropower and market price forecasts, short-term sales are updated beginning in FY 2022 and held constant over time (see Section 4.1.2, *Market Prices* and 4.1.3, *Revenue Credits* for discussion of market prices and secondary sales).

4.2.1.8 Long-Term Sales Assumptions

The transmission rate pressure analysis assumes that customers would use the rights under existing contractual arrangements for point-to-point service to meet transmission needs prior to purchasing additional long-term service from Bonneville. For the conventional Least-Cost resource replacement scenario, this assumption results in no change to Bonneville's long-term sales. For the zero-carbon resource replacement portfolio (which include solar power), however, long-term sales increased because the cumulative transmission demand is assumed to exceed the rights under existing contractual arrangements at certain times. This is because a greater amount of additional solar resources is required to meet baseline requirements in these portfolios given that solar generation is dependent on time of day, location, and seasonality.

The analysis assumes 75 percent of installed solar capacity would require firm transmission service, with 5 percent attributable to additional sales. These additional sales would begin in 2025, the year of assumed resource energization. Table 4-13 below presents the long-term

sales added to each zero-carbon resource replacement scenario by alternative. No additional sales were assumed for gas-fired resources given that these resources are generally dispatchable upon demand.

Table 4-13. Changes in Long-Term Sales by Zero-Carbon Alternative (MW)

Alternative	Solar Capacity Added	Additional Long-Term Sales
NAA	N/A	N/A
MO1	1,200	45
MO2	0	0
MO3	2,550	96
MO4	5,000	188
PA	0	0

4.2.1.9 Geographic Rate Pressure Inputs

To provide a proxy geographic distribution for the transmission rate pressure, as needed for the geographic analysis described in the socioeconomic analysis, the rate pressure geographic distribution relies on the rate impacts to individual customers in the BP-20 transmission customer impact model. The BP-20 transmission customer impact model was used as a starting point for the proxy geographic distribution due to the absence of information on how customers might change over time or where additional sales might be generated in the future. To generate the geographic rate pressure, each customer's portion of the overall average rate pressure was identified based on each customer's impact from the BP-20 rates.

The geographic rate pressure distribution is based on sales assumptions from the BP-20 rate case. In order to capture the potential impacts on sales of customers converting from the network point-to-point product to network integration service in the future, the analysis assumes that eligible customers would convert their service when their existing reservation term expires. Although it may be possible under Bonneville policy for customers to convert some service earlier than assumed in the analysis, the assumption used in the analysis provides a reasonable proxy for the long-term effects of product conversion. Other than the assumptions about product conversion, the geographic rate pressure distribution relies on the BP-20 transmission customer impact model and makes no other assumptions about changes in the type or amount of service taken, the location of additional sales, or changes in Bonneville transmission customers.

The analysis estimated the effective rate pressure by customer by applying each customer's percent of the overall rate change from BP-20 rates with any potential service conversion adjustments, to the rate pressure change calculated in the alternatives. This estimate of rate pressure paired with the customer's geographic region provided the input for the geographic rate pressure analysis in the socioeconomic analysis to evaluate retail rate implications (see Limitations and Caveats section for further discussion and Chapter 5, *Social and Economic Effects of Changes in Power and* Transmission*,* for a discussion of the retail rate pressure).

For load-serving utilities, transmission usage will likely tie to the geographic region in which the utility resides. Due to the nature of transmission sales and product flexibility, however, geographic impacts may not directly tie to the customer's location of sale. Although the analysis tries to geographically distribute the rate pressures based on the location of the utility, there are limitations to the accuracy of these estimates.

4.2.3 Summary of Transmission Rate Pressure by Alternative

Table 4-14 summarizes the estimated rate pressure by CRSO EIS alternative and resource replacement portfolio as compared to the No Action Alternative through FY 2028.

Table 4-14. Cumulative and Annualized Rate Pressure by Alternative and Portfolio without additional coal plant retirements (%)

Alternative	Resource Replacement Portfolio	Cumulative Rate Pressure	Annualized Rate Pressure
MO1	Zero-Carbon	5.09%	0.62%
	Conventional Least-Cost	6.06%	0.74%
MO2	N/A	0.89%	0.11%
MO3	Zero-Carbon	12.91%	1.53%
	Conventional Least-Cost	11.26%	1.34%
MO4	Zero-Carbon	16.52%	1.93%
	Conventional Least-Cost	13.52%	1.60%
PA	N/A	0.70%	0.09%

Under MO1, capital costs under the zero-carbon resource replacement portfolio would exceed capital costs under the conventional Least-Cost resource replacement portfolio. However, the rate pressure under the conventional Least-Cost resource replacement portfolio exceeds the rate pressure under the zero-carbon resource replacement portfolio because the zero-carbon resource replacement portfolio include an additional 45 MW of long-term sales from the additional 1,200 MW of solar generating capacity. Short-term sales are also higher under the zero-carbon resource replacement portfolio, reflecting the changes to hydropower and pricing (see Section 4.1, *Power Rate Pressure Analysis* for discussion of secondary sales). The resulting cumulative upward transmission rate pressures would be 6.06 percent for the least-cost replacement scenario and 5.09 percent for the zero-carbon resource replacement portfolio.

Under MO2, there would be no changes to capital-related costs or long-term sales. Additionally, this alternative does not include separate resource replacement portfolios. The rate pressure under MO2 instead reflects changes in short-term sales compared to the No Action Alternative. Therefore, hydropower and pricing changes drive the rate pressure under this alternative (see Section 4.1.3, *Revenue Credits* for discussion of secondary sales). The resulting cumulative upward transmission rate pressure would be 0.89 percent.

MO3 includes capital investment in both gas and solar replacement resources for reinforcement of the south Tri-Cities in the absence of Ice Harbor Dam generation. These investments account for approximately $94.5 million of the direct costs, or $129 million of the

loaded costs in each resource replacement scenario. The remaining capital-related costs under this alternative reflect resource-specific investment needs. This alternative also includes the short-term sales updates and the solar long-term sales updates. The resulting cumulative upward transmission rate pressure would be 11.26 percent and 12.91 percent for the least-cost and zero-carbon scenarios respectively.

This analysis estimates that upward rate pressure would be highest under MO4, reflecting the fact that capital investment additions are highest under this alternative. MO4 also would result in the largest need for additional capacity, with either 3,240 MW of gas or 5,000 MW of solar required, depending on the portfolio (without additional coal retirements). The addition of solar capacity would result in 188 MW of long-term sales increases under the zero-carbon resource portfolio. Additionally, both resource portfolios include updates for hydropower and pricing changes (refer to Section 4.1, *Power Rate Pressure Analysis*, for discussion of changes in power rates). The resulting cumulative upward transmission rate pressure would be 13.52 percent and 16.52 percent for the least-cost and zero-carbon scenarios respectively.

Under the Preferred Alternative, there would be no changes in capital investments or long-term transmission sales. Upward transmission rate pressure would be about 0.09 percent annually (0.7 percent cumulatively over an 8-year period) relative to the No Action Alternative because transmission short-term sales would likely change as a result of the changes in hydropower generation and associated market pricing.

CHAPTER 5 - SOCIAL AND ECONOMIC EFFECTS OF CHANGES IN POWER AND TRANSMISSION

To provide additional perspective on how people may be affected by the changes in how power is produced and delivered across the Pacific Northwest, this analysis evaluates the following categories of social and economic effects:

- **Social welfare effects:** The social welfare effects analysis provides information on the changes in the value of the national output of goods and services. These social welfare effects are sometimes referred to as National Economic Development (NED) effects, which are concerned only with economic efficiency at national societal level (i.e., these effects do not consider economic gains by one group at the expense of another, which are referred to as "transfers" of benefits). Social welfare gains or losses from the national perspective in this analysis are due to the changes in the marginal costs of producing power.
- **Regional economic effects:** Regional economic effects consider a regional or local perspective on changes in spending patterns and economic productivity resulting from the changes in power and transmission. This analysis provides information on how the changes in the cost of providing power affects the cost of living and doing business across Pacific Northwest residents, and commercial and industrial enterprises. In addition, this analysis employs IMPLAN to assess the effects of changing in spending on the wider regional economy through "multiplier" effects.
- **Other social effects:** The analysis of other social effects considers additional relevant dimensions of how the changes in power and transmission affect people's well-being, outside of the changes in economic value and financial cost implications. Other social effects in this analysis focus on potential health and safety outcomes of the alternatives.

The following sections provide additional detail on the methods, data, and results of these analyses, as described in Section 3.7.3 of the main body of the EIS, *Power and Transmission Environmental Consequences*. The analysis relies on the "base-case" assumptions for coal retirements described in Section 2.3, *2.3 Sensitivity of LOLP to Assumptions About Coal* Capacity, which assumes 4,246 MW of coal dedicated to serving regional load.

5.1 SOCIAL WELFARE EFFECTS ANALYSIS

From an economic perspective, the conceptual basis for measuring economic value is society's "willingness-to-pay" (WTP) for a good or service.[37] Absent data to directly measure WTP, it is common to use available information on market prices and other estimates of the marginal costs of production to quantify social welfare values of changes in power generation and transmission. This analysis applies two separate methods to estimate social welfare values of the changes in power generation and transmission: the market price method and the

[37] WTP measures the maximum amount that an individual (or population) would be willing to pay rather than do without a good or service above and beyond what the individual (or population) does pay.

production cost method. These methods are both consistent with the Corps' guidance for valuing social welfare effects of changes in power, and are presented as changes relative to the No Action Alternative.[38]

These two methods are distinct approaches for estimating the social welfare effects of the alternatives. Therefore, the resulting value estimates are not additive. The social welfare effects provide a national perspective on the economic effects of changes in power and transmission but do not consider how these changes affect particular populations or regional economies, which are covered in the regional economic effects analysis.

The "**market price method**" describes the incremental changes in Pacific Northwest hydropower generation (from the HYDSIM model) under each alternative valued at the market price of power (from the AURORA model). AURORA estimates market prices based on hourly demand and operating cost information for each generating plant. The market price method multiplies the average monthly market prices by the monthly changes in power generation and sums over months to estimate the average annual value of the change in hydropower generation under each alternative relative to the No Action Alternative. At market equilibrium, the market price of a good (i.e., power) exactly equals the marginal value to the buyers and the marginal cost to the sellers. Thus, the market price method is an estimate of the value (i.e., societal WTP) for the lost (or gained) hydropower generation.

However, if the change in output (i.e., power generation) is enough to affect its market price, or if there are structural changes in demand or supply, the market prices may not provide a valid measure of the economic value of the change. In this analysis, the change in hydropower generation may affect market prices and is also subject to structural changes in supply (e.g., replacing hydropower with other sources of hydropower generation). This analysis therefore applies an alternative method based on the costs of providing equivalent power output under each alternative.

The second method, the "**production cost method**" quantifies the value of the changes in power generation based on the costs of providing an equivalent amount of power (i.e., maintaining reliability for consumers).[39] The production cost method estimates economic

[38] These methods for quantifying social welfare effects are consistent with the Corps' guidance for valuing national economic development effects of changes in power, which describes the following: "Primary benefit measure for hydropower: Market value of output, or alternative cost of providing equivalent output when market price does not reflect marginal costs." Source: U.S. Army Corps of Engineers Institute for Water Resources. June 2009. National Economic Development Procedures Manual.

[39] The U.S. Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies and the associated Corps' guidance specify that this cost-based method (referred to as the "cost of the most likely alternative") may be used to estimate WTP if the alternative means of producing the power reflected in the costs is the "most likely" alternative means, and that society would, in fact, undertake the alternative means. In this case, it is reasonable to find that the foregone power would be replaced as the demand for power is relatively inelastic. As there is some uncertainty regarding how reductions in hydropower generation would be replaced, however, the analysis provides a range of social welfare effects based on this method.

effects based on changes in the fixed and variable costs of meeting regional demand for power. The fixed costs include the annualized capital costs of developing new capacity (i.e., replacement resources) and connecting it to the system (i.e., transmission infrastructure interconnection). The variable costs include the changes in the cost of fuel, variable operations and maintenance, start-up costs and emissions penalties (in California) for the various generating resources under each alternative relative to the No Action Alternative. The production cost method provides a range of results based on the alternative replacement resource portfolios without additional coal retirements (as described in Chapter 2 of this appendix, *Power Supply and Replacement* Resources).

For the power system reliability benefit under MO2 the production cost method also estimates the fixed and variable costs of the resource portfolio required to bring the No Action to the same LOLP as MO2 (5 percent). Chapter 3 describes the portfolio for the MO2 potential avoided build and this section quantifies the related social welfare effects; the values presented in each table for the production cost method represent the MO2 alternative with this potential avoided build. The social welfare analysis does not estimate potential avoided builds for the PA.

5.1.1 Social Welfare Effects Based on the Market Price Method

To develop welfare estimates, the market price approach multiplies changes in Pacific Northwest hydropower generation from HYDSIM by the average market price reported by AURORA.

5.4.1.1 Monthly Hydropower Generation

The HYDSIM model estimates the level of hydropower generation across the Pacific Northwest for the No Action Alternative and each of the MOs. The generation levels account for the total generation of the Pacific Northwest-United States system, which includes Federal and non-Federal hydropower projects across the Pacific Northwest, as defined in Chapter 1, *Introduction* of Appendix J, *Hydropower*.[40] As described in Section 3.7 of the main body of the EIS, *Power and Transmission,* the CRSO alternatives have the potential to affect generation at other non-federal hydropower projects. HYDSIM estimates generation levels on a monthly basis, with April and August divided into two periods, creating a fourteen-period year. Additional definitions, methodologies for the hydropower analysis, and detailed hydropower generation results are found in Chapter 3, *Impacts of the Alternatives on Hydropower, of* Appendix J*, Hydropower*.

Table 5-1 presents the monthly generation for the No Action Alternative and each MO in MWh relative to the No Action Alternative. These values are estimates of monthly aMW from HYDSIM modelling converted to MWh assuming equal half month periods for the two April and August periods.

[40] The hydropower modelling uses 80 historical water years to estimate monthly and annual hydropower generation levels. The values used in this analysis reflect the average of the 80 water years.

Exhibit 9 in Appendix J, *Hydropower,* provides the full operating year values including both April and August periods. The negative estimates identify a reduction in generation in the time period whereas positive estimates identify an increase in generation.

Table 5-1. Average Monthly Hydropower Generation under No Action Alternative, and Relative to each MO (MWh)

Month	Generation (MWh) NAA	Change in Generation Relative to No Action (MWh)				
		MO1	MO2	MO3	MO4	PA
January	11,000,000	+170,000	+420,000	-910,000	+180,000	+210,000
February	11,000,000	+12,000	+340,000	-1,100,000	-36,000	+180,000
March	10,000,000	-85,000	-280,000	-1,100,000	-2,600,000	-95,000
April	9,500,000	-320,000	+110,000	-1,600,000	-2,000,000	-760,000
May	12,000,000	-370,000	+800,000	-2,000,000	-2,000,000	-1,000,000
June	13,000,000	-110,000	+260,000	-1,500,000	-1,800,000	-360,000
July	10,000,000	-190,000	+560,000	-840,000	-1,300,000	+2,900
August	8,000,000	-420,000	+1,100,000	+510,000	-1,100,000	+230,000
September	6,700,000	+67,000	+130,000	-590,000	-220,000	+100,000
October	6,800,000	-61,000	+4,400	-470,000	-330,000	+140,000
November	8,900,000	-12,000	+160,000	-170,000	-61,000	-57,000
December	9,900,000	-180,000	+330,000	-280,000	-290,000	+730
Average Annual Generation	**120,000,000**	**-1,500,000**	**+4,000,000**	**-10,000,000**	**-12,000,000**	**-1,400,000**

Note: Estimates are rounded to two significant digits and may not sum to the totals reported due to rounding.

MONTHLY MARKET PRICES

The market prices used in this analysis are the average monthly prices from the Mid-Columbia market hub (Mid-C) calculated using the hydropower generation across 80 water conditions. These prices are considered the best indicator of societal WTP for the hydropower for the social welfare analysis because they are reflective of the broader regional power market (not limited to any one producer or customer). These market prices are estimated in AURORA by water condition (for the 80 water conditions modelled) by month and expressed as dollars per MWh, ($/MWh), adjusted to 2019 dollars. The AURORA market price estimates do not include replacement resources to evaluate how the market would respond to the operational and structural measures directly.

Table 5-2 presents the average monthly market price for the No Action Alternative and the annual average, weighted by monthly generation. Market prices in the Pacific Northwest tend to fluctuate with hydropower generation, when hydropower generation is high, particularly in the spring run-off period the average market price tends to drop while in the fall and winter when generation is lower market prices increase.

Table 5-2. Average Monthly Market Prices ($/MWh 2019$)

Month	$/MWh
January	22.32
February	21.35
March	17.78
April	16.50
May	8.71
June	4.96
July	20.18
August	23.98
September	23.33
October	21.60
November	23.35
December	24.89
Weighted Average Price	**18.32**

Note: The weighted average price represents the average monthly market price weighted by the hydropower generation for that month. The social welfare effects analysis is based on the monthly generation change presented in Table 5-1 and the corresponding monthly price presented above.

MONTHLY MARKET PRICE EFFECT

The market price approach estimates the average annual social welfare effect by multiplying the change in generation by the average monthly market price and summing over time. The intent is to approximate the change in the marginal cost of producing power, which theoretically should be reflected in the price. Table 5-3 presents these effects by month relative to the No Action Alternative. Positive values indicate a net economic gain whereas negative values indicate a net economic loss relative to the No Action Alternative.

Table 5-3. Average Monthly Market Effect (2019$)

Month	Total Market Value NAA	Monthly Effect Relative to No Action				
		MO1	MO2	MO3	MO4	PA
January	$250 million	$3.7 million	$9.3 million	-$20 million	$4.0 million	$4.6 million
February	$240 million	$250,000	$7.3 million	-$23 million	-$760,000	$3.8 million
March	$180 million	-$1.5 million	-$4.9 million	-$19 million	-$46 million	-$1.7 million
April	$160 million	-$5.3 million	$1.9 million	-$26 million	-$33 million	-$12 million
May	$100 million	-$3.2 million	$7 million	-$18 million	-$18 million	-$8.7 million
June	$63 million	-$530,000	$1.3 million	-$7.4 million	-$8.9 million	-$1.8 million
July	$210 million	-$3.8 million	$11 million	-$17 million	-$27 million	$59,000
August	$190 million	-$10 million	$26 million	$12 million	-$27 million	$5.5 million
September	$160 million	$1.5 million	$3 million	-$14 million	-$5.3 million	$2.3 million
October	$150 million	-$1.3 million	$95,000	-$10 million	-$7.2 million	$3 million
November	$210 million	-$290,000	$3.8 million	-$4 million	-$1.4 million	-$1.3 million

Month	Total Market Value NAA	Monthly Effect Relative to No Action				
		MO1	MO2	MO3	MO4	PA
December	$250 million	-$4.4 million	$8.2 million	-$6.9 million	-$7.3 million	$36,000
Total	**$2,100 million**	**-$25 million**	**+$75 million**	**-$150 million**	**-$180 million**	**-$6.7 million**

Note: Estimates are rounded to two significant digits and may not sum to the totals reported due to rounding.

AVERAGE ANNUAL SOCIAL WELFARE EFFECTS BASED ON THE MARKET PRICE METHOD

Table 5-4 provides the average annual social welfare effect for each alternative by summing the monthly effects over the year. The average annual social welfare effect based on this market price approach ranges from a net economic cost of $190 million under MO4 to a net economic gain of $75 million under MO2. The changes in generation are valued at the monthly No Action Alternative prices presented in Table 5-2.

Table 5-4. Market Prices Method Average Annual Social Welfare Effects (2019$)

Scenario	Change in Generation (aMW)	Change in Generation (MWh)	Average Annual Social Welfare Effect
MO1	-170	-1.5 million	**-$25 million**
MO2	+450	+4.0 million	**+$75 million**
MO3	-1,100	-10 million	**-$150 million**
MO4	-1,300	-12 million	**-$180 million**
PA	-160	-1.4 million	**-$6.7 million**

Note: The change in generation and the social welfare effect are rounded to two significant digits and may not sum to the totals reported due to rounding.

5.1.2 Social Welfare Effects Based on the Production Cost Method

As previously described, the market price method most likely underestimates the social welfare effects of the alternatives because it does not fully account for the marginal cost of producing power in the region under each of the alternatives. Where hydropower generation is reduced, there are additional costs associated with adding capacity in order to maintain power system reliability that are not reflected in the AURORA market price outputs for each alternative.

Specifically, the production cost method constitutes a "bottom up" approach to estimating the marginal cost of producing power based on changes in the fixed and variable costs of the system. This method sums three cost components to estimate the economic effects of the CRSO alternatives on the cost of producing and delivering power across the Western Interconnection: 1) the fixed cost of building replacement resources; 2) the fixed costs of building the necessary transmission infrastructure; and 3) the changes in the variable costs of operating the plants (e.g., the cost of fuel and other variable costs associated with fossil fuel resources).

5.4.1.2 Annualized Fixed Costs of Replacement Resources

Chapter 2 of this appendix, *Power Supply and Replacement* Resources*,* describes the methodology for calculating the costs of adding generating capacity to the system to return to

the regional level of power system reliability (measured in LOLP) under the No Action Alternative assuming 4,246 MW of coal dedicated to serving regional load.

As described in Chapter 2, the analysis uses NW Council 7th Power Plan and Midterm Assessment values for the capital costs of natural gas and solar power. The annualized costs of these resources assume a four percent interest rate and 30-year period for the debt repayment.[41]

Table 5-5 lists the power resource costs by alternative. These costs do not include any fuel costs but they do include insurance, fixed operations and maintenance, and the capital expense. These estimates represent the fixed costs of providing power to maintain power system reliability under each alternative (i.e., returning LOLP to the No Action Alternative level of 6.6 percent).

Table 5-5. Power Resources Annualized Fixed Costs for the Base Case Without Additional Coal-Plant Retirements (2019$)

Alternative	Zero-Carbon	Conventional Least-Cost
MO1	-$160 million	-$27 million
MO2[1/]	+$140 million	+$19 million
MO3	-$420 million	-$140 million
MO4	-$580 million	-$160 million
PA[1/]	--	--

Note: Estimates are rounded to two significant digits and may not sum to the totals reported due to rounding. Positive values in the table represent a decrease (net benefit) in the cost of producing power while negative values represent an increase (net cost) in the cost of producing power.

1/MO2 has a reliability benefit relative to the No Action Alternative that results in a net economic benefit of +$140 million or +$19 million for the zero-carbon and conventional least-cost portfolios, respectively. These positive values reflect a benefit in terms of the reduction in new power resources that would be required to meet reliability standards. Without considering these avoided builds there are no fixed costs associated with MO2. The Preferred Alternative also has a slightly reliability benefit, however it is small and no potential builds are quantified.

Because LOLP is five percent under MO2, this alternative is associated with a net economic benefit relative to the No Action Alternative. To estimate the value of this power system reliability benefit, the analysis estimates the capacity and generation of resources required under the No Action Alternative to reach the same LOLP level as MO2 (5 percent). The estimate of the annual avoided power replacement capital costs for MO2 is $140 million for the zero-carbon portfolio and $19 million for the conventional least-cost portfolio for the base case without additional coal-plant retirements.

[41] Both portfolios use the Bonneville FY 2019 tax-exempt borrowing 30-year rate for financing.

5.4.1.3 Annualized Fixed Costs of Transmission Infrastructure

The transmission analysis described in Chapter 3, *Transmission System Reliability and Congestion,* identified the total infrastructure cost for connecting the replacement power resources to the electric grid. For the social welfare analysis these costs were annualized using financing assumptions consistent with the power resources analysis (interest rate of 4 percent and a 30-year period). Table 5-6 presents the amortized fixed costs by alternative for transmission infrastructure. Since MO2 avoids new power resources there are also avoided transmission infrastructure costs, however these costs were not estimated.

Table 5-6. Transmission Fixed Costs (2019$)

Alternative	Zero-Carbon	Conventional Least-Cost
MO1	$3.9 million	$3.8 million
MO2[1/]	--	--
MO3	$13 million	$9.1 million
MO4	$19 million	$12 million
PA[1/]	--	--

Note: Estimates are rounded to two significant digits and may not sum to the totals reported due to rounding.
1/This analysis did not estimate the potential avoided transmission fixed costs under MO2 and the Preferred Alternative; thus the benefits (i.e., avoided costs) of MO2 and Preferred Alternative are likely an underestimate.

5.4.1.4 Average Annual Variable Costs

This analysis relies on AURORA model estimates of the fuel price and total fuel consumed in MMBTU for three regions in the western interconnection: the Pacific Northwest, California, and the rest of the western United States. Variable costs include natural gas and coal, which make up the majority of the fuel-based changes in power generation. Table 5-7 lists the fuel price for coal and natural gas. The fuel prices for each region are dollars per MMBTU.

Table 5-7. Fuel Prices by Region, dollars per million British thermal unit ($/MMBTU, 2019$)

Fuel Price	Pacific Northwest	California	Western U.S.
Coal	1.39	2.20	1.71
Natural Gas	2.08	3.02	2.08

Note: Prices reflect the annual average price from AURORA. Canada was excluded from the analysis but AURORA does generate estimates. Some very minor variation occurs between the prices in each alternative however this variation is not apparent when averaging across regions due to rounding.

AURORA estimates the amount of fuel consumed for coal and natural gas power production in MMBTU by month and water year for each region. AURORA is also able to estimate the total production cost defined as the fuel costs, startup costs, variable operations and maintenance as well as emissions penalties (in California). The fuel consumption is multiplied by the fuel price to produce a monthly fuel cost, which is averaged across water years and summed to produce an average annual total production costs which consist of the fuel cost and additional variable costs.

Table 5-8 presents the average annual fuel consumption for coal by Region and CRSO action alternative and Table 5-9 presents the average annual fuel consumption for natural gas. Because the alternatives add different resources to the regional fuel mix (i.e., natural gas versus renewables), the amount of fuel consumption differs by resource portfolio. For the zero-carbon portfolios, fossil fuel consumption does increase in certain scenarios where the replacement solar power generation is not able to sufficiently meet demand, thus requiring existing fossil fuel plants to increase generation. For example, even when solar power is added under MO1 with a zero-carbon portfolio, coal generation reduces in the Pacific Northwest, however coal generation increases in California and the rest of the Western United States. This is potentially due to the reduction in the timing and volume of hydropower exports relative to the No Action Alternative. The changes in fuel use in California for coal are much smaller than than the other regions given the smaller capacity of existing coal power resources compared to the rest of the Western United States.

Table 5-8. Fuel Consumption for Coal Power Generation under the No Action Alternative, and Change from No Action by Alternative (MMBTU)

Alternative	Pacific Northwest	California	Western U.S.
NAA	85 million	3.5 million	510 million
Difference Relative to No Action			
MO1 – Zero-Carbon	-1.4 million	+7,100	+3.2 million
MO1 – Conventional Least-Cost	+580,000	+960	+1.5 million
MO2[1/]	-5.2 million	+4,400	-1.5 million
MO3 – Zero-Carbon	+6.6 million	+110	+5.4 million
MO3 – Conventional Least-Cost	+5.6 million	-23,000	-5.4 million
MO4 – Zero-Carbon	+5.2 million	+7,900	+2.3 million
MO4 – Conventional Least-Cost	+9.1 million	-13,000	+2.3 million
PA	+660,000	-2,300	+850,000

Note: Estimates are rounded to two significant digits and may not sum to the totals reported due to rounding.
1/The MO2 values in this table do not consider avoided builds.

Table 5-9. Fuel Consumption for Natural Gas Generation under the No Action Alternative, and Change from No Action by Alternative (MMBTU)

Alternative	Pacific Northwest	California	Western U.S.
NAA	240 million	720 million	990 million
Difference Relative to the No Action Alternative			
MO1 – Zero-Carbon	-7.1 million	+1.3 million	+1.3 million
MO1 – Conventional Least-Cost	+5.4 million	+1.7 million	+1.6 million
MO2[1/]	-12 million	-5.6 million	-3.5 million
MO3 – Zero-Carbon	+7.3 million	+8 million	+4.8 million
MO3 – Conventional Least-Cost	+52 million	+1.7 million	+470,000
MO4 – Zero-Carbon	-4 million	+5.4 million	+630,000
MO4 – Conventional Least-Cost	+43 million	+11 million	+8.2 million
PA	+3.9 million	+2.1 million	+1.5 million

Note: Estimates are rounded to two significant digits and may not sum to the totals reported due to rounding.
1/The MO2 values in this table do not consider avoided builds.

Multiplying the annual fuel consumed by the average annual fuel price generates the total variable costs for each alternative. Total variable costs reflect the difference in fuel costs between the No Action and MOs. Table 5-10 presents these total variable costs for all the alternatives relative to the No Action. Note that Table 5-10 does not present the production cost estimate for the potential avoided build of MO2. The avoided fuel cost benefits of the MO2 avoided resource build would be $22 million for a zero-carbon portfolio or $55 million for a conventional least-cost portfolio.

Table 5-10 presents the total production cost effect for each alternative by region from AURORA. The following table, Table 5-11, summarizes the effect by calculating a total variable cost effect (i.e., adding the three regions together) for each alternative relative to the No Action Alternative.

Table 5-10. AURORA Total Production Cost by Alternative and Region (2019$)

Alternative	Pacific Northwest	California	Western U.S.
NAA	$900 million	$3,800 million	$4,400 million
Difference Relative to the No Action Alternative			
MO1 – Zero-Carbon	-$24 million	+$9.9 million	+$16 million
MO1 – Conventional Least-Cost	+$19 million	+$8.4 million	+$8.7 million
MO21/	-$51 million	-$25 million	-$12 million
MO3 – Zero-Carbon	+$43 million	+$42 million	+$30 million
MO3 – Conventional Least-Cost	+$160 million	+$2.8 million	-$25 million
MO4 – Zero-Carbon	+$8.7 million	+$33 million	+$15 million
MO4 – Conventional Least-Cost	+$160 million	+$48 million	+$21 million
PA	+$12 million	+$9.7 million	+$4.8 million

Note: Estimates are rounded to two significant digits and may not sum to the totals reported due to rounding.
1/The MO2 values in this table do not consider avoided builds.

Table 5-11. Annual Variable Benefits/Costs Relative to the No Action Alternative by Alternative (2019$)

Alternative	Zero-Carbon	Conventional Least-Cost
MO1	-$2 million	-$33 million
MO2[1/]	+$55 million	+$22 million
MO3	-$110 million	-$130 million
MO4	-$53 million	-$210 million
PA[/2]	-$25 million	-$25 million

Note: Estimates are rounded to two significant digits and may not sum to the totals reported due to rounding.
Positive values in the table represent a decrease (net benefit) in the cost of producing power while negative values represent an increase (net cost) in the cost of producing power.
1/MO2 reduces natural gas and coal fuel use resulting in a net benefit for variable costs. The results presented in this table consider potential fuel costs for avoided new generating resources under MO2. The avoided fuel cost benefits of the MO2 avoided resource build would be $22 million for a zero-carbon portfolio or $55 million for conventional least-cost. This benefit is distinct and not additive to the $55 million benefit of MO2 when not including the potential build.

2/ The Preferred Alternative does not have replacement resource portfolios. The change in variable costs is the system wide change due to changes in fossil fuel generation under the Preferred Alternative.

5.4.1.5 Average Annual Social Welfare Effects based on the Production Cost Method

The marginal cost of producing power based on the production cost method is a sum of the changes in fixed and variable costs. Table 5-12 presents the average annual social welfare effects of each alternative based on the production cost approach.

The effects range from a benefit of $82 million under MO2 to a cost of $650 million under MO4. Table 5-11 does not present the production cost estimate for the potential avoided build of MO2. These estimates would be a benefit of $170 million ($140 million in avoided fixed costs and $22 million in avoided variable costs) for a zero-carbon portfolio and $74 million ($19 million in avoided fixed costs and $55 million in avoided variable costs) for a conventional least-cost portfolio.

Table 5-12. Production Cost Method Average Annual Social Welfare Effects (2019$)[1]

Alternative	Zero-Carbon			Conventional Least-Cost		
	Total Fixed Cost	Variable Costs	Total Social Welfare Effect	Total Fixed Costs	Variable Costs	Total Social Welfare Effect
MO1	-$160 million	-$2.5 million	-$170 million	-$27 million	-$33 million	$64 million
MO2/1	+$140 million	+$22 million	+$170 million	+$19 million	+$55 million	+$74 million
MO3	-$420 million	-$110 million	-$540 million	-$140 million	-$130 million	$270 million
MO4	-$580 million	-$53 million	-$650 million	-$160 million	-$210 million	$380 million
PA/1	--	-$25 million	-$25 million	--	-$25 million	-$25 million

Note: Estimates are rounded to two significant digits and may not sum to the totals reported due to rounding. Positive values in the Table 5-represent a decrease (net benefit) while negative values represent an increase (net cost) in the cost of producing power.

/1. This table presents the social welfare effects associated with the potential avoided resources required under MO2. The resource portfolio equivalent to the improvement in reliability from the No Action Alternative to MO2 would have a value ranging up to $170 million annually for a zero-carbon portfolio or a value of $74 million for a conventional least-cost portfolio. The avoided builds associated with the Preferred Alternative were not analyzed given the small changes to regional reliability.

5.1.3 Summary of Social Welfare Effects

Table 5-13 presents the total social welfare effects by alternative. Under the market price approach, the social welfare effects of the CRSO EIS alternatives range from a net economic loss of $180 million per year for MO4 to a net economic gain of $75 million per year under MO2. The production cost method results identify that the social welfare effects range from a net economic loss of $650 million per year under MO4 to a net economic gain of $55 million per year under MO2 (effects for each alternative are presented as a range based on replacement resource portfolio assumption). As previously described, the two approaches are not additive but reflect alternative approaches to estimating the social welfare effects of the alternatives. Note that Table 5-13 presents the production cost estimate for the potential avoided build of MO2. This estimate would be a benefit of up to $170 million per year for the base case without

additional coal-plant retirements. With additional coal-plant retirements, the benefit for MO2 would increase, the cost for MO3 would increase, and the cost for MO1 and MO4 would be slightly smaller relative to No Action Alternative. Additionally, the benefit of MO2 would be larger if fish collection at McNary were implemented with a more cost-effective option.

As previously described, there is considerable uncertainty regarding how the social welfare effects may change over the 50-year timeframe of the analysis. For example, regulatory and policy changes, technology, and the cost of technology change over time influence this value. However, if the average annual effects persist over a 50-year timeframe (2022-2071), the net present value of the social welfare effects would be as follows[42]:

- MO1: 50-year present value cost of $680 million based on the market price method, or $1.7 billion to $4.6 billion based on the production cost method for estimating social welfare effects.
- MO2: 50-year present value benefit of $2.0 billion based on the market price method, or $2.2 billion based on the production cost method for estimating social welfare effects.
- MO3: 50-year present value cost of $4.2 billion based on the market price method, or $7.4 billion to $15 billion based on the production cost method for estimating social welfare effects.
- MO4: 50-year present value cost of $4.8 billion based on the market price method, or $10 billion to $18 billion based on the production cost method for estimating social welfare effects.
- Preferred Alternative: 50-year present value cost of $180 million based on the market price method, or $670 million based on the production cost method of estimating social welfare effects.

Table 5-13. Summary of Average Annual Social Welfare Effects (2019$)

Alternative	Market Price Method	Production Cost Method	
		Zero-Carbon	Conventional Least-Cost
MO1	-$25 million	-$170 million	-$64 million
MO2[1/]	+$75 million	+$170 million	+$74 million
MO3	-$150 million	-$540 million	-$270 million
MO4	-$180 million	-$650 million	-$380 million
PA[1/]	-$6.7 million	-$25 million	-$25 million

Note: Estimates are rounded to two significant digits and may not sum to the totals reported due to rounding. Positive values in the Table 5-represent a decrease (net benefit) while negative values represent an increase (net cost) in the cost of producing power and market price valuation method.

1/ The main numbers in this table presents the social welfare effects associated with the potential avoided resources required under MO2. The resource portfolio equivalent to the improvement in reliability from the No

[42] The present values of social welfare effects in this analysis are expressed in 2019 dollars and assume a 2.875 discount rate, which is the 2019 Federal water resources planning discount rate.

Action Alternative to MO2 would have a value ranging up to $170 million annually for a zero-carbon portfolio or a value of $74 million for a conventional least-cost portfolio.

5.2 REGIONAL ECONOMIC EFFECTS ANALYSIS AND METHODOLOGY

The regional economic effects analysis considers how the alternatives affect the costs of living and doing business in the Pacific Northwest. This involves estimating how the rate pressure may affect retail rates (rates paid by the residential, commercial, and industrial sectors) based on the modelled wholesale power rates, market effects, and the transmission rate pressure. The key metric provided in this analysis is average expenditures on electricity for each ratepayer sector. The geographic scale of the regional effects analysis is county-level, accounting for differences in both retail rates and consumption at this level.

The regional economic effects analysis relies on a variety of external data sources including:

- NW Council 7th Power Plan and Midterm Assessment provides a wealth of modelled power and economic data that the socioeconomic analysis used to forecast retail rates and socioeconomic data (e.g., the total number of households).
- EIA data and definitions provide various assumptions to the modeling of rates across end user groups. In addition, EIA survey data provides details on how end users consume electricity and the breakdown of costs that influence retail rates.
- U.S. Census – the CRSO rates analysis sourced demographic, county level data from the U.S. Census for a variety of household and business data. U.S. Census sources also provided geographic data.
- U.S Department of Energy (DOE) and National Renewable Energy Laboratory (NREL) – the U.S. Utility Rate Database supplies historical retail rates for each end-user group by utility where available.

The following sections provide additional detail on methods and data sources employed to estimate the regional economic effects of the alternatives. The detailed results by county can be found in Chapter 6 - Retail Rates by County (Table 6-1).

5.2.1 Retail Rate Pressure Estimation

This analysis first estimates retail rate pressure by ratepayer sector based on changes in the Bonneville wholesale power rate pressure and transmission rate pressure described in Sections 4.1, *Power Rate Pressure* Analysis and 4.2, *Transmission Rate Pressure* Analysis. For each action alternative, changes in wholesale power and transmission rate pressure and changes in market-power purchases influence retail rate pressure, which may then lead to changes in retail rates (i.e., rates charged by retail utilities, not Bonneville or other wholesale power sellers).

Bonneville wholesale power rate pressure. Section 4.1, *Power Rate Pressure Analysis,* presents these results and elaborates on the methodology for estimating these rate changes. For Bonneville's power customers, changes in wholesale power rates directly affect utility

expenditures for the share of load they serve with Federal power purchased from Bonneville. To estimate the effect on retail rate pressure, the analysis spreads this change in expenditures over total utility load based on load and resource data provided by Bonneville for each action alternative. Table 5-14 presents the average Bonneville wholesale rates. This is not the rate charged to all or any specific utility, it is the average across Bonneville customers.

Table 5-14. Average Wholesale Power Rate by Alternative for the Base Case Analysis Without Additional Coal-Plant Retirements ($/MWh)

Resource Replacement Scenario	NAA	MO1	MO2	MO3	MO4	PA
Bonneville Finances Zero-Carbon	$34.56	$37.53	$34.28[1/]	$41.23	$43.32	$35.47
Region Finances Zero-Carbon		$36.83		$37.84	$40.88	
Bonneville Finances Conventional Least-Cost		$36.64		$37.88	$42.70	
Region Finances Conventional Least-Cost		$36.14		$37.41	$39.87	

1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection at McNary could be achieved by a less costly option. Without the structure, wholesale PF rates under MO2 would be 4% lower than under the No Action Alternative as opposed to the less than one percent decrease when including the structure.

With additional coal-plant retirements, the rate pressures would likely be higher for MO3, lower for MO2, and not as much higher than the No Action Alternative for MO1 and MO4. When considering all cost pressure sensitivities (i.e., not only coal retirements but other regional cost pressures, such as replacement resource financing assumptions or renewable integration services), the analysis generally finds that potential upward rate pressure effects are understated.

Market purchases. For Bonneville and all utilities in the region (i.e., Bonneville's power customers and non-Bonneville customers), the analysis estimates how changes in market power prices and purchases (from the AURORA model) would affect overall utility expenditures. The analysis then spreads these changes over total load to estimate implications on retail rate pressure. For non-Bonneville customers, public utility disclosure data from the EIA and Washington State fuel disclosures as well as IOU IRPs allocated the estimated market effects. As presented in Section 4.1, *Power Rate Pressure Analysis*, AURORA estimated the average market prices. Table 4-8 presents the average annual market prices. Section 4.1 describes these results in further detail.

With additional coal-plant retirements, the rates would likely be higher for MO3, lower for MO2, and not as much higher than the No Action Alternative for MO1 and MO4. When considering all cost pressure sensitivities (i.e., not only coal retirements but other regional cost pressures, such as replacement resource financing assumptions or renewable integration services), the analysis generally finds that potential upward rate pressure effects are understated.

Bonneville transmission rate pressure. Section 4.2, *Transmission Rate Pressure Analysis*, describes the transmission rate pressure results and methodology and Table 4-14 presents the results by alternative for both the cumulative and annualized transmission rate pressure. The

transmission rate pressure for each action alternative is the percentage difference in the transmission rate relative to the No Action Alternative. The analysis did not estimate a specific monetized rate and instead estimated a total cumulative rate pressure and an annualized value running from the BP-20 Proposal through the BP-28 rate period (i.e., 8 years).

To integrate the transmission rate pressure into the retail rate estimates the annualized rate pressures, as described above, the analysis translates into a geographic rate pressure (see Section 4.2.1.3, *Revenue Requirement*) and then applies to the assumed transmission rate (13 percent of the 2022 retail rate) to estimate a cents per kWh effect for an individual utility. Historical retail rate data and the fraction of the rate were based on FERC and EIA retail rate information. To account for the cumulative rate pressure over time the analysis first infers the share of the retail rate that comes from transmission costs for the year 2022. It then increases that share over time based on the annualized transmission rate pressure estimates for each action alternative. The transmission rate pressure analysis assumes rate pressure is 0 following the BP-28 period as this is beyond the current transmission planning horizon and uncertainty exists in forecasting rates.

Changes in Regional Total Production Cost. The changes in hydropower generation under each Alternative cause other regional power generating resources to respond and adjust their own generation. These changes in the power generation mix result in changes in the total production cost across the Western Interconnection under each MO compared to the No Action Alternative. The total production cost includes fuel costs, start-up costs, variable operations and maintenance as well as emissions penalties (in California) for existing coal and natural gas power plants. This analysis uses the AURORA model to estimate changes in the total production cost for three regions (Pacific Northwest, California and the rest of the Western United States) as described in Section 5.1.2, *Social Welfare Effects* Based on the Production Cost Method.

Table 5-10 presents the total production costs by region for the No Action Alternative and the difference for each alternative. The replacement resource variable costs are included in these totals as well. This retail rate estimation analysis only applies the change in production costs for the Pacific Northwest region and excludes the replacement resource variable costs (which are already accounted for in the resource financing scenarios). The AURORA model is not able to directly allocate these costs to utilities as this analysis requires so to allocate these costs to regional IOUs the amount of fossil fuel use for each utility was estimated with recent generation data. The change in production costs was then applied to the retail rates of regional IOUs based on their respective levels of fossil fuel generation.

Retail Rate Calculation. Taking the components described above, the analysis calculates and forecasts retail rates for 2022. The calculation for retail rate effects for utilities that purchase Bonneville wholesale power is:

Estimated retail rate = weighted wholesale power rate + transmission rate pressure + other non-wholesale power costs

Where the wholesale power rate is a weighted combination of the Bonneville wholesale price, the market price and any replacement resource costs ($/MWh); the transmission rate pressure is a cents per kWh value derived by multiplying the utility specific rate pressure by the assumed transmission portion of the retail rate; and the other non-wholesale power costs includes administrative costs, distribution costs and transmission costs included in end-user retail rates.

The analysis weights the wholesale power rate by the fraction of total retail load purchased directly from Bonneville and then assumes the rest (net of owned existing resources) would be purchased from the market at the average annual market price for that action alternative. The analysis discounts the difference between each action alternative and the No Action Alternative wholesale rate based on the fraction of owned resources used by utility to best reflect the mixture of wholesale power costs utilities pay. For the region-finances scenarios, the wholesale power rate estimate also includes the replacement resource costs assuming 4,246 MW of coal dedicated to serving regional load (see below).

For other non-wholesale power costs, the analysis assumes the MOs do not affect these costs and holds the estimated costs constant between MOs. The analysis takes these costs from the forecasted 2022 retail rate, using NW Council rate forecasts and historical retail rate data. For entities that do not buy firm power on a long-term basis, which include some regional public bodies and IOUs, the analysis examines the transmission rate pressure, changes in production costs and the market effect as the effects on their retail rates. These utilities do not purchase firm power from Bonneville and the replacement resource analysis assumes they do not to participate in the "consortium" of utilities that purchase replacement power in the Region-finance scenario, as described below. The estimate of changes in production costs and market effects distributes the difference relative to the No Action Alternative across the entire total utility retail load along with the transmission rate pressure for that action alternative to determine effects on non-Bonneville customer retail rate pressure.

Table 5-15. Example Retail Rate Pressure Calculation, (Illustrative Example)

Utility / Column	Wholesale Rate ($/MWh) / A	Market Price ($/MWh) / B	Portion of Power from Bonneville (%) / C	Weighted Wholesale ($/MWh) / E[1/]	Non-Power Costs ($/MWh) / F	Transmission Rate Delta (cents/kWh) / G	Estimated Retail Rate (cents/kWh) / H[2/]
Utility A	30	22	100	30.0	35	0.01	6.51
Utility B	40	22	90	38.2	50	0.02	8.82
Utility C	50	22	90	47.2	40	0.01	8.73

1/ Weighted Wholesale (column E) = (C*A)+((1-C)*B)
2/Estimated Retail Rate (H) = (E+F)/1000+G

One important analytical step in the retail rate pressure analysis is the differentiation of replacement resource financing between the Bonneville or Region financing scenario. Following the calculation of Bonneville wholesale power rates, this step of the analysis determines the total cost of the replacement resource and the total generation dispatch of the replacement resources. Chapter 2 of this appendix, *Power Supply and Replacement* Resources presents the

costs of the replacement resources by scenario and AURORA produced the average generation for the replacement resources for each action alternative assuming 4,246 MW of coal dedicated to serving regional load. Table 5-16 summarizes these results in MWh by alternative and portfolio. The analysis assumes that the generation of these resources does not change based on who finances the resource.

Table 5-16. Generation from Replacement Resources Estimated by AURORA, for the Base Case Without Additional Coal-Plant Retirements (MWh)

Alternative	Zero-Carbon (solar generation)	Conventional Least-Cost (natural gas generation)
MO1	2.8 million	240,000
MO2	N/A	
MO3	6.0 million	6.0 million
MO4	12 million	1.4 million
PA	N/A	

Note: Estimates rounded to two significant digits. MO2 and the Preferred Alternative do not require replacement resources to match the reliability of the No Action Alternative.

The rate estimation allocates costs and the generation of the replacement resources based on the amount of non-federal power acquired by a regional public utility. The rate estimation spread the replacement resource costs across the total retail load of the regional utilities. If a utility does not purchase any of its power supply from Bonneville and thus would not lose power from Bonneville in MO1, MO3, or MO4 then no costs for replacement resources were allocated to that utility. Thus, the region finance scenario reflects a hypothetical group or "consortium" of regional public utilities that are no longer receiving as much power from Bonneville coming together to finance and acquire power from the replacement resources to serve their load and to restore regional reliability to the No Action Alternative level.

For both MO3 and MO4, the total generation estimated from solar power under the zero-carbon portfolio exceeded the total retail load needs of the consortium. To best reflect the total costs, the excess generation from the replacement resources the analysis assumed the consortium utilities would sell this power at the average market price. These analytical steps generated a wholesale power cost for each utility assumed to be a part of the consortium, the retail rate analysis then used this wholesale power cost for all power not coming from Bonneville.

Under each financing scenario, financing assumptions led to small differences in the total cost of replacement portfolios. Chapter 2, *Power Supply and Replacement* Resources and Chapter 4 of this appendix, *Wholesale Power and Transmission* Rates detail these portfolios and the cost assumptions, respectively. In addition, the Bonneville estimate of variable costs (fuel) for the conventional least-cost portfolio relies on critical water year generation, for consistency with typical Bonneville forecasting practice in its ratemaking procedure. This results in higher generation from the gas-fired power plants than in the region-replace scenario. While the

analysis did not deviate from Bonneville's ratemaking forecasting practice, regional utilities would not be bound by such practice.

5.4.1.6 Retail Rate Structures and Cost Mechanisms

The retail rate pressure analysis assumes that multiple components of retail rate costs do not change with the CRSO MOs. These components include administrative costs or delivery charges that an individual utility may charge their customers either as a flat service fee or based on usage (such as per kWh consumed). In addition, the basis for these estimates come from the most recent year of retail rate data forecasted out with 2022, without accounting for additional potential changes in rate structures or more complex ratemaking adjustments by individual utilities. These rate changes could have changes in wholesale PF power rates that could affect end user retail rates, but analysis of the exact effects is too speculative at this time. Similarly, the analysis did not make any assumptions about future power plant construction or planned changes beyond the baseline dataset, which could affect the load of certain utilities in the future, instead as noted it follows the "base-case" analysis of no additional coal retirements.

The retail rate pressure analysis also does not estimate the exact cost associated with power generating resources used by public utilities that are also served by Bonneville as determining that cost would be too speculative. Instead the retail rate analysis weighted the increase in Bonneville wholesale power rate pressure by the percentage of the total retail load served by owned and existing resources. For example, if a specific utility would experience a $5/MWh increase in their Bonneville rate under an action alternative but they serve 20 percent of their total retail load with their own resources then the effect on their retail rate would be $4/MWh ($5 multiplied by one minus 20%).

5.4.1.7 Inclusion of Non-Bonneville Wholesale Power Customers

The regional economic effects analysis includes all utilities in the Pacific Northwest. This includes both Bonneville firm power customers and those that do not currently purchase firm requirements power under long-term contracts from Bonneville. IOUs and public utilities that do not purchase firm power from Bonneville are still affected through market purchases and transmission rate pressure; however they would not be impacted by wholesale power changes, the more direct effect of the CRSO EIS alternatives. As such, the end user rate pressures, presented in aggregate and weighted geographically as described above, may not highlight the direct impact to Bonneville's firm power customers. These customers would bear a larger portion of the costs. Therefore, in the geographic presentation of rates the counties with larger effects are generally those served by a firm power customer of Bonneville.

5.2.1.1 End User Groups

The analysis estimates retail rate pressure for three end user groups with unique electricity rate and consumption characteristics: residential, commercial and industrial. As with the whole rates analysis, this analysis estimates the potential change in retail rates assuming that retail rate pressures lead to an increase in the actual retail rates (though this may not always be the

case if utilities are able to balance out some of the added costs under the MOs). To distribute the effects of each retail rate aspect above, the DOE and NREL (2018) utility rate database identifies different historical retail rates for each end user group. The EIA defines the three end user groups as:

- **Residential**: consumers using electricity for household purposes such as heating, cooking, appliance use or any other residential uses in single and multi-family dwellings, apartments or mobile homes.
- **Commercial**: service-providing businesses as well as the equipment of businesses. The commercial sector includes government facilities as well as institutional living quarters and sewage treatment facilities. Typical electricity uses include using a wide range of equipment, lighting, refrigeration and heating/cooling.
- **Industrial**: all facilities that produce, process or assemble goods. Typical electricity uses include powering machinery, lighting and heating/cooling. Many industrial sector energy consumers generate electricity and use the heat produced from those processes within industrial activity. The North American Industry Classification System (NAICS) codes defined for industrial end users are:
    - NAICS 31-33: Manufacturing
    - NAICS: 11: Agriculture, forestry, fishing and hunting
    - NAICS 21: Mining, including oil and gas extraction
    - NAICS 23: Construction

The analysis uses the number of households as the estimate for residential end users. The commercial end user group includes all commercial establishments, except for those that are in the industrial NAICS codes listed above (i.e., all business establishments minus the industrial businesses). The industrial end user group includes all business entities included in the NAICS codes listed above.

For any utility that did not have historical data available on specific end user retail rates, the analysis adopts the average regional retail rate. The majority of regional utilities have public rate information available with only a small portion of end users being covered by utilities without this information.

RETAIL RATE RESULT BY END USER GROUP

Table 5-17 presents the average retail rate results by alternative for residential, commercial and industrial end-users. Section 5.2.2, *Regional Economics Results and Geographic Analysis*, describes how the analysis further breaks down these rate effects by county to generate a range of county level rate estimates and categorizes the effects into a range to contextualize the effects. Table 5-19 below presents the rate results showing the number of households and businesses that experience the specific range of average effects.

Table 5-17. Weighted Average Retail Rates by Action Alternative and Scenario (cents per kWh)

End User Group	Scenario	NAA	MO1	MO2[1 and 2/]	MO3	MO4	PA[2/]
Residential	Bonneville Finances Zero-Carbon	10.21	10.27	10.16	10.57	10.48	10.24
	Region Finances Zero-Carbon		10.28		10.55	10.48	
	Bonneville Finances Conventional Least-Cost		10.27		10.37	10.52	
	Region Finances Conventional Least-Cost		10.27		10.36	10.48	
Commercial	Bonneville Finances Zero-Carbon	8.89	8.96	8.85	9.26	9.17	8.93
	Region Finances Zero-Carbon		8.96		9.23	9.17	
	Bonneville Finances Conventional Least-Cost		8.96		9.05	9.21	
	Region Finances Conventional Least-Cost		8.95		9.05	9.17	
Industrial	Bonneville Finances Zero-Carbon	7.25	7.31	7.20	7.61	7.52	7.28
	Region Finances Zero-Carbon		7.31		7.59	7.52	
	Bonneville Finances Conventional Least-Cost		7.31		7.40	7.55	
	Region Finances Conventional Least-Cost		7.31		7.40	7.52	

1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection at McNary could be achieved by a less costly option. Without the structure, rates under MO2 would be lower.

2/ MO2 and the Preferred Alternative do not include separate estimates by scenario since they do not require replacement resources.

5.2.2 Regional Economics Results and Geographic Analysis

To estimate the effect of CRSO alternatives on specific populations and regions, the analysis combines retail rates for regional Bonneville and non-Bonneville customers into average county retail rates using a geographic weighting process. To determine average county-level retail rates for the socioeconomic analysis, the analysis weights utility rates at the county level based on the estimated portion of households, commercial and industrial entities served by a utility in that county. The regional analysis uses ArcGIS, the industry standard geographic information system (GIS) program developed by Esri to analyze and map the results of the socioeconomic analysis.

The analysis examines county and zip-code level data with utility matching information provided by Bonneville and relies on publicly available GIS data sourced from Bonneville and its

Geospatial Portal to confirm the matching of utilities.[43] The data available includes shapefiles for the Bonneville service area (the area of analysis for the power rates and socioeconomic analysis) and for public utilities across the region. The geographic analysis allowed allocation of retail rate changes to specific counties. An estimate of the households per county and a "centroid method," using geographic information system (GIS) software, utility data and census data, generate an estimate of the percent of each county served by each utility.[44] Some counties are served by multiple utilities while others are served by a single utility. In addition, counties are variably served by Bonneville public utilities customers, public utilities that are not Bonneville customers, IOUs, or some combination of utilities. Section 5.2.3, *Summary of Regional Economic Effects Results*, presents the mapped results of county level rate effects.

Table 5-18 provides an example of the geographic weighting that generated county-level retail rate pressures. County-level data from the U.S. Census determines the number of residential, commercial and industrial end-users in each county. In addition, the analysis uses U.S. Census data matched to state and county boundaries primarily using TIGER/Line shapefiles.[45] This data allowed linking the retail rate results by county to the results maps (see Section 5.2.3, , *Summary of Regional Economic Effects Results*, and Figure 5-1. Average 2022 Estimated Residential Rate, No Action Alternative (cents per kWh) through Figure 5-6. Preferred Alternative Average Residential Rate Pressure by County (% Change from the No Action Alternative)). For the purpose of estimating rates, the analysis assumes that geographic boundaries across counties do not shift over time (i.e., no utility service territories change over time).

Table 5-18. Geographic Weighting Process (Illustrative Example)

County / A	Utility / B	Portion of County Households Served / C	Utility Retail Rate (cents/kWh) / D	Weighted Retail Rate (cents/kWh) / E[1/]	County Retail Rate (cents/kWh) / F[2/]
County X	Utility A	25%	10	2.5	10.5
	Utility B	50%	12	6	
	Utility C	25%	8	2	

1/Weighted retail rate (column E) = C*D

2/ County Retail Rate (column F) = D1+D2+D3

[43] The Bonneville Geospatial portal provides GIS shapefiles of all utilities that purchase power from Bonneville in the Pacific Northwest as well as regional IOUs and Bonneville transmission infrastructure. This geospatial data is available at: https://bpagis.maps.arcgis.com/home/index.html

[44] The centroid method identifies the center of individual census block groups (the smallest geographic unit of census data) and then matches the corresponding utility based on which utility overlaps the center. This analysis uses utility shapefiles and census American Community Survey data. This method was not directly applied to utility weighting (i.e., the percent of a county served by a specific utility) but was instead applied to validate the estimated weighting provided by other data sources.

[45] The U.S. Census generates geographic data as Tiger/Line files that provide a standard geographic identifier to link census surveys and data for GIS mapping. These files do not provide demographic data but can be linked to demographic data from the American Community Survey. Tiger/Line data is available at: https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
American Community Survey data is available at: https://data.census.gov/cedsci/.

The analysis weights rates by county for each end-user group to estimate residential, commercial and industrial rate pressure.

The rates analysis weights the average rate pressure effect across the region by residential customers (i.e., households) to estimate the average rate pressure effect by county and then categorizes the number of households experience a specific range of rate pressure effects. Table 5-19 presents this categorization and the results by alternative. For context, the average year-to-year upward rate pressure is between 2 and 3 percent. As noted above, certain counties that are not directly affected by wholesale power and transmission changes would largely have no or very little effect. The counties served by utilities that get most or all of their power from Bonneville would experience larger upward rate pressure effects in the base case. Increases or decreases relative to the No Action Alternative are expected to be larger for MO2 (i.e. larger downward rate pressure) and MO3 (larger upward rate pressure) with additional coal-plant closures. As described in Section 3.7.3.3 of the main body of the EIS, the analysis considers the sensitivity of these results to additional factors as well as coal retirements (such as integration services and financing assumptions) potentially affecting power and transmission rates, generally finding that potential upward rate pressure effects are understated.

Table 5-19. Percent of Households in Northwest that Experience the Range of the Rate Pressures, for the Base Case Without Additional Coal-Plant Closures

Scenario		Percent of Regional Households Experiencing the Range of Rate Pressure					
		Increase Above 10%	Increase above 5%	Increase between 2.5 and 5 %	Increase below 2.5% above 1%	Increase from 0% to 1%	Decrease
MO1	Bonneville Finances Zero-Carbon	0%	0%	6.0%	24%	45%	25%
	Region Finances Zero-Carbon	0%	1.2%	3.1%	25%	46%	25%
	Bonneville Finances Conventional Least-Cost	0%	0.0%	0.0%	27%	73%	0%
	Region Finances Conventional Least-Cost	0%	0%	1.2%	14%	85%	0%
MO2	MO2[1/]	0%	0%	0%	0%	2.9%	97%
MO3	Bonneville Finances Zero-Carbon	0%	21%	58%	18%	3.1%	0%
	Region Finances Zero-Carbon	1.6%	4.8%	70%	20%	3.9%	0%
	Bonneville Finances Conventional Least-Cost	0%	0%	20%	44%	37%	0%
	Region Finances Conventional Least-Cost	0%	2.0%	12%	49%	37%	0%

Scenario		Percent of Regional Households Experiencing the Range of Rate Pressure					
		Increase Above 10%	**Increase above 5%**	**Increase between 2.5 and 5 %**	**Increase below 2.5% above 1%**	**Increase from 0% to 1%**	**Decrease**
MO4	Bonneville Finances Zero-Carbon	0.25%	26%	9.6%	33%	31%	0%
	Region Finances Zero-Carbon	3.9%	17%	13%	29%	37%	0%
	Bonneville Finances Conventional Least-Cost	0.0%	20%	21%	47%	12%	0%
	Region Finances Conventional Least-Cost	0.79%	10%	25%	51%	12%	0%
PA	PA	0.0%	0.0%	0.0%	0.66%	99%	0%

Note: Values are rounded to two significant digits and may not sum to 100 due to rounding.
1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection could be achieved by a less costly option. Without the structure, rates under MO2 would be lower.

The regional economic analysis also considers different geographic categorization: CRSO Regions and rural or urban areas. The geographic analysis takes additional county-level data and assigns each county to the CRSO Regions. The analysis of regions follows the standard CRSO regions (A, B, C, D and Other) presented throughout the EIS. Figure 1-2 presents a map of the regions. The rates analysis assigns all counties that did not fall into Regions A through D counties to be in the "Other" Region. Table 5-20 presents the residential retail rate pressures by CRSO Region.

Table 5-20. Average No Action Alternative Residential Retail Rate and Rate Pressure (Percent Change) for Each MO by CRSO Region for the Base Case Without Additional Coal-Plant Closures

Scenario		Region A	Region B	Region C	Region D	Other
NAA	NAA Rate	10.13	8.32	10.04	9.43	10.49
MO1	Bonneville Finances Zero-Carbon	1.1%	0.63%	0.36%	1.2%	0.66%
	Region Finances Zero-Carbon	0.86%	1.2%	0.31%	1.7%	0.58%
	Bonneville Finances Conventional Least-Cost	0.81%	0.60%	0.44%	1.0%	0.69%
	Region Finances Conventional Least-Cost	0.64%	0.75%	0.39%	1.0%	0.56%
MO2	MO21/	-0.40%	-0.32%	-0.34%	-0.37%	-0.40%
MO3	Bonneville Finances Zero-Carbon	4.6%	2.4%	1.7%	4.2%	3.6%
	Region Finances Zero-Carbon	3.1%	3.5%	1.3%	5.0%	3.1%
	Bonneville Finances Conventional Least-Cost	1.6%	1.6%	1.0%	2.4%	1.6%
	Region Finances Conventional Least-Cost	1.2%	2.0%	0.92%	2.8%	1.5%

Scenario		Region A	Region B	Region C	Region D	Other
MO4	Bonneville Finances Zero-Carbon	3.8%	3.0%	1.6%	5.0%	2.6%
	Region Finances Zero-Carbon	2.3%	4.0%	1.3%	6.1%	2.4%
	Bonneville Finances Conventional Least-Cost	3.4%	2.9%	2.0%	4.6%	3.1%
	Region Finances Conventional Least-Cost	2.3%	3.3%	1.7%	4.7%	2.6%
PA	PA	0.34%	0.24%	0.21%	0.44%	0.34%

1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection could be achieved by a less costly option. Without the structure, rates under MO2 would be lower.

For the designation of rural and urban areas, the analysis applies Rural Urban Continuum (RUC) codes. RUC codes use U.S. Census Bureau data to subdivide the Office of Management and Budget's classification of metropolitan and non-metropolitan areas into a more detailed breakdown of nine county distinctions. These categories distinguish between counties within, adjacent to, or nonadjacent to, a metropolitan area by population levels. Table 5-21 lists these categories and their definitions.

Table 5-21. Rural-Urban Continuum (RUC) Codes and Definitions

RUC Code	Definition
1 – Metro	Counties in metro areas of 1 million population of more
2 – Metro	Counties in metro areas of 250,000 to 1 million population
3 - Metro	Counties in metro areas of fewer than 250,000 population
4 – Nonmetro	Urban population of 20,000 or more, adjacent to a metro area
5 – Nonmetro	Urban population of 20,000 or more, not adjacent to a metro area
6 – Nonmetro	Urban population of 2,500 to 19,999, adjacent to a metro area
7 – Nonmetro	Urban population of 2,500 to 19,999, not adjacent to a metro area
8 - Nonmetro	Completely rural or less than 2,500 urban population, adjacent to a metro area
9 – Nonmetro	Completely rural or less than 2,500 urban population, not adjacent to a metro area

For the CRSO EIS analysis, the regional economic effects analysis matches each county to the appropriate RUC code and generated a weighted average rate pressure for each categorization. Table 5-22 presents the breakdown of the average rate pressure by scenario by county type. The rate pressure would be larger for customers of public utilities receiving power from Bonneville and lower for others.

Table 5-22. Average No Action Alternative Residential Rate and Rate Pressure Relative to the No Action by RUC Code, for the Base Case Without Additional Coal-Plant Closures

CRSO Alternative and Scenario		Rural-Urban Continuum Code								
		1	2	3	4	5	6	7	8	9
		Metropolitan			Urban				Rural	
NAA	NAA Rate	10.37	10.17	10.02	10.21	10.09	9.67	9.72	10.22	11.64
MO1	Bonneville Finances Zero-Carbon	0.88%	0.57%	0.16%	0.97%	0.73%	1.0%	1.3%	0.56%	0.47%
	Region Finances Zero-Carbon	0.79%	0.70%	0.40%	0.99%	0.60%	1.4%	1.2%	0.61%	0.35%
	Bonneville Finances Conventional Least-Cost	0.82%	0.56%	0.42%	0.90%	0.74%	0.83%	1.0%	0.54%	0.48%
	Region Finances Conventional Least-Cost	0.65%	0.55%	0.48%	0.78%	0.61%	0.89%	0.83%	0.51%	0.37%
MO2	MO2[/1]	-0.35%	-0.36%	-0.54%	-0.39%	-0.56%	-0.29%	-0.37%	-0.32%	-0.30%
MO3	Bonneville Finances Zero-Carbon	4.1%	3.1%	2.8%	3.7%	3.9%	3.4%	4.5%	3.4%	2.5%
	Region Finances Zero-Carbon	3.6%	3.3%	3.2%	3.5%	3.0%	3.5%	3.3%	3.1%	1.8%
	Bonneville Finances Conventional Least-Cost	1.8%	1.4%	1.2%	2.0%	1.6%	1.7%	2.0%	1.2%	1.0%
	Region Finances Conventional Least-Cost	1.7%	1.5%	1.4%	2.0%	1.4%	1.9%	1.7%	1.2%	0.79%
MO4	Bonneville Finances Zero-Carbon	3.2%	2.5%	1.6%	3.8%	3.0%	3.6%	4.6%	2.3%	1.8%
	Region Finances Zero-Carbon	3.1%	2.8%	2.0%	3.9%	2.1%	3.7%	3.6%	2.0%	1.1%
	Bonneville Finances Conventional Least-Cost	3.5%	2.7%	2.3%	3.9%	3.3%	3.4%	4.1%	2.4%	2.0%
	Region Finances Conventional Least-Cost	3.0%	2.6%	2.4%	3.5%	2.5%	3.1%	3.1%	2.1%	1.4%
PA	PA	0.40%	0.25%	0.22%	0.43%	0.36%	0.36%	0.43%	0.25%	0.23%

1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection could be achieved by a less costly option. Without the structure, rates under MO2 would be lower.

5.2.2.1 Expenditure Effects Analysis

Following the estimation of average retail rates by county, quantified in Step 5, the regional economic effects analysis forecasts the rate effects over time and translates the county-level retail rate effects into changes in spending on electricity and the costs of living and doing business for Pacific Northwest residents and businesses under each alternative compared to the No Action Alternative. The analysis quantifies the effects that alternatives would have on spending levels for residents and businesses for electricity over the 20-year timeframe. This requires forecasting the average county-level retail rate and load over the following 20 years using load and rate forecasts from the NW Council and described below. The forecasts for retail rates and loads for residential consumers include low, medium, and high scenarios, which reflect the uncertainty regarding assumptions.

The analysis forecasts retail electricity rates and the loads by end user from 2022 to 2041 to generate a long term rate and expenditures forecast. The analysis presents rate dollar values in 2019 dollars deflated using the Bonneville common agency financing assumptions. For each action alternative the retail rate forecast and load forecasts all derive from NW Council data and are not adjusted between alternatives. To reflect uncertainty, the analysis considers three levels of forecasts: high, medium and low. Table 5-23 below presents the average regional forecast rates.

Table 5-23. Forecast Growth of Regional Electricity Rates, for the Base Case Without Additional Coal-Plant Closures

Scenario	Rate Forecast (real growth rate, adjusted for inflation)	Load Forecast		
		Residential	Commercial	Industrial
High	+0.98%	-1.4%	+0.50%	+1.0%
Medium	-0.68%	-1.6%	+0.22%	+0.71%
Low	-0.98%	-1.9%	-0.21%	+0.29%

The transmission rate pressure estimates an annualized effect that extends out through BP-28. To forecast retail rates beyond 2022, the analysis relies on NW Council data and applies the annualized transmission rate pressure for each year through 2029 (i.e., BP-28). This results in increasing differences between the No Action Alternative and the Multiple-Objective Alternatives (MOs). The transmission rate pressure is the only retail rate variable that fluctuates year over year in the analysis. The power rates analysis (see Section 4.2, *Transmission Rate Pressure* Analysis*,* of this analysis) estimates wholesale power rates before and after the alternative is implemented, projected, calculated for 2022. Table 5-24**,** Table 5-25 and Table 5-26 below present the average residential retail rate pressure over time for each action alternative relative to the No Action Alternative. All rate pressures (i.e., transmission rate pressure) are held constant after 2030 through 2041.

Table 5-24. Residential Rate Pressures Over Time, Medium Scenario, for the Base Case Without Additional Coal-Plant Closures

Scenario		2022	2024	2026	2028	2030
NAA	NAA Rate	10.21	10.07	9.93	9.79	9.66
MO1	Bonneville Finances Zero-Carbon	0.71%	0.87%	1.03%	1.2%	1.3%
	Region Finances Zero-Carbon	0.74%	0.90%	1.1%	1.2%	1.3%
	Bonneville Finances Conventional Least-Cost	0.70%	0.89%	1.1%	1.3%	1.4%
	Region Finances Conventional Least-Cost	0.62%	0.81%	1.00%	1.2%	1.3%
MO2[1/]	MO2[1/]	-0.39%	-0.37%	-0.34%	-0.31%	-0.29%
MO3	Bonneville Finances Zero-Carbon	3.6%	4.0%	4.4%	4.8%	5.0%
	Region Finances Zero-Carbon	3.4%	3.8%	4.2%	4.6%	4.8%
	Bonneville Finances Conventional Least-Cost	1.6%	2.0%	2.3%	2.7%	2.9%
	Region Finances Conventional Least-Cost	1.6%	2.0%	2.3%	2.7%	2.8%
MO4	Bonneville Finances Zero-Carbon	2.9%	3.4%	3.9%	4.4%	4.6%
	Region Finances Zero-Carbon	2.9%	3.4%	3.9%	4.4%	4.6%
	Bonneville Finances Conventional Least-Cost	3.2%	3.6%	4.0%	4.4%	4.6%
	Region Finances Conventional Least-Cost	2.8%	3.2%	3.6%	4.0%	4.3%
PA	PA	0.33%	0.36%	0.38%	0.40%	0.41%

Note: Rate effect is held constant after 2030 through 2041.

1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection could be achieved by a less costly option. Without the structure, rates under MO2 would be lower.

Table 5-25. Residential Rate Pressures Over Time, High Scenario, for the Base Case Without Additional Coal-Plant Closures

Scenario		2022	2024	2026	2028	2030
NAA	NAA Rate	10.21	10.41	10.61	10.82	11.04
MO1	Bonneville Finances Zero-Carbon	0.71%	0.87%	1.0%	1.2%	1.2%
	Region Finances Zero-Carbon	0.74%	0.90%	1.0%	1.2%	1.3%
	Bonneville Finances Conventional Least-Cost	0.70%	0.89%	1.1%	1.2%	1.3%
	Region Finances Conventional Least-Cost	0.62%	0.80%	0.98%	1.2%	1.2%
MO2[/1]	MO2[1/]	-0.39%	-0.37%	-0.34%	-0.31%	-0.30%
MO3	Bonneville Finances Zero-Carbon	3.6%	4.0%	4.4%	4.7%	4.9%
	Region Finances Zero-Carbon	3.4%	3.8%	4.1%	4.5%	4.7%
	Bonneville Finances Conventional Least-Cost	1.6%	2.0%	2.3%	2.6%	2.8%
	Region Finances Conventional Least-Cost	1.6%	1.9%	2.3%	2.6%	2.8%
MO4	Bonneville Finances Zero-Carbon	2.9%	3.4%	3.8%	4.3%	4.5%
	Region Finances Zero-Carbon	2.9%	3.4%	3.8%	4.3%	4.5%
	Bonneville Finances Conventional Least-Cost	3.2%	3.6%	3.9%	4.3%	4.5%
	Region Finances Conventional Least-Cost	2.8%	3.2%	3.6%	4.0%	4.2%
PA	PA	0.33%	0.36%	0.38%	0.40%	0.41%

Note: Rate effect is held constant after 2030 through 2041.

1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection could be achieved by a less costly option. Without the structure, rates under MO2 would be lower.

Table 5-26. Residential Rate Pressures Over Time, Low Scenario, for the Base Case Without Additional Coal-Plant Closures

Scenario		2022	2024	2026	2028	2030
NAA	NAA Rate	10.21	10.01	9.81	9.62	9.43
MO1	Bonneville Finances Zero-Carbon	0.71%	0.87%	1.0%	1.2%	1.2%
	Region Finances Zero-Carbon	0.74%	0.90%	1.1%	1.2%	1.3%
	Bonneville Finances Conventional Least-Cost	0.70%	0.89%	1.1%	1.3%	1.4%
	Region Finances Conventional Least-Cost	0.62%	0.81%	1.0%	1.2%	1.3%
MO2[1/]	MO2[1/]	-0.39%	-0.37%	-0.34%	-0.31%	-0.29%
MO3	Bonneville Finances Zero-Carbon	3.6%	4.0%	4.4%	4.8%	5.0%
	Region Finances Zero-Carbon	3.4%	3.8%	4.2%	4.6%	4.8%
	Bonneville Finances Conventional Least-Cost	1.6%	2.0%	2.3%	2.7%	2.9%
	Region Finances Conventional Least-Cost	1.6%	2.0%	2.3%	2.7%	2.8%
MO4	Bonneville Finances Zero-Carbon	2.9%	3.4%	3.9%	4.4%	4.7%
	Region Finances Zero-Carbon	2.9%	3.4%	3.9%	4.4%	4.6%
	Bonneville Finances Conventional Least-Cost	3.2%	3.6%	4.0%	4.4%	4.6%
	Region Finances Conventional Least-Cost	2.8%	3.2%	3.6%	4.1%	4.3%
PA	PA	0.33%	0.36%	0.38%	0.40%	0.41%

Note: Rate effect is held constant after 2030 through 2041.

1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection could be achieved by a less costly option. Without the structure, rates under MO2 would be lower.

Finally, the analysis estimates end-user responses to price changes (i.e., reducing demand due to price increase), also referred to as elasticity of demand, which considers the estimated short- and long-term elasticities for residential and commercial user groups based on EIA data. The elasticities section below describes these estimates and the literature review surrounding them. All of the rate and spending estimates are compared back to the No Action Alternative to produce dollar value changes and percentage changes relative to the No Action Alternative.

END-USER CONSUMPTION

The rates analysis derives end-user electricity consumption for households from NW Council load forecasts and the forecast of the number of households. The estimate of average household electricity consumption equals the total residential load divided by total number of households estimated in 2022.

The NW Council does forecast commercial and industrial load, however it does not forecast the number of commercial or industrial entities in the same manner as households, instead focusing on commercial floor space and industrial production ($ by industry). Thus, the analysis relies on EIA data to provide average consumption information for commercial and industrial end users. The average monthly consumption from the EIA was multiplied to get an annual value then forecasted to 2022 estimated levels based on NW Council load forecasts for commercial and industrial end-users, consistent with the rate estimates. The analysis does not consider county or utility level differences between consumption, only state level estimates

based on NW Council and EIA data. For the counties outside of the Pacific Northwest, the forecast applies the regional average load growth to 2022.

Table 5-27. 2022 Annual Consumption Estimates, (MWh/year)

State	Residential	Commercial	Industrial
Idaho	10	54	290
Montana	12	42	590
Oregon	9.7	63	610
Washington	10	76	930
California	6.8	64	380
Nevada	11	57	4,100
Wyoming	11	61	1,000

Note: Estimates are rounded to two significant figures.

As described in Section 3.7.3 *Power and Transmission Environmental Consequences*, for context and comparison of changes in generation, the analysis assumes that roughly 796 regional households consume 1 aMW per year (NW Council 2019). This equates to an average across the region of 11 MWh per household per year. For example, the city of Everett, WA consumes roughly 136 aMW per year. This average household consumption is slightly lower than the end user consumption estimates generated from EIA and NW Council data. However, the analysis uses this figure to generate comparisons and provide context for the amount of power generation change in each action alternative not explicitly for the spending and consumption estimates.

Over time, the consumption estimates change based on the forecasted growth rates in Table 5-27**.** The analysis multiplies this average consumption by the average rate in each county to estimate the annual expenditures by end user group and by county. For each action alternative, the regional economic analysis applies elasticity estimates to the level of consumption estimate, based on the percentage rate change and the elasticities described below. Table 5-30 below presents the expenditure results.

ELASTICITIES AND EXPENDITURE EFFECTS

Consistent with economic theory, price increases typically cause consumers to adjust their consumption based on the price effect. For most goods, when price increases, demand falls. These demand changes based on price changes are the “price elasticity” of a good. The CRSO EIS analysis includes a literature review to determine the most appropriate elasticity estimates for all three end user groups. Economists often identify short-run and long-run elasticities due to the fact that consumers might not be able to adapt consumption immediately, but with a sustained price increase, would adjust over time. Long-run elasticities are thus larger than short-run elasticities.

EIA estimates for the short run are in a similar range with short-run elasticities of -0.12 for year 1 and -0.21 for year 2. For industrial end users the EIA uses various data sources to consider ranges for energy-intensive industries and non-energy-intensive industries. EIA estimates ranged from -0.2 to -1.3 depending on the industry and the level of energy-intensiveness. Estimates for industrial end users often consider all energy and not just electricity with some considering potential fuel changing between fossil fuels and electricity (EIA 2018).

There is little consensus on the exact responsiveness of consumers to price effects; however most literature agrees that consumers do respond to price changes, despite relatively "inelastic" short-run responses (Electric Power Research Institute [EPRI] 2008; NREL 2006; National Economic Research Associates [NERA] 2015). Literature identifies multiple potential estimates for price elasticities for electricity, with most having very close to fully inelastic results in the short term (i.e., close to 0). Epsey and Epsey (2004) in a meta-analysis, identified a residential elasticity of -0.35 while Garcia-Cerruti (2000) found estimates for California of -0.17 with a wide range between different counties. A review of state, sector and temporal data for the U.S. found elasticities similarly inelastic at -0.1 in the short-run increasing to -1 in the long run (Abayasekara 2017). A review of literature in 2015 identified short-run elasticities ranging from -0.2 to -0.35 for residential end users and 0 to -0.22 for commercial and industrial end users (NERA 2015). These estimates are much higher for the long-run where some literature has identified elasticities over -1 for industrial end users and close to -1 for commercial and residential end users (NERA 2015).

Some literature has identified region and state specific elasticities (NREL 2006). The range for the Pacific Northwest short-run residential elasticity identified by NREL was +0.1 to -0.26. There is also the potential that price elasticity fluctuates with income levels, however the CRSO analysis does not take this potential range of elasticities into consideration (Reiss and White 2001).

For the CRSO EIS, the rates analysis uses EIA estimates for residential and commercial electricity use. These are consistent with other estimates provided in economics literature and are from a Federal source that was also relied upon for other electricity data.

Table 5-28. EIA Elasticity Estimates

End User Group	Year 1	Year 2	Year 3	Year 25
Residential	-0.12	-0.21	-0.24	-0.40
Commercial	-0.12	-0.20	-0.25	-0.82

Given the range of activities performed by industrial entities and the various industries that they represent, the analysis applies a conservative estimate for the short-term of -0.2 (the same as commercial entities). There is the potential in the longer term for industrial customers to be far more elastic (reduce consumption more), which would result in larger decreases in load and thus bills. As described above, there is a large range of elasticities for industrial end-users presented in the literature with potentially large variations between industries (EPRI 2008; EIA 2018).

The CRSO electricity expenditures analysis calculates the first-year elasticity effect to determine the amount of consumption that end users reduce based on the retail rate changes relative to the No Action Alternative rates. All expenditure estimates presented in the Power and Transmission Rates analysis factor in these elasticities estimates. Table 5-29 presents the estimated changes in expenditures when considering elasticities for each alternative

Table 5-29. Average Expenditures per Household by Alternative, Total Annual Expenditures under No Action and Percentage Difference by Action Alternative, for the Base Case Without Additional Coal-Plant Retirements

End User Group	Scenario	NAA Expenditures	Difference relative to NAA, %				
			MO1	MO2[1/]	MO3	MO4	PA
Residential	Bonneville Finances Zero-Carbon	$1,100	0.71%	-0.39%	3.6%	2.9%	0.33%
	Region Finances Zero-Carbon		0.74%		3.4%	2.8%	
	Bonneville Finances Conventional Least-Cost		0.70%		1.6%	3.1%	
	Region Finances Conventional Least-Cost		0.62%		1.6%	2.8%	
Commercial	Bonneville Finances Zero-Carbon	$5,900	0.75%	-0.48%	4.1%	3.0%	0.36%
	Region Finances Zero-Carbon		0.77%		3.8%	3.0%	
	Bonneville Finances Conventional Least-Cost		0.74%		1.7%	3.4%	
	Region Finances Conventional Least-Cost		0.66%		1.7%	3.0%	
Industrial	Bonneville Finances Zero-Carbon	$58,000	1.0%	-0.58%	5.1%	4.1%	0.48%
	Region Finances Zero-Carbon		1.0%		4.8%	4.1%	
	Bonneville Finances Conventional Least-Cost		0.98%		2.3%	4.5%	
	Region Finances Conventional Least-Cost		0.86%		2.2%	4.0%	

1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection could be achieved by a less costly option and rates would be lower under MO2.

In addition to the rate and load forecast, incomes increased by a real rate of 3.1 percent based on the NW Council 7th Power Plan economic appendices. To estimate the percent of income spent on electricity for residential end users, the analysis divided the total annual expenditures

by the estimated 2022 incomes, grown at the NW Council growth rate and deflated to 2019 dollars.

The analysis multiplied the estimated rates by estimates of annual consumption for each end-user group to determine the potential effect on average spending on electricity. The socioeconomic analysis then compared differences between MOs to the No Action Alternative level of expenditures.

Table 5-30. Average Percent of Household Income Spent on Electricity

Scenario	NAA	MO1	MO2[1/]	MO3	MO4	PA
Bonneville Finances Zero-Carbon	1.69%	1.70%	1.68%	1.75%	1.74%	1.70%
Region Finances Zero-Carbon		1.70%		1.75%	1.74%	
Bonneville Finances Conventional Least-Cost		1.70%		1.72%	1.74%	
Region Finances Conventional Least-Cost		1.70%		1.72%	1.4%	

Note: there is some variation between the financing and resource replacement portfolios, however they are not evident due to rounding.

1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection could be achieved by a less costly option. Without the structure, rates under MO2 would be lower.

IMPLAN MODELLING

The regional economic analysis consider how changes in the cost of electricity affects productivity (e.g., employment and output) across interconnected industries within the regional economy. This may occur, for example, if the increased cost of electricity changes household spending patterns, reducing the demand for other goods and services in the region. This analysis applies IMPLAN to model the increased spending on electricity as a reduction in household income (direct effect), and quantifies the multiplier effects on interrelated economic sectors (indirect and induced effects). IMPLAN is a widely used industry-standard input-output data and software system that is used by many Federal and state agencies to estimate regional economic effects.[46] The underlying data for IMPLAN is derived from multiple sources, including the Bureau of Economic Analysis, the Bureau of Labor Statistics, and the U.S. Census Bureau.

This analysis used IMPLAN to model the effect at the household levels as a change in household income and for commercial and industrial models it in IMPLAN as a change in output. All IMPLAN modelling was done at the state level and then aggregated to the regional level. The region was defined as Oregon, Washington and Idaho as well as the western counties in Montana that fall within the Bonneville service area. The counties in the Bonneville service area in Nevada, California, Wyoming and Utah were excluded from the IMPLAN analysis since the overall effect in these areas was relatively small.

Before using the IMPLAN model at the state level, the analysis estimates the total change in spending on electricity for each of the three sectors. To estimate this effect for each alternative

[46] For more information on the IMPLAN® system, visit http://www.implan.com/.

the total spending change was calculated by summing the effect by county (as described above) multiplied by the estimate of the number of customers, either households or commercial and industrial businesses, in that county. This generated state level changes in spending for each alternative compared to the No Action Alternative. These values were input into IMPLAN where state level multipliers were used.

The IMPLAN model traces expenditures by sector through the regional economy using industry-specific multipliers to estimate the total regional economic effects in terms of jobs, labor income, and sales. However, since IMPLAN does not categorize commercial and industrial electricity end users specifically, this analysis uses NAICS codes and the corresponding IMPLAN sector codes to identify the appropriate sector to examine changes in expenditure specific to commercial and industrial end users. Using the identified sectors in IMPLAN, the percentage of regional electricity spending was assessed in the model and the change in total spending was then assigned to these sectors using the appropriate multipliers.

There are four distinct multiplier effects that IMPLAN the model uses and the power and transmission analysis considers: output (sales), value added, labor income and employment.[47] IMPLAN further breaks down effects into direct, indirect and induced; this analysis presents the total effect across these three categories. Table 5-31, Table 5-32 and Table 5-33 provide the total output, value added, labor income and employments at the residential, commercial and industrial level by alternative.

[47] For more information on IMPLAN multipliers see: https://implanhelp.zendesk.com/hc/en-us/articles/115009505707-Understanding-Multipliers

2834 **Table 5-31. Household Income IMPLAN Results, by Alternative**

Alternative	Scenario	Output	Value Added	Labor Income	Employment
MO1	Bonneville Finances Zero-Carbon	$42 million	$25 million	$14 million	270 jobs
	Bonneville Finances Conventional Least-Cost	$42 million	$25 million	$14 million	270 jobs
	Region Finances Zero-Carbon	$43 million	$26 million	$14 million	270 jobs
	Region Finances Conventional Least-Cost	$37 million	$22 million	$12 million	240 jobs
MO2	MO2	-$25 million	-$15 million	-$8.3 million	-170 jobs
MO3	Bonneville Finances Zero-Carbon	$230 million	$130 million	$75 million	1,500 jobs
	Bonneville Finances Conventional Least-Cost	$99 million	$59 million	$33 million	630 jobs
	Region Finances Zero-Carbon	$210 million	$120 million	$69 million	1,400 jobs
	Region Finances Conventional Least-Cost	$97 million	$58 million	$32 million	620 jobs
MO4	Bonneville Finances Zero-Carbon	$170 million	$100 million	$56 million	1,100 jobs
	Bonneville Finances Conventional Least-Cost	$190 million	$110 million	$63 million	1,200 jobs
	Region Finances Zero-Carbon	$170 million	$100 million	$56 million	1,100 jobs
	Region Finances Conventional Least-Cost	$170 million	$100 million	$56 million	1,100 jobs
PA	PA	$20 million	$12 million	$6.7 million	130 jobs

2835 **Table 5-32. Commercial Spending IMPLAN Results, by Alternative**

Alternative	Scenario	Output	Value Added	Labor Income	Employment
MO1	Bonneville Finances Zero-Carbon	$21 million	$13 million	$6.7 million	140 jobs
	Bonneville Finances Conventional Least-Cost	$21 million	$13 million	$6.8 million	140 jobs
	Region Finances Zero-Carbon	$21 million	$13 million	$6.8 million	140 jobs
	Region Finances Conventional Least-Cost	$18 million	$12 million	$5.9 million	120 jobs
MO2	MO2	-$14 million	-$8.3 million	-$4.3 million	-97 jobs
MO3	Bonneville Finances Zero-Carbon	$120 million	$72 million	$38 million	810 jobs
	Bonneville Finances Conventional Least-Cost	$49 million	$31 million	$16 million	330 jobs
	Region Finances Zero-Carbon	$110 million	$68 million	$35 million	750 jobs

Alternative	Scenario	Output	Value Added	Labor Income	Employment
	Region Finances Conventional Least-Cost	$49 million	$31 million	$16 million	330 jobs
MO4	Bonneville Finances Zero-Carbon	$84 million	$53 million	$27 million	560 jobs
	Bonneville Finances Conventional Least-Cost	$96 million	$60 million	$31 million	650 jobs
	Region Finances Zero-Carbon	$85 million	$54 million	$27 million	560 jobs
	Region Finances Conventional Least-Cost	$86 million	$54 million	$27 million	580 jobs
PA	PA	$10 million	$6.5 million	$3.3 million	70 jobs

2836 **Table 5-33. Industrial Spending IMPLAN Results, by Alternative**

Alternative	Scenario	Output	Value Added	Labor Income	Employment
MO1	Bonneville Finances Zero-Carbon	$75 million	$47 million	$24 million	490 jobs
	Bonneville Finances Conventional Least-Cost	$76 million	$48 million	$24 million	490 jobs
	Region Finances Zero-Carbon	$74 million	$47 million	$24 million	480 jobs
	Region Finances Conventional Least-Cost	$65 million	$41 million	$21 million	420 jobs
MO2	MO2	-$44 million	-$27 million	-$14 million	-300 jobs
MO3	Bonneville Finances Zero-Carbon	$400 million	$250 million	$130 million	2,700 jobs
	Bonneville Finances Conventional Least-Cost	$170 million	$110 million	$56 million	1,100 jobs
	Region Finances Zero-Carbon	$370 million	$230 million	$120 million	2,400 jobs
	Region Finances Conventional Least-Cost	$170 million	$110 million	$55 million	1,100 jobs
MO4	Bonneville Finances Zero-Carbon	$310 million	$200 million	$99 million	2,000 jobs
	Bonneville Finances Conventional Least-Cost	$340 million	$220 million	$110 million	2,300 jobs
	Region Finances Zero-Carbon	$310 million	$200 million	$99 million	2,000 jobs
	Region Finances Conventional Least-Cost	$300 million	$190 million	$97 million	2,000 jobs
PA	PA	$37 million	$23 million	$12 million	240 jobs

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5.2.3 Summary of Regional Economic Effects Results

Table 5-34 presents the average estimated retail rates for each of the three end user groups and the MOs. The results weighted the change in rates by the number of entities (e.g., households) in each county and compared the rates to the No Action Alternative retail rate. Table 5-35 presents these final rate estimates with a weighted average effect in percentage terms as well as the full range (minimum and maximum effect) across the counties of the Pacific Northwest. Figure 5-1. Average 2022 Estimated Residential Rate, No Action Alternative (cents per kWh) through Figure 5-6. Preferred Alternative Average Residential Rate Pressure by County (% Change from the No Action Alternative) present the residential retail rate pressure results by county in map form for comparison. Chapter 6 (Table 6-1) contains the residential rate result by county for the entire study area.

This analysis did not include the effects of additional coal-plant retirements that were announced regionally after the analysis was initiated. Factoring in the effect of additional coal-plant retirements would likely raise the rates in MO3, lower them in MO2, and not raise them as much in MO1 and MO4 relative to the No Action Alternative (the overall change in rates from the coal-plant retirement on No Action Alternative was not considered.) When considering all cost pressure sensitivities (i.e., not only coal retirements but other regional cost pressures, such as replacement resource financing assumptions or renewable integration services), the analysis generally finds that potential upward rate pressure effects are understated.

Table 5-34. Weighted Average Retail Rates by Action Alternative and Scenario (cents per kWh), for the Base Case Without Additional Coal-Plant Retirements (Changes Could be Larger for MO2 and MO3, Smaller for MO1 and MO4, with Additional Coal-Plant Retirements)

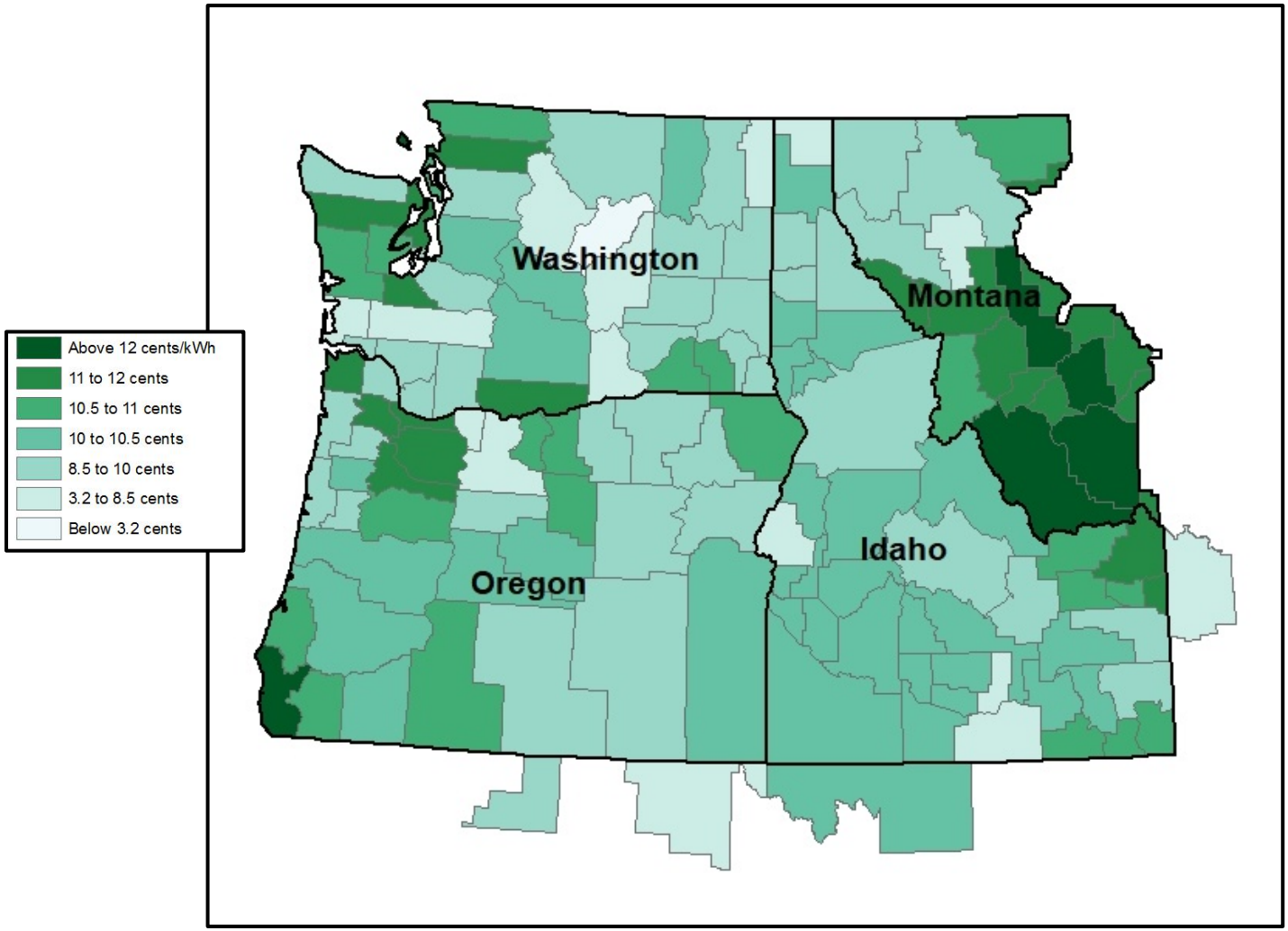
End User Group	Scenario	NAA Rate	MO1	MO2[1/]	MO3	MO4	PA
Residential	Bonneville Finances Zero-Carbon	10.21	10.27	10.16	10.57	10.48	10.24
	Region Finances Zero-Carbon		10.28		10.55	10.48	
	Bonneville Finances Conventional Least-Cost		10.27		10.37	10.52	
	Region Finances Conventional Least-Cost		10.27		10.36	10.48	
Commercial	Bonneville Finances Zero-Carbon	8.89	8.96	8.85	9.26	9.17	8.93
	Region Finances Zero-Carbon		8.96		9.23	9.17	
	Bonneville Finances Conventional Least-Cost		8.96		9.05	9.21	
	Region Finances Conventional Least-Cost		8.95		9.05	9.17	
Industrial	Bonneville Finances Zero-Carbon	7.25	7.31	7.20	7.61	7.52	7.28
	Region Finances Zero-Carbon		7.31		7.59	7.52	
	Bonneville Finances Conventional Least-Cost		7.31		7.40	7.55	
	Region Finances Conventional Least-Cost		7.31		7.40	7.52	

1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection could be achieved by a less costly option. Without the structure, rates under MO2 would be lower.

Table 5-35. Summary of Rate Pressures Relative to the No Action Alternative (cents/kWh and % Difference) for the Base Case Without Additional Coal-Plant Retirements

Scenario		NAA Rate (cents/kWh)	Rate Pressures Relative to NAA, Weighted Average and Range (% change)				
			MO1	MO2[/1]	MO3	MO4	PA
Residential	Bonneville Finances Zero-Carbon	10.21 (2.97 to 13.42)	0.71% (-0.481% to 3.4%)	-0.39% (-1.3% to 0.46%)	3.6% (0.1% to 8.1%)	2.9% (0.041% to 10.8%)	0.33% (less than 0.01% to 1.1%)
	Region Finances Zero-Carbon		0.74% (-0.41% to 7.6%)		3.4% (0.1% to 15%)	2.9% (0.041% to 18.3%)	
	Bonneville Finances Conventional Least-Cost		0.70% (0.048% to 2.4%)		1.6% (0.13% to 4.7%)	3.2% (0.062% to 9%)	
	Region Finances Conventional Least-Cost		0.62% (0.041% to 3.4%)		1.6% (0.10% to 7.2%)	2.8% (0.062% to 11.2%)	
Commercial	Bonneville Finances Zero-Carbon	8.89 (2.91 to 12.01)	0.75% (-0.69% to 3.8%)	-0.48% (-1.9% to 0.46%)	4.1% (0.070% to 9%)	2.9% (0.041% to 11%)	0.36% (less than 0.01% to 1.3%)
	Region Finances Zero-Carbon		0.77% (-0.589% to 8.2%)		3.8% (0.070% to 15%)	2.9% (0.041% to 18%)	
	Bonneville Finances Conventional Least-Cost		0.7% (0.048% to 2.7%)		1.7% (0.10% to 5.3%)	3.2% (0.062% to 9%)	
	Region Finances Conventional Least-Cost		0.7% (0.041% to 3.6%)		1.7% (0.13% to 7.4%)	2.8% (0.062% to 11%)	
Industrial	Bonneville Finances Zero-Carbon	7.25 (2.29 to 17.18)	1.0% (-1.1% to 5.9%)	-0.6% (-2.4% to 0.57%)	5.2% (0.13% to 13%)	4.2% (0.051% to 18%)	0.48% (less than 0.01% to 1.9%)
	Region Finances Zero-Carbon		1.0% (-1.0% to 12%)		4.8% (0.13% to 29%)	4.2% (0.051% to 35.7%)	
	Bonneville Finances Conventional Least-Cost		1.0% (0.48% to 4.0%)		2.3% (0.10% to 7.6%)	4.5% (0.13% to 15%)	
	Region Finances Conventional Least-Cost		0.86% (0.041% to 4.9%)		2.2% (0.13% to 14%)	4.0% (0.13% to 22%)	

1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection could be achieved by a less costly option. Without the structure, rates under MO2 would be lower.



2867
2868 **Figure 5-1. Average 2022 Estimated Residential Rate, No Action Alternative (cents per kWh)**

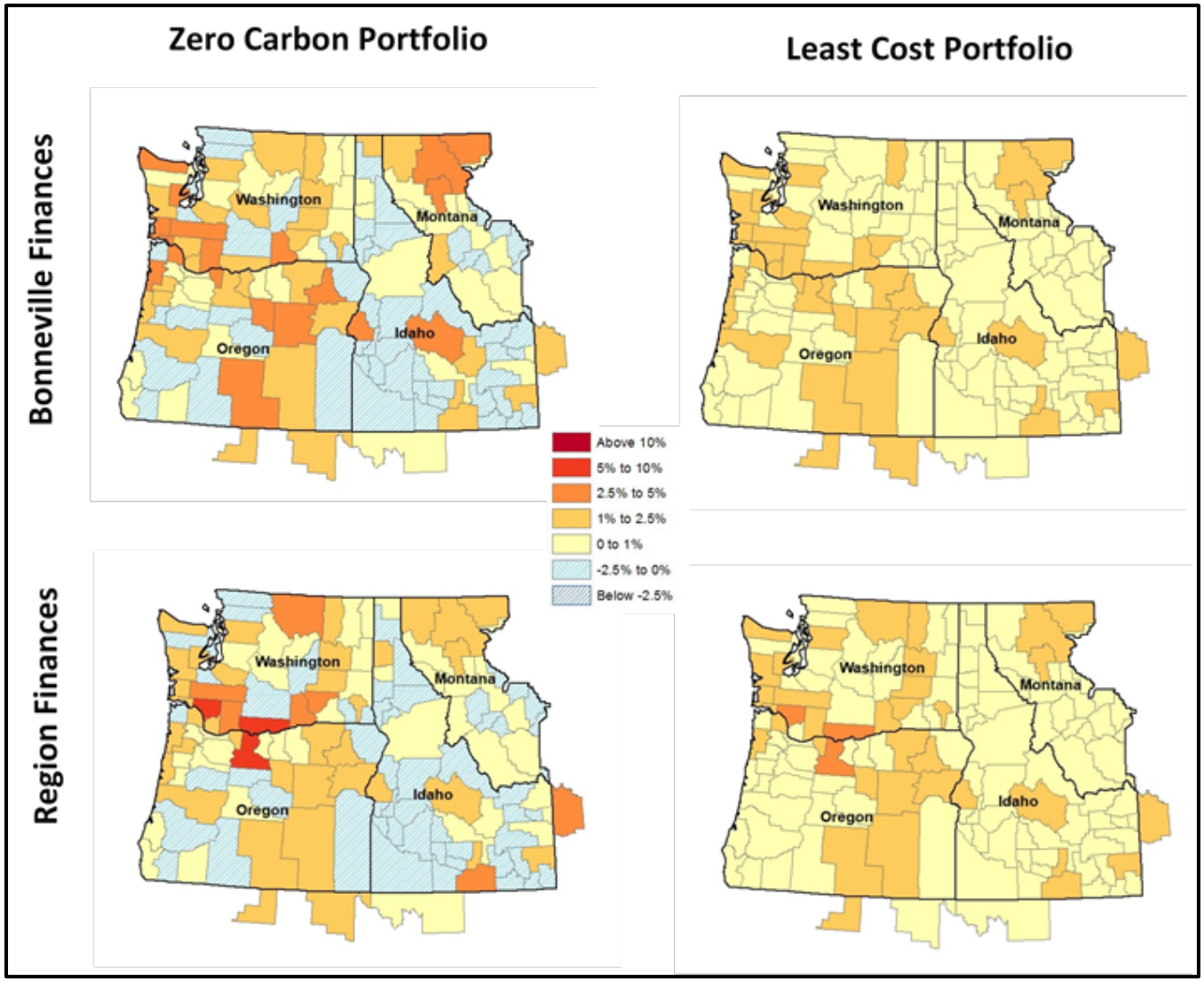


Figure 5-2. MO2 Average Residential Rate Pressure by County (% Change from the No Action Alternative)

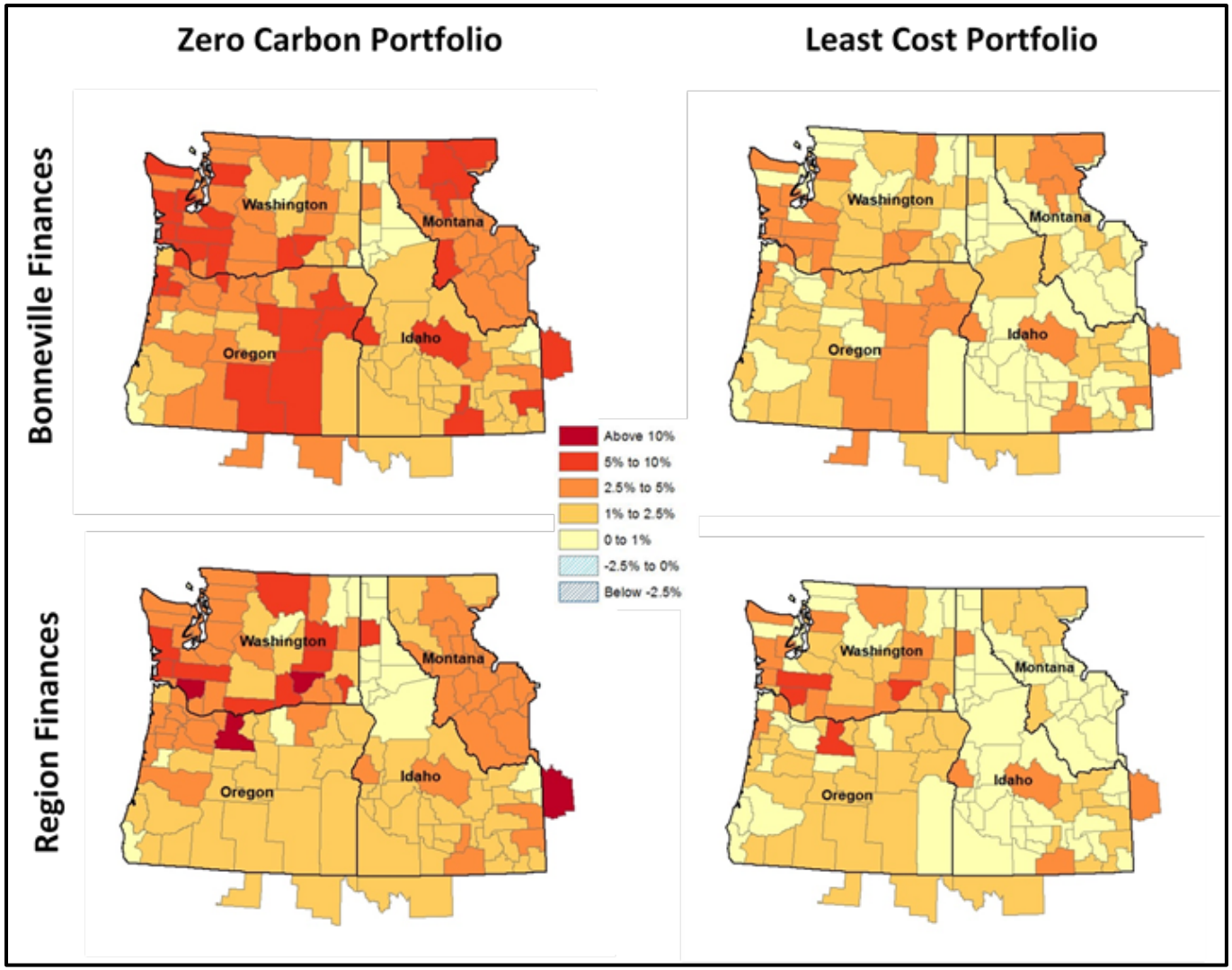
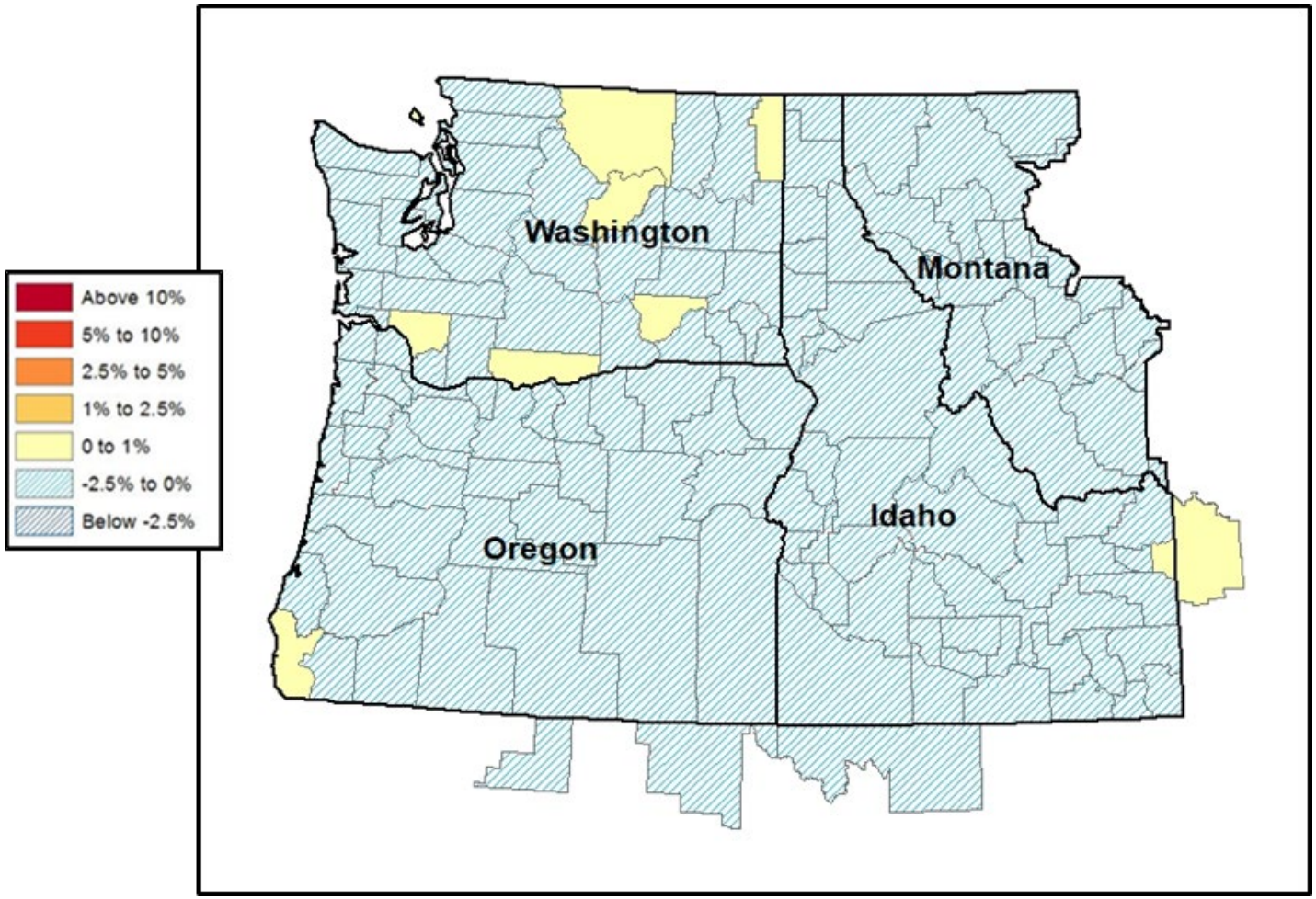


Figure 5-3. MO1 Average Residential Rate Pressure by County (% Change from the No Action Alternative)



2874

2875 **Figure 5-4. MO3 Average Residential Rate Pressure by County (% Change from the No Action Alternative)**

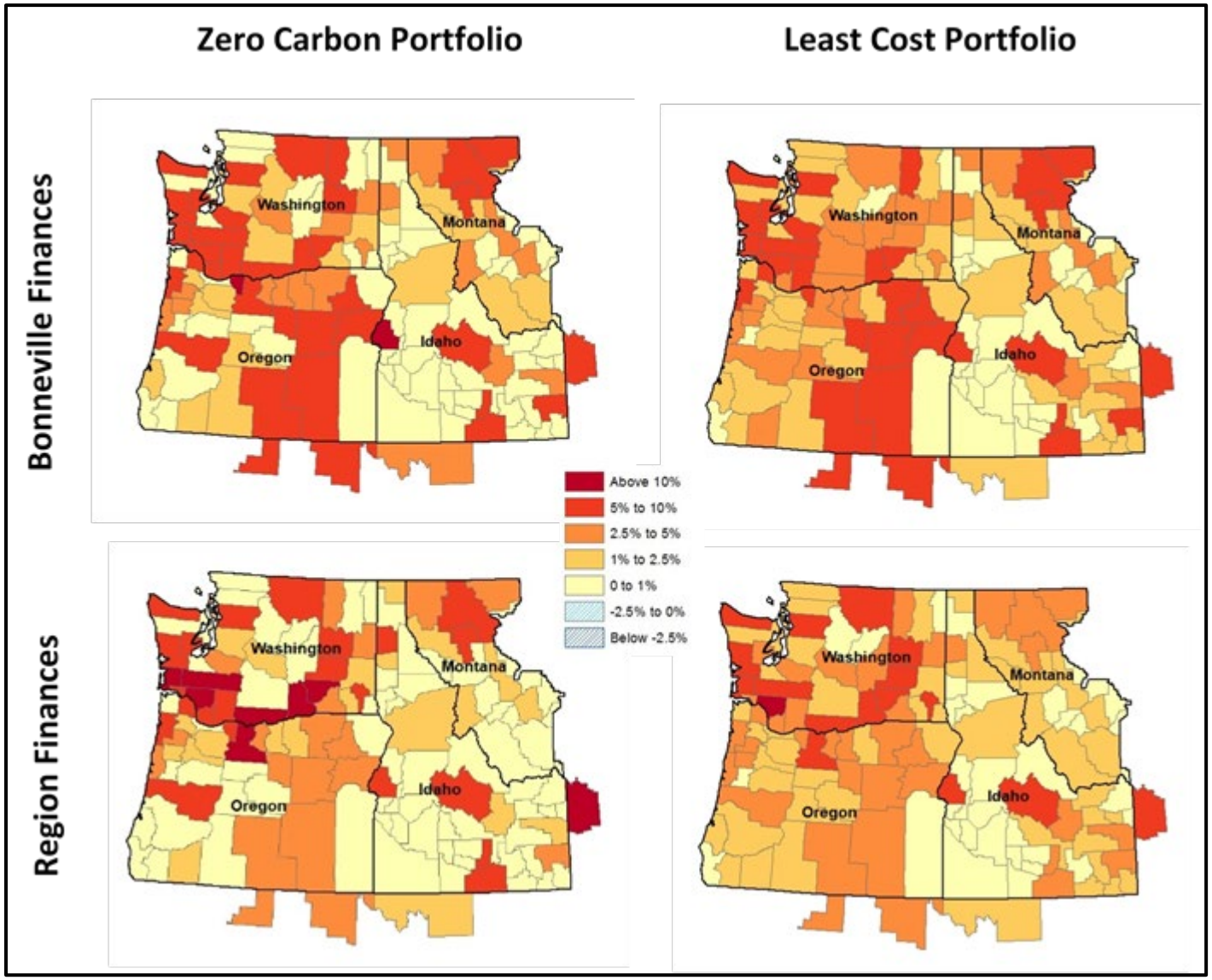
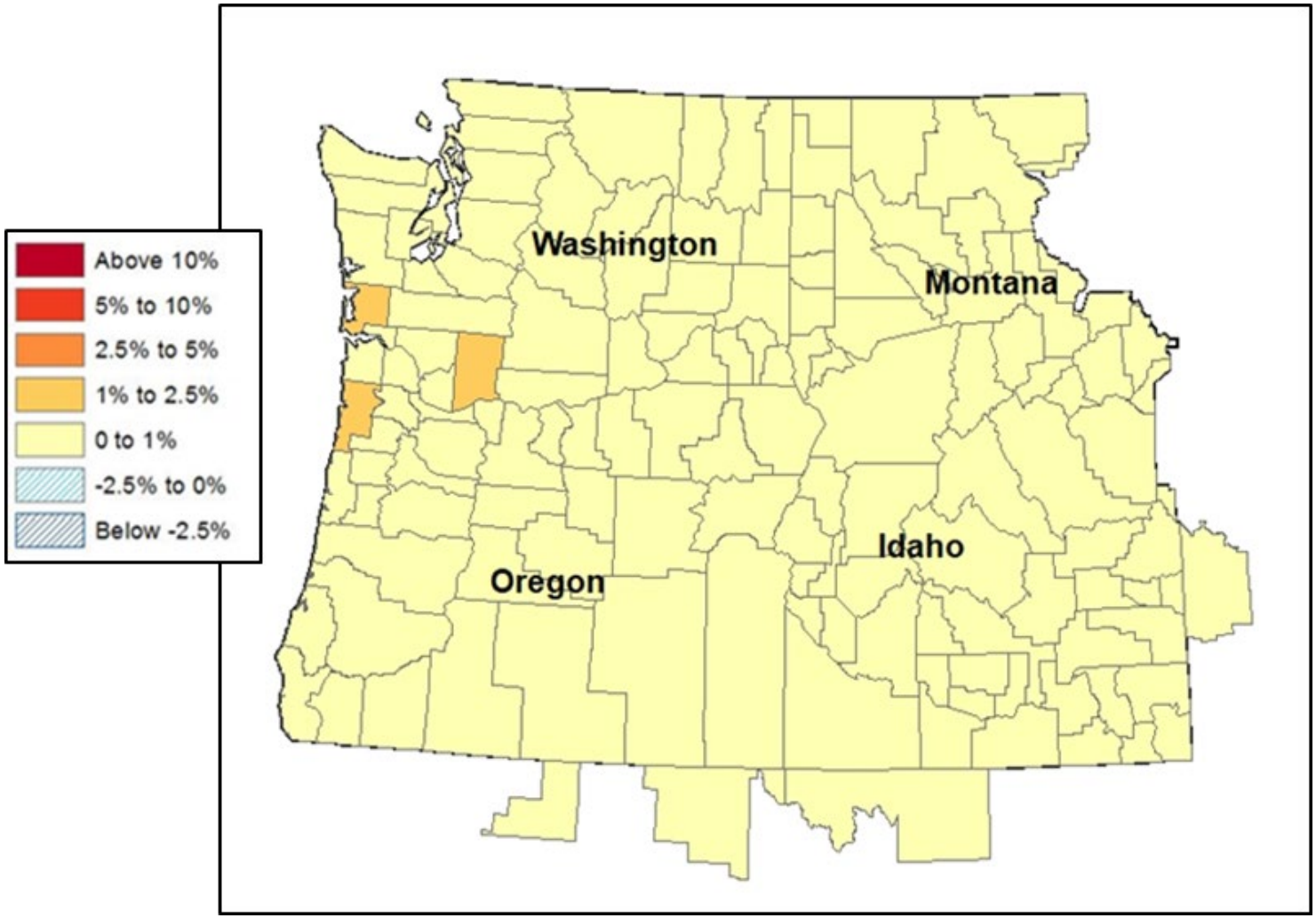


Figure 5-5. MO4 Average Residential Rate Pressure by County (% Change from the No Action Alternative)



2878

2879 **Figure 5-6. Preferred Alternative Average Residential Rate Pressure by County (% Change from the No Action Alternative)**

2880

5.3 OTHER SOCIAL EFFECTS

This analysis examines other social effects in the context of historical rate changes as well as specifically for safety and health effects associated with the reliability of the power system. To examine affordability and effects on household wellness, the analysis reviews recent literature and analysis on the affordability of electricity. Large rate pressures could lead to potential energy insecurity if households have to forego other purchases. The Pacific Northwest has historically had relatively low electricity prices compared to the rest of the country; however, lower income households are more vulnerable to electricity price changes and would likely experience retail rate pressures more acutely than higher income households. Given this vulnerability, these households would be more likely to forego purchases and experience energy insecurity due to a higher electricity burden on their household spending. The Environmental Justice analysis (Chapter 3.15, *Environmental Justice*) provides additional context and analysis on the energy burden of low-income households under each alternative.

To qualitatively examine the potential health and safety effects due to changes in reliability, the analysis assumes that replacement resources are added to the region to provide an LOLP at the level of the No Action Alternative. Given the amount of replacement resources that would need to be successfully added to the regional power system, the reliability effects would not be constant across MOs. If these replacement resources are added, then no differences in health and safety effects in the region due to potential loss of power shortages or blackouts would occur; however, if replacement resources are delayed or otherwise not available to address reliability effects, then health and safety effects would occur. Certain populations, such as the elderly, or those who are already in poor health, may experience these effects more acutely because vital services such as heating, cooling and medical equipment often require electricity. MO2, with an increase in reliability and generation, would increase reliability and decrease health and safety concerns relative to the No Action Alternative.

5.3.1 Timing and Permitting Considerations

Many of these replacement resource projects for both power and transmission, as noted in the previous sections, require multiple years or planning and permitting as well as potential other analyses followed by construction. To the extent this analysis identifies potential needs for replacement resources or transmission infrastructure, and if Bonneville proposes to take such action related to those potential needs in the future, Bonneville would do so consistent with the Northwest Power Act and complete additional site-specific planning, analysis, and compliance with environmental laws, including NEPA. If the replacement resources or transmission infrastructure were not acquired as the analysis assumes, there would be a potential increase in power shortages and blackouts, both of which could lead to additional health and safety concerns due to the loss of power.

Given the respective LOLP levels relative to the No Action Alternative described in Chapter 2, MO4 would have the highest increase in potential health and safety concerns due to decreases in power system reliability. Under MO3, which has a higher LOLP relative to the No Action

Alternative, there is also potential that a transmission reinforcement project in the Tri-Cities area would be needed before Ice Harbor dam is breached. The timing of the reinforcement project for MO3 could occur sooner than the reinforcement project would be needed under the No Action Alternative (see Chapter 3, *Transmission System Reliability and* Congestion). If the reinforcement project were not in service before the lower Snake Dams were breached, there would likely be a decrease system reliability and increase health and safety concerns from the loss of power. The effects would be larger for customers of utilities who receive power from Bonneville, and lower for others.

CHAPTER 6 - RETAIL RATES BY COUNTY

Table 6-1 below lists the residential retail rates by county, relative to the No Action Alternative.

2930 **Table 6-1. Residential Retail Rate by County for No Action and the Percentage Difference by Alternative, for the Base Case Without Additional Coal-Plant Retirements**

		MO1				MO2/1	MO3				MO4				PA
State, County	NAA Rate	Bonneville Zero-Carbon	Bonneville Conv. Least-Cost	Region Zero-Carbon	Region Conv. Least-Cost	MO2	Bonneville Zero-Carbon	Bonneville Conv. Least-Cost	Region Zero-Carbon	Region Conv. Least-Cost	Bonneville Zero-Carbon	Bonneville Conv. Least-Cost	Region Zero-Carbon	Region Conv. Least-Cost	PA
ID, Ada	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Adams	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Bannock	10.34	-0.10%	0.18%	-0.10%	0.18%	-0.36%	1.7%	0.57%	1.7%	0.57%	0.30%	1.0%	0.30%	1.0%	0.10%
ID, Bear Lake	10.54	-0.23%	0.25%	-0.23%	0.25%	-0.64%	2.0%	0.87%	2.0%	0.87%	0.35%	1.6%	0.35%	1.6%	0.16%
ID, Benewah	9.72	0.42%	0.47%	0.37%	0.39%	-0.27%	1.5%	0.99%	0.94%	0.87%	1.7%	1.5%	1.2%	1.5%	0.22%
ID, Bingham	10.41	-0.14%	0.20%	-0.14%	0.20%	-0.46%	1.8%	0.67%	1.8%	0.67%	0.32%	1.2%	0.32%	1.2%	0.12%
ID, Blaine	10.06	0.11%	0.27%	0.03%	0.23%	-0.34%	2.0%	0.72%	1.7%	0.63%	0.83%	1.1%	0.57%	1.1%	0.12%
ID, Boise	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Bonner	10.15	-0.10%	0.14%	-0.06%	0.14%	-0.25%	0.39%	0.46%	0.39%	0.47%	0.21%	0.78%	0.21%	0.78%	0.079%
ID, Bonneville	9.35	0.44%	0.74%	0.34%	0.62%	-0.73%	3.5%	2.0%	2.8%	1.8%	2.8%	3.3%	2.3%	3.3%	0.42%
ID, Boundary	7.46	1.2%	0.67%	0.74%	0.36%	-0.61%	3.2%	1.4%	0.93%	0.74%	4.7%	2.0%	2.2%	2.0%	0.015%
ID, Butte	8.99	1.0%	0.87%	0.49%	0.61%	-0.70%	4.0%	2.1%	2.3%	1.5%	3.8%	2.9%	2.1%	2.9%	0.35%
ID, Camas	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Canyon	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Caribou	9.31	1.8%	1.4%	1.4%	1.1%	-0.60%	5.4%	2.8%	2.9%	2.1%	5.9%	3.9%	3.8%	3.9%	0.67%
ID, Cassia	8.05	2.3%	1.7%	2.5%	1.5%	-0.44%	5.7%	3.0%	4.0%	2.7%	7.4%	4.7%	5.8%	4.7%	0.74%
ID, Clark	10.70	-0.33%	0.30%	-0.33%	0.30%	-0.86%	2.2%	1.1%	2.2%	1.1%	0.38%	2.1%	0.38%	2.1%	0.21%
ID, Clearwater	10.35	-0.080%	0.13%	-0.04%	0.12%	-0.20%	0.34%	0.41%	0.34%	0.42%	0.19%	0.68%	0.19%	0.68%	0.068%
ID, Custer	8.51	3.0%	2.1%	2.2%	1.5%	-0.45%	6.9%	3.7%	3.1%	2.9%	8.9%	5.1%	5.9%	5.1%	0.95%
ID, Elmore	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Franklin	10.65	-0.30%	0.28%	-0.30%	0.28%	-0.79%	2.1%	1.0%	2.1%	1.0%	0.37%	1.9%	0.37%	1.9%	0.20%
ID, Fremont	11.08	-0.048%	0.10%	0.01%	0.09%	-0.08%	0.52%	0.28%	0.52%	0.30%	0.14%	0.43%	0.14%	0.43%	0.043%
ID, Gem	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Gooding	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Idaho	9.93	0.31%	0.45%	0.15%	0.36%	-0.43%	1.7%	1.1%	0.99%	0.89%	1.6%	2.3%	2.2%	2.3%	0.21%
ID, Jefferson	10.70	-0.33%	0.30%	-0.33%	0.30%	-0.86%	2.2%	1.1%	2.2%	1.1%	0.38%	2.1%	0.38%	2.1%	0.21%
ID, Jerome	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Kootenai	9.60	0.77%	0.65%	1.9%	1.0%	-0.29%	2.6%	1.7%	5.1%	2.6%	3.6%	4.3%	6.1%	4.3%	0.23%
ID, Latah	10.34	-0.081%	0.13%	-0.04%	0.12%	-0.20%	0.34%	0.41%	0.34%	0.43%	0.19%	0.69%	0.19%	0.69%	0.069%
ID, Lemhi	10.31	-0.053%	0.19%	-0.06%	0.19%	-0.33%	1.7%	0.55%	1.6%	0.55%	0.37%	0.96%	0.35%	0.96%	0.10%
ID, Lewis	10.34	-0.082%	0.13%	-0.04%	0.12%	-0.20%	0.34%	0.42%	0.34%	0.43%	0.19%	0.69%	0.19%	0.69%	0.069%
ID, Lincoln	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Madison	10.98	-0.16%	0.17%	-0.12%	0.17%	-0.37%	1.1%	0.59%	1.1%	0.60%	0.22%	1.0%	0.22%	1.0%	0.11%
ID, Minidoka	7.27	2.4%	1.5%	2.2%	1.3%	-0.83%	6.4%	3.1%	3.7%	2.5%	8.4%	4.8%	5.6%	4.8%	0.49%
ID, Nez Perce	10.34	-0.081%	0.13%	-0.04%	0.12%	-0.20%	0.34%	0.42%	0.34%	0.43%	0.19%	0.69%	0.19%	0.69%	0.069%
ID, Oneida	10.70	-0.32%	0.29%	-0.32%	0.29%	-0.85%	2.2%	1.1%	2.2%	1.1%	0.38%	2.1%	0.38%	2.1%	0.21%
ID, Owyhee	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%

State, County	NAA Rate	MO1				MO2/1	MO3				MO4				PA
		Bonneville Zero-Carbon	Bonneville Conv. Least-Cost	Region Zero-Carbon	Region Conv. Least-Cost	MO2	Bonneville Zero-Carbon	Bonneville Conv. Least-Cost	Region Zero-Carbon	Region Conv. Least-Cost	Bonneville Zero-Carbon	Bonneville Conv. Least-Cost	Region Zero-Carbon	Region Conv. Least-Cost	PA
ID, Payette	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Power	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Shoshone	9.65	-0.18%	0.22%	-0.18%	0.22%	-0.53%	0.65%	0.75%	0.65%	0.75%	0.32%	1.4%	0.32%	1.4%	0.14%
ID, Teton	11.26	0.0072%	0.05%	0.09%	0.04%	0.10%	0.07%	0.10%	0.07%	0.13%	0.074%	0.07%	0.074%	0.074%	0.006%
ID, Twin Falls	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Valley	10.32	-0.080%	0.17%	-0.08%	0.17%	-0.33%	1.6%	0.53%	1.6%	0.53%	0.30%	0.93%	0.30%	0.93%	0.090%
ID, Washington	7.12	3.4%	2.3%	2.3%	1.7%	-0.60%	8.1%	4.2%	3.3%	2.7%	10.0%	5.2%	5.9%	5.2%	0.98%
MT, Beaverhead	12.14	0.15%	0.28%	0.04%	0.21%	-0.45%	4.5%	0.73%	4.0%	0.56%	1.1%	1.2%	0.55%	1.2%	0.15%
MT, Broadwater	11.93	-0.091%	0.16%	-0.13%	0.13%	-0.45%	4.6%	0.52%	4.4%	0.46%	0.41%	0.98%	0.21%	0.98%	0.12%
MT, Cascade	11.83	-0.21%	0.09%	-0.21%	0.09%	-0.45%	4.7%	0.41%	4.7%	0.41%	0.041%	0.88%	0.041%	0.88%	0.10%
MT, Chouteau	11.83	-0.21%	0.09%	-0.21%	0.09%	-0.45%	4.7%	0.41%	4.7%	0.41%	0.041%	0.88%	0.041%	0.88%	0.10%
MT, Deer Lodge	11.83	-0.21%	0.10%	-0.21%	0.10%	-0.45%	4.7%	0.42%	4.7%	0.41%	0.052%	0.88%	0.046%	0.88%	0.10%
MT, Flathead	9.26	2.5%	1.6%	2.3%	1.3%	-0.57%	6.1%	3.1%	3.3%	2.4%	8.7%	4.5%	5.6%	4.5%	0.59%
MT, Gallatin	11.85	-0.18%	0.11%	-0.19%	0.10%	-0.44%	4.6%	0.44%	4.5%	0.42%	0.15%	0.90%	0.090%	0.90%	0.10%
MT, Glacier	10.54	2.7%	1.7%	1.7%	1.1%	-0.34%	6.0%	3.2%	2.3%	2.1%	7.8%	3.8%	4.4%	3.8%	0.64%
MT, Granite	11.83	-0.21%	0.09%	-0.21%	0.09%	-0.45%	4.7%	0.41%	4.7%	0.41%	0.041%	0.88%	0.041%	0.88%	0.10%
MT, Jefferson	12.67	0.71%	0.57%	0.44%	0.40%	-0.45%	4.1%	1.2%	2.8%	0.79%	2.9%	1.6%	1.4%	1.6%	0.23%
MT, Lake	6.79	3.1%	2.1%	2.2%	1.5%	-0.36%	7.2%	3.7%	2.9%	2.3%	9.2%	4.3%	5.0%	4.3%	0.90%
MT, Lewis And Clark	11.85	-0.18%	0.11%	-0.19%	0.10%	-0.45%	4.6%	0.44%	4.6%	0.43%	0.14%	0.91%	0.086%	0.91%	0.10%
MT, Lincoln	9.35	1.5%	0.99%	1.3%	0.79%	-0.32%	4.1%	1.9%	2.4%	1.5%	5.0%	2.7%	3.2%	2.7%	0.38%
MT, Madison	12.42	0.45%	0.44%	0.26%	0.32%	-0.45%	4.3%	1.0%	3.3%	0.69%	2.1%	1.4%	0.99%	1.4%	0.19%
MT, Meagher	11.83	-0.21%	0.09%	-0.21%	0.09%	-0.45%	4.7%	0.41%	4.7%	0.41%	0.041%	0.88%	0.041%	0.88%	0.10%
MT, Mineral	11.66	0.15%	0.32%	0.06%	0.25%	-0.41%	4.8%	0.77%	4.4%	0.62%	1.1%	1.3%	0.59%	1.3%	0.20%
MT, Missoula	11.59	0.31%	0.41%	0.18%	0.32%	-0.39%	4.9%	0.92%	4.2%	0.71%	1.5%	1.4%	0.83%	1.4%	0.24%
MT, Park	11.83	-0.21%	0.09%	-0.21%	0.09%	-0.45%	4.7%	0.41%	4.7%	0.41%	0.041%	0.88%	0.041%	0.88%	0.10%
MT, Pondera	11.56	0.33%	0.39%	0.15%	0.29%	-0.43%	4.9%	0.94%	4.2%	0.72%	1.5%	1.4%	0.86%	1.4%	0.20%
MT, Powell	12.36	0.71%	0.59%	0.45%	0.42%	-0.43%	4.3%	1.2%	3.1%	0.83%	2.8%	1.7%	1.4%	1.7%	0.26%
MT, Ravalli	10.74	1.2%	0.89%	0.83%	0.71%	-0.39%	5.5%	1.8%	3.6%	1.2%	4.0%	2.4%	2.2%	2.4%	0.38%
MT, Sanders	10.00	0.53%	0.46%	0.38%	0.35%	-0.20%	3.2%	0.92%	2.4%	0.66%	1.8%	1.2%	1.0%	1.2%	0.22%
MT, Silver Bow	11.85	-0.18%	0.11%	-0.19%	0.10%	-0.45%	4.6%	0.44%	4.6%	0.42%	0.13%	0.90%	0.084%	0.90%	0.10%
MT, Teton	11.83	-0.21%	0.09%	-0.21%	0.09%	-0.45%	4.7%	0.41%	4.7%	0.41%	0.041%	0.88%	0.041%	0.88%	0.10%
OR, Baker	9.86	2.3%	1.6%	1.6%	1.2%	-0.37%	5.4%	2.8%	2.3%	1.9%	6.7%	3.4%	3.8%	3.4%	0.71%
OR, Benton	9.95	-0.044%	0.09%	0.03%	0.08%	-0.05%	0.42%	0.26%	0.42%	0.27%	0.15%	0.40%	0.15%	0.40%	0.038%
OR, Clackamas	11.26	0.41%	0.32%	0.37%	0.29%	-0.57%	3.6%	0.93%	3.4%	0.87%	1.2%	1.6%	1.0%	1.6%	0.19%
OR, Clatsop	11.83	-0.24%	0.23%	-0.22%	0.23%	-0.62%	1.7%	0.85%	1.7%	0.86%	0.32%	1.6%	0.32%	1.6%	0.16%
OR, Columbia	9.39	2.5%	1.8%	2.1%	1.4%	-0.30%	5.9%	3.2%	3.4%	2.7%	7.6%	4.6%	5.7%	4.6%	0.84%
OR, Coos	10.96	0.062%	0.38%	0.03%	0.33%	-0.54%	2.0%	1.0%	1.8%	0.98%	1.0%	1.8%	0.86%	1.8%	0.22%
OR, Crook	10.48	-0.29%	0.27%	-0.29%	0.27%	-0.76%	2.0%	1.0%	2.0%	1.0%	0.35%	1.9%	0.35%	1.9%	0.19%

State, County	NAA Rate	MO1				MO2/1	MO3				MO4				PA
		Bonneville Zero-Carbon	Bonneville Conv. Least-Cost	Region Zero-Carbon	Region Conv. Least-Cost	MO2	Bonneville Zero-Carbon	Bonneville Conv. Least-Cost	Region Zero-Carbon	Region Conv. Least-Cost	Bonneville Zero-Carbon	Bonneville Conv. Least-Cost	Region Zero-Carbon	Region Conv. Least-Cost	PA
OR, Curry	12.32	0.0072%	0.05%	0.09%	0.04%	0.10%	0.09%	0.10%	0.09%	0.13%	0.090%	0.09%	0.090%	0.090%	0.006%
OR, Deschutes	10.13	0.17%	0.48%	0.05%	0.40%	-0.66%	2.5%	1.3%	1.9%	1.1%	1.6%	2.1%	0.95%	2.1%	0.27%
OR, Douglas	10.47	-0.065%	0.26%	-0.05%	0.23%	-0.43%	1.5%	0.77%	1.4%	0.76%	0.59%	1.4%	0.52%	1.4%	0.15%
OR, Gilliam	10.70	0.99%	0.85%	0.60%	0.62%	-0.70%	3.6%	1.9%	1.9%	1.3%	4.1%	2.6%	2.0%	2.6%	0.37%
OR, Grant	9.84	2.9%	1.9%	2.0%	1.4%	-0.38%	6.4%	3.4%	2.4%	2.2%	8.3%	4.1%	4.7%	4.1%	0.87%
OR, Harney	9.11	2.5%	1.6%	1.7%	1.1%	-0.55%	5.7%	3.0%	2.0%	1.8%	7.9%	3.7%	4.0%	3.7%	0.66%
OR, Hood River	7.76	3.2%	2.0%	2.1%	1.4%	-0.67%	7.5%	3.8%	2.8%	2.4%	11.0%	4.8%	5.4%	4.8%	0.73%
OR, Jackson	10.41	0.11%	0.56%	0.03%	0.49%	-0.82%	2.8%	1.4%	2.3%	1.3%	1.5%	2.5%	1.1%	2.5%	0.33%
OR, Jefferson	9.98	-0.043%	0.30%	-0.04%	0.27%	-0.48%	1.6%	0.85%	1.5%	0.81%	0.68%	1.5%	0.52%	1.5%	0.18%
OR, Josephine	10.70	-0.33%	0.30%	-0.33%	0.30%	-0.86%	2.2%	1.1%	2.2%	1.1%	0.38%	2.1%	0.38%	2.1%	0.21%
OR, Klamath	10.54	-0.094%	0.41%	-0.16%	0.37%	-0.82%	2.5%	1.3%	2.2%	1.2%	1.0%	2.2%	0.70%	2.2%	0.26%
OR, Lake	8.64	2.8%	2.0%	2.1%	1.5%	-0.13%	6.2%	3.4%	2.4%	2.2%	8.9%	4.1%	4.5%	4.1%	0.99%
OR, Lane	10.33	1.5%	1.1%	1.4%	0.91%	-0.10%	3.9%	2.3%	3.8%	2.3%	5.1%	4.0%	5.6%	4.0%	0.49%
OR, Lincoln	9.88	1.4%	1.2%	1.2%	0.97%	-0.57%	4.5%	2.3%	3.8%	2.2%	4.7%	3.9%	4.4%	3.9%	0.60%
OR, Linn	10.68	-0.32%	0.29%	-0.31%	0.29%	-0.83%	2.1%	1.1%	2.1%	1.1%	0.39%	2.0%	0.39%	2.0%	0.21%
OR, Malheur	10.30	-0.070%	0.18%	-0.07%	0.18%	-0.33%	1.6%	0.54%	1.6%	0.53%	0.33%	0.94%	0.31%	0.94%	0.092%
OR, Marion	11.13	0.62%	0.48%	0.52%	0.40%	-0.56%	3.9%	1.1%	3.3%	1.0%	1.8%	1.9%	1.4%	1.9%	0.26%
OR, Morrow	9.41	0.85%	0.57%	0.61%	0.39%	-0.19%	2.1%	1.1%	0.74%	0.70%	3.0%	1.3%	1.4%	1.3%	0.21%
OR, Multnomah	11.44	0.26%	0.23%	0.26%	0.23%	-0.59%	3.4%	0.79%	3.4%	0.79%	0.79%	1.5%	0.79%	1.5%	0.15%
OR, Polk	10.14	1.1%	0.88%	0.74%	0.68%	-0.56%	4.4%	1.9%	3.0%	1.5%	3.7%	2.8%	2.2%	2.8%	0.43%
OR, Sherman	10.97	1.2%	1.1%	0.91%	0.89%	-0.57%	4.0%	2.1%	2.3%	1.6%	4.0%	3.0%	2.6%	3.0%	0.57%
OR, Tillamook	9.68	3.1%	2.2%	2.3%	1.6%	-0.38%	7.0%	3.7%	2.8%	2.5%	9.0%	4.6%	5.3%	4.6%	1.0%
OR, Umatilla	9.14	1.4%	1.3%	1.0%	1.0%	-0.66%	4.6%	2.4%	2.7%	2.0%	4.6%	3.6%	3.1%	3.6%	0.66%
OR, Union	9.74	2.9%	1.9%	2.0%	1.4%	-0.39%	6.5%	3.4%	2.4%	2.2%	8.4%	4.1%	4.7%	4.1%	0.87%
OR, Wallowa	10.67	-0.31%	0.29%	-0.31%	0.29%	-0.82%	2.2%	1.1%	2.2%	1.1%	0.38%	2.0%	0.38%	2.0%	0.21%
OR, Wasco	7.27	1.6%	1.3%	7.6%	3.4%	-0.15%	4.2%	2.4%	14%	6.9%	5.7%	9.7%	16%	9.7%	0.58%
OR, Washington	11.28	0.38%	0.28%	0.37%	0.28%	-0.57%	3.6%	0.89%	3.5%	0.86%	1.1%	1.6%	1.0%	1.6%	0.16%
OR, Wheeler	10.85	2.5%	1.8%	2.0%	1.4%	-0.32%	5.7%	3.0%	2.3%	2.1%	7.3%	3.7%	4.4%	3.7%	0.86%
OR, Yamhill	9.55	1.4%	0.90%	1.3%	0.78%	-0.58%	5.1%	2.0%	4.4%	1.8%	4.0%	3.2%	3.5%	3.2%	0.41%
WA, Adams	8.58	1.2%	0.79%	2.3%	1.1%	-0.14%	3.2%	2.1%	6.3%	3.1%	4.8%	5.2%	7.6%	5.2%	0.28%
WA, Asotin	9.72	-0.17%	0.21%	-0.16%	0.21%	-0.49%	0.61%	0.71%	0.61%	0.72%	0.31%	1.3%	0.31%	1.3%	0.13%
WA, Benton	8.38	2.6%	1.6%	3.4%	1.7%	0.00%	6.7%	4.0%	8.1%	4.5%	9.7%	7.5%	11%	7.5%	0.47%
WA, Chelan	3.48	0.41%	0.36%	0.33%	0.30%	-0.09%	2.2%	0.65%	1.7%	0.57%	1.3%	0.93%	0.96%	0.93%	0.16%
WA, Clallam	9.39	3.1%	2.1%	2.4%	1.6%	-0.29%	7.0%	3.7%	3.3%	2.8%	9.2%	5.0%	6.0%	5.0%	0.98%
WA, Clark	9.34	1.4%	1.1%	1.2%	0.80%	-0.22%	3.9%	2.4%	4.0%	2.4%	5.0%	4.2%	5.9%	4.2%	0.55%
WA, Columbia	10.70	-0.22%	0.32%	-0.07%	0.38%	-0.80%	2.3%	1.2%	2.6%	1.3%	0.70%	2.4%	1.0%	2.4%	0.21%
WA, Cowlitz	8.52	2.1%	1.1%	6.0%	2.5%	0.26%	6.0%	4.0%	15%	7.2%	9.3%	11%	18%	11%	0.30%
WA, Douglas	2.97	0.10%	0.11%	0.10%	0.11%	0.02%	0.24%	0.21%	0.24%	0.21%	0.30%	0.25%	0.30%	0.25%	0.013%

State, County	NAA Rate	MO1				MO2/1	MO3				MO4				PA
		Bonneville Zero-Carbon	Bonneville Conv. Least-Cost	Region Zero-Carbon	Region Conv. Least-Cost	MO2	Bonneville Zero-Carbon	Bonneville Conv. Least-Cost	Region Zero-Carbon	Region Conv. Least-Cost	Bonneville Zero-Carbon	Bonneville Conv. Least-Cost	Region Zero-Carbon	Region Conv. Least-Cost	PA
WA, Ferry	10.18	2.1%	1.6%	1.7%	1.2%	-0.37%	5.0%	2.7%	2.5%	2.4%	6.2%	4.1%	4.5%	4.1%	0.79%
WA, Franklin	9.17	2.3%	1.2%	4.2%	1.8%	0.46%	6.1%	4.0%	11%	5.6%	9.3%	9.0%	14%	9.0%	0.28%
WA, Garfield	9.41	1.1%	0.86%	2.1%	1.2%	-0.29%	4.4%	2.3%	6.1%	3.0%	5.0%	5.0%	6.2%	5.0%	0.31%
WA, Grant	6.04	-0.48%	0.49%	-0.41%	0.44%	-1.3%	1.3%	1.5%	1.0%	1.5%	0.75%	3.0%	0.51%	3.0%	0.38%
WA, Grays Harbor	10.76	2.2%	1.6%	2.2%	1.2%	-0.05%	6.1%	3.9%	6.6%	4.0%	7.8%	6.6%	9.6%	6.6%	0.61%
WA, Island	10.86	0.26%	0.55%	0.20%	0.46%	-0.52%	3.8%	1.5%	3.3%	1.4%	1.9%	2.4%	1.7%	2.4%	0.30%
WA, Jefferson	11.16	0.003%	0.36%	-0.05%	0.32%	-0.59%	3.3%	1.0%	3.0%	0.91%	0.90%	1.7%	0.66%	1.7%	0.21%
WA, King	10.47	0.47%	0.62%	0.46%	0.51%	-0.29%	3.3%	1.3%	3.2%	1.3%	2.0%	2.2%	2.1%	2.2%	0.29%
WA, Kitsap	11.17	-0.22%	0.24%	-0.22%	0.24%	-0.62%	3.1%	0.82%	3.1%	0.82%	0.33%	1.5%	0.33%	1.5%	0.16%
WA, Kittitas	10.06	1.1%	0.94%	0.74%	0.70%	-0.54%	4.6%	2.0%	2.7%	1.4%	4.3%	2.7%	2.3%	2.7%	0.41%
WA, Klickitat	11.09	1.8%	1.2%	5.5%	2.5%	0.22%	4.1%	2.5%	9.8%	5.0%	6.4%	7.2%	11%	7.2%	0.54%
WA, Lewis	8.13	2.6%	1.9%	3.5%	2.0%	-0.22%	7.1%	4.3%	9.8%	5.4%	9.4%	9.1%	14%	9.1%	0.89%
WA, Lincoln	8.84	1.4%	0.89%	2.5%	1.3%	-0.05%	3.8%	2.2%	5.8%	3.0%	5.5%	5.0%	6.9%	5.0%	0.29%
WA, Mason	10.57	2.7%	2.0%	2.2%	1.5%	-0.31%	6.1%	3.2%	3.3%	2.5%	7.8%	4.4%	5.6%	4.4%	0.93%
WA, Okanogan	8.74	1.5%	0.88%	3.7%	1.6%	0.37%	3.7%	2.1%	8.0%	3.9%	5.5%	5.9%	9.9%	5.9%	0.19%
WA, Pacific	8.35	2.7%	2.1%	2.1%	1.5%	-0.43%	7.6%	4.7%	7.5%	4.6%	9.8%	8.1%	11%	8.1%	1.0%
WA, Pend Oreille	7.11	0.12%	0.13%	0.11%	0.12%	0.01%	0.29%	0.22%	0.24%	0.21%	0.37%	0.28%	0.34%	0.28%	0.027%
WA, Pierce	9.29	1.4%	1.3%	1.2%	0.98%	-0.29%	5.1%	2.7%	4.1%	2.5%	5.3%	4.2%	5.0%	4.2%	0.61%
WA, San Juan	13.42	0.0072%	0.05%	0.09%	0.04%	0.10%	0.06%	0.10%	0.06%	0.13%	0.062%	0.06%	0.062%	0.062%	0.006%
WA, Skagit	11.17	-0.22%	0.24%	-0.22%	0.24%	-0.62%	3.1%	0.82%	3.1%	0.82%	0.33%	1.5%	0.33%	1.5%	0.16%
WA, Skamania	9.10	3.2%	2.4%	2.5%	1.8%	-0.41%	7.3%	3.8%	3.1%	2.8%	9.3%	4.9%	5.7%	4.9%	1.1%
WA, Snohomish	9.69	2.3%	1.9%	2.0%	1.4%	-0.07%	6.6%	4.2%	4.1%	3.7%	8.4%	6.2%	7.5%	6.2%	0.89%
WA, Spokane	9.15	0.58%	0.57%	0.86%	0.65%	-0.38%	2.2%	1.5%	2.7%	1.7%	2.7%	2.9%	3.0%	2.9%	0.24%
WA, Stevens	9.51	0.064%	0.38%	0.02%	0.34%	-0.53%	1.1%	0.99%	0.85%	0.93%	0.99%	1.7%	0.75%	1.7%	0.21%
WA, Thurston	11.16	-0.21%	0.24%	-0.22%	0.24%	-0.62%	3.1%	0.83%	3.1%	0.83%	0.35%	1.5%	0.35%	1.5%	0.16%
WA, Wahkiakum	9.40	3.1%	2.1%	2.2%	1.5%	-0.36%	7.0%	3.6%	2.6%	2.3%	8.9%	4.3%	5.2%	4.3%	0.97%
WA, Walla Walla	10.68	0.065%	0.39%	0.58%	0.59%	-0.65%	2.5%	1.3%	3.7%	1.8%	1.5%	3.1%	2.7%	3.1%	0.19%
WA, Whatcom	10.97	-0.080%	0.32%	-0.12%	0.30%	-0.61%	3.3%	0.96%	3.1%	0.90%	0.74%	1.7%	0.55%	1.7%	0.19%
WA, Whitman	9.61	0.18%	0.34%	0.43%	0.41%	-0.35%	1.3%	0.99%	1.7%	1.2%	1.4%	2.0%	1.7%	2.0%	0.15%
WA, Yakima	10.39	-0.029%	0.42%	-0.13%	0.36%	-0.85%	2.6%	1.3%	2.1%	1.1%	1.3%	2.2%	0.77%	2.2%	0.23%
CA, Modoc	9.20	1.6%	1.4%	1.2%	1.1%	-0.38%	4.6%	2.5%	2.3%	1.8%	5.6%	3.3%	2.9%	3.3%	0.73%
NV, Humboldt	8.38	1.9%	1.2%	1.1%	0.78%	-0.78%	4.7%	2.5%	1.4%	1.3%	7.2%	3.0%	3.1%	3.0%	0.38%
NV, Elko	10.24	0.91%	0.68%	0.80%	0.51%	-0.09%	2.1%	1.1%	1.7%	1.1%	2.7%	1.8%	2.4%	1.8%	0.32%
WY, Teton	7.76	2.2%	1.6%	5.0%	2.4%	0.00%	7.1%	3.0%	11%	4.8%	7.9%	7.4%	11%	7.4%	0.71%

1/ MO2 includes the cost of fish passage structures at McNary with a costly feature for fish collection. If MO2 were implemented, fish collection could be achieved by a less costly option. Without the structure, rates under MO2 would be lower.

Draft Columbia River System Operations Environmental Impact Statement

Appendix I
Hydroregulation

Executive Summary

Introduction

This appendix discusses the hydroregulation modeling processes conducted for the Columbia River System Operations (CRSO) Environmental Impact Statement (EIS). The Bonneville Power Administration (Bonneville), U.S. Army Corps of Engineers (Corps), and U.S. Bureau of Reclamation (Reclamation) are co-lead agencies in developing the CRSO EIS, which is required for the agencies' compliance with the National Environmental Policy Act (NEPA). This appendix is part of a larger set of CRSO EIS documents that detail the efforts of the co-lead agencies in evaluating alternatives for the future operation and configuration of 14 major projects of the Federal Columbia River Power System (FCRPS) collectively referred to as the Columbia River System (CRS).

This appendix focuses on the process of executing the hydroregulation studies for the CRSO EIS alternatives. The studies were conducted by Bonneville in close coordination with the Corps and Reclamation. Outputs from the hydroregulation study processes were used in determining changes to hydropower generation, power system reliability, streamflows, lake levels, habitat, water quality, and other purposes. Bonneville also reviewed the potential effects of climate change on the relative effects of the alternatives. The results of these changes are detailed in other appendices, including the *Hydropower Appendix* and the *Hydrology and Hydraulics Appendix (H&H Appendix).*

Columbia River System Projects

The CRS consists of the 14 major projects operated in coordination with each other for several congressionally authorized purposes, including flood risk management (FRM), navigation, hydropower production, irrigation, fish and wildlife conservation, recreation, municipal and industrial water supply, and water quality. They are a subset of the FCRPS, a network of 31 multi-purpose dam and reservoir projects constructed in the Columbia River and its tributaries in the Pacific Northwest and operated by the Corps and Reclamation. The FCRPS also includes the transmission system built and operated by Bonneville to market and deliver electric power.

The CRS projects examined in detail in the CRSO EIS fall into two major categories: storage and run-of-river projects. There are six Federal storage projects in the CRS: Libby, Hungry Horse, Albeni Falls, Grand Coulee, Dworshak and John Day. There are eight Federal run-of-river projects in the CRS: Chief Joseph, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, The Dalles, and Bonneville.

Operations at several non-Federal projects in the Columbia River basin are potentially affected by the CRSO EIS alternatives. These projects, being downstream from the 14 CRS projects, may exhibit some differences due to upstream flow changes, but operational goals and procedures remain the same throughout all CRSO EIS alternatives. These include five mid-Columbia River dams downstream of Grand Coulee Dam and Chief Joseph Dam; several non-Federal United States and Canadian dams on the Flathead, Clark Fork, and Pend Oreille Rivers downstream of

Hungry Horse and Albeni Falls Dams; and several Canadian dams on the Kootenay River downstream of Libby Dam. Notable non-Federal dams in the Columbia Basin that are not affected include three Columbia River Treaty (CRT) projects (Mica, Arrow, and Duncan) and Revelstoke Dam in Canada; and the Hells Canyon complex (Brownlee, Oxbow, and Hells Canyon Dams) on the Snake River.

The operation of these dams is coordinated for several purposes. The storage operation of five CRS storage projects, the Hells Canyon complex, and three CRT dams in Canada is coordinated for flood risk management to reduce flooding either locally or for the Columbia River reach below Bonneville Dam. United States and Canadian power production is coordinated per terms of the CRT. All the dams are connected to the Western Interconnection power system and contribute to providing a safe and reliable source of electricity. The 14 CRS projects are also operated to meet several objectives in Biological Opinions intended to reduce and mitigate the effects of the dams.

CRSO EIS Alternatives

In 2016 the co-lead agencies implemented a public scoping process with the public, tribes, local and state governmental agencies, non-government entities, and other stakeholders to identify issues that addressed the general purpose and need of the EIS: to review the management of the CRSO projects. The co-lead agencies used the information to develop measures to address the issues. Then the agencies combined these measures into four multiple objective (MO) alternatives. A no-action alternative (NAA) was also developed for comparing the effects of the alternatives. The following alternatives were modeled:

- NAA – includes operations and structures in place when the Notice of Intent for the EIS was published in September 2016.
- MO1 – includes a number of measures to benefit fish survival, water management, water supply, and hydropower production.
- MO2 – includes measures that emphasize power production, renewable resource integration, and reduction of use of carbon-producing generation resources while also providing for water management and some measures to benefit fish survival.
- MO3 – includes breaching of four lower Snake River dams and adds other measures beneficial to anadromous and resident fish as well as some measures for water management, water supply, and hydropower production.
- MO4 – includes other measures to aid anadromous fish survival without breaching the Snake River dams as well as some measures for resident fish, water management, water supply, and hydropower production.
- PA – combines a number of measures as the preferred alternative to meet the purpose and need, EIS objectives, and environmental, economic, and sociological criteria. In addition, new information about spill operations from the 2018 and 2019 spring fish spill pilot operations that benefit downstream migration of juvenile anadromous fish became available after the range of alternatives was developed. Using this new information, the

co- lead agencies modified the measure for juvenile fish spill operation for the preferred alternative using the analysis from the range of spill levels evaluated in the MOs.

Modeling Processes

Bonneville conducted the hydroregulation studies in cooperation with the Corps to develop and refine the input data sets. Existing Hydsim, ResSim, and other computer programs and processing tools were used to pre- and post-process the data in the modeling process. Output results of the MO alternatives were then post processed and compared to the NAA model outputs. These results are presented in the EIS and the various appendices.

Conclusion

This document identifies the computer models, software tools, data sets, and sequence of steps used in the hydroregulation modeling process. The MO and PA alternatives' operational and physical changes are discussed, with further details included in Exhibit 4. Results of the modeling processes and assessment of the impacts to the CRS are found in other EIS appendices.

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Abbreviations, Acronyms, and Glossary

aMW	average megawatts
AOP	Assured Operating Plan
BiOp	biological opinion
Bonneville	Bonneville Power Administration
cfs	cubic foot per second
Corps	U.S. Army Corps Of Engineers
CRS	Columbia River System (14 of the 31 FCRPS Projects)
CRSO	Columbia River System Operations
CRT	Columbia River Treaty
DEIS	Draft Environmental Impact Statement
Entity/Entities	Each country that is party to the Columbia River Treaty has a designated Entity; see U.S. Entity and Canadian Entity
ESA	Endangered Species Act
F0	Flood 0
FCRPS	Federal Columbia River Power System
FRM	Flood Risk Management
ft	foot or feet
GENESYS	GENeration Evaluation SYStem
HEC	Hydrologic Engineering Center
HEC-ResSim	Hydrologic Engineering Center reservoir system simulation software
HEC-WAT	Hydrologic Engineering Center watershed analysis tool software
HLH	heavy load hour
HOSS	Hourly Operations Scheduling Simulator
HYDSIM	Bonneville hydropower simulation model
Kcfs	thousand cubic feet per second
LLH	light load hour
LOM	Lack of Market limit
Maf	million acre-feet
MO1	Multiple-Objective Alternative 1
MO2	Multiple-Objective Alternative 2
MO3	Multiple-Objective Alternative 3
MO4	Multiple-Objective Alternative 4
MOP	minimum operating pool
MW	megawatts
NAA	No-Action Alternative
NEPA	National Environmental Policy Act
NGVD29	National Geodetic Vertical Datum of 1929
NMFS	National Marine Fisheries Service

NOAA	National Oceanic and Atmospheric Administration
NOAA Fisheries	formerly National Marine Fisheries Service
Northwest	States in the Northwest portion of the United States, including Washington, Oregon, Idaho, and Montana
PRMS	Precipitation Runoff Modeling System
RCP	representative concentration pathway
Reclamation	U.S. Bureau of Reclamation
ResSim or HEC-ResSim	Hydrologic Engineering Center reservoir system simulation software program
RMJOC	River Management Joint Operating Committee
SKQ	Sèliš Ksanka Qĺispè
Spill	discharge from a dam through its spillway
SRD	storage reservation diagram
TDG	total dissolved gas
Treaty	Columbia River Treaty
TSR	Treaty Storage Regulation
URC	upper rule curve
VarQ	variable discharge Flood Risk Management procedures
VIC	variable infiltration capacity
WAT or HEC-WAT	watershed analysis tool

CHAPTER 1 - INTRODUCTION TO COLUMBIA RIVER SYSTEM OPERATIONS AND HYDROREGULATION

This appendix presents the hydroregulation performed by Bonneville Power Administration (Bonneville) for its hydropower analyses conducted for the Columbia River System Operations (CRSO) Environmental Impact Statement (EIS). The Bonneville, U.S. Army Corps of Engineers (Corps), and U.S. Bureau of Reclamation (Reclamation) are co-lead agencies in developing the CRSO EIS, which is required for National Environmental Policy Act (NEPA) compliance. This appendix is part of a larger set of CRSO EIS documents that detail the efforts of the co-lead agencies in evaluating alternatives for the future operation and configuration of 14 Federal Columbia River Power System (FCRPS) major projects. These 14 FCRPS projects are collectively referred to as the Columbia River System (CRS).

This appendix focuses on hydroregulation models and modeling techniques Bonneville used to assess the effects of the CRSO EIS alternatives on Columbia River hydropower. It is supported by several other CRSO EIS documents that provide additional details on the EIS processes, alternatives, system operation and modeling, and other uses affected by the alternatives. Details about the NEPA process and alternative development are presented in the CRSO EIS. Modeling details for this hydropower assessment are presented in this appendix and the *Hydrology and Hydraulics Appendix* (*H&H Appendix*) prepared by the Corps. The hydroregulation results in this appendix contribute to other analyses in the CRSO EIS, including analyses of socioeconomic, air quality, and water quality effects. The results of those other effects are detailed in the main report of the CRSO EIS and appropriate appendices.

1.1 COLUMBIA RIVER SYSTEM PROJECTS

As defined for this study, the CRS consists of the 14 major projects operated in coordination with each other. They are a subset of the FCRPS, a network of 31 multi-purpose Federal dam and reservoir projects constructed in the Columbia River and its tributaries in the Pacific Northwest and operated by the Corps and Reclamation. The FCRPS also includes the Federal transmission system built and operated by Bonneville to market and deliver electric power.

The United States Congress authorized the Corps and Reclamation to construct, operate, and maintain the FCRPS projects to meet multiple specified purposes, including flood risk management (FRM), navigation, hydropower production, irrigation, fish and wildlife conservation, recreation, municipal and industrial water supply, and water quality. Although not every project is authorized for each of these purposes, all 14 FCRPS projects are authorized for hydropower.

1.1.1 FCRPS Projects in the CRS

The 14 FCRPS projects on the Columbia River and its major tributaries are operated as a coordinated system known as Columbia River System (CRS). The CRSO EIS focuses on these 14 FCRPS projects: Libby, Hungry Horse, Albeni Falls, Grand Coulee, Chief Joseph, Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and

Bonneville. Figure 1-1 shows the geographic locations of the 14 projects. Table 1-1 summarizes the general characteristics of the 14 projects.

The CRS projects examined in detail in the CRSO EIS fall into two major categories: storage and run-of-river projects. There are six Federal storage projects in the CRS: Libby, Hungry Horse, Albeni Falls, Grand Coulee, Dworshak and John Day. There are eight Federal run-of-river projects in the CRS: Chief Joseph, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, The Dalles, and Bonneville.

Storage is key to operating the CRS for multiple uses. The total water storage available in the reservoirs on the Columbia River and its tributaries is approximately 55 million acre-feet (Maf). About 20 Maf of that storage capacity is in Canada and 17 Maf in the six CRS storage projects. In general, the storage reservoirs capture streamflow during relatively high spring snowmelt flow periods. Refill is managed to reduce downstream flooding and store water for release for multiple objectives in times of relatively low streamflows during late summer and fall months. Computer models operate or regulate storage projects using tools to store and fill, release and draft, or pass inflows.

Run-of-river projects have limited storage capacity. These projects release water at the dam at nearly the same rate it enters the reservoir. The reservoirs behind run-of-river projects often are operated for hydropower resulting in frequent, relatively minor fluctuations in water levels. Reservoir levels behind these projects typically vary only 3 to 5 feet in normal operations. In hydroregulation models, these projects release their inflows and maintain a constant reservoir level. The modeler has several tools to specify the distribution of releases through powerhouse flows, spillway flows, fish passage facility flows, and to compensate for navigation lockages, and/or dam leakage.

1.1.2 Other FCRPS Projects

The remaining 17 FCRPS projects are operated independently of the 14 CRS projects and are located in the upper Snake River basin in southern Idaho, the Yakima River basin in Washington, and the Willamette and Rogue River basins in Oregon. Their operation is replicated in the modeling of each alternative (i.e., their project storage operations, outflows, and generation are the same in each CRSO EIS alternative).

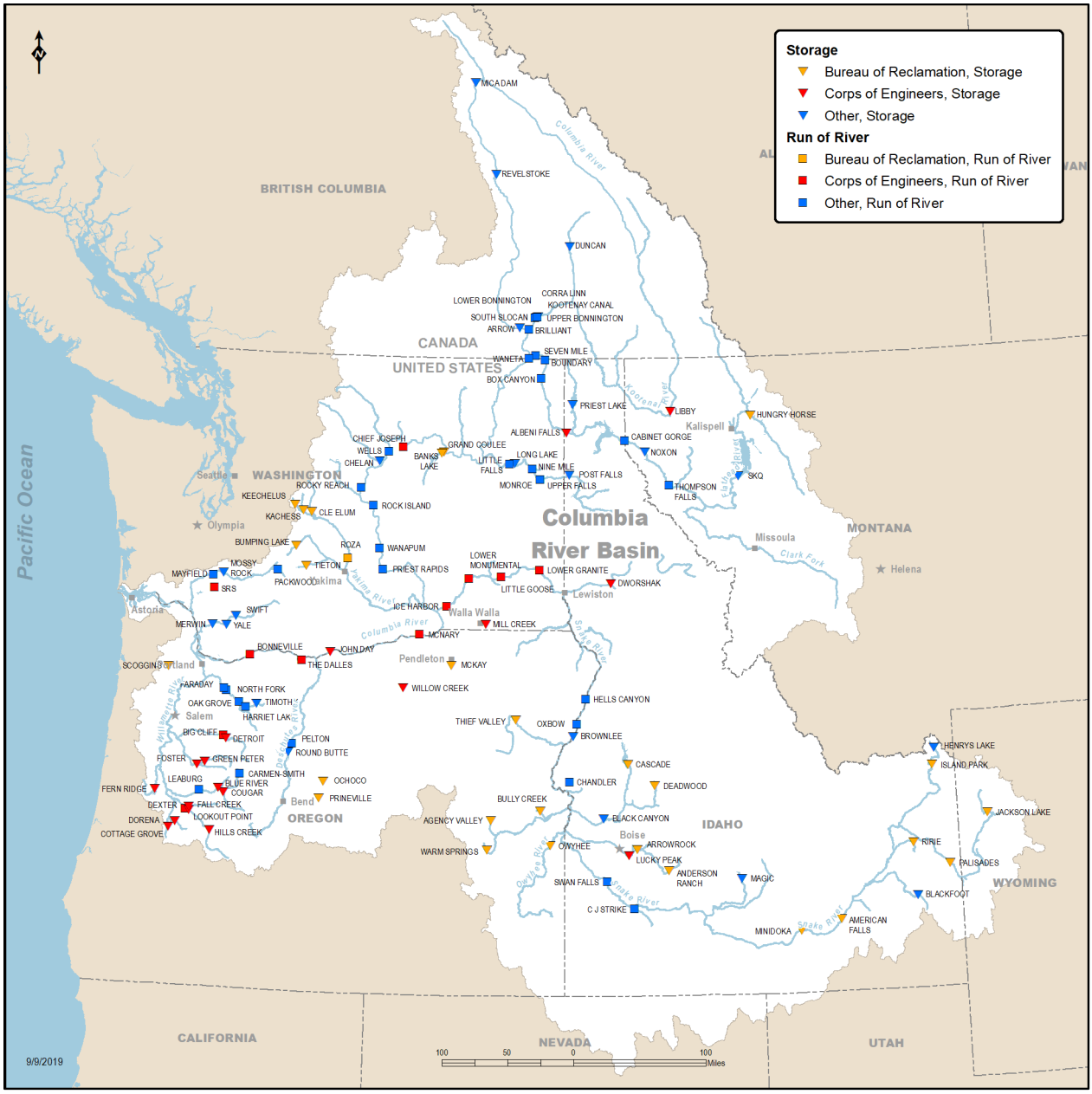

Figure 1-1. Geographic Location for the CRSO Projects

Note: SKQ on the Flathead River in Montana refers to Sèliš Ksanka Qĺispè Dam, formerly known as Kerr Dam.

Table 1-1. General Characteristics of the Columbia River System Projects

Project	Reservoir/ Lake	Project Type	Storage Volume (MAF)	Hydropower (no. of units - capacity)
Libby	Koocanusa	Storage	5.0	5 units – 525 MW
Hungry Horse	Hungry Horse	Storage	3.0	4 units – 428 MW
Albeni Falls	Pend Oreille	Storage	1.2	3 units – 42 MW
Grand Coulee	Roosevelt	Storage	5.4	24 units, 6 pump/generators – 7,015 MW
Chief Joseph	Rufus Woods	Run-of-river	-	27 units – 2,000 Mw

Project	Reservoir/ Lake	Project Type	Storage Volume (MAF)	Hydropower (no. of units - capacity)
Dworshak	Dworshak	Storage	2.0	3 units – 400 MW
Lower Granite	Lower Granite	Run-of-river	-	6 units – 810 MW
Little Goose	Bryan	Run-of-river	-	6 units – 810 MW
Lower Monumental	Herbert G. West	Run-of-river	-	6 units – 810 MW
Ice Harbor	Sacajawea	Run-of-river	-	6 units – 603 MW
McNary	Wallula	Run-of-river	-	14 units – 980 MW
John Day	Umatilla	Storage	0.5	16 units – 2,480 MW
The Dalles	Celilo	Run-of-river	-	22 units – 2,080 MW
Bonneville	Bonneville	Run-of-river	-	18 units – 1,200 MW

Project information from http://www.crso.info/index.html

1.1.3 Non-Federal Dams and Reservoirs

There are numerous other dam and reservoir projects in the Columbia River and its tributaries that are operated by Federal and non-Federal entities in the United States and Canada. These include both storage and run-of-river projects that can affect or be affected by CRS project operations. Exhibit 1 identifies these non-Federal projects, and annotates with an asterisk those projects affected by CRSO Draft EIS alternatives. Locations of major non-Federal projects are shown in Figure 1-1.

1.1.3.1 Canadian Projects

Mica, Arrow, and Duncan (Columbia River Treaty[1] Projects) are major storage projects in Canada with 15.5 Maf of Columbia River Treaty (CRT or Treaty) storage and 5 Maf of non-Treaty storage. The 15.5 Maf of Treaty storage is operated by British Columbia Hydro and Power Authority for FRM and hydropower in accordance with the terms of the Treaty. In addition, there is a non-Treaty storage operation under separate mutual agreements between the United States and Canadian entities to provide resident fish benefits in Canada and anadromous fish benefits in the United States. Operation of these projects is held constant and included in all of the CRSO EIS alternatives being analyzed.

There are several other projects operated by British Columbia Hydro and Power Authority and other entities in Canada on the lower Kootenay and Pend d'Oreille Rivers. Power production at these other Canadian projects is affected by the CRSO EIS alternatives. Canadian projects are listed in Exhibit 1, and are shown in Figure 1-1.

[1] See Bonneville website for information on the Columbia River Treaty at: https://www.bpa.gov/Projects/Initiatives/Pages/Columbia-River-Treaty.aspx

1.1.3.2 Mid-Columbia River Projects

Three Washington State Public Utility Districts (PUDs) operate five run-of-river dams in the mid-Columbia River. These projects are operated under licenses from the FERC:

- Wells, operated by Douglas County PUD
- Rocky Reach and Rock Island, operated by Chelan County PUD
- Wanapum and Priest Rapids, operated by Grant County PUD

These Mid-Columbia Projects are shown in Figure 1-1. They are hydrologically affected by upstream Federal storage project operations which influence flows through the PUD projects particularly from Grand Coulee Dam. Power production at the five PUD dams would be affected by the CRSO EIS alternatives.

1.1.3.3 Middle Snake River Dams

The Idaho Power Company operates three FERC-licensed dams, collectively known as the Hells Canyon Complex, located on the middle Snake River on the Oregon/Idaho border. The Hells Canyon, Oxbow, and Brownlee Projects are hydropower facilities that affect flows on the lower Snake River. Hells Canyon and Oxbow are run-of-river projects downstream of Brownlee Dam. Brownlee Dam is the most significant for CRSO, as this reservoir has a total storage capacity of 1.4 Maf, of which 980,000 acre-feet are used jointly for FRM and power production. Brownlee also is operated for recreation, navigation below Hells Canyon, and provides flow augmentation for the lower Snake and Columbia River juvenile fish migration. Power production at these dams would not be affected by the CRSO EIS alternatives. Operation of these dams is replicated in all the CRSO EIS alternatives.

1.1.3.4 Other Columbia River Non-Federal Dams in the United States

There are other non-Federal dams in the United States located below the CRS storage projects at Hungry Horse and Albeni Falls dams. They include Sèliš Ksanka Qĺispè (SKQ) on the Flathead River and Thompson Falls, Noxon Rapids, and Cabinet Gorge on the Clark Fork River below Hungry Horse Dam; and Box Canyon and Boundary dams are located on the Pend Oreille River below Albeni Falls Dam. All are run-of river with the exception of SKQ Dam which regulates the storage at Flathead Lake in Montana. Power production at these dams would be affected by the CRSO EIS alternatives.

There are numerous other dam and reservoir projects in the Columbia River and its tributaries that are operated by non-Federal entities in the United States and Canada. These include both storage and run-of-river projects that can affect or be affected by CRS project operations. A listing of the Federal and non-Federal dams pertinent to this hydropower analysis is provided in Exhibit 1.

1.2 DESCRIPTIONS OF THE ALTERNATIVES

The CRSO EIS contains four multiple objective alternatives and the No-Action Alternative (NAA). The NAA represents reservoir operations and dam structures in place or scheduled for construction when the Corps filed a Notice of Intent for the EIS in September 2016.

The four multiple objective alternatives contain different combinations of operational and structural measures to address issues identified in the CRSO EIS public scoping meetings. Operational measures include: differing storage operations at the Federal upstream storage projects and differing spill and powerhouse flow levels at the Federal downstream run-of river projects. Structural measures include: differing juvenile and adult fish passage system improvements; installation of more efficient turbines with improved fish passage at select projects; and dam breaches at the four lower Snake River dams.

Summary descriptions and effects of the NAA and four multiple-objective alternatives are provided in the following sections and limited to the measures pertinent to this hydropower assessment. More complete, detailed descriptions of the no-action and multiple-objective alternatives are provided in Chapter 2 of the CRSO EIS. Specific details for how the alternatives were modeled for hydropower assessments are provided in this appendix. Exhibit 2 includes a matrix that lists all the measures in each multiple-objective alternative. Measures that do not affect hydropower production are not listed in the multiple-objective alternative descriptions below.

1.2.1 No-Action Alternative (NAA)

The NAA includes the operation and structures in place or committed for construction when the Notice of Intent for the CRSO EIS was published in the Federal Register in September 2016 and applied to forecast future years. In summary, those pertinent to this hydropower assessment include:

- FRM Operations per Corps current criteria for the five CRS storage projects, three CRT projects in Canada, and United States FERC-licensed projects (Brownlee and SKQ).
- Canadian Treaty project (Mica, Arrow, and Duncan) storage operations for FRM are as defined in the Flood Control Operating Plan[2]; power operations are as defined in the 2022 Assured Operating Plan. Also includes Canadian storage operations for non-power uses as defined in current agreements between the United States and Canadian CRT Entities.
- Project operating criteria as specified in authorizing legislation and water control manuals including minimum and maximum discharge rates of change and minimum and maximum forebay elevations.

[2] See Columbia River Flood Control Operating Plan prepared by Corps (May 2003) at: http://www.nwd-wc.usace.army.mil/cafe/forecast/FCOP/FCOP2003.pdf

- Flow augmentation objectives consistent with the 2008 BiOp (as amended in 2010 and 2014) issued by NMFS for salmon and steelhead including spring and summer flow targets at Lower Granite and McNary Dams, chum spawning operations below Bonneville Dam, and spawning and rearing operations below Priest Rapids Dam.
- Spill operations for juvenile fish passage consistent with the 2008 BiOp (as amended in 2010 and 2014) issued by NMFS for salmon and steelhead including fish passage spill operations at the eight lower Snake and Columbia River dams.
- Summer drafts at Libby and Hungry Horse dams to meet September 30 targets of 10 feet from full in most years or 20 feet from full in dry years.
- Loads/Resources for hydropower modeling are for 2022 forecasts.
- Turbine-generator unit maintenance/outage schedule for Federal projects is a generic future year based on five-year maintenance averages and includes Grand Coulee turbine-generator overhaul plus forthcoming upgrades to McNary and Ice Harbor turbines.

1.2.2 Multiple-Objective 1 (MO1)

MO1 includes a number of measures to benefit fish and some measures for water management, power production, and water supply. Not all measures in MO1 affect hydropower modeling; MO1 contains the following departures from the NAA that affect the power assessment:

- Fish Passage Spill:
    - The amount of spill in MO1 is more than the NAA, but less than provided by flexible spill operations regional entities agreed to implement in 2020/2021.
    - Block spill: two different spill blocks are provided for spring fish passage — one block is spill to 120/115 percent of the total dissolved gas (TDG) cap level and the other is performance standard spill. Alternative years will have the different spill blocks occurring first or second within the modeling process.
    - NAA summer spill levels are provided, but a fish-count trigger can potentially end summer spill earlier at the lower Snake River projects in August to benefit power when few juvenile fish are migrating.
    - Power contingency reserves can be carried within juvenile fish spill.
- Water Management:
    - Account for local runoff volumes in Libby variable discharge (VarQ)[3] draft and refill operations when the Libby water supply forecast is 6.9 Maf or less.

[3] The VarQ FRM procedure was developed to improve the multi-purpose operation of Libby and Hungry Horse dams while not reducing the level of flood protection in the Columbia River. VarQ details are available in the Water Control Manuals for Libby and Hungry Horse dams. CRSO EIS FRM Appendix.

- Replace Libby end-of-December variable draft target with single 2,420-foot target elevation.
- Apply updated Upstream Storage Correction method to determine end of April draft requirement for Grand Coulee.
- Update Grand Coulee storage reservation diagram (SRD) to account for a reduced planning draft rate limit of 0.8 feet/day and added FRM protection for winter rain-induced flooding below Bonneville Dam.
- Limit Grand Coulee maximum outflow to account for forecasted increase in outages. Use accelerated maintenance schedule for power plant and spillways instead of NAA five-year average.

- Water Supply
  - Increase water supply diversion from Grand Coulee Dam, below Hungry Horse Dam, and from Chief Joseph Dam.
- Storage
  - Sliding scale summer target elevation at Libby and Hungry Horse dams.
  - Dworshak cool water releases are made earlier (June and July) and later (September) with reduced flow in August.
  - Increase John Day target elevation in April and May by 1 foot to reduce avian predation.
- Run-of-River
  - Increased lower Snake Dam operating range (minimum operating pool [MOP][4] + 1.5 feet).
  - Increased John Day forebay operating range (MOP + 2 feet).
- Structural
  - Construct powerhouse surface passage routes at McNary and Ice Harbor dams; this will affect the powerhouse availability at those projects since fish screens will no longer need to be installed.
  - Construct powerhouse surface passage routes at McNary and Ice Harbor dams; this will affect the powerhouse availability at those projects since fish screens will no longer need to be installed.

1.2.3 Multiple-Objective 2 (MO2)

MO2 represents operations that might be implemented if climate change becomes the primary policy driver in the future. More emphasis is placed on hydropower production and flexibility to integrate other renewable resources to reduce carbon emissions from fossil fuel generating

[4] MOP is the lowest forebay operating limit for a run-of-river project.

412 resources. Not all measures in MO2 affect hydropower; MO2 contains the following departures
413 from the NAA that affect the power assessment:

414 • Fish passage spill
415 ○ Fish passage spill amounts are reduced from the NAA, near 110 percent TDG at most
416 projects except when minimum spill levels are higher for powerhouse surface passage
417 routes, for the spillway weirs, and/or for adult attraction to fish ladders.
418 ○ Fish passage spill is curtailed on August 1.
419 ○ Power contingency reserves are carried within fish spill.
420 • Water Management
421 ○ Libby VarQ draft and refill operations are modified when water supply forecast is
422 6.9 Maf or less.
423 ○ Libby end-of-December variable draft procedure replaced with a 2,420-foot target
424 elevation.[5]
425 ○ Additional draft below FRM elevation for hydropower allowed at Libby, Hungry Horse,
426 Albeni Falls, Grand Coulee, and Dworshak.
427 ○ Updated upstream Storage Corrections Method is applied to the Grand Coulee SRD.
428 ○ Update Grand Coulee SRD to account for a reduced planning draft rate limit of
429 0.8 feet/day and added FRM protection for winter rain-induced flooding below
430 Bonneville Dam.
431 ○ Limit Grand Coulee maximum outflow to account for forecasted increase in outages.
432 Use accelerated maintenance schedule for power plant and spillways instead of NAA
433 five-year average.
434 • Water Supply
435 ○ Water supply measures are unchanged from NAA.
436 • Storage
437 ○ Sliding scale summer target elevation at Libby and Hungry Horse dams.
438 ○ Storage projects are allowed to draft to meet power demand during the most valuable
439 periods of high demand in the fall and winter allowing slightly more generation in the
440 winter and slightly less during the spring.
441 • Run-of-River
442 ○ Unrestricted forebay operations (i.e., no restrictions to MOP and minimum irrigation
443 pool [MIP]) provide more flexibility for power generation at the lower Snake and

[5] Note that when this measure for an end-of December target of 2,420 feet NGVD29 is combined with the measure that allows deeper drafting for hydropower at storage projects, the resultant modeled end-of December target is 2,400 feet NGVD29.

Columbia River run-of-river projects and benefit integration of more renewables and meeting peak load demand and obligations or prices in energy markets.

- Operate turbines across their full range of capacity year-round.
- Zero generation operations may occur on lower Snake River projects November through February.

- Structural
  - New higher efficiency turbines with improved fish passage survival replaced older turbines at John Day.
  - Added powerhouse surface passage at John Day, McNary, and Ice Harbor Dams, which increases the minimum spill relevant for MO2.

1.2.4 Multiple-Objective 3 (MO3)

MO3 breaches the four lower Snake River dams and adds other measures beneficial to resident and mainstem anadromous fish. For power purposes, a generic future year after the dams are breached is being modeled. Not all measures in MO3 affect hydropower; MO3 contains the following departures from the NAA that affect the power assessment:

- Dam Breach
  - Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams are breached by removing earthen embankments.
- Fish Passage Spill
  - Spring spill for fish passage at the four lower Columbia River dams up to 120 percent TDG.
  - Reduced duration of summer juvenile fish passage spill (curtailed on August 1).
  - Power contingency reserves are carried within fish spill.
- Water Management
  - Libby VarQ draft and refill operations are modified when water supply forecast is 6.9 Maf or less.
  - Libby end-of-December variable draft procedure replaced with a 2,420-foot target elevation with allowance for additional draft of 20 feet below FRM for hydropower (2,400-foot elevation).[6]
  - Updated Upstream Storage Corrections Method is applied to the Grand Coulee SRD.
  - Update Grand Coulee SRD to account for a reduced planning draft rate limit of 0.8 feet/day.

[6] This measure is modeled with an end-of-December elevation of 2,400 feet NGVD29.

476 - Limit Grand Coulee maximum outflow to account for forecasted increase in outages.
477 Use accelerated maintenance schedule for power plant and spillways instead of NAA
478 five-year average.

479 • Water Supply

480 - Increased water supply diversion from Grand Coulee Dam; below Hungry Horse Dam,
481 and from Chief Joseph Dam.

482 • Storage

483 - Sliding scale summer target elevation at Libby and Hungry Horse dams.

484 • Run-of-River

485 - John Day allowed to operate up to full pool except as needed for flood risk
486 management.

487 - Lower Columbia project turbines operated within and above 1 percent peak efficiency in
488 juvenile fish passage season.

489 • Structural

490 - New higher efficiency turbines with improved fish passage survival replaced older
491 turbines at John Day.

492 - Added powerhouse surface passage at McNary Dam.

493 ### 1.2.5 Multiple-Objective 4 (MO4)

494 MO4 includes aggressive measures to aid anadromous fish survival without breaching the lower
495 Snake River dams. Not all measures in MO4 affect hydropower; MO4 contains the following
496 departures from the NAA that affect the power assessment:

497 • Fish Passage Spill

498 - Spill through modified spillway weirs at Lower Granite, Little Goose, Lower
499 Monumental, Ice Harbor, McNary and John Day projects during October and November
500 for steelhead overshoots, overwintering steelhead, and kelt.

501 - Spill to 125 percent TDG for juvenile anadromous fish passage is provided from March 1
502 to August 31.

503 - Power contingency reserves may be carried during fish spill.

504 • Water Management

505 - Libby VarQ draft and refill operations account for local runoff volumes when that same
506 water supply forecast is 6.9 Maf or less.

507 - Replace Libby end-of-December variable draft procedure with a 2,420-foot target
508 elevation.

509 - Apply updated upstream Storage Corrections Method to the Grand Coulee SRD.

510 - Update Grand Coulee SRD to account for a reduced planning draft rate limit of
511 0.8 feet/day and added FRM protection for winter rain-induced flooding below
512 Bonneville Dam.
513 - Limit Grand Coulee maximum outflow to account for forecasted increase in outages.
514 Use accelerated maintenance schedule for power plant and spillways instead of
515 NAA five-year average.
516 • Water Supply
517 - Increased water supply diversion from Grand Coulee Dam; below Hungry Horse Dam,
518 and from Chief Joseph Dam.
519 • Storage
520 - Release up to 2 Maf of additional water from upstream Federal storage projects to
521 support 220 kcfs spring and 200 kcfs summer target flows at McNary.
522 - Sliding scale summer target elevations at Libby and Hungry Horse dams.
523 - Manage Libby outflow November through March to limit Bonners Ferry stage to
524 maximum of 1,753 feet National Geodetic Vertical Datum of 1929 (NGVD29) for riparian
525 habitat protection.
526 • Run-of-River
527 - The eight Lower Snake River and Lower Columbia River projects are operated within
528 MOP+1.5 feet from mid-March to late August.
529 - Operate lower Snake and Columbia River dam turbines within or above 1 percent peak
530 efficiency during fish passage season.
531 • Structural
532 - Construct additional powerhouse surface passage routes to meet system-wide PITPH[7]
533 target at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, and/or
534 John Day Dams.

535 ### 1.2.6 Draft Preferred Alternative (PA)

536 PA combines a number of measures to benefit fish as well some measures for water
537 management, power production, and water supply. PA contains the following departures from
538 the NAA that affect the power assessment:

539 • Fish Passage Spill:
540 - This measure is a revised juvenile fish passage spill operation based upon results of the
541 spring 2019 Flexible Spill Test Operation and analysis of the four MO Alternatives.

[7] PITPH is a metric that estimates the proportion of juvenile fish passing a dam via the powerhouse. It is based on the relationship between the proportion of juvenile fish that pass via spill and the proportion that pass via the turbines and bypass systems at the dam.

- In a 24-hour period, the Juvenile Fish Passage Spill measure would involve 16 hours of spill operations up to 125% TDG at most projects for juvenile outmigration. For the remaining 8 hours, the projects would spill at a lower level, up to 125% TDG. These spill levels are slightly variable, depending on the project (see Chapter 7). These operations would be implemented during the spring juvenile migration, April 3 – June 21, at the lower Snake River projects, and April 10 – June 16 at 5 the lower Columbia River projects. When Flex Spill ceases, the projects would transition to summer spill operations.
- NAA summer spill levels are described in Chapter 7 with a late summer transition spill operation from August 15 - 31.
- Power contingency reserves can be carried within juvenile fish passage spill.

- Water Management:
  - Account for local runoff volumes in Libby variable discharge (VarQ)[8] draft and refill operations when the Libby water supply forecast is below 6.9 Maf. Revert to NAA operation for years with water supply forecasts above 6.9 Maf.
  - Apply updated Upstream Storage Correction method to determine end of April draft requirement for Grand Coulee.
  - Update Grand Coulee storage reservation diagram (SRD) to account for a reduced planning draft rate limit of 0.8 feet/day.
  - Reduce limit on Grand Coulee maximum outflow to account for forecasted increase in outages. Use accelerated maintenance schedule for power plant and spillways instead of the NAA 5-year average.
- Water Supply
  - Increase water supply diversion from Lake Roosevelt by 45,000 acre-feet of water above the NAA.
- Storage
  - Sliding scale summer target elevation at Libby and Hungry Horse dams.
  - Dworshak will be operated with a variable draft elevation target to increase hydropower generation in the winter and reduce non-fish passage spill in the spring, while protecting the refill of the reservoir.
  - Operate John Day pool between 264.5 – 266.5 feet during April 10 – June 15to reduce avian predation.

[8] The VARQ FRM procedure was developed to improve the multi-purpose operation of Libby and Hungry Horse dams while not reducing the level of flood protection in the Columbia River. VarQ details are available in the CRSO DEIS FRM Appendix.

- Run-of-River
  - Increased lower Snake Dam operating range (MOP[9] + 1.5 feet).
  - Increased John Day forebay operating range (MOP + 2 feet).
  - John Day full pool measure would allow for operation of the reservoir across the full range 262.0 – 266.5 feet elevation outside of fish passage season, except as needed for structural measures
  - Zero generation operations may occur on lower Snake River projects October 15 – February with revised timing of the measure to provide hydropower flexibility to integrate new renewable resources and while minimizing impacts to ESA-listed fish.
- Structural:
  - Use new higher-efficiency turbines with improved fish passage survival in place of older turbines at John Day.

Construct powerhouse surface passage routes at McNary and Ice Harbor dams, which increases the minimum spill relevant for PA and affects turbine availability.

[9] MOP or minimum operating pool is the lowest forebay operating elevation for a run-of-river project.

CHAPTER 2 - MODELING OVERVIEW FOR ALTERNATIVES

2.1 HYDROREGULATION IN THE COLUMBIA RIVER MANAGEMENT AREA

Hydroregulation modeling is performed using one or more computational models that simulate reservoir, powerhouse, and dam operation of the hydropower system over a period of time. Different hydroregulation models are used in a specific sequence to compute outputs to assess the impact on a goal or measure from the operations protocols or physical limitations input into the model.

Hydroregulation models are developed to solve a specific set of mathematical computations, answer a specific set of questions, and satisfy a specific set of needs. Different hydroregulation models cover different timeframes, have different capabilities, and have different strengths and weaknesses. The outputs from one model may be used as inputs to other models to refine the computations or answer different questions, and they output a separate set of results.
The outputs from an existing condition or NAA model run are compared to the outputs from model runs with alternative operations. The differences are quantified to determine the impact to a resource, such as water quality parameters, recreation season reservoir levels, aquatic habitat quantity and suitability, or Heavy Load Hour (HLH) generation (HE 7 am to HE 10 pm, except Sundays and Holidays).

Model inputs are created from a combination of physical components (e.g., reservoir volume curves and powerhouse performance) and operational conditions (i.e., required spill flows or reservoir elevation refill targets). These inputs are created from the objectives or goals of a model run by staff familiar with the hydropower system. Once inputs have been entered and the model run, output results are examined to verify the success of meeting the goals and objectives.

Computer model logic simulates normal reservoir and powerhouse operation, and perhaps even some non-standard operations, but there are numerous instances where operations in real life may differ from model outputs. Examples of the deviations from normal operations include emergency operating requirements, maintenance outages, and differences caused by actual versus forecasted hydrology, and differences in actual versus modeled withdrawals and evaporation. Models also do not cover operations that occur on timeframes shorter than the model's resolution. To meet a specific goal (i.e., a maximum TDG concentration below a dam) modelers input a specific maximum spill constraint. However, in real life, the TDG limit may be achieved at a different spill rate due to temperature, rainfall, reservoir level, wind, and other environmental variables.

2.2 OVERALL MODELING APPROACH

The modeling approach for the CRSO EIS aligned different model approaches and types to provide similar representations of key operations for all impact assessments. Figure 2-1 describes the three primary steps of the modeling approach: input, modeling (or study/task), and output. This section describes the steps applied to achieve outputs for each alternative. Results from the hydroregulation modeling were used in subsequent modeling steps to provide results for different impact assessments.

The results from the Bonneville hydropower simulation model (HYDSIM) portion of the hydroregulation studies were detailed sets of 80-year by 14-period (April and August being split months) project outflows, reservoir elevations, reservoir contents, spillway flows, and power generation data at the 31 projects in the FCRPS and several other electric projects in the Northwest United States and Canada (Exhibit 1). The CRSO EIS focuses on the 14 CRS projects and select non-Federal projects affected by the EIS alternatives.

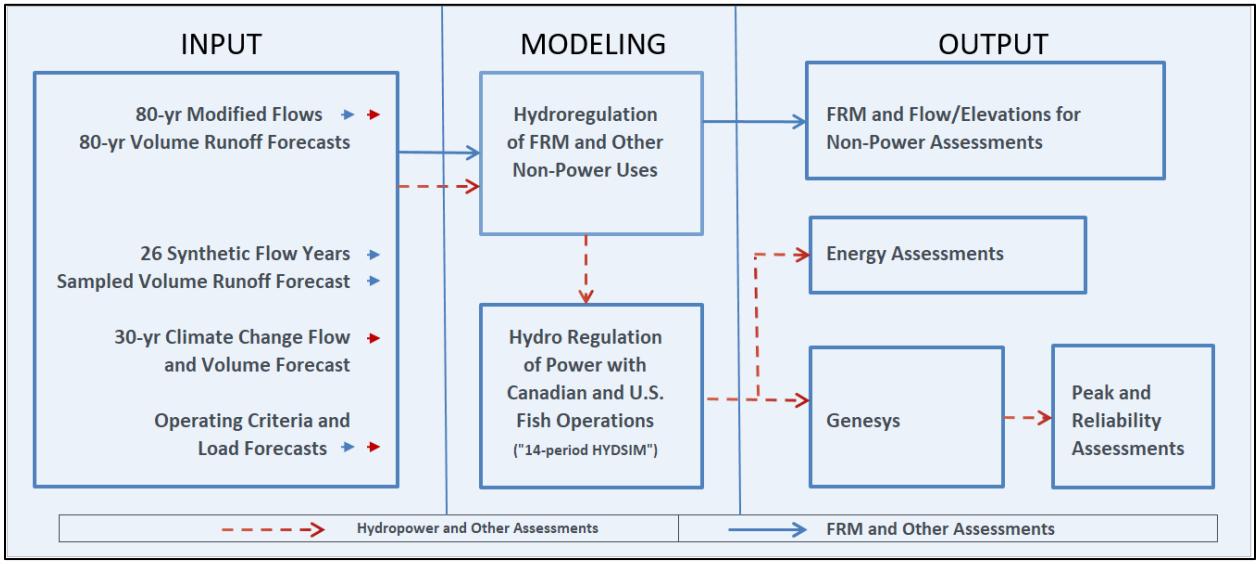

Figure 2-1. Modeling Approach

2.3 HYDROREGULATION MODELS

Models used for hydroregulation for the CRSO EIS primarily include Hydro System Simulator (HYDSIM), Reservoir System Simulation Model (ResSim), and Hourly Operations Scheduling Simulator (HOSS). Other computerized programs are used to develop inputs that influence reservoir storage operations, these inputs include Energy Content Curves (ECC), refill curves, and upper rule curves (URC) that represent FRM requirements. The hydroregulation computations are performed using HYDSIM and ResSim. The ResSim hydroregulation model described here is limited to its role in the overall hydroregulation modeling sequence; further information is in the H&H Appendix (Appendix A, Part 3 – HEC-ResSim/WAT Documentation and Part 1 – H&H Data Analysis).

The general hydroregulation simulation process is for Bonneville staff to develop inputs for HYDSIM from the 80-year Modified Flow dataset, Energy Content Curve inputs, power demand,

plant performance inputs from Pacific Northwest Coordination Agreement submissions and other requirements. Input quality control is provided by other modeling staff before the HYDSIM model is run. Outputs are reviewed by multiple modeling staff to ensure the model is implementing the conditions as desired, and no conflicting requirements cause the model to not satisfy a desired operating condition. Further, all the hydroregulation of the CRSO alternatives with the 80-year Modified Flow dataset were run through both the HYDSIM and ResSim models, and the outputs compared by a group of hydro modelers for quality control.

HYDSIM models the system in 14 periods, monthly with two split months, April and August. The outputs are end of period project elevations, period average generation, and period average turbine and spillway outflows. ResSim models are used to model the system on a daily basis, which is better suited to simulate intra-month reservoir elevations, dam outflows, and evaluate potential flooding events.

The HYDSIM output is supplied to the HOSS model. HOSS is used to convert the 14-period generation output into hourly generation. Verification of inputs and outputs are performed by a primary modeler and a modeler who performs quality control checking of the datasets.

Generation outputs from HYDSIM and HOSS are used to evaluate CRSO generation and the ability to meet loads. River flow and reservoir elevation outputs from ResSim are used to evaluate the model run impacts to water quality, fish habitat, navigation, and other affected operating objectives.

CHAPTER 3 - HYDROPOWER MODELING

Bonneville and the Corps modeled the CRSO EIS alternatives, respectively, with HYDSIM producing 14-period output and ResSim producing daily output. These models share common inputs and also rely on output from each other. For example, end of month elevations, flows, and proportional draft points from HYDSIM are used as inputs to ResSim, which develops daily time-step end of day elevations and average flows, ultimately producing upper rule curves (URCs). These URCs then become conditions for the US operation that HYDSIM must meet.

These models interact and are interdependent, and therefore operations in both models need to be similar for each alternative. Bonneville and Corps modelers coordinated extensively throughout the CRSO EIS analyses to assure both models and related outputs are in sync and aligned. For example, regulated project elevations were compared and, if necessary, appropriate adjustments made to the modeling inputs to attain similar results. Bonneville and the Corps also compared 14-period outflow average volumes of both models to assure the operations for the NAA and each MO were similar.

3.1 HYDSIM

The HYDSIM model simulates power production for the month-to-month operation of the Pacific Northwest hydropower system. It is used to determine the hydropower system generation and resulting project outflows, ending storage contents under varying inputs of inflows, power loads, operating procedures and constraints, and physical plant data.

The HYDSIM model is not an optimizer; instead, it is a deterministic model that uses rule curves and flow limits or storage constraints to achieve operating objectives, especially for power, FRM, fish flows and spill, and recreation. HYDSIM uses a 14-period time step. April and August are split into two half-periods because these months tend to have significant natural flow differences between their first and second halves. The model simulates one period at a time, not using any forwarding-looking process.

HYDSIM uses the 2010 Level Modified Flows for water year sequences 1929 through 2008 as input. The model is run in a continuous mode where the same load and resource parameters are applied to all water years and the ending elevations for each historical water year become the starting elevations for the next water year.

For each period, the model reads input files containing unregulated streamflow, power load forecasts, operating rule curves, and operating requirements (more details available in other sections and exhibits). The model follows a priority list of constraints to determine the final operation for each project.

The HYDSIM studies performed for the CRSO EIS simulated hydropower system operation to estimate the hydropower generation produced while meeting the objectives of each of the alternatives. The results provide 80 years of generation averages with each year comprised of 14 periods of generation averages.

3.2 RESSIM

The Reservoir System Simulation (HEC-ResSim) software developed by the U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center is used to model reservoir operations at one or more reservoirs for a variety of operational goals and constraints. The ResSim model for the Columbia River System is used several times in the CRSO EIS modeling sequence. First, the Flood 0 (F0) sequence is used to compute URCs that meet requirements of the operating constraints and FRM. The URCs are then passed to HYDSIM, which operates the reservoirs given these and other inputs. The outputs from this HYDSIM process then go back to the Corps for subsequent modeling, with the final ResSim output coming from the Flood1 model, which produces daily regulation results reflecting the multiple-purpose operation of the system. Detailed information on the ResSim model for the Columbia River System, including a description of model inputs and how HEC-ResSim interfaces with the Watershed Analysis Tool (HEC-WAT), is contained in the several sections of the H&H Appendix (Appendix A, Part 3 – HEC-ResSim/WAT Documentation; Appendix A, Parts 4 and 5 – Hydrologic Data Development and Extended Observed Flows). Output from the HEC-ResSim model is presented in the H&H Appendix (Appendix A, Part 1 – H&H Data Analysis) as well as in the H&H Environmental Consequences section in Chapter 3 of the main CRSO EIS report

3.3 AURORA

AURORA is a production cost model, developed by Energy Exemplar, Ltd Pty., used by hundreds of utilities globally to forecast short- and long-term electricity prices. Given model inputs (resource build, load forecast, fuel cost, etc.), AURORA produces a price forecast by calculating the least cost solution of meeting system-wide load on an hourly basis, subject to a number of operating constraints. The cost of producing and delivering an additional unit of energy to a location in the system is assumed to approximate the price at that location.

Bonneville uses AURORA to create price distributions by using Monte Carlo sampling of projected loads, hydro generation, gas prices, transmission capacity, wind generation, and Columbia Generating Station (CGS) capability. Given 80 years of month-average hydropower energy estimates provided by HYDSIM for each of the CRSO EIS modeling studies, AURORA estimates month-average prices and month-average Lack of Market (LOM) spill MW quantities. LOM spill occurs in AURORA when available hydro generation exceeds transmission capabilities and system load net of lower cost or must-run generation. The AURORA LOM spill estimates are then included as LOM limits in a second pass of HYDSIM.

Energy revenue estimates are developed by applying AURORA prices to the energy differences between each alternative and the reference NAA case.

3.4 GENESYS

The GENeration Evaluation SYStem (GENESYS) is an economic dispatch model that uses Monte Carlo sampling to simulate short-term load uncertainty, and uncertainty in streamflows, wind, solar, and forced outages for thermal generation plants. The model performs a detailed constrained dispatch of the regulated hydropower projects in the watershed of the Columbia

River and a simple dispatch of Pacific Northwest regional thermal plants against an extra-regional import market.

The model was developed by Northwest Power and Conservation Council (NWPCC), Bonneville, and other regional entities, and is used to perform studies requiring detailed hydropower dispatch for planning purposes. More specifically, NWPCC uses GENESYS for annual adequacy assessments, periodic regulated hydropower flow studies and periodic analysis of lost revenue due to hydropower dispatch change. The adequacy of the regional power supply is assessed probabilistically in GENESYS by evaluating any regional shortfall against NWPCC's adequacy standard. This standard was designed to assess whether the region has sufficient resources to meet growing demand for electricity in future years. Regulated hydropower flow studies have been performed for fish passage survival and life-cycle studies, and climate change scenarios.

For the CRSO EIS alternatives, the GENESYS model was run by Bonneville staff. Datasets containing hydropower generation plant parameters and constraints (inputs similar to HYDSIM and ResSim), thermal generation plant parameters and constraints, and other generation sources and constraints (i.e., wind and solar power plants) were input into the model. Power demand loads and both long- and short-term generation commitments also were entered into the model.

3.5 HOSS

HOSS is a hydroregulation model that shapes longer-period average flows and reservoir ending elevations into hourly time steps based on load shape. It is designed to simulate the decision making process of a Bonneville duty scheduler[10]. It uses time-step starting and ending conditions from HYDSIM along with other user entered constraints to simulate hourly operations of the 14 CRS projects (i.e., Libby, Hungry Horse, Albeni Falls, Dworshak, Grand Coulee, Chief Joseph, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and Bonneville dams). Libby, Hungry Horse, Albeni Falls, and Dworshak flows are modelled flat every hour of every day with no shaping. At the remaining 10 projects, the model targets HYDSIM month end elevation targets while shaping flows to follow load shape; as a result, generation is shaped more into heavy load hours and less into light load hours.

Inputs consist of HYDSIM flow and elevation targets, residual power load, turbine outages, plant operational constraints (min/max elevation, flow, draft rates, etc.) and non-power constraints such as Banks Lake operations and fish spill operations.

Outputs for inventory purposes are average, HLH, light load hour (LLH), super-peak, and graveyard hydropower generation and inventory. Other output reports include generation by project, plus monthly (28 day), weekly, daily, and hourly operation of the hydropower system by water year.

[10] Bonneville duty schedulers coordinate the real-time hourly operation of Grand Coulee, Chief Joseph, and the eight Federal lower Snake and lower Columbia River dams.

CHAPTER 4 - HYDROPOWER MODEL INPUTS

This chapter provides a general overview of the inputs Bonneville used to model the system operation under the CRSO EIS alternatives. These inputs also are common to those used by the Corps to model the CRSO EIS alternatives.

The hydrologic datasets contain the Columbia River streamflows and runoff volume forecasts common to all of the alternatives. The project descriptors and operational parameters provide the physical and operational parameters that produce the sideboards or limits on operational flexibility. The climate change streamflows and forecasts are modifications to the hydrologic datasets that reflect potential streamflow changes from potential climate change.

4.1 HYDROLOGIC DATASETS

Hydrologic datasets used in modeling are a time series of data points, where each node or location in a watershed has an inflow value for each time-step (e.g., each day has a daily average inflow value). The base hydrologic dataset for this study is the 80-year Modified Flow dataset.

4.1.1 80-year Modified Flow Dataset

The base source of water inflow time series into reservoirs and stream reaches, used in both HYDSIM and ResSim modeling, is the 80-year Modified Flow dataset (Bonneville 2011). This dataset is computed for the Columbia River hydroelectric system and associated tributaries, and used by the numerous internal and external groups for a variety of studies. Bonneville, Reclamation and the Corps perform hydroregulation studies of the Columbia River basin for analysis of environmental impacts, changes to operation criteria from BiOps, power revenue forecasts, FRM studies, operations planning, downstream benefit calculations, and effects of new projects or plant data. A wide range of other regional organizations, including the NWPCC, Northwest Power Pool, Pacific Northwest Utilities Conference Committee, fishery agencies and organizations, universities, research organizations, contractors, and public interest groups also need a consistent and accepted regional streamflow dataset. Modified flows are defined as the historical streamflows that would have been observed if current irrigation depletions existed in the past and the effects of reservoir regulation were removed (except at the upper Snake, Deschutes, and Yakima basins where current upstream reservoir regulation practices are included). Because irrigation practices and evaporation rates have changed since the historical flows were observed, historical streamflows need to be adjusted to account for current levels of irrigation depletions and evaporative losses. The 2010 modified flow study includes 80 years of flows (1929 to 2008) adjusted to 2010 irrigation depletions and evaporation rates.

4.1.2 Synthetic Events

In addition to the 80-year record described above, a hydrologic dataset with 26 synthetic water years is applied in ResSim modeling. The 26 synthetic water years consist of 17 spring synthetics and 9 winter synthetics. This synthetic event hydrology dataset is described in the H&H

Appendix (Appendix A, Part 4 – Hydrologic Data Development) and is not used in HYDSIM for hydroregulation study analysis for power purposes.

4.1.3 2008 to 2016 Flow for Water Quality Assessment

When modeling the CRS for water quality metrics, an inflow dataset for 2008 to 2016 was used instead of the 80-year Modified Flow dataset because prior to 1995, there is little water temperature or TDG data in the Corps Water Management System[11] database or the U.S. Geological Survey National Water Information System database. The Corps Water Management System provides consistent, basin-wide temperature and TDG data from 2005 to 2016. Unfortunately, the current period of record dataset available for input into the water quality models spans from 1929 to 2008, leaving only three years of overlap between good water quality datasets and flow/weather information. As a result, it was decided to model more recent water years where consistent water quality data exists, which also has a variety of flow and meteorological conditions.

These more recent Extended Observed Flows from 2008 to 2016 were generated by the Corps. The development of this dataset is described in the H&H Appendix (Appendix A, Part 5 – Columbia River System Extended Observed Flows Water Years 2008-2016).

The following three files associated with Bonneville's HYDSIM runs using the 2008 to 2016 Extended Observed Flows were provided to the Corps to assist with their Spill Allocation Process. The Spill Allocation Process is detailed the H&H Appendix (Appendix A, Part 2 – Spill Analysis).

- Hydro availability input specifies the percent of time the hydro generators were available to run at each project.
- LOM spill data resulting from the AURORA run indicates the estimated energy spilled due to a lack of secondary market.
- The specific spill operation at the eight lower Snake and lower Columbia River projects were provided to the Corps.

4.2 RUNOFF VOLUME FORECASTS

Runoff volume forecasts are required inputs for the regulation and simulation of reservoir operations for FRM and hydropower generation. Runoff volume forecasts are an important input as predictors of seasonal reservoir operations of the Columbia River Basin. The operation of certain projects use various periods of runoff volume forecasts. Because reservoirs require months to draft space, they must use runoff volume forecasts to plan ahead to achieve the FRM and BiOp operational goals. Operational guidance for flood storage and power generation can vary depending on water supply volume forecasts during the winter and spring seasons, when storage projects are operating to balance FRM, refill, power generation, and fish

[11]Corps Water Management System is accessible at: https://www.nwd.usace.army.mil/CRWM/Water-Control-Data/

objectives. Information on the development of runoff volume forecasts is provided in the H&H Appendix (Appendix A, Part 4 – Hydrologic Data Development).

4.3 COLUMBIA RIVER SYSTEM AND PROJECT OPERATING PARAMETERS

This section provides a generic description of the types of controls/operations that reservoirs (collectively or individually) can affect with summary (also in tabular format) of the parameters by reservoir and alternative. This section includes the physical and practical operational constraints at the modeled projects.

The 14 CRS projects are operated and modeled to meet several system and project-specific objectives. Flow-related system objectives are managed through the coordinated storage and release of water at Federal storage reservoirs, non-Federal storage reservoirs, and Canadian reservoirs. Generally, project objectives are managed through at-site outflows and upper and lower forebay elevation limits to the reservoirs. CRSO EIS alternative modeling involves meeting alternative objectives to the extent possible while meeting system and project operating parameters.

4.3.1 System Operations

4.3.1.1 System Flood Risk Management

The CRS is authorized to provide FRM in the Columbia Basin. System water managers operate the storage dams and reservoirs in a coordinated manner to balance inflow and outflow with the general objective of minimizing flood consequences throughout the Columbia River Basin. The FRM parameters used by Bonneville for its modeling are the upper rule curves developed and used by the Corps to model the CRSO EIS alternatives. Details for on operations for FRM are provided in the H&H Appendix (Appendix A, Part 3 – HEC-ResSim/WAT Documentation) and in the Flood Risk Management Appendix (Appendix H).

4.3.1.2 Conservation of Fish and Wildlife

The 2008 NOAA Fisheries BiOp, supplemented in 2010 and 2014, and the 2000 USFWS BiOp, supplemented in 2006, provide strategies to prioritize operations with FRM, power, and other objectives. The CRS projects are operated and modeled to the following priorities (in order) for flow management and individual reservoir operations after ensuring adequate FRM is provided:

- Operate storage projects to meet minimum flow and ramp rate criteria for resident fish
- Refill storage projects and provide summer flow augmentation
- Operate Grand Coulee and Hungry Horse to their April 10 elevation objectives to provide spring flow augmentation
- Operate Grand Coulee to balance the needs of chum flow augmentation and spring flow augmentation from the start of chum spawning in November through the end of chum emergence (approximately April)

Flow objectives are provided and prioritized in the 2008, 2010, and 2014 NOAA Fisheries BiOps. The Corps, Reclamation and Bonneville make every effort to follow flow priorities while implementing and modeling operations as they occur chronologically during the year. Objectives include:

- Storage reservoir draft limits in late summer are a higher priority than the summer flow objectives to meet other project uses and provide carry-over storage for the following year.
- Operate the storage reservoirs to achieve the April 10 elevation objectives with a high probability. These levels will vary with the runoff forecast. The April 10 objectives are linear interpolations between the March 31 and April 15 forecasted FRM elevations.
- Refill the storage reservoirs by about June 30 while minimizing spill (except as needed to maintain FRM) to maximize available storage of water for the benefit of summer migrating fish.
- Manage the available storage to augment summer (July and August) flows in the lower Columbia River and lower Snake River in an attempt to meet flow objectives and minimize increases in water temperature.

More detail on the objectives is in the CRSO EIS Anadromous Fish and Resident Fish appendices.

OPERATIONS FOR WATER QUALITY

Throughout the CRS, elevated levels of TDG are observed where spill occurs at CRS projects. Bonneville modeling helps estimate spill location, amount, and timing due to lack of power markets during periods of relatively high streamflows and for lack-of-turbine when river flows exceed the turbine capacity plus any planned spill for fish passage.

Bonneville modeling reflects the objectives of a TDG management plan included in the annual water management plan. This TDG management plan describes fish passage spill and LOM and lack-of-turbine spill, use of the spill priority list, the process for setting spill caps, TDG management policies, and the TDG monitoring program.

4.3.1.3 Power Generation

One of the authorized purposes of all the 14 CRS projects reviewed in this EIS is electricity generation. Bonneville modeled the CRSO EIS alternatives to identify potential power effects. Bonneville modeling considers several aspects of the CRS projects' hydropower capabilities and parameters in this subsection.

Bonneville is the Federal power-marketing administration within the Department of Energy that markets and transmits power generated at 31 FCRPS dams including the 14 CRS projects listed in Table 4-1. Nameplate capacity is the maximum rated output of the generators and commonly expressed in megawatts (MW). The availability of water and other constraints determine how much power is generated at these projects, up to this capacity limit.

Table 4-1. Total Nameplate Capacity (MW) for the 14 CRS Projects

Project Name	Type	Location	Total Nameplate Capacity (MW)
Lower Granite	Run-of-River	Lower Snake River	810
Little Goose			810
Lower Monumental			810
Ice Harbor			603
McNary		Lower Columbia River	980
John Day[2]			2,480
The Dalles			2,080
Bonneville			1,200
Grand Coulee	Storage	Middle Columbia River	7,015[1]
Chief Joseph	Run-of-River	Middle Columbia River	2,000
Hungry Horse	Storage	South Fork Flathead River	428
Libby		Kootenai River	525
Dworshak		North Fork Clearwater	400
Albeni Falls		Pend Oreille River	42
		Total	**20,183**

1Capacity includes pump generation.
2 John Day has 0.5 Maf of storage. It operates like a run-of-river project except during periods of high streamflows when its storage may be used to reduce flows below Bonneville Dam.

For each CRSO EIS alternative, Bonneville modeled the amount of electricity generated at the 31 FCRPS projects as a result of the objectives of each alternative.

Energy supply (including generation, imports, and exports) must equal load (demand for electricity) at all times. When needed, Bonneville participates in the wholesale electricity market to buy and sell electricity to ensure electricity demand and supply on the Federal system remains balanced. Bonneville modeling also simulates the interactions between CRS power production and the wholesale electricity markets.

OPERATING RESERVES

Bonneville modeling also captures operating reserve requirements. Bonneville, as the North American Electric Reliability Corporation registered balancing authority, is responsible for maintaining the balance between generation and load.

Bonneville manages and provides generation operating reserves based on a required reserve obligation using dispatchable energy generation[12] to ensure generation within the Balancing

[12] Dispatchable energy generation refers to sources of electricity that can be dispatched (generation is increased or decreased) at the request of power grid operators or the plant owner to meet fluctuations in demand or supply. Often, baseload power plants such as nuclear or coal cannot be turned on and off in less than several hours. The time it takes a dispatchable generation plant to be turned on or off may vary in seconds, minutes, or hours. Wind and solar power are also not considered dispatchable because they cannot increase generation whenever it would be beneficial for grid operations.

Authority Area matches load at all times. The most common dispatchable power plants for reserve obligations in the Northwest are hydropower[13] and natural gas; therefore, Bonneville sets aside a certain portion of hydropower generation capability to meet its reserves obligation for unexpected increases or decreases in generation or load in the Bonneville Balancing Authority Area.

TRANSMISSION

As a registered North American Electric Reliability Corporation - transmission operator, Bonneville also is responsible for maintaining the safety and reliability of the transmission grid. Certain transmission system needs can affect water management functions at the projects. For example, Bonneville's management of its transmission system in response to a transmission line outage can influence the location and amount of power generation required to maintain system reliability.

MINIMUM GENERATION

Both Snake River and Columbia River projects have minimum generation requirements to support power system reliability, and operate efficiently (which may reduce fish turbine passage mortality by reducing adverse conditions for the fish within the scroll cages). These parameters are incorporated into Bonneville modeling. The Corps has identified minimum generation powerhouse outflow values derived from actual generation records when turbines were operating within ±1 percent of best efficiency There may be instances where turbine generator units are operated outside of the best efficiency point ±1 percent to generate with the water instead of spilling.

Each of the lower Snake River powerhouses may be required to keep one generating unit online at all times for power system reliability under low river flow conditions resulting in a reduction of spill at that project. Low flow operations at lower Snake and Columbia River projects are triggered when inflow is insufficient to meet both minimum generation requirements and planned Fish Operations Plan spill levels.

4.3.1.4 Irrigation and Water Supply

The total acreage in the United States portion of the Columbia River Basin that is irrigated by Reclamation projects (including Hungry Horse, Columbia Basin Project[14], Chief Joseph, Yakima, Umatilla, The Dalles, Deschutes, and Crooked River) is about 1.4 million acres. Bonneville models the irrigation diversions for the Columbia Basin Project using specific monthly pumping

[13] Hydropower is dispatchable as long as there is flexibility to increase or decrease generation, which sometimes means having the ability to increase or decrease flows coming from an upstream reservoir. For example, there is little capacity to hold reserves at the Lower Snake River dams when the forebays are maintained within a narrow operating range at MOP. This operating range restriction constrains reservoir storage capability and therefore limits the ability to hold many reserves.

[14] The Columbia Basin Project serves east central Washington. The main facilities of the project include Grand Coulee Dam, John W. Keyes III pump/generator plant, Lake Roosevelt, and Banks Lake. From www.usbr.gov/pn/grandcoulee/cbp/ .

volumes from Lake Roosevelt through the John W. Keyes III pump/generating plant. The remaining irrigation diversions, depletions, and return flows are incorporated into the streamflow record used for modeling the CRSO EIS alternatives.

4.3.1.5 Navigation

The Corps maintains a shallow draft navigation channel on the lower Snake and Columbia Rivers to provide commercial barge transport. This depth is generally met in reservoirs and by meeting the minimum flow objectives below Bonneville Dam. It is not a high priority objective in Bonneville modeling; however, it is important enough to draft Lake Roosevelt to support these navigation flows.

4.3.1.6 Recreation

The Corps and Reclamation operate projects to support recreation in various ways including the provision of certain outflows or lake levels during prime recreation seasons. Specific objectives are described in each individual project section.

4.3.2 Reservoir Operating Parameters

Operating and modeling the CRS projects for system objectives considers several on-site operating parameters at each project. Parameters generally include the physical and practical operational constraints that produce the sideboards or limits on operational flexibility. These parameters are generally met in modeling unless an alternative includes measures specifically intended to operate contrary to the parameters.

More detailed information for these parameters can be found in the modelling data sheets in Exhibit 4. Bonneville modelers prepare the data sheets to document the measures included in each HYDSIM study. (Similarly, the Corps modelers' data sheets for ResSim modeling are provided in the H&H Appendix (Appendix A, Part 3 – HEC-ResSim/WAT Documentation). Additional detail is also available in the individual water control manuals for each project. A summary level description of these parameters is provided by project in the following subsections.

4.3.2.1 Libby Project

GENERAL

Libby Dam and Lake Koocanusa are located on the Kootenai River in Northwest Montana and extends into Canada. It is a Corps storage project providing 5.0 Maf of space between its maximum forebay elevation of 2,459 feet NGVD29 and minimum forebay elevation of 2,287 feet NGVD29. It has an installed powerhouse of 5-units, 525-MW, with a maximum total discharge capacity of about 26 kcfs. Its authorized purposes are FRM, fish and wildlife conservation, power, and recreation.

FLOOD RISK MANAGEMENT

Libby Dam operations regulate spring flows in the Kootenai River to provide local FRM as measured at Bonners Ferry, Idaho, and system FRM in the mainstem Columbia River, as measured at The Dalles, Oregon. Currently, Libby Dam is operated consistently with VarQ FRM procedures that influence fall/winter drawdown and spring refill. VarQ procedures also are intended to improve the multiple purpose operation of Libby and Hungry Horse Dams while maintaining the level of local and mainstem FRM in the Columbia River Conservation of Fish and Wildlife

Libby Dam minimum discharges and ramp rates (hourly and daily maximum outflow changes) are intended to benefit downstream resident fish and wildlife by limiting fluctuations in river flow. A tiered volume of water is released from Libby Dam for white sturgeon measures based on the May water supply volume forecasts. The volume in mid- to late May and early June supplements the amount of minimum flow provided for bull trout.

From July through September, Libby discharge is managed to augment flows for the out-migration of juvenile salmon in the Columbia River and resident fish in the Kootenai River. The reservoir is drafted to an elevation of 2,449 feet NGVD29 (10 feet from full) by the end of September, except in the driest 20 percent of years based on The Dalles' May WSF, when the draft will increase to target an elevation of 2,439 feet NGVD29 (20 feet from full).

POWER GENERATION

Five generating units at the Libby project discharge into the Kootenai River. The units have an estimated discharge capacity estimate of up to 5,200 cubic feet per second (cfs) each.

Hourly and daily load shaping may occur primarily from October through February for optimized power production while providing protection for resident fish and maintaining FRM. During October through February, daily load shaping above the minimum 6,000 cfs flow and within the ramping rate constraints provides protection for aquatic biota inhabiting the mainstem river channel.

Transmission limitations in the Flathead Valley can, under certain conditions, require Libby Dam to reduce generation. Bonneville implemented transmission system protection measures to minimize generation modifications at Libby Dam and maintain power system reliability within required standards.

OTHER

Libby Dam also provides temperature control of its powerhouse outflows and Lake Koocanusa has boat ramps, docks, and shoreline recreation sites. These all are important factors to consider in real-time operations, but do not affect Bonneville modeling of Libby operations. Libby Dam does not operate for irrigation, water supply, or navigation purposes.

4.3.2.2 Hungry Horse Project

GENERAL

Hungry Horse Dam and reservoir are located on the South Fork of the Flathead River in Northwest Montana. It is a Reclamation storage project providing about 3 Maf of space between its maximum forebay elevation of 3,560 feet NGVD29 and minimum forebay elevation of 3,336 feet NGVD29. It has a 4-unit, 285-MW powerhouse with a maximum total discharge capacity of about 12 kcfs. Its authorized purposes are FRM, fish and wildlife conservation, power, irrigation, and recreation. The Corps developed a water control manual for Hungry Horse Dam that Reclamation uses as guidance for dam operations to meet FRM needs.

FLOOD RISK MANAGEMENT

Hungry Horse Dam regulates spring flows in the Flathead River to provide local FRM as measured at Columbia Falls, Montana, and system FRM in the mainstem Columbia River, as measured at The Dalles, Oregon. VarQ procedures influence fall/winter drawdown and spring refill and are intended to improve fish and wildlife conditions in the Flathead River.

Reclamation coordinates FRM operations of Hungry Horse with Energy Keepers, Inc., the operators of SKQ Dam on Flathead Lake downstream from Hungry Horse.

CONSERVATION OF FISH AND WILDLIFE

Releases from Hungry Horse Dam are maintained to help benefit resident fish and habitat in the Flathead River. Minimum discharges and ramp rates (hourly and daily maximum outflow changes) are intended to benefit downstream resident fish by limiting fluctuations in river flow and maintaining minimum flows downstream at Columbia Falls, Montana. Hungry Horse Dam provides spring flow augmentation by managing the reservoir to achieve an April 10 objective elevation and follow the VarQ operating procedure. In the summer and early fall, Reclamation drafts Hungry Horse as low as elevation 3,550 feet NGVD29 by the end of September in the wettest 80 percent and 3,540 feet NGVD29 in the driest 20 percent of water years based on The Dalles' May WSF.

POWER GENERATION

Four generating units at Hungry Horse project discharge into the South Fork Flathead River. Each unit has an estimated discharge capacity up to 3,000 cfs. Variations to maximize the value of power generated at the Hungry Horse project are limited to the water available for release, minimum flows, and hourly and daily discharge ramping rates.

Transmission limitations in the Flathead Valley can, under certain conditions, require Hungry Horse Dam to reduce generation. Bonneville implemented transmission system protection measures to minimize generation modifications at Libby and Hungry Horse Dams and maintain power system reliability within required standards.

OTHER

Hungry Horse Dam also provides temperature control of its powerhouse outflows and is operated to avoid spill. The reservoir has boat ramps and shoreline recreation sites. Hungry Horse Dam is authorized for irrigation, but there are currently no water contracts. These are important factors to consider in real-time operations, but do not affect Bonneville modeling of Hungry Horse operations. It does not operate for navigation purposes.

4.3.2.3 Albeni Falls Dam

GENERAL

Albeni Falls project is a Corps project that regulates the level of Lake Pend Oreille providing a useable storage of approximately 1 Maf within the normal operating range from 2,051 to 2,062.5 feet NGVD29, as measured at the gauge located at Hope, Idaho. It has a three unit powerhouse that can generate about 42.6 MW.

FLOOD RISK MANAGEMENT

Albeni Falls project usually begins its fall drawdown of Lake Pend Oreille on September 18 or the third Sunday of September, whichever is later, and drafts to an elevation no lower than 2,060 feet NGVD29 by September 30, followed by further drafts to within half of a foot of 2,051 feet NGVD29 by November 15. Lake Pend Oreille remains near 2,051 feet NGVD29 throughout the winter, subject to flexible winter power operations, and is used for winter FRM. Spring snowmelt runoff in the Pend Oreille Basin generally begins in early April and peaks in May or June. During this period, the lake is refilled and Albeni Falls project occasionally used for FRM.

CONSERVATION OF FISH AND WILDLIFE

Albeni Falls operations for fish and wildlife conservation primarily consist of managing the elevation of Lake Pend Oreille during the fall and winter to support kokanee survival, a critical food source of Endangered Species Act (ESA)-listed bull trout. During the summer, Albeni Falls maintains Lake Pend Oreille between elevation 2,062.0 and 2,062.5 feet NGVD29. The Lake is held above 2,062.0 feet NGVD29 through the third Sunday in September, or September 18, whichever is later.

Starting October 1, Albeni Falls begins drafting to a target elevation of 2,051.0 feet NGVD29 by mid-November, prior to when kokanee are expected to begin spawning. Flows released during the draft also support ESA-listed salmon in the Columbia River, particularly chum salmon downstream of Bonneville Dam.

POWER GENERATION

From the end of kokanee spawning or December 31 whichever is earlier, to the end of March, Albeni Falls may be operated to release or store water for downstream hydropower purposes. The range of fluctuation is between the minimum elevation established for kokanee spawning and elevation 2,056 feet NGVD29 from around December 15 to March 31.

RECREATION

Recreation at Lake Pend Oreille includes fishing, boating, swimming, and camping, and other activities. There are numerous marinas, boat ramps, campgrounds, and shoreline recreation sites around the lake, which depend on managed lake levels in the summer.

OTHER

Albeni Falls is not operated for irrigation or water supply, thus these concerns do not impact modeling.

4.3.2.4 Grand Coulee Dam and Lake Roosevelt

GENERAL

Grand Coulee Dam and Lake Roosevelt is a Reclamation storage project on the mid-Columbia River in central Washington. It provides approximately 5 Maf of useable storage within the normal operating range from 1,290 to 1,208 feet NGVD29. It has 24 generating units in 3 powerhouses. The John W. Keyes III pump/generating station is part of the project and has 6 pumps and 6 pump/generators. The 24 powerhouse generators and 6 pump/generators can produce a total of about 7,015 MW. Water from Lake Roosevelt is pumped into Banks Lake for irrigation of the Columbia Basin project and can be returned to Lake Roosevelt through the pump/generators.

FLOOD RISK MANAGEMENT

From January through April, Lake Roosevelt drafts to prepare for spring runoff. The FRM space requirement is based on the water supply forecast for unregulated runoff at The Dalles, the upstream available storage, and Grand Coulee's FRM SRD. For more information, refer to the H&H Appendix (Appendix A, Part 3 – HEC-ResSim/WAT documentation).

CONSERVATION OF FISH AND WILDLIFE

Outflow from Grand Coulee is provided to maintain a 36,000 cfs minimum discharge below Priest Rapids Dam. Higher flows are provided to meet instream fish flows, serve firm loads, or meet FRM requirements.

From January through April, Grand Coulee's operation maintains an 85 percent probability of reaching the April 10 elevation objective to provide more storage water for spring flow augmentation.

From April 10 through June 30 Grand Coulee is operated to help meet the 135 kcfs spring flow objective at Priest Rapids Dam. During dry years, the initial flow can be as low as 60 kcfs on a weekly basis; however, flow typically begins at 90 kcfs and ramps up incrementally based on water supply forecast and streamflow conditions.

To enhance recreation at Lake Roosevelt, Grand Coulee will typically be operated to fill no higher than elevation 1,287 feet NGVD29 on the Friday prior to July 4. In the week after July 4, operations at Grand Coulee target a refill elevation near 1,290 feet. An amount of refill is foregone to implement the Lake Roosevelt Incremental Storage Release Program to ensure this withdrawal for irrigation does not impact flow during the spring and early summer portion of the juvenile migration period.

After July 4, Grand Coulee is operated during the summer (July and August) to help meet flow objectives for juvenile salmon out-migration. Grand Coulee will draft to support salmon flow objectives during July and August with a variable draft limit of 1,278 to 1,280 feet NGVD29 by August 31 based on the water supply forecast. The amount of refill foregone to implement the Lake Roosevelt Incremental Storage Release Program also is included in the August 31 draft requirement to ensure flow objectives are not impacted by the irrigation withdrawal.

During November and December, Grand Coulee is operated to store or release water to target a tailwater elevation of 11.5 feet at Bonneville Dam for chum salmon spawning and to limit suitable chum spawning habitat in other locations. Release of storage from the Grand Coulee Project to reach an 11.5-foot tailwater elevation to support chum spawning downstream of Bonneville Project is limited to drafting to an elevation of 1,275 feet NGVD29 by the end of November and 1,270 feet NGVD29 by the end of December.

Also, in November and December, Grand Coulee is operated to provide flows to support fall chinook spawning in the Hanford Reach of the Columbia River below Priest Rapids Dam. Similar to the chum operation, a minimum flow is set during the spawning period and must be maintained to avoid dewatering redds.

Grand Coulee is generally operated to refill to elevations between 1,285 and 1,288 feet NGVD29 by the end of October to provide sufficient storage for chum spawning operation and winter power generation. To aid resident fish, Reclamation attempts to operate the Grand Coulee project and Lake Roosevelt to refill to elevation 1,283 feet NGVD29 by September 30. This fall target minimum elevation is met unless streamflow conditions require Grand Coulee to maintain minimum flows at Bonneville Dam instead of achieving the 1,283-foot NGVD29 elevation by September 30. In this instance, the elevation 1,283-foot NGVD29 elevation would be expected by early October instead.

POWER GENERATION

Power generation facilities at Grand Coulee Dam are among the largest in the world with a total generating capacity rated at 7,015 MW. In addition, Lake Roosevelt's large storage capacity provides the ability to capture and store water released from upstream dams. The combination of power production capacity and reservoir storage capacity provides Bonneville the ability to shape Lake Roosevelt outflows to meet real-time power demands with minimal effect on short-term reservoir levels.

IRRIGATION/WATER SUPPLY

The Columbia Basin project diverts up to 3.318 Maf of water from the Columbia River for irrigation most of which is pumped from Lake Roosevelt via the John W. Keyes III pump/generating station. When Lake Roosevelt is below elevation 1,240 feet NGVD29, only six pumps are available to deliver water. If the full demand cannot be met through the pumps then irrigation water is delivered by drafting Banks Lake, then refilling when Lake Roosevelt elevation raises above elevation 1,240 feet NGVD29.

NAVIGATION

Grand Coulee is authorized but not operated for downstream navigation purposes, but two ferries operate on Lake Roosevelt. When reservoir elevations drop below 1,240 feet NGVD29, the Keller Ferry must be moved to a location a short distance upstream on the Sanpoil River. The Inchelium-Gifford Ferry is modeled to be out of service when Lake Roosevelt drafts below elevation 1,229 feet NGVD29. In very low flow years some draft may be provided from Lake Roosevelt to maintain the 70 kcfs flow from Bonneville Dam.

RECREATION

Lake Roosevelt is a National Recreation Area and is operated to expose beaches for recreation; other recreational activities include camping, swimming, motor boating, fishing, and picnicking.

OTHER

The drum gates at Grand Coulee require periodic maintenance for safety and operational integrity. In modeling the 80-year Modified Flow dataset, drum gate operations are applied during February, March, and April if certain criteria are met. Overall, these criteria are based on the February forecast of the April 30 URC, annual frequency requirements, and finally, forced drum gate maintenance years.

There are other important factors such as spill operations that are considered in real-time operation, but do not affect the Bonneville modeling of Grand Coulee operations.

4.3.2.5 Chief Joseph Project

GENERAL

Chief Joseph Dam is a run-of-river Corps project located on the Columbia River downstream of Grand Coulee Dam. Its normal operating range is 950 to 956 feet NGVD29. Its 27-unit powerhouse can produce 2,000 MW.

POWER GENERATION

The Chief Joseph project is a run-of-river dam and passes inflow within the available hydraulic capacity of the powerhouse. An average daily discharge of 35,000 cfs at Chief Joseph is required to meet the mandatory minimum flow of 36,000 cfs below Priest Rapids Dam.

OTHER

There are several important factors that are considered in real-time operation, but do not affect the Bonneville modeling for hydropower. They include TDG management, irrigation/water supply, and recreation.

4.3.2.6 Dworshak Dam and Reservoir

GENERAL

Dworshak Dam and Reservoir is a Corps storage project on the North Fork of the Clearwater River in northern Idaho. It provides useable storage of approximately 2 Maf within the normal operating range from 1,445 to 1,600 feet NGVD29. It has a 3-unit powerhouse that can generate up to 400 MW with two 90-MW units and a 220-MW unit.

FLOOD RISK MANAGEMENT

Dworshak operations for FRM are based on the SRDs for system requirements at The Dalles and local requirements on the Clearwater River at Spalding. URCs are developed for Dworshak based on the forecasted runoff for the April-July period, which establishes FRM draft requirements. The Dworshak system, forecasted runoff volume, and local SRDs help determine the amount of space required to meet system or local FRM objectives. Dworshak also has a unique SRD that accommodates shifting storage space for system FRM to Grand Coulee.

Refill target computations for Dworshak attempt to reduce system flows at The Dalles and provide a 95 percent confidence of refill.

CONSERVATION OF FISH AND WILDLIFE

During the spring snowmelt runoff (April – May or June) Dworshak is operated to maximize the probability of refilling the reservoir for summer flow augmentation while providing flows to meet spring objectives in the lower Snake River during the downstream migration of juvenile salmon and steelhead.

Summer flow augmentation (July – September) is provided from Dworshak to increase survival of ESA-listed adult fish by moderating river temperature and increasing water velocities in the lower Snake River. Dworshak is generally drafted to elevation 1,535 feet NGVD29 by the end of August and 1,520 feet NGVD29 by the end of September.

POWER GENERATION

FRM and fish operations generally limit project flexibility for power generation. During modeling, project releases for FRM and fish flows generally are made through the generating units; however, certain fish flow augmentation and temperature control requirements do require spilling to implement.

OTHER

Dworshak is authorized for navigation for the movement of harvested timber in the reservoir, but the logging industry has abandoned water-based timber movement. Recreation at Dworshak reservoir includes swimming, fishing, boating, hiking, hunting, and camping. There are several marinas, boat ramps, campgrounds, picnic areas, and shoreline recreation sites around the lake; most are designed for water access only. There is no authorization for irrigation/water supply at Dworshak.

4.3.2.7 Lower Snake River Projects

GENERAL

Lower Granite, Little Goose, Lower Monumental, and Ice Harbor are run-of-river Corps projects on the lower Snake River. Their normal operating range is 3 to 5 feet between minimum and maximum forebay levels. All have 6-unit powerhouses. Lower Granite, Little Goose, and Lower Monumental can each produce 810 MW; Ice Harbor can produce 603 MW. All have a navigation lock for passage of commercial and non-commercial river traffic.

LOWER GRANITE FLOOD RISK MANAGEMENT

All four dams do not have authorized flood storage space. However, during periods of high inflow, the operation of Lower Granite is restricted to a reduced maximum forebay elevation to maintain adequate freeboard at the levees near Lewiston, Idaho.

CONSERVATION OF FISH AND WILDLIFE

Turbines at all projects on the lower Snake and lower Columbia Rivers target an operation within ±1 percent of peak turbine efficiency during the juvenile and adult migration seasons, April 1 through October 31. This helps reduce fish injuries and cavitation damage to turbines.

All four lower Snake River projects operate to minimize water travel time for the benefit of juvenile fish migration by operating the forebays in the MOP 1-foot range from April 3 until approximately September 1, though elevations may be adjusted to meet other authorized project purposes (e.g., navigation).

Spring and summer spill for juvenile fish passage is implemented at all four lower Snake River projects from April 3 through August 31, pursuant to the 2016 Fish Operations Plan or other objectives specified by the CRSO EIS alternatives.

The spring flow objective to benefit ESA fish is measured as a target season average outflow at Lower Granite Dam from April 3 through June 20. The target is determined by the final April forecast for Lower Granite project runoff volume over the April through July period. When the forecast is less than 16 Maf, the flow objective is 85 kcfs. If the forecast is between 16 and 20 Maf, the flow objective is linearly interpolated between 85 and 100 kcfs. If the forecast is greater than 20 Maf, the flow objective is 100 kcfs. Spring lower Snake River flows are supplemented by drafting at Dworshak Dam and by flow augmentation water from other

projects in the Upper Snake River. The spring flow objective is not always met throughout the entire migration season because there is limited stored water available for flow augmentation.

The summer flow objective to benefit ESA fish is measured as a target season average outflow at Lower Granite Dam from June 21 through August 31. The target is determined by the final June forecast for Lower Granite project runoff volume over the April through July period. When the forecast is less than 16 Maf, the flow objective is 50 kcfs. If the forecast is between 16 and 28 Maf, the flow objective is linearly interpolated between 50 and 55 kcfs. If the forecast is greater than 28 Maf, the flow objective is 55 kcfs. The summer Snake River flows are augmented by the release of water stored upstream of the Lower Granite project. The summer flow objective is not always met throughout the entire migration season because there is limited stored water available for flow augmentation.

POWER GENERATION

All four projects are run-of-river dams and pass inflow within the available hydraulic capacity of their powerhouses. The hourly ramp rate is a maximum tailwater rate of change of 1.5 foot per hour or 70 kcfs per hour at Lower Granite, Little Goose, and Lower Monumental; and 20 kcfs per hour at Ice Harbor. At least one generator must be operated at each dam for most of the year to maintain power system reliability.

OTHER

There are several important factors at these dams that are considered in real-time operation, but do not affect the Bonneville modeling for hydropower. They include the juvenile fish transport program, irrigation/water supply withdrawals around the reservoirs, navigation, recreation, and waterfowl hunting.

4.3.2.8 Lower Columbia River Projects

GENERAL

McNary, John Day, The Dalles, and Bonneville Dams are all run-of-river Corps projects on the lower Columbia River with powerhouses: McNary has 14 generators with a capacity of 980 MW; John Day has 16 generators with a capacity of 2,480 MW; The Dalles has 22 generators with a capacity of 2,080 MW; and Bonneville has 18 generators with a capacity of 1,200 MW. All have a navigation locks for passage of commercial and non-commercial river traffic.

FLOOD RISK MANAGEMENT

Only John Day is operated for FRM. The John Day project is routinely operated as run-of-river, but has approximately 0.5 Maf of flood storage available for system FRM of the lower Columbia River. The reservoir storage is primarily designed for use during winter and spring rain events to help reduce flooding at the Portland Harbor (and the lower Columbia River in general), but can also be used for similar purposes during peak spring freshet flows.

CONSERVATION OF FISH AND WILDLIFE

Turbines at all projects on the lower Snake and lower Columbia Rivers target an operation within ±1 percent of peak turbine efficiency during the juvenile and adult migration seasons, April 1 through October 31. This helps reduce fish injuries and cavitation damage to turbines.

Spring and summer spill operations for juvenile fish passage are implemented at lower Columbia River projects from April through August, pursuant to the 2016 Fish Operations Plan.

The lower Columbia River spring flow objective is measured as the season average outflow at McNary Dam from April 10 through June 30. The objective is determined by the final April forecast for The Dalles project runoff volume over the April through August period. The flow objective is not always met throughout the migration season because there is variability in volume and shape of the natural runoff.

The lower Columbia River summer flow objective is measured as the season average outflow at McNary Dam from July 1 through August 31. The summer flow objective is 200 kcfs. Lower Columbia River summer flow is augmented by the release of water from upstream storage projects. The flow objective is not always met because there is a limited amount of stored water for flow augmentation and the natural shape of the runoff generally produces decreasing streamflows from July through August.

POWER GENERATION

All four lower Columbia River dams normally operate as run-of-river dams and pass inflow within the available hydraulic capacity of the powerhouses. All have maximum hourly rates of outflow change that vary from 1.5 to 3.0 feet per hour change in tailwater elevation. During periods of high runoff, water may be spilled due to lack of load and carrying reserves for power system reliability. Generation from a minimum outflow of 50 kcfs must be maintained at all times at McNary, John Day, and The Dalles for transmission system voltage stability.

IRRIGATION/WATER SUPPLY

All four dams provide minimum lake elevations from which pump stations can withdraw water for irrigation and water supply. From April 10 through September 30, the John Day project is operated to minimize water travel time for downstream-migrating juvenile salmon using the forebay within the minimum irrigation pool (MIP) range of 262.5 to 264.0 feet (the lowest pool elevation that allows irrigation withdrawals).

OTHER

There are several important factors at all four projects that are considered in real-time operation, but do not affect modeling for hydropower. They include navigation, recreation, docking for offloading of U.S. Navy nuclear disposal packages, waterfowl hunting, Tri-City Water Follies hydroplane races, Umatilla Landing Days, tribal treaty fishing, and others.

4.4 POWER SYSTEMS LOADS

When conducting hydropower studies such as those for the CRSO EIS, the generation resulting from an alternative is often compared to a load forecast. These comparisons inform analysts of several factors including the need for additional resources, availability of surpluses, and reliability.

Energy comparisons in the CRSO EIS are made by contrasting HYDSIM output to a regional residual hydropower load (i.e., that portion of regional load intended to be served by HYDSIM generation). Regional residual hydropower load is calculated by subtracting forecasted generation of non-modeled resources from the regional load. Non-modeled resources are comprised of non-hydropower resources (nuclear, fossil-fuel, bio-fuel, wood-waste), renewable resource generation (wind, solar, and geothermal), and other hydropower independent resource generation (independent and small hydro).

Hourly or peak load comparisons for the CRSO EIS are made using HOSS output only for the Federal system. Bonneville prepares a Federal residual hydropower load by adjusting the Federal load forecast for contracts and resources not modeled in HOSS.

Reliability comparisons are made for the CRSO EIS using GENESYS model outputs. Hourly regional (Pacific Northwest) load forecasts[15] for historical weather from 1929 to 2006 were produced by the NWPCC and are adjusted for non-hydropower resource production.

15 Details for load descriptions are provided in NWPCC's Pacific Northwest Power Supply Adequacy Assessment for 2022.

CHAPTER 5 - HYDROREGULATION MODELING STEPS FOR NO-ACTION ALTERNATIVE

5.1 STUDY ASSUMPTIONS AND DESIGN

CRSO modeling is performed through the execution of a specific sequence of steps, as shown on a high level in Figure 5-1. Model inputs for a specific study are developed to implement one or more objectives. The inputs are then run in a model, and output results are analyzed to assess if the objectives were met, and impacts to generation, reservoir levels, flows, and other metrics. Outputs from one model sequence, or step, may be subsequently used as an input into another model or processor to develop finer detail. For example, end of month elevations, flows and proportional draft points from HYDSIM are used as inputs to ResSim, which develops daily time-step end of day elevations and average flows. HYDSIM outputs also are used in HOSS to determine HLH, LLH, 120-Hour (SuperPeak), and other generation metrics.

Inputs for the NAA study are based on the operation and structures in place when the Notice of Intent for the CRSO EIS was published in the Federal Register in September 2016, and those data are applied to current operations and expected future operations and requirements.

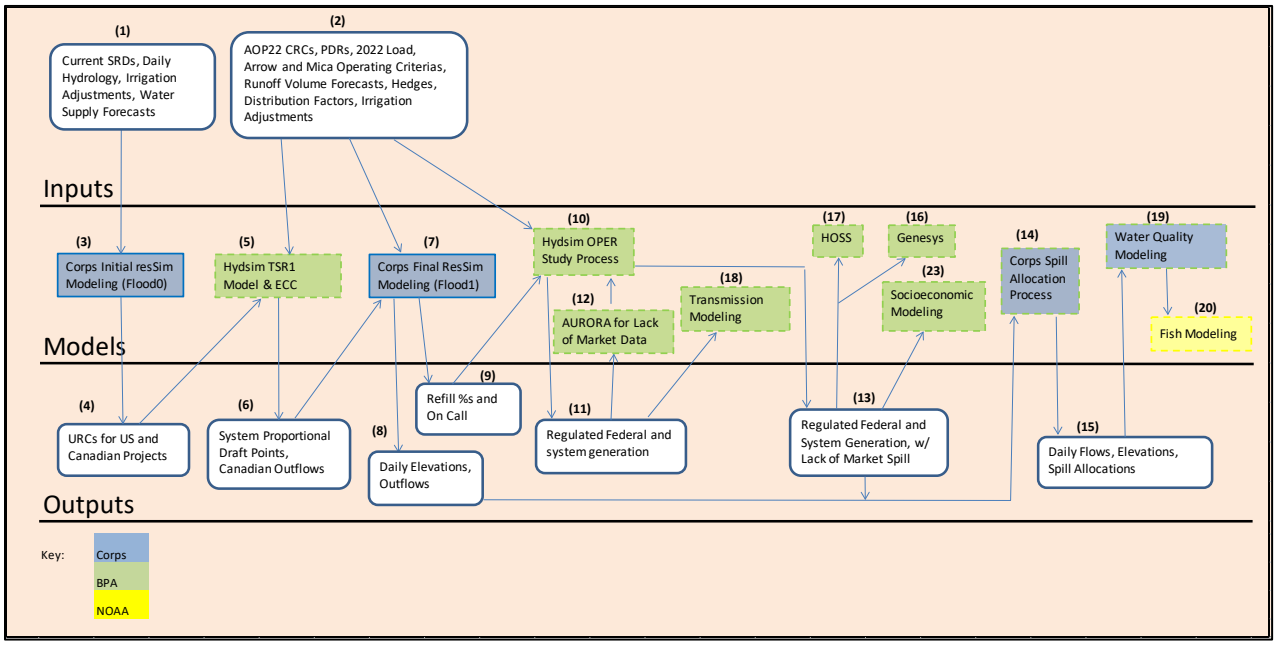

Figure 5-1. CRSO EIS Modeling Schematic

Figure 5-1 shows the steps for a complete study sequence; however, each step may not be needed for alternative MO studies.

5.2 DETERMINISTIC HYDROREGULATION MODELING STEPS

5.2.1 Inputs to Models

Datasets read by the model software include a few different types of data. Paired data, time series data, and operating rule sets are three general categories of inputs. Some of the input

data is relatively fixed, not changing over time (i.e., reservoir storage curves), while other datasets can vary depending on other input assumptions (i.e., generation load). For example, residual hydropower load will vary depending upon the assumptions of alternative generation sources, such as wind power and thermal.

Models use paired data to establish a relationship between parameters (i.e., reservoir storage and water surface elevation, or spill flow rates and TDG levels). Generally, paired data allows the model to compute one output metric and have a relationship to another metric available for reference.

Time series data includes datasets such as the Modified Flows Streamflow dataset for each reservoir or measurement point for each time-step. HYDSIM uses monthly average inflows between each dam (incremental flows), in addition to the upstream plant's release, to determine gross inflows into a reservoir.

The model uses the first two data types, time series and paired data, and the model's scheduling logic to operate the plant to stay within the operating rules. Operating rules are generally a time-specific requirement met by the reservoir or powerhouse (i.e., an end of month target elevation or a required spill flow during fish passage season). There may be situations where all operating rules cannot be met simultaneously (i.e., maintaining full reservoirs and keeping spill flows below a certain value). For these situations, operating rules are prioritized to meet the most preferred requirement and the least costly violation first. Thus, the model's logic and inputs could be set to meet the spill flows limitation at the expense of having to draw the reservoir down to contain high runoff events.

5.2.2 Sources of Input

Input data is developed from numerous processes. Reservoir elevation-storage curves are developed using topographic surveys, either before or after the dam is constructed. Once these datasets are developed, they can be adjusted to measure the sedimentation impacts or increase data accuracy from new studies using new measurement and survey technologies. The Modified Flows Streamflow dataset was developed during a multiple-year study process that examined historical observations and computations of current irrigation depletion rates. Because these inputs are used in CRSO modeling and other modeling, the datasets are developed, documented, and shared among the co-lead agencies and other parties for reuse and consistent application of the best available data.

Operating rules may originate from BiOp objectives, such as maximum TDG or temperature limits. Bonneville modelers are provided flow limits that equate to suitable TDG and temperature ranges, which are then entered into the model. Other inputs may be from other studies or steps in the same study sequence, such as the FRM F0 step that determines elevation upper limits required for flood risk management.

5.3 RESSIM F0 – STEP 3

The ResSim F0 model step represents the pre-2024 flood operations without on-call. Both the United States and Canadian reservoirs were operated to URCs that reflect firm energy load carrying capability. Input to the F0 model step included the streamflow dataset and URCs. Details of these system operations are presented in the H&H Appendix (Appendix A, Part 3 – HEC-ResSim/WAT Documentation). The output included URCs that include both draft and refill. These URCs were input to the HYDSIM/Treaty Storage Regulation (TSR) modeling in Step 5.

5.4 HYDSIM TSR1 – STEP 5

An Assured Operating Plan (AOP) is developed annually to determine Canadian storage operation guidelines and other metrics. These plans are prepared annually for the sixth succeeding operating year. AOPs are designed to achieve an optimum power operation in both Canada and the United States. The AOP provides a guaranteed default operation that enables orderly planning of the power systems in Canada and the United States, which are dependent on and coordinated with the operation of treaty storage.

The optimum power operation is created by first determining the monthly residual hydro load shape for the coordinated hydropower system to meet peak load and energy. In this study, the load and resource forecasts for 2022, based on historical metered loads and consultations with Bonneville customers, were obtained from the 2017 White Book (Bonneville 2017). The White Book is a Pacific Northwest loads and resources study to obtain a snapshot of the Federal system and Pacific Northwest regional loads and resources for the upcoming 10-year period. Resource forecasts are determined from NWPCC and Pacific Northwest Utilities Conference Committee submittals, and adjustments are made to the resource forecasts for renewable resources for compliance with state renewable portfolio standards and known closures of coal power plants. The residual hydro load is the net result of Pacific Northwest area loads minus thermal resources, renewables, firm imports and exports, hydro-independent resources, and other non-hydro resources.

The AOP operating criteria consist primarily of a series of rule curves and requirements that guide reservoir operations for FRM and optimum power generation. Typically, Canadian Treaty reservoirs are guided by operating rule curves and requirements that ensure FRM, optimum power, and refill for the coordinated system in average and wetter-than-average water years. During low flow conditions, critical rule curves guide reservoir operations for firm power needs. Procedures for flow and storage content objectives at Mica, together with storage and flow limits at Mica and Arrow, help optimize Canadian power generation within the overall system operation.

TSR1 is a hydro-regulation study that implements the detailed operating plan operating criteria that determines operations for Canadian CRT projects.

The TSR used Energy Content Curves that were developed for the CRSO EIS forecast volumes. The TSR also used the current CRT Flood Control Operating Plan Canadian FRM curves and Libby and Hungry Horse FRM rule curves developed in forecast mode by the F0 ResSim model. During

the low flow conditions, proportional draft is triggered when system generation is less than the firm energy load carrying capability determined by the critical period study, which is based on the worst water conditions with expected load and planned non-hydro resources. During proportional draft, the system drafts each reservoir proportionally between its respective critical rule curves. The end draft point for each reservoir resulting from proportional draft is called a proportional draft point. The proportional draft points of various projects are then fed into the ResSim F1 model.

5.5 RESSIM F1 – STEP 7

The ResSim F1 Model uses information from the previous steps to produce the Corps final daily modeling results. The output included daily elevations and outflow, on-call years, and refill statistics. Details of these system operations are presented in the H&H Appendix (Appendix A, Part 3 – HEC-ResSim/WAT Documentation).

5.6 HYDSIM OPER – STEP 10

The HYDSIM OPER Step 10 was performed to further fine-tune Canadian and United States Federal project operations where possible, with the intent of more closely reflecting actual operations. For Federal projects: Libby provided uniform summer drafts, a pulse of water for white sturgeon in the spring, and year-round minimum flows including spring/summer bull trout flows; Hungry Horse provided uniform summer drafts, year-round minimum flows for bull trout and FRM while minimizing spill; Dworshak provided uniform summer drafts, minimum flow, and FRM targets while minimizing spill; Grand Coulee operated to support multiple operations all year that included chum November to April, Vernita Bar October to June, FRM drafts March to April, spring flows in the Mid-Columbia April to June, uniform summer drafts to satisfy BiOp operations, and the Columbia River Water Management Program and refill in September for November kokanee spawning. Output from a first iteration of Step 10 through Steps 11 and 12 determines the LOM spill. This LOM spill data is used in a second iteration through Step 10. LOM spill occurs almost every spring when streamflow and generation are high and require spill according to a spill priority list, similar to that used in actual operations.

5.7 AURORA – STEP 12

Aurora is software used by Bonneville to calculate the variable cost of the marginal resource in a competitively priced electric energy market. This power price curve shows that summer and fall have relatively high market prices. The December to February period has the highest prices, with the maximum average price typically occuring in December.

5.8 CORPS SPILL ALLOCATION PROCESS – STEP 14

Step 14 receives as input the daily elevations and outflows from ResSim and the LOM spill from AURORA, the Hydro availability file, and spill operation at each plant. This process allocates spill between CRS projects based on a priority that directs spill to projects with the least negative effect of increased spill. The resulting outflows and spill allocations are used as inputs to water quality modeling and fish habitat/requirements modeling. Note that because the Corps adds

spill (including lack-of-turbine spill) after flows are calculated in ResSim, there is no feedback loop from these two spill steps to the flow calculation. This occasionally results in instances where flows are so high that there is lack-of-turbine spill on some days immediately before or immediately after days when the flow is below the maximum turbine flow. In actual operations, flows would be smoothed between the days to minimize lack-of-turbine spill and to optimize generation (absent other constraints). For more details on the methodology and results from this Spill Allocation Process, refer to the H&H Appendix (Appendix A, Part 2 – Spill Analysis).

5.9 GENESYS MODELING – STEP 16

The GENESYS modeling step receives end-of-period elevations, flows, spill, and system load from the 14 periods per year HYDSIM output. GENESYS dispatches the generation in hourly periods subject to minimum and maximum limits to meet the GENESYS load, taking into account non-dispatchable resources such as wind and solar. This step involves multiple runs with randomly changing inputs (i.e., generation from wind, temperature, load demand, and rainfall). The studies measure the likelihood of meeting load demand, adequacy of regional generation, and costs of implementing various operating rules (i.e., fish spill requirements).

5.10 HOSS – STEP 17

The HOSS modeling step receives end of period elevations and flows from HYDSIM output. The HOSS model develops an hourly schedule of flows, generation, and elevations based on the monthly time-step HYDSIM output. Output includes various metrics (i.e., flexibility of the system [ability to shift generation from LLH to HLH] within a day, and total HLH/LLH hydro generation).

CHAPTER 6 - HYDROREGULATION MODELING FOR MULTIPLE-OBJECTIVE ALTERNATIVES

6.1 MULTIPLE-OBJECTIVE DESCRIPTION/DETAIL/SUMMARY

To visualize potential future states of the CRS, four MO alternatives were developed with different objectives. Objectives were developed and grouped into these MO alternatives to focus on various potential condition improvements (i.e., habitat or fish passage). To meet an objective, specific measures were developed that would cause or contribute to the objective being met. The quantification of the success of meeting the objectives, and the side effects or impacts to other operational metrics, were answered by modeling through the hydroregulation modeling process and other modeling processes.

Measures were divided into two categories: structural measures and operational measures. Structural measures are changes to dams, fishways, fish ladders, spillways, or other hard, physical attributes of a dam, powerhouse, or other structure. Operational measures are changes to operating rules or protocols implemented by system water managers. A crosswalk of these measures is provided in Exhibit 3.

Each measure, whether structural or operational, is described with a specific purpose, measure location, frequency and duration, and intended benefit. These detailed measures and descriptions are found in the CRSO EIS. Sections below provide general description of each MO. Overall, the steps of the hydro modeling process for each MO were identical to the modeling of the NAA, with the following exception: The NAA study determined the Canadian operation for the three Treaty Projects (Mica, Duncan, and Arrow); these operations were ‘frozen’ and fed into each MO study. Hence, the TSR step was performed for NAA, but not for each MO, and the operation of Mica, Arrow, and Duncan is identical between the NAA and each MO.

Each MO alternative evaluates the CRS’s ability to meet all or part of the following objectives:

- Improve ESA-listed anadromous salmonid juvenile fish rearing, passage, and survival within the CRSO project area, through actions including but not limited to project configuration, flow management, spill operations, and water quality management.
- Improve ESA-listed anadromous salmonid adult fish migration within the CRSO project area, through actions including but not limited to project configuration, flow management, spill operations, and water quality management
- Improve ESA-listed resident fish survival and spawning success at CRSO projects through actions including but not limited to project configuration, flow management, improving connectivity, project operations, and water quality management.
- Provide an adequate, efficient, economical, and reliable power supply that supports the integrated CRS power system.
- Minimize greenhouse gas emissions from power production in the Pacific Northwest by generating carbon-free power through a combination of hydropower and integrations of other renewable energy sources.

- Maximize operating flexibility by implementing updated, adaptable water management strategies to be responsive to changing conditions, including hydrology, climate, and environment.
- Meet existing contractual water supply obligations and provide for authorized additional regional water supply.

Additionally, the following secondary objective was considered during development of the alternatives:

- Improve conditions for the lamprey within the CRSO project area through actions potentially including but not limited to project configurations, flow management, spill operations, and water quality management.

One of the objectives at Grand Coulee applicable to MO1, MO2, and MO4, is an updated SRD. Part of the intent of this updated SRD is the inclusion of additional reservoir volume used to protect against rain-induced flooding. This additional storage was omitted in the modeling of these MOs in the month of December, but was applied for other applicable months. At John Day, installation of high-efficiency/capacity turbines was unintentionally omitted from the H/K table (plant change input file) applicable to all four MO alternatives, and should have reflected a 4.5 percent increase in efficiency. The estimated average megawatt effect of these two omissions are presented in the EIS Hydropower Appendix.

6.2 MULTIPLE-OBJECTIVE 1 ALTERNATIVE – MODELING

MO1 includes operational changes to Libby, Hungry Horse, Grand Coulee, Dworshak, and John Day Dams, notably modified operations at Libby and Grand Coulee Dams to maximize operating flexibility and improve overall systems operations including winter FRM; modified operations to meet existing contractual water supply obligations and provide for authorized additional regional water supply including increased or new diversions at Banks Lake, Flathead Lake, and below Chief Joseph Dam; and modified summer draft at Dworshak Dam to control temperatures for ESA-listed adult fish in the lower Snake River.

6.2.1 Hydroregulation Modeling Steps

The hydroregulation modeling process shown in Figure 5-1 was generally followed, with the exception that in Step 3 there was an alternative URC development process. This is because Alternative MO1 contains measures calling for different URCs than the NAA at certain CRSO projects. All URCs were then combined and the remaining overall modeling process was the same.

Changes to the HYDSIM model for MO1 included:

- The flows in powerhouse surface passage routes constructed at McNary and Ice Harbor projects are reflected by an 8 kcfs and 4 kcfs, respectively, increase in other spill at those projects, with the same start and end dates as other fish passage spill at the project.
- Upgrades to adjustable spillway weirs assumed included in the spill totals already present.

- Spring spill designed in a block pattern, with 6 weeks of performance standard plus spill patterns and 6 weeks of spill to gas cap spill in alternating order every year.
- Summer spill in performance standard plus, ending in August at the lower Snake River projects based on the historical average date when counts of passing sub-yearling chinook surpassed 300 for four consecutive days (2010-2017); lower Columbia projects end spill on August 31.
- Contingency reserves may be held within fish passage spill on the lower Snake River and lower Columbia River projects. This reduces the reserve obligation held by other projects in the system, resulting in a higher availability at those projects.
- Changes to FRM are incorporated via Corps-provided URCs and refill tables.
- Changes to the upstream storage correction method incorporated via an updated Grand Coulee URC shift algorithm.
- Updated availability of Grand Coulee generators reflects ongoing maintenance of power plants that is more accelerated than current schedule of outages.
- Water supply measures (increased water pumped from Lake Roosevelt, Chief Joseph diversions, and Flathead River) are incorporated via a negative adjustment to the flows into relevant projects.
- Changes for adult fish: modified timing of lower Snake basin reservoir draft (Section 4.3.2.7).
- Changes for Resident fish: Changes to summer draft at Libby and Hungry Horse (Sections 4.3.2.1 and 4.3.2.2).
- John Day change for Avian Predators (Section 4.3.2.8).

For more details, refer to the Modeling Data Sheets in Exhibit 4.

6.2.2 Differences between Alternative MO1 and No-Action Alternative Results

For details on differences between this MO and the NAA, refer to the CRSO EIS Hydropower Appendix and the H&H Appendix.

6.3 MULTIPLE-OBJECTIVE 2 ALTERNATIVE – MODELING

MO2 includes operational changes to Libby, Hungry Horse, Grand Coulee, Dworshak, and John Day Dams, notably modified operations at Libby and Grand Coulee Dams to maximize operating flexibility and improve overall systems operations including winter FRM; modified operations to meet existing contractual water supply obligations and provide for authorized additional regional water supply including increased or new diversions at Banks Lake, Flathead Lake, and below Chief Joseph Dam; and modified summer draft at Dworshak Dam to control temperatures for ESA-listed adult fish in the lower Snake River.

6.3.1 Hydroregulation Modeling Steps

The hydroregulation modeling process shown in Figure 5-1 was generally followed, with the exception that in Step 3 there was an alternative URC development process. This is because Alternative MO2 contains measures calling for different URCs than the NAA at certain CRSO projects. All URCs were then combined and the remainder of the modeling process was the same.

Changes to the HYDSIM model for MO2 included:

- Increased flows to account for powerhouse surface passage routes constructed at John Day, McNary, and Ice Harbor projects reflected by an increase of 8 kcfs, 8 kcfs and 4 kcfs, respectively, in other spill at those projects, with the same start and end dates as other fish passage spill.
- The powerhouse surface passage routes eliminate the need to install fish screens, resulting in an increase in turbine availability from the NAA for periods where fish screens would have been installed.
- Upgrades to adjustable spillway weirs assume spill of 11 kcfs per weir in spring and 7 kcfs per weir in summer. If spill at the projects needs to be increased over that called for by the NAA to accommodate the new adjustable spillway weirs, it was increased to cover the required spill. The end of spring spill is June 15 in the lower Columbia projects, and June 20 on the lower Snake River projects.
- Fish passage spill is limited to 110 percent TDG, but is marginally higher where additional spill is required for powerhouse surface passage routes, weirs, and/or adult ladder attraction. Spill starts April 3 at lower Snake River projects and April 10 at lower Columbia River projects; fish passage spill ends July 31.
- Flow and pool elevation restrictions are lifted as outlined in individual projects.
- Restrictions to operate turbines within 1 percent of peak efficiency are eliminated, resulting in increased availability during fish passage season.
- Contingency reserves were held within fish passage spill on the lower Snake River and lower Columbia River projects. This reduced the reserve obligation held by other projects in the system, resulting in a higher availability at those projects.
- Changes to FRM were incorporated via the Corps-provided URCs and refill tables.
- The variable end-of-December draft target at Libby was replaced with a single draft target.
- Changes to the upstream storage correction method were incorporated using an updated Grand Coulee URC shift algorithm.
- Grand Coulee turbine availability was modified to reflect ongoing maintenance that is more accelerated than current outages.
- Summer elevation and draft targets were modified at Libby and Hungry Horse (Sections 4.3.2.1 and 4.3.2.2).

- All other assumptions are unchanged from the NAA.

For more details, refer to the Modeling Data Sheets in Exhibit 4.

6.3.2 Differences between MO2 and No-Action Alternative

For details on differences between this MO and the NAA, refer to the CRSO EIS Hydropower Appendix and the H&H Appendix.

6.4 MULTIPLE-OBJECTIVE 3 ALTERNATIVE – MODELING

MO3 includes removal of the four lower Snake River dams; major operational changes to Libby, Hungry Horse, and Grand Coulee; and minor changes to the lower Columbia project operations.

6.4.1 Hydroregulation Modeling Steps

The hydroregulation modeling process shown in Figure 5-1 was generally followed, with the exception that in Step 3 there was an alternative URC development process. This is because Alternative MO3 contains measures calling for different URCs than the NAA at certain CRSO projects. All URCs were then combined and the remainder of the modeling process was the same.

Changes to the HYDSIM model for MO3 included:

- Lower Snake River dams are simulated as removed by designating them as non-generating reservoirs and passing inflow; in HYDSIM all inputs associated with generation, flow requirements, and content targets are removed.
- Increased flows to account for powerhouse surface passage routes to be constructed at McNary project are reflected by an 8 kcfs increase in other spill with the same start and end dates as other fish passage spill at the project.
- The powerhouse surface passage routes eliminate the need to install fish screens, resulting in an increase in turbine availability from the NAA for the duration in those periods where there would have been fish screens installed.
- Upgrades to adjustable spillway weirs assumed included in the spill totals already present.
- Spring fish passage spill is set to levels determined to cap at 120 percent TDG, or as close as possible while maintaining minimum turbine flow requirements. Spring spill starts April 10 at all lower Columbia River projects, and ends June 15.
- Summer spill at the lower Columbia River projects is the same as the NAA, but will end at midnight July 31.
- The State of Washington spill cap waiver is assumed to be 120 percent TDG during both spring and summer spill season (no 115 percent in the downstream forebay requirement) to accommodate the spring spill regime.
- Flow and pool elevation restrictions at John Day are lifted (Section 4.3.2.8).

- Turbine operation within and above 1 percent peak efficiency only increases turbine availability at relevant projects during the fish passage season.
- Summer elevation and draft targets were modified at Libby and Hungry Horse (Sections 4.3.2.1 and 4.3.2.2).
- Contingency reserves may be held within fish passage spill on the lower Columbia River projects. This reduced the reserve obligation held by other projects in the system, resulting in a higher availability at those projects.
- Changes to FRM were incorporated via Corps-provided URCs, SRDs, and refill tables.
- The end-of-December variable draft target at Libby was replaced with a single draft target.
- Changes to the upstream storage correction method incorporated via an updated Grand Coulee URC shift algorithm (Section 4.3.2.4).
- Grand Coulee turbine availability was modified to reflect ongoing maintenance that is more accelerated than current outages.
- Water Supply measures (increased water pumped from Lake Roosevelt, Chief Joseph diversions, and Flathead River) are incorporated via a negative adjustment to the flows into relevant projects.
- All other assumptions are unchanged from the NAA.

For more details, refer to the Modeling Data Sheets in Exhibit 4.

6.4.2 Differences between MO3 and No-Action Alternative

For details on differences between this MO and the NAA, refer to the CRSO EIS Hydropower Appendix and the H&H Appendix.

6.5 MULTIPLE-OBJECTIVE 4 ALTERNATIVE – MODELING

MO4 Alternative includes major operational changes to Libby, Hungry Horse, and Grand Coulee, and minor changes to operations the lower Columbia and Snake River projects.

6.5.1 Hydroregulation Modeling Steps

The hydroregulation modeling process shown in Figure 5-1 was generally followed, with the exception that in Step 3 there was an alternative URC development process. This is because Alternative MO4 contains measures calling for different URCs than the NAA at certain CRSO projects. All URCs were then combined and the remainder of the modeling process was the same.

Changes to the HYDSIM model for MO4 included:

- The flows in powerhouse surface passage routes constructed at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, John Day, and McNary projects are reflected by a 4 kcfs

(lower Snake River dams) or 8 kcfs (lower Columbia River dams) increase, in other spill at those projects, with the same start and end dates as other fish passage spill at the project.

- The additional structure for passage means there will be no need for installation of fish screens, resulting in an increase in turbine availability from the NAA for the duration of those periods where there would have been fish screens installed.
- Additional 2 kcfs of spill October 1 – November 30 at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, and John Day dams for steelhead through a structural change in the spillway.
- Fish passage spill is set to 125 percent TDG. Spill starts March 1 and ends August 31 at all projects.
- Allow turbines to operate within or above 1 percent peak efficiency at lower Snake and lower Columbia projects during fish passage season.
- Contingency reserves may be held above the 1% peak efficiency operating limits during fish passage spill on the lower Snake River and lower Columbia River projects. This reduces the reserve obligation held by other projects in the system, resulting in a higher availability at those projects.
- Draft up to an additional 2.0 MAF from Libby, Hungry Horse, Albeni Falls, and Grand Coulee to support spring flow objectives at McNary Dam (Sections 4.3.2.1, 4.3.2.2, 4.3.2.3, and 4.3.2.4).
- Reservoir drawdown to MOP+1.5 feet and associated changes.
- Changes for Resident fish include changes to summer draft at Libby and Hungry Horse (Sections 4.3.2.1 and 4.3.2.2).
- Changes to FRM are incorporated via Corps-provided URCs, SRDs, and refill tables.
- Changes to Libby December draft (Section 4.3.2.1).
- Changes to the upstream storage correction method incorporated via an updated GCL URC shift algorithm (Section 4.3.2.4).
- Updated availability of Grand Coulee turbines reflects ongoing maintenance of power plants that is more accelerated than current outages to represent a broader range of possible hydraulic capacity during maintenance activities.
- Water Supply measures (increased water pumped from Lake Roosevelt, Chief Joseph diversions, and Flathead River) are incorporated via a negative adjustment to the flows into relevant projects.
- All other assumptions are unchanged from the NAA.

For more details, refer to the Modeling Data Sheets in Exhibit 4.

6.5.2 Differences between MO4 and No-Action Alternative

For details on differences between this MO and the NAA, refer to the CRSO EIS Hydropower Appendix and the H&H Appendix.

6.6 DRAFT PREFFERRED ALTERNATIVE – MODELING

PA includes operational changes to Libby, Hungry Horse, Grand Coulee, Dworshak, and John Day Dams, notably modified operations at Libby and Grand Coulee Dams to maximize operating flexibility and improve overall systems operations including winter FRM; modified operations to meet existing contractual water supply obligations and provide for authorized Lake Roosevelt additional water supply.

6.6.1 Hydroregulation Modeling Steps

The hydroregulation modeling process shown in Figure 5-1 was generally followed, with the exception that in Step 3 there was an alternative URC development process. This is because the PA contains measures calling for different URCs than the NAA at certain CRSO projects. All URCs were then combined and the remainder of the modeling process was the same.

Changes to the HYDSIM model for PA included:

- Cease installation of fish screens at Ice Harbor, McNary and John Day projects once IFP turbines are installed if warranted biologically. This measure would result in an increase in turbine availability from the NAA for periods where fish screens would have been installed.
- Fish passage spill is a revised juvenile fish passage spill operation based upon results of the spring 2019 Flexible Spill Test Operation and analysis of the four MO Alternatives. In a 24- hour period, the Juvenile Fish Passage Spill measure would involve 16 hours of spill operations up to 125% TDG at most projects for juvenile outmigration. For the remaining 8 hours, the projects would spill at a lower level, up to 125% TDG. These spill levels are slightly variable, depending on the project (see Chapter 7). These operations would be implemented during the spring juvenile migration, April 3 – June 21, at the lower Snake River projects, and April 10 – June 16 at 5 the lower Columbia River projects. When Flex Spill ceases, the projects would transition to summer spill operations. PA summer spill levels are described in Chapter 7 with a late summer transition spill operation from August 15 – 31.
- Contingency reserves were held within fish passage spill on the lower Snake River and lower Columbia River projects. This reduced the reserve obligation held by other projects in the system, resulting in a higher availability at those projects.
- Pool elevation restrictions are lifted as outlined in individual projects.
- Restrictions to operate turbines within and above 1 percent of peak efficiency during fish passage season lower Snake River and lower Columbia River projects.
- Contingency reserves were held within fish passage spill on the lower Snake River and lower Columbia River projects. This reduced the reserve obligation held by other projects in the system, resulting in a higher availability at those projects.
- Changes to FRM were incorporated via the Corps-provided URCs and refill tables.
- Changes to the upstream storage correction method were incorporated using an updated Grand Coulee URC shift algorithm.

- Grand Coulee turbine availability was modified to reflect ongoing maintenance that is more accelerated than current outages.
- Flexibility to shift timing of fill at Grand Coulee as the system sets up for winter chum operations.
- Summer elevation and draft targets were modified at Libby and Hungry Horse (Sections 4.3.2.1 and 4.3.2.2).

For more details, refer to the Modeling Data Sheets in Exhibit 4.

6.6.2 Differences between PA and No-Action Alternative

For details on differences between this PA and the NAA, refer to the CRSO EIS Hydropower Appendix and the H&H Appendix.

CHAPTER 7 - POTENTIAL IMPACTS OF CLIMATE CHANGE

The methodology, analyses, and conclusions in this section do not comply with the policies or technical guidance of the Corps or Reclamation for evaluating the preparedness and resilience of water resource systems using climate change affected hydrology. Bonneville required a quantitative analysis of power generation and revenue to include in this appendix of the CRSO EIS. It was not possible for Bonneville to use an approach that would meet the policies or technical guidance of the Corps or Reclamation under the time frame of the EIS. The technical approach and findings contained in this section are those of the Bonneville and should not be construed as an official Department of the Army or Department of Interior position, policy or decision.

7.1 CLIMATE CHANGE STREAMFLOWS AND FORECASTS

The River Management Joint Operating Committee (RMJOC) of the co-lead agencies is continuously evaluating climate change to identify potential vulnerabilities, risk, and resiliency of the FCRPS. The co-lead agencies used the unregulated (naturalized) streamflow scenarios developed by the University of Washington for Part 1 of the RMJOC 2018[16] study to assess potential climate-related impacts for the CRSO EIS. The 160 unregulated streamflow projections in this study provide a wide range of projected climate change impacts on CRS streamflows, which incorporate not only uncertainties in future climate itself, but also the uncertainties introduced by climate model downscaling and the hydrologic modeling process. The full range of 160 unregulated scenarios is considered in a qualitative sense for the other resources evaluated in the CRSO EIS Chapter 4.

Additionally, Bonneville selected four 30-year scenarios from the RMJOC (2018) projections to substitute for the 80-year Modified Flow dataset (1929–2008) that were used in HYDSIM modeling of the NAA and MO alternatives. Each scenario has a 30-year projection (2020–2049, referred to as the 2030s) of flows based on temperature and precipitation assumptions from the selected scenarios.

Hydrologic changes from these projections resulted in changes to the CRS reservoir elevations, streamflows, and hydropower generation. The effects of these changes were assessed quantitatively for potential climate-related impacts on power generation in the CRS. Having a quantifiable understanding of how future climate may impact EIS alternatives was is important to Bonneville's understanding of impacts to generation and revenue in the future. For the other multiple uses, climate change effects are being derived qualitatively from the 160 RMJOC (2018) unregulated streamflow projections. Those qualitative effects are presented in the CRSO EIS.

Bonneville used HYDSIM to produce generation results that can be assessed quantitatively for energy impacts. Bonneville specifically assessed impacts to hydropower under four different climate scenarios selected to roughly represent high, medium, and low annual water conditions, and then assessed the hydropower impacts for the United States, CRS (Federal), and

[16] RMJOC (2010): https://www.bpa.gov/p/Generation/Hydro/hydro/cc/RMJOC-II-Report-Part-I.pdf

Mid-Columbia systems. The net generation impact range for these projects will be used to assess potential resulting impacts to reliability, and revenues are provided in the following sections as well.

In selecting the four scenarios, Bonneville sought to assess hydropower impacts across the broad range of available temperature and precipitation and streamflow projections yet included scenarios that were down-selected for further hydropower evaluation as part of the RMJOC (2018) research effort. Bonneville focused on the carbon emissions pathway (Resource Concentration Pathway 8.5), which is aligned with current observed emissions.

Bonneville also sought to capture at least some of the additional uncertainties resulting from the hydrologic modeling process. Different hydrologic models and model calibrations used in RMJOC (2018) yielded some runoff timing and summer flow differences that were independent from climate change itself. The differences were important to consider relative to the NAA and MOs, particularly with respect to spring and summer natural streamflows.

It is important to note that the four scenarios do not represent the *complete* range of potential climate impacts on the Columbia River – neither from RMJOC (2018) nor from climate change in general. However, they do capture a broad range of expected potential climate impacts on streamflow, which allowed the Action Agencies to compare how NAA and each MO may perform as regional climate changes through the 2030s.

The four climate scenarios selected by Bonneville as representative of a likely and potential spread of annual temperature and precipitation trends by the 2030s (2020-2049), while also leveraging the hydrologic model diversity from the RMJOC (2018) project. The hydrologic diversity includes two hydrologic models, one of which was calibrated with three different methods and historical datasets. While the selection of four scenarios is not as comprehensive as modeling the 19 and 160 scenarios evaluated for the RMJOC (2018) project by Bonneville and the Corps respectively, it provides a range of potential climate scenarios and resulting generation impact.

This approach was developed to provide an assessment of the potential impacts of climate change on impacted resources and alternatives for the CRSO EIS, while providing Bonneville with additional quantifiable information to inform its evaluation of the alternatives.

The four scenarios from RMJOC (2018) used for this analysis included:

- CC1: CanESM2-MACA-PRMS-P1

  CanESM2 was the warmest on all RMJOC (2018) scenarios, with a basin average temperature increase of 5.3°F observed between the historical period (1970-1999) and the 2030s (2020-2049). It was also one of the wetter scenarios on an annual basin-average perspective, with a precipitation increase between the historical period and the 2030s of about 7 percent (warmest/wettest scenario). Although other scenarios in the set of 160 showed even higher future precipitation and annual volume, this scenario was on the high end of projected annual runoff compared to the other 160 scenarios (around 161 Maf by the 2030s, compared to the historical annual runoff of around

132 Maf). It also projected the highest annual average volume runoff into Grand Coulee in the 2030s. The Precipitation Runoff Modeling System (PRMS) hydrologic model results tended to project higher winter flows than the other hydrologic model iterations used for RMJOC (2010), but also lower summer flows.

- CC2: MIROC5-BCSD-VIC-P3

  The MIROC5 climate model projected a little less average annual warming (about 4.4°F) and a little less of a precipitation increase (about 5 percent). This yielded an annual volume of about 155 Maf at The Dalles. One interesting characteristic of this scenario was that the MIROC5 tended to concentrate future precipitation increases above Grand Coulee, with some decrease in precipitation in the Snake River Basin. The Variable Infiltration Capacity (VIC) Macroscale Hydrologic model parameterization used for this scenario (P3) tended to show lower flows in the winter and spring periods, but higher and slightly later spring peak flows compared to the other hydrologic model iterations.

- CC3: HadGEM2-CC-MACA-VIC-P1

  The climate scenario is similar to CC2 in that it projects about 4.5°F of average annual warming by the 2030s, on average, and about a 7 percent precipitation increase. The difference in this scenario, though, is that more of the precipitation and annual volume increases tended to be larger in the Snake Basin compared to the upper Columbia. This VIC hydrologic model parameterization (P1) was the most closely calibrated hydrologic model used in RMJOC (2018), and thus tended to perform best in the historical period, but with a tendency for higher winter flows compared to the other VIC parameterizations.

- CC4: GFDL-ESM2M-BCSD-VIC-P2

  The scenario is one which projects still significant, but less average annual warming across the Columbia Basin, with an average temperature increase around 2.5°F by the 2030s relative to the historical period. However, it is also the driest climate model projection used for RMJOC (2018) for the 2030s, with a slight decrease in annual precipitation (about 2 percent). As a result, it projects the lowest average annual volume for the Columbia Basin at around 138 Maf – similar to what is currently experienced in the Columbia Basin in the historical period. The VIC hydrologic model parameterization (P2) also tended to have lower winter and spring flows compared to the PRMS and VIC-P1 parameterizations, but higher and earlier spring runoffs, with lower summer flows.

Figure 7-1 through Figure 7-3 depict where the four scenarios (shown in yellow) fall in relation to the larger set of the scenarios for the RMJOC (2018) project. The four scenarios are part of the Bonneville-selected 19 scenarios (shown in red) and part of the overall set of 80 RMJOC (2018) Representative Concentration Pathway 8.5 scenarios.

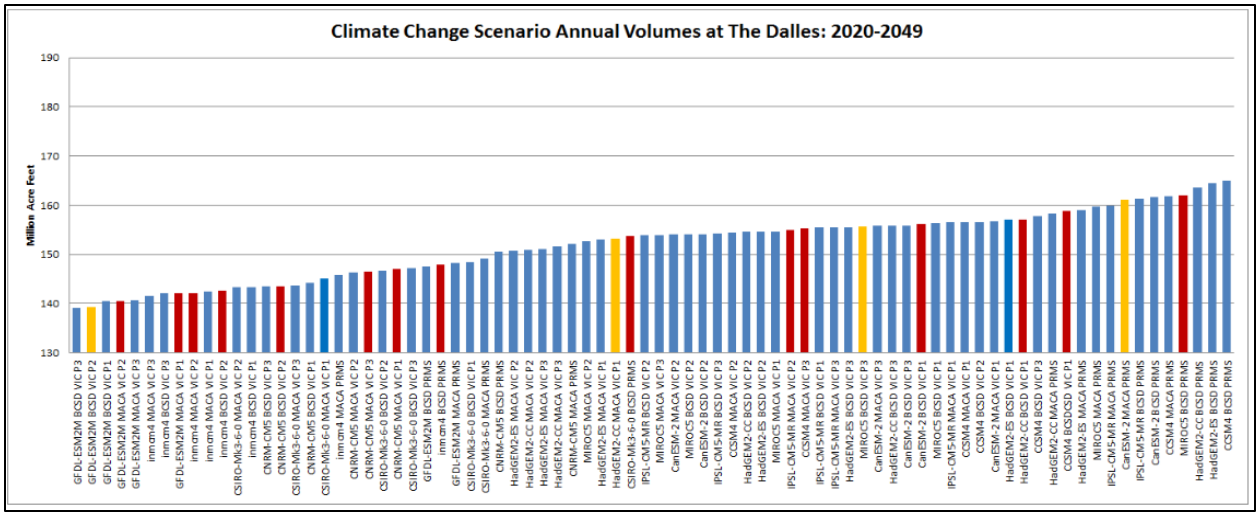

Figure 7-1. Climate Change Scenario Annual Volumes at The Dalles: 2020-2049

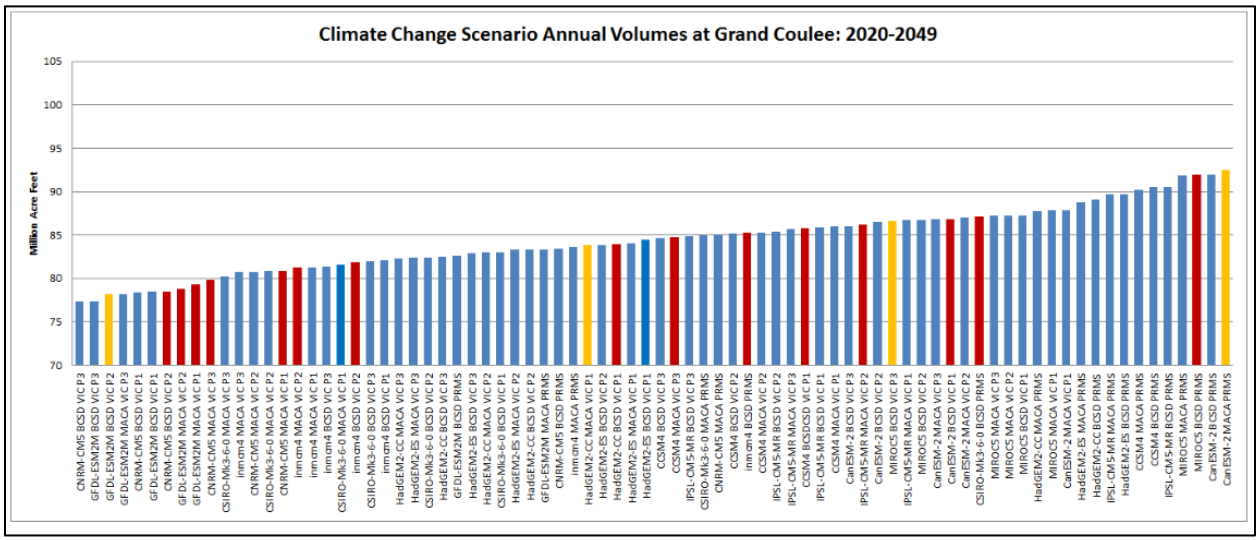

Figure 7-2. Climate Change Scenario Annual Volumes at Grand Coulee: 2020-2049

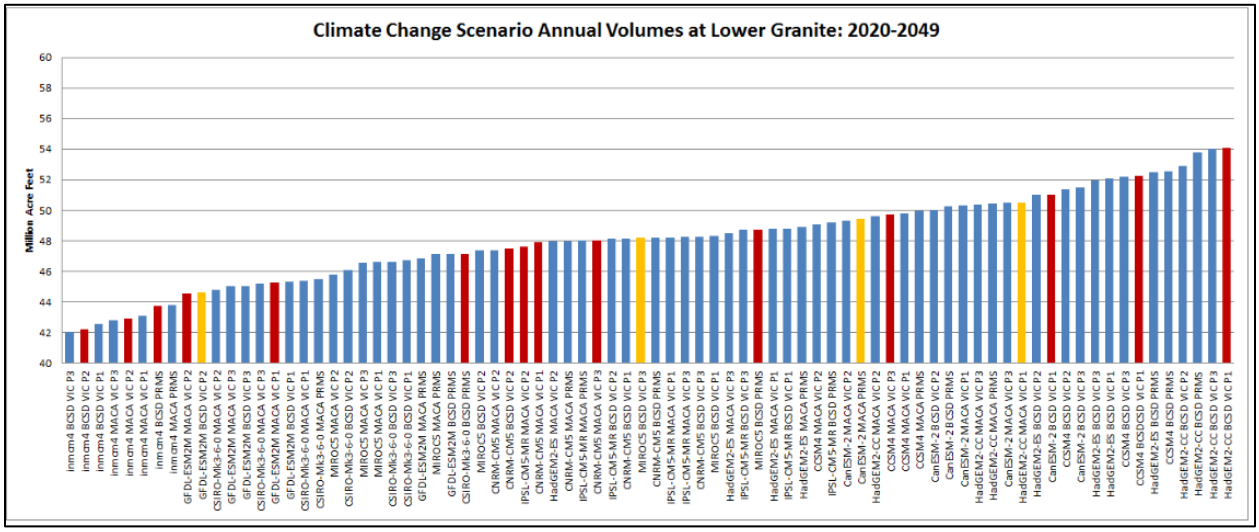

Figure 7-3. Climate Change Scenario Annual Volumes at Lower Granite: 2020-2049

7.2 FLOOD RISK MANAGEMENT INPUTS TO CLIMATE CHANGE MODELING IN HYDSIM

The primary differences in model inputs between the non-climate change scenarios and climate change scenarios are the unregulated (naturalized) streamflow dataset and the associated water supply forecasts. The 80-year Modified Flows dataset and associated forecast flows datasets used as inputs in Figure 5-1 Step 1 are replaced with the climate change inflow dataset and revised water supply forecast dataset. Using these revised inflows and forecasts, the modeling steps determine revised URCs and refill percentage targets to capture runoff to avoid flooding conditions. The URCs define the maximum reservoir elevations for each day to capture forecast runoff and snowmelt and reduce instances of flooding.

7.3 URCS FOR THE NAA ALTERNATIVE WITH CLIMATE CHANGE

For the NAA scenario, the steps outlined in Figure 5-1 were followed, where the results of Step 3, ResSim F0, define the spring snowmelt runoff URCs. The Treaty On-Call FRM operations are performed in the Corps ResSim F1 model, Step 7, along with winter FRM and BiOp operations. The January to April drawdown period of the Treaty On-Call operations modeled in ResSim are used directly in the HYDSIM hydroregulations. The April through July refill values are modeled using HYDSIM. The winter FRM operations from the ResSim F1 model were not used in the Hydsim modeling as they are considered within month real-time operations that are not currently captured in the Hydsim hydroregulation modeling process. The URCs for the NAA modeling of the four climate change scenarios were originally developed for Part II of the RMJOC-II climate change project which is scheduled to be completed in 2020.

7.4 URCS FOR MULTIPLE-OBJECTIVE ALTERNATIVES WITH CLIMATE CHANGE

The URCs for the MO climate change scenarios were developed in the following manner. The URCs for the MO scenarios were assembled from information provided in the NAA climate change URC development, and combined with external calculations of the unique Grand Coulee and Libby winter drawdown requirements defined for each MO. They do not represent comprehensive ResSim modeling output as defined by Figure 5.1 since this modeling was not performed. The summary of the URC computation process is described below.

- The URCs for Mica, Arrow, Duncan, Hungry Horse, Brownlee, and Dworshak were taken directly from the climate change NAA ResSim F0 modeling for each of the scenarios. These URCs represent both the December through March winter drawdown that are predicated on the FRM SRD procedures, the climate change water supply forecasts, and the spring April through July refill from the ResSim modeling.
- The URCs for Libby were developed by applying the new FRM SRD procedure defined for the CRSO. Specifically, the winter drawdown at Libby was computed in an Excel spreadsheet using the climate change scenario water supply forecasts and the new CRSO SRD. Spring refill was calculated in the same manner as the NAA modeling using a HYDSIM modeling spreadsheet of the VarQ outflow procedure.
- At Grand Coulee, the winter drawdown was computed using the climate change water supply forecasts and the two new CRSO SRDs representing a new drawdown rate of 0.8 feet

per day and additional space for winter rainfall events along with the new upstream space adjustment procedure. The spring refill was calculated using refill information from the climate change modeling of the NAA for each climate change scenario. The use of the spring refill parameters from the climate change NAA modeling was assumed to be sufficient for the CRSO MO modeling since the new CRSO FRM procedure for Grand Coulee was designed to reach a similar winter evacuation as the current FRM procedure. The calculations were made with the MatLab URC Program and the HYDSIM Excel Grand Coulee upstream space adjustment spreadsheet. The Grand Coulee/Dworshak shift was calculated using the HYDSIM Excel spreadsheet.

Once the URCs, runoff data set, and forecast data sets were identified, each MO alternative was set with their specific operational and physical constraints, then run through Hydsim to obtain the regulation of each project. The model run generation, elevation, and flow outputs were then compared back to NAA outputs. For details on the impacts of climate change variations on the MO alternatives, refer to the CRSO EIS Hydropower Appendix.

CHAPTER 8 - REFERENCES

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Exhibit 1. Project List for United States, CRS, Mid-Columbia, and Canadian Systems

This exhibit provides a listing of projects that are modelled by Bonneville for the CRSO EIS. The projects highlighted with an asterisk (*) are affected by the CRSO EIS alternatives. The remaining projects are not affected by the alternatives, but are part of the Bonneville hydropower models; their operation is replicated in each alternative.

Table E4 - 1. Identification of Hydropower Projects within each Group

	Hydro Project Grouping			
Projects	**US System**	**Canadian System**	**Mid-Columbia**	**Federal System (CRS)**
Cushman 1	✓			
Cushman 2	✓			
Alder	✓			
Lagrand	✓			
Ross	✓			
Diablo	✓			
Gorge	✓			
Upper Baker	✓			
Lower Baker	✓			
Mica		✓		
Revelstoke		✓		
Arrow		✓		
Libby*	✓			✓
Bonners Ferry *	✓			
Duncan				
Corra Linn*		✓		
Canal Plant*		✓		
Upper Bonnington*		✓		
Lower Bonnington*		✓		
South Slocan*		✓		
Brilliant*		✓		
Hungry Horse*	✓			✓
Columbia Falls*	✓			
SKQ*	✓			
Thompson Falls*	✓			
Noxon Rapids*	✓			
Cabinet Gorge*	✓			
Priest Lake				
Albeni Falls*	✓			✓
Box Canyon*	✓			
Boundary*	✓			
Seven Mile*		✓		

	Hydro Project Grouping			
Projects	**US System**	**Canadian System**	**Mid-Columbia**	**Federal System (CRS)**
Waneta*		✓		
Coeur d'Alene Lake				
Post Falls	✓			
Upper Falls	✓			
Monroe Street	✓			
Nine Mile	✓			
Long Lake	✓			
Little Falls	✓			
Grand Coulee*	✓			✓
Chief Joseph*	✓			✓
Wells*	✓		✓	
Chelan	✓			
Rocky Reach*	✓		✓	
Rock Island*	✓		✓	
Wanapum*	✓		✓	
Priest Rapids*	✓		✓	
Brownlee				
Oxbow				
Hells Canyon				
Dworshak*	✓			✓
Lower Granite*	✓			✓
Little Goose*	✓			✓
Lower Monumental*	✓			✓
Ice Harbor*	✓			✓
McNary*	✓			✓
John Day*	✓			✓
Round Butte	✓			
Pelton	✓			
Pelton Rereg	✓			
The Dalles*	✓			✓
Bonneville*	✓			✓
Timothy	✓			
Oak Grove	✓			
North Fork	✓			
Faraday	✓			
River Mill	✓			
Swift 1	✓			
Swift 2	✓			
Yale	✓			
Merwin	✓			

	Hydro Project Grouping			
Projects	**US System**	**Canadian System**	**Mid-Columbia**	**Federal System (CRS)**
Packwood Lake				
Mossyrock	✓			
Mayfield	✓			

(* indicates project may be directly affected by CRSO EIS Alternatives)

2041 # Exhibit 2. CRSO Alternatives Crosswalk

	Measure Category	CRSO Measure Name	Multi-Objective #1 (MO1)	Multi-Objective #2 (MO2)	Multi-Objective #3 (MO3)	Multi-Objective #4 (MO4)	Preferred Alternative (PA)
Structural	Structural	Additional Powerhouse Surface Passage	X	X	X	X	
		Upgrade to Adjustable Spillway Weirs	X	X	X		
		Lower Granite Trap Modifications	X			X	X
		Modify Bonneville Ladder Serpentine Weir	X		X		X
		Lower Snake Ladder Pumps	X	X		X	
		Spillway Weir Notch Inserts				X	
		Fewer Fish Screens		X	X		X
		Improved Fish Passage Turbines at John Day	X	X	X	X	X
		Lamprey Passage Structures	X	X	X	X	X
		Turbine Strainer Lamprey Exclusion	X	X	X	X	X
		Bypass Screen Modifications for Lamprey	X	X	X	X	X
		Closeable Floating Orifice Gates					X
		Lamprey Passage Ladder Modifications	X	X	X	X	X
	Dam Breach	Breach Snake Embankments			X		
		Lower Snake Infrastructure Drawdown			X		
		Drawdown Operating Procedures			X		
		Drawdown Contingency Plans			X		
Operational	Fish Passage	Block Spill Test (Base + 120/115%)	X				
		Summer Spill Stop Trigger	X				
		Early Start Transport	X				X
		Contingency Reserves within Juvenile Fish Passage Spill	X	X	X	X	X
		Spill to 110% TDG		X			
		Spring & Fall Transport				X	
		No Summer Transport				X	
		Reduced Summer Spill			X		
		Spill to 125% TDG				X	
		Spring Spill to 120% TDG			X		
		Juvenile Fish Passage Spill Operations					X
		Spill for Adult Steelhead				X	
		Increase Juvenile Fish Transportation		X			
	Water Management	Modified Draft at Libby	X	X	X	X	X
		December Libby Target Elevation	X	X	X	X	
		Update System FRM Calculation at Grand Coulee	X	X	X	X	X
		Planned Draft Rate at Grand Coulee	X	X	X	X	X
		Grand Coulee Maintenance Operations	X	X	X	X	X
		Winter System FRM Space	X	X		X	
	Water Supply	Lake Roosevelt Additional Water Supply	X		X	X	X
		Hungry Horse Additional Water Supply	X		X	X	
		Chief Joseph Dam Project Addt'l Water Supply	X		X	X	
	Hydropower	Increased Forebay Range Flexibility	X				X
		Slightly Deeper Draft for Hydropower		X			
		Slightly Deeper Draft for Hydropower (Dworshak)					X
		Fall Operational Flexibility for Hydropower (Grand Coulee)					X
		Ramping Rates for Safety		X	X		
		John Day Full Pool		X	X		X
		Full Range Reservoir Operations		X			
		Full Range Turbine Operations		X			
		Above 1% Turbine Operations			X	X	X
		Zero Generation Operations		X			X
	Other Operational Measures	McNary Flow Target				X	
		Drawdown to MOP				X	
		Predator Disruption Operations	X				X
		Modified Dworshak Summer Draft	X				
		Sliding Scale at Libby and Hungry Horse	X	X	X	X	X
		Winter Stage for Riparian				X	

2042
2043

Exhibit 3. Summary of Results Provided to EIS Workgroups for all Alternatives

EIS Workgroup	Results Provided
Transmission	• Average Generation for all Projects (14x80 matrices in aMW, from pre-Lack-of-Market HYDSIM study) • Raw Independent and Small Hydro Data • Max and Min Generation from HOSS
Transmission Rates Analysis	The Dalles Regulated Outflow (14x80 matrix in cfs)
Power Rates Analysis	• Purchase Table to Support 4(h)(10)(C) Calculation • Hydsim and HOSS study results to load data-base for socioeconomic analysis • Grand Coulee 14x80 generation matrix to support Colville Payment calculation • Loss of Load Probability results and CVaR parameters determined Replacement Resources for Low Cost and Low Carbon Scenarios
Water Quality Team (for Spill Allocation Process)	• Hydro Availability Hydsim input • Lack of Market data from AURORA run • Detailed Description of Spill Operation at each Project

Exhibit 4. Modeling Sheets for each Alternative

Detailed modeling are provided in this exhibit for each CRSO EIS alternative. Each sheet contains a table of contents, a summary of the objectives, changes from the NAA, and a project-by-project listing of the considerations made for each project to meet the objectives.

Modeling Data Sheet: No Action Alternative

Alternative Modeling Summary – No Action Alternative

Table E4 - 2. Alternative Summary – No Action Alternative

Name:	**CRSO No Action Alternative**
CRSO Projects:	Projects are modeled to represent the current 2016 operating rules and constraints
Flood Risk	U.S. projects follow FCOP with current URCs Canadian projects follow FCOP with current URCs On Call FRM (after FLEX in ResSim)
Power	Coordinated Treaty Hydropower Operations Operating criteria and U.S. objectives (both power and non-power) based on current Treaty planning methodologies and procedures based on AOP22 including Critical Rule Curves (CRCs) and Power Discharge Requirements (PDRs). Loads and resources from AOP22 Flex operation at Mica with modified operation (additional flow augmentation) at Arrow (in ResSim)
Biological and Water Supply Objectives	Implements current operations and objectives
Modeling System Configuration	Current configuration of the Columbia River System with no major changes in levees, dams, and reservoirs from the current system
Canadian Treaty Projects:	Current Treaty operating protocols and procedures
Hydrologic Data Sets Used for Monte Carlo Evaluation	ResSim & HydSim: 80-year 2010 Level Modified Flows from 1929 - 2008. 9-year Extended Observed flows from 2008 – 2016 are needed only for the Water Quality analysis. Adjustments to both these stream flows sets are made in this study according to the Bureau of Reclamation's updated Grand Coulee pumping schedule for the Columbia Basin Project in their February 1, 2016, preliminary PNCA data submittal for OY17, plus full implementation of Odessa and M&I.
Hydrologic Data Sets Used for Monte Carlo Evaluation	ResSim: 106-year dataset based on 80-year 2010 Level Modified Flows, plus 26 synthetic water years (17 spring synthetics and 9 winter synthetics)
Water Supply Forecast Used for Monte Carlo Evaluation	Refined water supply forecasts developed at the Corps (not Rate Case forecasts)
Water Supply Forecast Used for FRA Evaluation	FRA water supply forecasts adjusted for statistical consistency

Note: all elevations are in NGVD 29

HydSim Assumptions (General)

- Continuous 80 year study
- Begin October 1, 1928 and ends September 30, 2008
- 14 periods averages, with April and August split into two periods each, with the first fifteen days as the first period and the rest of the month as the second period.
- Non-federal projects are run to the resulting contents from the AER step. This allows the federal projects to operate without causing the non-Federal projects to adjust operations to meet system load.
- Outages for all projects are from 2026 projections from BPA Federal Hydro Projects Operations
- Initial contents for the major federal projects are from the 2016-2018 finalized Rate Case.
- The HydSim hydro availability file reflects:
    - Average availability of the turbines based on current 5-year maintenance plan, expressed as a percent of capacity.
    - Operating at 1 percent efficiency. Turbine operations at the four lower Snake River projects (Lower Granite, Little Goose, Lower Monumental and Ice Harbor) and the four lower Columbia River projects (McNary, John Day, The Dalles and Bonneville) are required to operate within 1 percent of peak efficiency April 1 through October 31 for fish survival benefits. This will reduce turbine availability at those projects in those periods.
    - Installation of fish screens. Turbine availability at a project is reduced when fish screens are in place.
    - Reserve requirements distributed through the system. Carrying reserves reduces turbine availability. The size of the reduction depends total system reserve requirements, and on what portion of the system's reserves are allocated to any particular project in any particular time period. The Minimum Operating Pool at the lower Snake River projects do not allow them to carry reserves during fish passage season.
- H/K tables used in calculations to convert flows and head to generation are based on historical observations.
- Spill levels when spill plan involves Total Dissolved Gas ("TDG") amounts are based on the spill level estimates created by the Water Quality Team in December 2018.
- Market calculations when estimating Lack of Market spill are based on Fiscal Year 2022 estimates of regional load, market conditions and generation resources.
- "Other spill" values based on 2016 PNCA data submittals encompassing leakage, lockage, and other flows that do not go through the spillway or the turbines.

Projects

Canadian Projects

GENERAL CANADIAN OPERATION

- Canadian projects operate for power per TSR based on the AOP22 and DOP18 updates.
- Canadian projects operate in consideration of SRDs for flood risk
- Canadian operation includes proportional draft.
- HydSim Canadian operation is initialized to the 80-year TSR22 study including proportional draft with the following additions:
  - Flow augmentation as detailed in the table below
  - The trout spawning operation is included at Arrow where April 16 through April 30 flows are at least 15,000 cfs and May and June flows are equal to or greater than the preceding month whenever possible. No more than a 5,000 cfs decrease is allowed.
  - Canadian Operations include On Call

ON CALL LOGIC (MICA, ARROW, DUNCAN, GRAND COULEE)

HydSim Considerations

- HydSim uses On Call URCs January to April as provided by Corps
- HydSim refill based on Power operation
- Non Power Uses (NPU) Storage and release of water for NPU are as outlined below:

Table E4 - 3. Non Power Uses Canadian Storage and Release

NPU Element	MAF	Storage Location	Target Storage Schedule	Target Release Schedule
Flow Augmentation - Normal Year	1.0	Treaty (Arrow/Mica)	***January – March*** Subject to: January: Minimum flow at Arrow of 20 kcfs. February-March: minimum flow at Arrow of 10 kcfs	***May – July*** Except if dry conditions, release May-July or May-June if required to support MCN minimum flow objectives.
Flow Augmentation - Dry Conditions*	1.0	Treaty (Arrow/Mica)	***January – February*** Subject to: January: Minimum flow at Arrow of 30 kcfs. February: minimum flow at Arrow of 10 kcfs	***February- March*** If dry conditions, release ½ balance in February and/or and full balance in March.
NTSA dry period provision**	0.5	Non-Treaty (Mica)	N/A	***May-June*** In dry years, release uniformly during May-June through Arrow

Notes:
*SOA Dry Conditions = When the February or March Water Supply Forecast (April – August) at The Dalles is <75 MAF
**NTSA Dry Year = When the May Water Supply Forecast (April – August) at The Dalles is <72.5 MAF

MICA

Flows

- Min Flows: 0 cfs
- Max Flows: can vary by period due to higher priority constraints

Elevation/Content

- Min Elevation: can vary by period due to higher priority constraints
- Max Elevation: 2,470 ft (5,825.1 ksfd)

HydSim Considerations

- NPU storage occurs at Mica
- Release all NPU storage by July 31

Specific Operations for Flood Risk:

- Upper rule curves per the FCOP are considered in operations
- On-call operations, per the FCOP, may be implemented in certain years

Specific Operations/Assumptions in Power Modeling:

- See General Canadian Operation (above)

Specific Operations/Assumptions in BiOp Modeling:

- See General Canadian Operation (above)

DUNCAN

Flows

- Min flows: 100 cfs
- Max flows: 10,000 cfs
- Targets:
    - Refill May-Jun at 0.1 kcfs, then pass inflow if treaty full.

Elevation/Content

- Min elevation: 1,794.2 ft (0 ksfd)
- Max elevation: 1,892 ft (705.8 ksfd)

HydSim Considerations

- Operates to TSR, constrained by PDP or ECC

Specific Operations/Assumptions in Flood Risk Modeling:

- Upper rule curves per the FCOP are considered in operations.
- On-call operations, per the FCOP are implemented in certain years.

Specific Operations/Assumptions in Power Modeling:

- See General Canadian Operation (above)

Specific Operations/Assumptions in BiOp Modeling:

- See General Canadian Operation (above)

ARROW

Flows:

- Min flow: 5,000 cfs
- Max flow: can vary by period due to higher priority constraints

Elevation/Content:

- Min elevation: 1,377.9 ft (0 ksfd)
- Max elevation: 1,444 ft (3,579.6 ksfd)

HydSim Considerations

- Operates to TSR, constrained by PDP or ECC

Specific Operations/Assumptions in Flood Risk Modeling:

- Generally operates to FLEX outflows at the Border unless supporting Grand Coulee to meet the ICF
- On-call operations, per the FCOP, may be implemented in certain years

Specific Operations/Assumptions in Power Modeling:

- See General Canadian Operation (above)

Specific Operations/Assumptions in BiOp Modeling:

- Follow the table contained in General Canadian Operation (above) for flow augmentation and provisional draft storage and release target schedules
- Re-store the additional 0.5 MAF back into Canada evenly in May/June when TDA unregulated forecast is above average (May-350 kcfs, June 450 kcfs)
- If another dry year follows a previous dry year so the volume has not been re-stored, then it is not possible to release an additional 0.5 MAF until that volume has been replenished.
- For trout spawning, Arrow outflow operates to minimum flow of 15,000 cfs in April 15, between 15,000 cfs and 25,000 cfs in April 30, between 15,000 cfs and 35,000 cfs in May-June. During April through June the outflow at Arrow cannot decline unless the TSR balance by June 30 is below the target composite TSR balance plus any remaining Flow Augmentation volume. Then the outflow is allowed to reduce up to 5,000 cfs in Trout Spawning periods.

CORRA LINN

Flows:

- Min flow:
- Max flow:

Elevation/Content:

- Min elevation: 1,738 ft (0 ksfd)
- Max elevation: 1,770 ft (1,953.4 ksfd)

HydSim Considerations

- Project follows IJC rule curve as possible

Specific Operations/Assumptions in Flood Risk Modeling:

- None, follows IJC rule curve as possible.

Specific Operations/Assumptions in Power Modeling:

- See General Canadian Operations (above)

Specific Operations/Assumptions in BiOp Modeling:

- See General Canadian Operations (above)

US Headwater

LIBBY

Flows:

- Min flow: 4,000 cfs
- Max flow: 25,000 cfs (max 20,000 cfs in Nov/Dec)

Elevation/Content:

- Min elevation: 2,287 ft (0 ksfd)
- Max elevation: 2,459 ft (2,510.5 ksfd)
- Targets:

HydSim Considerations

- Shift flows to previous months to prevent spill, January-April, with max outflow 25,000 cfs
- Maximum end of July content: 2,395 ksfd (2,454 ft)
- Allow June fill when flow out is greater than 30,000 cfs
- Otherwise max desired discharge, May-Aug: 25,000 cfs
- Summer draft operation: “Montana Proposal” of ending 10 ft below full by the end of September (20 ft below in dry years)

Specific Operations/Assumptions in Flood Risk Modeling:

- Begin refill 10 days before ICF date or if FCRC triggers refill
- VARQ flows and elevations (including variable end-of-December URC drafts)
- Target refill to 5 ft from full by July 31
- Attempt to keep flows below 1,764 ft (NGVD29) at Bonners Ferry
- Attempt to limit spill during refill, keeping space reserved for flood control
- Special discharge regulation schedule to manage reservoir space below full
- Anticipatory drafts during the last part of the month in case WSF changes significantly
- Operate for winter flood risk management

Specific Operations/Assumptions in Power Modeling:

- 5.0 Maf of space between its maximum forebay elevation of 2,459 ft NGVD29 and minimum forebay elevation of 2,287 ft NGVD29 is operated to maximize power while maintaining other authorized purposes. Libby has five generating units with an estimated discharge capacity estimate of up to 5,200 cubic feet per second (cfs) each

Specific Operations/Assumptions in BiOp Modeling:

- Project outflow minimum per the Bull Trout BiOP:
  - May 15 – September 30: 6 kcfs minimum
  - July 1 (or after sturgeon pulse) – August 31: tiered minimum varying from 6 kcfs to 9 kcfs per the May final Libby April-August WSF
- Sturgeon Operation starting on May 15 per the tiered volumes based on the May Final April-August WSF for Libby. Target 2,454 ft by the end of July.
- Summer Flow Augmentation: draft to 2,449 or 2,439 ft by the end of September depending on the May final April-August WSF for The Dalles. If less than 72.5 MAF (low 20 percent water year), draft to the lower elevation. Target 2.5 ft above end of September values by the end of August to facilitate reaching the September targets without double peaking.

HUNGRY HORSE

Flows:

- Min flow: 300 cfs
- Max flow: 8,900 cfs powerhouse capacity, 14,000 cfs max outflow
- Target flows: minimum flows based on WMP minimum flows table.

Elevation/Content:

- Min elevation: 3,336 ft (0 ksfd)
- Max elevation: 3,560 ft (1,503.44 ksfd)
- Targets:

- Summer draft target for end of September "Montana Proposal", 20 ft from full in driest years; 10 ft from full in other years.

HydSim Considerations

- Force to be on Qmin or at flood control elevation January to March.
- April 15th and April 30th max elevation 3,545 ft (1,330.2 ksfd)
- June max content 3,558 (1,480.1 ksfd)
- Target 3,550 ft in AG1 and 3,540 ft in AG2
- Shape February-April to avoid spill
- Restrict flows in June to smooth summer flows
- Dry year refill strategy: refill more slowly in the driest 20 percent of years. When WSF for May to Sept @ HGH < 1,450, HGH Qmin is 50 percent of COLF Qmin

Specific Operations/Assumptions in Power Modeling

- January, February and March minimum elevations are set as Variable Draft Limits ("VDLs"). These VDLs are a minimum elevation with a 75 percent probability of reaching the April 10th elevation target for refill. Hungry Horse can operate between the VDLs and URC depending on power needs.
- When applying Lack of Market adjustments, when possible, reductions in generation may be realized by reducing draft at HGH.

Specific Operations/Assumptions in BiOp Modeling

- Maximum rate-of-change rules
- BiOp minimum flows vary based on the WSF:
  - Hungry Horse must release water to maintain a minimum flow (3,200 cfs to 3,500 cfs) at Columbia Falls
  - The minimum discharge varies between 400 cfs and 900 cfs.
- April and May flows shaped for smooth transition to VARQ flows. Adjusts flows near full pool to prevent overfilling

DWORSHAK

Flows:

- Min flow: 1,600 cfs (1,500 cfs powerhouse minimum plus 100 cfs hatchery)
- Max flow: 14,000 cfs powerhouse capacity, 25,000 cfs max outflow for flood control

Elevation/Content:

- Min elevation: 1,445 ft (0 ksfd)
- Max elevation: 1,600 ft (1,016 ksfd)

HydSim Considerations

- Max outflow at 25,000 cfs in order to meet elevation considerations; target period average flows of 14,000 cfs
- Shift flood control space to GCL when April to July Forecast at DWR > 3.0 MAF
- Reduce spill for January to April, up to 8,000 cfs, shifting outflows to earlier period.
- Smooth summer drafts with
    - End of August target of 1,535 ft
    - Target summer flow of 11,000 cfs in July and Aug1, with max Qo of 14,000.
    - Keep the flow drop from August 15th to August 30th under 25 percent drop.
- Draft July 1 to August 31 to support lower Snake BiOp objectives
- 100 cfs hatchery minimum flow modelled as "other spill"

Specific Operations/Assumptions in Flood Risk Modeling:

- Upper rules curves during draft are based on both local and system SRDs
- Shift to GCL allowed. Full shift usually followed until April 1st. Partial shift in April may occur as a result of other operations, but the full shift on April 15th is otherwise ignored; beginning April 15, reservoir releases to target April 30 elevation.
- Maximum release of 25,000 cfs for channel capacity
- Control flow at Spalding to 105,000 cfs as possible
- Upper rules curves during draft are based on both local and system SRDs
- Shift to GCL allowed. Full shift usually followed until April 1st. Partial shift in April may occur as a result of other operations, but the full shift on April 15th is otherwise ignored; beginning April 15, reservoir releases to target April 30 elevation.
- Maximum release of 25,000 cfs for channel capacity
- Control flow at Spalding to 105,000 cfs as possible
- Begin refill 2 days before ICF date, unless FCRC triggers refill
- Target refill by June 30
- Attempt to limit spill during refill

Specific Operations/Assumptions in Power Modeling:

- Lack of Market spill level one is at 30 percent of outflow, up to TDG gas cap per TMT spill priority list.

Specific Operations/Assumptions in BiOp Modeling:

- TDG cap of 110 percent assumed at 14,500 cfs

- Draft July 1 – August 31 to support lower Snake BiOp objectives, but refilling by June 30th takes precedence.

Specific Operations/Assumptions for Flood Risk:

- Upper rules curves during draft are based on both local and system SRDs
- Shift to GCL allowed. Full shift usually followed until April 1st. Partial shift in April may occur as a result of other operations, but the full shift on April 15th is otherwise ignored; beginning April 15, reservoir releases to target April 30 elevation.
- Maximum release of 25,000 cfs for channel capacity
- Control flow at Spalding to 105,000 cfs as possible
- Begin refill 2 days before ICF date, unless FCRC triggers refill
- Target refill by June 30
- Attempt to limit spill during refill

BROWNLEE

Flows:

- Min flow: 5,000 cfs
- Max flow: 35,000 cfs, can vary by period due to higher priority constraints

Elevation/Content:

- Min elevation: 1,976 ft (0 ksfd)
- Max elevation: 2,078.5 ft (502.9 ksfd)

HydSim Considerations

- Generic annual operation with the following in overrides in the OPER study step:
    - Hells Canyon minimums govern Brownlee outflow:
        - minimum flow of 9,000 cfs November through the middle of June; second half of June minimum of 5,000 cfs
        - Hells Canyon maximum Qout in January of 30,000 cfs
    - December end of month content target of 443.2 ksfd; January end of month content target 409.5 ksfd
    - Allow 30 kcfs outflow to have a higher priority than content target
    - Max Qout in all periods 35,000 cfs
    - Target end of month contents
        - July: 391.5 ksfd
        - August1: 373.5 ksfd
        - August2 349.4 ksfd

- September: 309.7 ksfd

Specific Operations/Assumptions in Flood Risk Modeling:

- Upper rules curves during draft are based on current SRDS
- Target refill by June 30.

Specific Operations/Assumptions in Power Modeling:

- Generic operation based on the AER.

Specific Operations/Assumptions in BiOp Modeling:

- Fall Chinook operation: 8,500-12,000 cfs flows from October 18-December 10.

GRAND COULEE

Flows:

- Min flow: 30,000 cfs
- Max flow: can vary by period due to higher priority constraints

Elevation/Content:

- Min elevation: 1,208 ft
- Max elevation: 1,290 ft (considered full at 1,288 ft)

HydSim Considerations

- OnCall GCL URCs received from ResSim and incorporated in HYMOD
- GCL draft rate limits are 1.3 ft/day for elevations above 1,240 ft, and 1 foot/day for elevations below 1,240 ft, switch in the HydDef.
- Targets:
  - October: Operate between 1,283 ft and 1,288 ft to keep BON Qo < 110 kcfs
  - November: Operate between 1,275 ft and 1,288 ft to meet BON Qo of 115 kcfs
  - December: Operate between 1,270 ft and 1,288 ft to meet BON qo of 125-140 kcfs
  - January-February: Upper limit 1,288 ft
  - June lower draft limit of 1,285 ft for MCN flow targets; upper draft limit of 1,288 ft; target 1,287 ft
  - Jul-AG2 fill no higher than 1,288 ft for flexibility
  - September: variable target, as September operation is based on economics
- Increase AG1 elevation target by up to 2 ft to smooth MCN Qo between AG1-AG2 (if drop is greater than 30 kcfs)
- GCL contents adjusted in January-March to smooth BON Qo.
- GCL can release to maintain a minimum of 70 kcfs at BON.

- AG2 draft target is variable based on July Water Supply forecast, either 2,217.5 ksfd or 2,295.3 ksfd; AG1 draft target is set to be higher than the AG2 target by 78 ksfd.
- Drumgate operations are set for February, May, April1 and April2 URCs if the Drumgate criteria are met. If the Drumgate criteria are met, the URCs are set to February: 1,267 ft; March, April1 and April2: 1,255 ft
- Whether a year meets Drumgate criteria are decided with the following priorities:
    - Forecast: based solely on the February forecast of the April 30 URC; if the April 30 URC is at 1,255 ft or lower, then the February-April 30 URCs is set as above.
    - Frequency: If frequency criteria (1 in 3 years, 2 in five years, 3 in seven years) are not met, force years to become Drumgate years with the Drumgate URCs.
    - Range Rule: If the February forecast of the April 30th URC is within 10 ft of the Drumgate elevation *and* the previous year was not a Drumgate year, force February-April URCs to Drumgate elevations.
- Variable Draft Limits (VDLs) in January-March set as a lower draft limit to maintain an 85 percent probability of reaching the April 10 elevation objective; set 10 ft below URC; Absolute minimum VDL: elevation 1,260 ft in January, 1,250 ft in February, 1,240 ft in March
- When applying Lack of Market adjustments, when possible, reductions in generation may be realized by reducing draft at GCL.

Specific Operations/Assumptions in Power Modeling:

- The September end of month elevations can vary widely due to power market considerations; this variation is simulated through 80 years of fixed end of month targets that vary according to January-July water volume at The Dalles.
- January, February and March minimum elevations are set as Variable Draft Limits ("VDLs"). These VDLs are a minimum elevation with an 85 percent probability of reaching the April 10th elevation target for refill. Grand Coulee can operate between the VDLs and URC depending on power needs.
- Based on flows at Bonneville in January, February, and March, Grand Coulee's outflows may be adjusted to attempt to equally distribute flows over this period.
- Lack of Market spill applied at GCL per TMT spill priority list; assumes regulating outlet ("RO") spill in March to June, and drumgate spill in remainder of the year.
- When applying Lack of Market adjustments, when possible, reductions in generation may be realized by reducing draft at GCL.

Specific Operations/Assumptions in BiOp Modeling:

- Vernita Bar and Steelhead flow objectives are met by drafting Grand Coulee.

Specific Operations/Assumptions for Flood Risk Modeling:

- Upper rules curves are based on current SRDs, adjusted for upstream storage.
- Minimum flow 30,000 cfs

- Supports minimum flows downstream of Bonneville (between 70 and 100 kcfs depending on average inflows)
- Refill begins 1 day before the ICF
- Refill operations target a straight-line refill to an end-of-June value of 1,287 ft. If the 5-day average flows at The Dalles are above 500 kcfs, the refill operation targets an elevation towards 1,282 ft to allow for more space to be reserved for flood risk management. If the project is filling too fast, the ICF is also adjusted upward. In July, final refill will occur after the 4th of July where Grand Coulee fills 25 percent of the remaining storage each day and targets a full elevation of 1,290 ft on July 7th.
- When needed, Grand Coulee refills in coordination with Arrow (SynRes) to control flows at TDA
- Full shift at GCL assumed between DWR and GCL. No Brownlee shift.
- On Call: Grand Coulee drafts to empty by April 30 (subject to draft rate limitations)

BANKS LAKE

Columbia Basin Irrigation Project Pumping (Banks Lake) data submittal estimates of pumping, which are based on the average of the past five years actual pumping and include the equivalent of 5 ft (65.5 ksfd) flow augmentation in August and the associated increase in pumping to return those 5 ft to Banks Lake. In ResSim, Banks Lake is modeled as a diversion (net pumping provided by USBR). Return flows are included in the 2010 Level Modified Flows.

Lower Snake River Projects

HYDSIM CONSIDERATIONS

- Lower Snake projects first-coded in HYMOD file to an average annual operation with Minimum Operating Pool ("MOP") during set period, and full the rest of the year.
    - LWG: on MOP April 3 – October 31, 733 ft/Full = 738 ft (245.8 ksfd)
    - LGS: on MOP April 3 – September 1, 633 ft/ Full = 638 ft.
    - LMN: on MOP Apil 3 – September 1, 537 ft/Normal Pool 540 ft
    - IHR: on MOP April 3 – September 1, 437 ft/Full = 440 ft
- Spill operation based on 2017 Fish Passage plan (see BiOp section) During fish passage season, the lower Snake projects are required to operate within 1 percent peak generation efficiency resulting in a decrease in availability at those projects in those periods.

Specific Operations/Assumptions in Flood Risk Modeling:

- None – same as above.

Specific Operations/Assumptions in Power Modeling:

- Lack of Market spill modelled per TMT spill priority list includes lower Snake projects in all periods.

- No reserves are carried by lower Snake projects when operating in MOP; reserves are allocated to the lower Snake River projects during all other periods, resulting in a reduction in the turbine availability for those projects in those periods.

Specific Operations/Assumptions in BiOp Modeling:

- Spill Operation based on 2017 Fish Passage Plan
  - IHR
    - April 3 – April 28: 45 kcfs daytime and Water Quality TDG waiver level at night.
    - April 29th through July 13: Alternating 2 days each, 30 percent of total outflow and 45 kcfs spill in daytime and Water Quality TDG waiver level at night
    - July 14th – August 31: 45 kcfs daytime and Water Quality TDG waiver level at night
  - LMN
    - April 3 – June 20: Spill to Water Quality TDG waiver level all hours
    - June 21 – August 31: Spill 17 kcfs all hours
  - LGS
    - April 3 – August 31: Spill 30 percent of total outflow all hours.
  - LWG
    - April 3 – June 20: Spill 20 kcfs all hours
    - June 21 – August 31: Spill 18 kcfs all hours

Mid-Columbia and Lower-Columbia River Projects

HYDSIM CONSIDERATIONS

- Mid-Columbia Projects:
  - Wells spill criteria: From April 12 to August 6 spill 6.5 percent when CHJ Qo < 140 kcfs; spill 10,200 cfs otherwise
  - Chelan: First coded to TSR
  - Priest Rapids:
    - default flow 36,000 cfs;
    - December-May flows dependent on Wanapum Qo
    - Tier1 GCL Qi Threshold: 90 kcfs/ PRD Qmin: 100 kcfs
    - Tier2 GCL Qi Threshold: 120 kcfs/ PRD Qmin 115 kcfs
- Lower Columbia Projects:
  - BON: model at 74.1 ft in all periods

- TDA: 158.1 ft
- MCN: 338.7 ft
- JDA includes Minimum Irrigation Pool ("MIP"): OCT-MAR, 265 ft; AP1-SEP: 262.5 ft

- Noxon operates to a FC operation from TSR ECC
- Spill operation based on 2017 Fish Passage plan (see BiOp section)
- During fish passage season, Bonneville and McNary projects are required to operate within 1 percent peak generation efficiency resulting in a decrease in availability at those projects in those periods.

Specific Operations/Assumptions in Flood Risk Modeling:

- JDA: Assist with winter FRM operations.

Specific Operations/Assumptions in Power Modeling:

- Lack of Market spill modelled per TMT spill priority list includes mid- and lower Columbia projects in all periods.
- Reserves are allocated to the lower Columbia River projects resulting in lower turbine availability at those projects; during fish passage season, McNary project does not hold any reserves.

Specific Operations/Assumptions in BiOp Modeling:

- GCL releases to support Priest Rapids/Vernita Bar steelhead flow objectives.
- Spill Operation at lower Columbia projects are based on 2017 Fish Passage Plan
  - BON: note that corner collector flows of 5,000 cfs are included in "other spill"; the corner collector is only operational when spill is at least 50,000 cfs.
    - April 10 – June 15: 100 kcfs all hours
    - June 16 – August 31: Alternating 2 days each of 85 kcfs day and 121 kcfs at night (day/night hours as outlined in the 2017 FPP), and 95 kcfs all hours
    - Spill for ladder attraction year round, daylight hours only; February and March are halved due to one ladder being closed for maintenance each month.
  - TDA
    - April 10 – August 31: Spill 40 percent of total outflow all hours
  - JDA: note that the minimum spill is 30 kcfs due to structural reasons.
    - April 10 – April 27: Spill 30 percent of total outflow all hours
    - April 28 – July 20: alternating 2 day blocks of spill 30 percent of total outflow all hours and spill 40 percent of total outflow all hours
    - July 21 – August 31: spill 30 percent of total outflow all hours

- September 1 – November 30 spill for ladder attraction, daylight hours only

  - MCN
    - April 10 – June 15: spill 40 percent of total outflow all hours
    - June 16 – August 31: spill 50 percent of total outflow all hours

Other US projects

SKQ

Flows:

- Min flow: 3,200 cfs
- Max flow: can vary by period due to higher priority constraints

Elevation/Content:

- Min elevation: 2,883.0 ft
- Max elevation: 2,893.0 ft (614.7 ksfd)

HydSim Considerations

- Coded to annual target elevations: 2,891 ft (488.6 ksfd) in October, 2,890 (426.3 ksfd) in November, 2,888 ft (302.8 ksfd) in December, 2,886.3 ft (198.8 ksfd) in January, 2,884.7 ft (101.8 ksfd) in February, 2,883.5 ft (29.9 ksfd) in March, 2,883.8 ft (47.8 ksfd) in April 15, 2,885.3 ft (138.1 ksfd) in April 30, 2,890 ft (426.3 ksfd) in May, full at 2,893 ft (614.7 ksfd) June through August, and 2,892.5 ft (583.1 ksfd) in September.

Specific Operations/Assumptions in Flood Risk Modeling:

- Delay refill after June 15 (but no later than June 30) for years with large and/or late runoff (based on remaining Hungry Horse forecast)

Specific Operations/Assumptions in Power Modeling:

- See HydSim Considerations (above)

ALBENI FALLS

Flows:

- Min flow: 4,000 cfs
- Max flow: 27,000 cfs powerhouse max

Elevation/Content:

- Min elevation: 2,050.99 ft
- Max elevation: 2,062.5 ft

HydSim Considerations

- Targets the following end of month contents:
  - October: 146.1 ksfd

- November through March: 68.6 ksfd
- April 15: 146.1 ksfd
- April 30: 234.7 ksfd
- May: 419 ksfd
- June through August: 570.7 ksfd
- September: 512.4 ksfd

Specific Operations/Assumptions in Flood Risk Modeling:

- Delay refill after June 15 (but no later than June 30) for years with large and/or late runoff (based on remaining Hungry Horse forecast)

Specific Operations/Assumptions in Power Modeling:

- Generic operation, see HydSim Considerations (above)

POST FALLS

Flows:

- Min flow: can vary by period depending on higher priority constraints
- Max flow: can vary by period depending on higher priority constraints

Elevation/Content:

- Min elevation: 2,116.7 ft
- Max elevation: 2,139 ft

HydSim Considerations

- Called Coeur d'Alene Lake: First code to the AER ECC curve.
  - October: 68 ksfd
  - November 47.3 ksfd
  - December: 26.9 ksfd
  - January: 6.7 ksfd
  - February: 0.0 ksfd
  - March: 40.1 ksfd
  - April 15: 84.4 ksfd
  - April 30 through August: 112.5 ksfd
  - September: 91.1 ksfd

Specific Operations/Assumptions in Flood Risk Modeling:

- None – same as above.

2572 **Specific Operations/Assumptions in Power Modeling:**

2573 • None

2574 **Specific Operations/Assumptions in BiOp Modeling:**

2575 • None

2576 **Modeling Data Sheet: Multi-Objective Alternative 1 (MO1)**

2577 ***Alternative Modeling Summary – Multiple-Objective 1***

2578 **Table E4 - 4 Alternative Modeling Summary – MO1**

Name:	**CRSO Multi Object Alternative 1**
CRSO Projects	Modified U.S. operations at multiple reservoirs
Flood Risk	Changes were made to the Grand Coulee and Libby upper rule curves for flood risk management. Additionally, winter flood space was included at Grand Coulee. The changes in rule curves designed with an intent to maintain the current level of flood risk.
Power	Some modifications to generation practices that are designed to increase hydropower generation efficiency.
Biological and Water Supply Objectives	Fully meet existing water supply obligations and provide for authorized additional regional water supply. Improve adult, juvenile, and resident fish migration, passage, rearing, and/or survival. Reduce greenhouse gas emissions in the Pacific Northwest.
Modeling System Configuration	Same as the No Action Alternative.
Canadian Treaty Projects	Same as the No Action Alternative.
Hydrologic Data Sets Used for Monte Carlo Evaluation	Same as the No Action Alternative.
Hydrologic Data Sets Used for Monte Carlo Evaluation	Same as the No Action Alternative.
Water Supply Forecast Used for Monte Carlo Evaluation	Same as the No Action Alternative.

2579 Note: all elevations are in NGVD 29

2580 ***Changes to HydSim Assumptions (General)***

2581 • The flows in powerhouse surface passage routes to be constructed at McNary and Ice
2582 Harbor projects are reflected by an 8 kcfs and 4 kcfs, respectively, increase in “other spill” at
2583 those projects, with the same start and end dates as other fish passage spill at the project.

- Upgrades to adjustable spillway weirs assumed to be included in the spill totals already present.
- Spring spill designed in a block pattern, with 6 weeks of "performance standard plus" spill patterns and 6 weeks of "Spill to Gas Cap" spill in alternating order every year.
- Summer spill in "performance standard plus", with the ending in August at the lower Snake projects based on the historical average date when counts of passing sub-yearling chinook surpassed 300 for four consecutive days, 2010-2017; lower Columbia projects end spill on August 31.
- Contingency reserves may be held within fish passage spill on the lower Snake River and lower Columbia River projects. This reduces the reserve obligation held by other projects in the system, resulting in a higher availability at those projects.
- Changes to flood risk management are incorporated via Corps-provided URCs and refill tables
- Changes to the Upstream Storage Correction method incorporated via an updated GCL URC shift algorithm, as described in the Grand Coulee section.
- Updated availability of Grand Coulee reflects ongoing maintenance of power plants that is more accelerated than current outages to represent a broader range of possible hydraulic capacity during maintenance activities are represented in the HYAVAIL file.
- Water Supply measures (Increased water pumped from Lake Roosevelt and Increased Chief Joseph diversions, and increased Flathead River diversions) are incorporated via a negative adjustment to the flows into relevant projects.
- Changes for Adult fish: Modified timing of lower Snake River Basin reservoir draft described in Dworshak section.
- Changes for resident fish: Changes to summer draft at Libby and Hungry Horse described in the relevant project sections
- John Day change for Avian Predators described in lower Columbia section.
- Updated John Day H/K tables based on estimates of 4.5 percent efficiency improvement after installation of new turbines was unintentionally omitted from the Plant Change file.
- All other assumptions are unchanged from the No Action Alternative

Projects

Canadian Projects

Canadian Projects are unchanged from NAA

US Headwater

LIBBY

HydSim Considerations

- Change to Libby draft and refill operations incorporated via updated URCs and refill table provided from ResSim . They operate to local flood control needs below 6.9MAF and to system needs (same as NAA_FC by end of April) above 6.9 MAF.
- Changes to Libby VarQ incorporated in updated algorithm for setting summer flows and releases.
- End of December elevation target set to 2,420 ft in all years .
- Summer draft operation: Based on the local Libby water supply forecast, set end of September elevation target by interpolating from the following table :

Lib May A-A WSF		September Elev. Target	
Percentile	**kaf**	**feet**	**ksfd**
0	0	2,439	2,061.34
15	4,656.0	2,439	2,061.34
25	5,007.0	2,449	2,280.3
75	6,782.0	2,449	2,280.3
85	7,328.0	2,454	2,394.889
100	99,999	2,454	2,394.889

- All other operations and constraints are same as NAA.

HUNGRY HORSE

HydSim Considerations

- Summer draft operation: Based on the local Hungry Horse water supply forecast, set end of September elevation target by interpolating from the following table :

HGH April-August Volume		September Elev. Target	
Percentile	**kaf**	**feet**	**ksfd**
0	0	3,535.8	1,228.7
10	1,407.0	3,535.8	1,228.7
20	1,579.0	3,546	1,341.3
100	9,999	3,546	1,341.3

- This table accommodates the 3,540 ft and 3,550 ft targets of the original sliding scale draft less an adjustment for the additional irrigation for water supply flexibility.
- COLF minimum flows are increased by 493 cfs when the flow augmentation draft is 20 ft.
- All other operations are the same as No Action Alternative.

DWORSHAK

HydSim Considerations

- Change summer draft operation to provide earlier and later cold water releases for adult fish. (O15)
  - Summer draft begins in June.
  - Target July 31 draft target of 1,560 ft in most years; allow up to 1,565 ft in wettest years.
  - Minimum August 30 elevation of 1,540 ft in wettest 20 percent of water years based on the April-August water supply forecast; 1,545 ft in all other years. Not a target.
  - Target outflows of 4.5 kcfs in AG1 and AG2 to retain water for cooling outflows in September.
  - Target September 30 elevation of 1,520 ft
  - Allow max outflows through entire month of September
- All other operations same as No Action Alternative.

BROWNLEE

No changes from No Action Alternative

GRAND COULEE

HydSim Considerations

- A new Grand Coulee Storage Reservation Diagram ("SRD") is implemented via updated URCs received from ResSim, and an updated refill percentage table. This new SRD was created using the planning draft rate of 0.8 ft/day. This draft rate does not affect operations planning. The SRD also represents increased space to protect against rain-induced flooding. *This increased space in December was inadvertently omitted from the HydSim runs; this space was included starting in January.*
- A new method was implemented to adjust the URCs for upstream storage. The new method used an unadjusted water supply forecast for The Dalles to determine the end of April target contents and then any correction (in terms of a lower target) for when upstream storage reservoirs are higher than flood control would dictate. The amount of the reduction in storage is calculated based on curves that weight the storage in upstream projects by relative flood risk benefits. This new algorithm is used in place of the previous GCL URC shift algorithm.
- The Hydro availability file HYAVAIL has been updated to reflect increased limitations on availably hydraulic capacity through each power plant and spillway to represent maintenance activities at Grand Coulee that are more accelerated than those used in NAA.
- Increased pumping from Lake Roosevelt is modelled as a reduction of natural flows into Grand Coulee.

LOWER SNAKE RIVER PROJECTS

HydSim Considerations

- An additional 0.5 ft of forebay operating range allows the lower Snake River projects to carry some reserves during fish passage season, and is reflected in the HYAVAIL file.
- Contingency reserves may be carried within lower Snake River juvenile fish passage spill. This will reduce the amount of reserves needed to be held at other (non-spilling) projects, resulting in increased availability in the HYAVAIL file for those projects.
- The spring spill operation is a block pattern whose order alternates every year. Spill is calculated on a month-average basis, prorated using a start date of April 3, switching from one block to the other on May 11 every year, and switching to summer spill June 21 every year. The spill operation would be as outlined below.
    - IHR
        - Block 1: Spill 30 percent of total outflow up to waiver-level gascap
        - Block 2: Spill to waiver-level gascap.
    - LMN
        - Block 1: Spill in the Bulk pattern to 120 percent TDG
        - Block 2: Spill in the Uniform pattern to 120 percent TDG
    - LGS
        - Block 1: Spill 30 percent of total outflow up to waiver-level gascap
        - Block 2: Spill to waiver level gascap
    - LWG
        - Block 1: Spill 20 kcfs
        - Block 2: Spill to waiver-level gascap
- The summer spill starting June 21 every year, and would end when the count of the subyearling chinook passing a project exceed 300 for four consecutive days. For modelling purposes, the counts from 2010-2017 (when the projects all had the same structures in place and construction was completed) were tallied and the average “end date” was calculated for each project. The spill calculations where then completed using these end dates to prorate month averages. The spill operation that resulted would be as outlined below.
    - IHR
        - Spill 30 percent of total outflow
        - End date August 6
    - LMN
        - Spill 17 kcfs

- End date August 6
  - LGS
    - Spill 30 percent of total outflow
    - End date August 21
  - LWG
    - Spill 18 kcfs
    - End date August 18

MID-COLUMBIA AND LOWER-COLUMBIA RIVER PROJECTS
HydSim Considerations

- Contingency reserves may be carried within lower Columbia juvenile fish passage spill. This will reduce the amount of reserves needed to be held at other (non-spilling) projects, resulting in increased availability in the HYAVAIL file for those projects.
- John Day has an additional 0.5 ft of forebay operating range, though this does not impact the amount of reserves we attribute to that project.
- Maintain John Day reservoir elevations to disrupt juvenile salmonid predator reproduction via 1 ft higher minimum elevations (resulting in an operating range of 263.5-265.0 ft) April 1 through May 31 (
- The spring spill operation is a block pattern whose order alternates every year. Spill is calculated on a month-average basis, prorated using a start date of April 10, switching from one block to the other on May 11 every year, and switching to summer spill June 16 every year. The spill operation would be as outlined below.
  - BON:
    - Block 1: Spill 100 kcfs
    - Block 2: Spill to waiver-level gas cap
    - Ladder attraction spill the same as NAA
  - TDA
    - Block 1: spill 40 percent of total outflow to waiver-level gas cap
    - Block 2: spill waiver-level gas cap all hours
  - JDA
    - Block 1: spill 32 percent of total outflow to waiver-level gascap
    - Block 2: spill waiver-level gas cap all hours
    - Ladder attraction spill the same as NAA

2738 - MCN
2739 - Block 1: Spill 48 percent of total outflow to waiver-level gas cap
2740 - Block 2: spill waiver-level gas cap all hours

2741 • The summer spill operation is a "performance plus" level of spill, starting June 16 all years
2742 and continuing to August 31.
2743 - BON: spill 95 kcfs all hours
2744 - TDA: spill 40 percent of total flow to waiver-level gas cap
2745 - JDA: spill 35 percent of total flow to waiver-level gas cap
2746 - MCN: spill 57 percent of total flow to waiver-level gas cap
2747 • An additional powerhouse surface passage ("PHSP") route to be constructed at McNary
2748 project is modelled by accounting for 8 kcfs flowing through this new structure via an
2749 incremental 8,000 cfs in the "other spill" category, April through the end of August.
2750 • With the PHSP route, fish screens will no longer be installed at McNary project. This will
2751 result in an increase in the availability ratios reflected in the HYAVAIL file.
2752 • *Installation of high-efficiency/capacity turbines at John Day were unintentionally omitted*
2753 *from the H/K table (Plant change input file) and should have reflected a 4.5 percent increase*
2754 *in efficiency.* The outage and availability values were appropriately updated in the HYAVAIL
2755 file.

2756 **OTHER US PROJECTS**
2757 **SKQ**

2758 No change to SKQ from the No Action Alternative.

2759 **Albeni Falls**

2760 No change to Albeni Falls from the No Action Alternative.

2761 **Post Falls**

2762 No change to Post Falls from the No Action Alternative.

Modeling Data Sheet: Multi-Objective Alternative 2 (MO2)

Alternative Modeling Summary – Multiple-Objective 2

Table E4 - 5. Alternative Modeling Summary – MO2

Name:	CRSO Multi Object Alternative 2
CRSO Projects	Modified U.S. operations at multiple reservoirs
Flood Risk	Changes were made to the Grand Coulee and Libby upper rule curves for flood risk management. Additionally, winter flood space was included at Grand Coulee. The changes in rule curves designed with an intent to maintain the current level of flood risk.
Power	Some modifications to generation practices that are designed to increase hydropower generation efficiency.
Biological and Water Supply Objectives	Fully meet existing water supply obligations, same as the No Action Alternative. Improve adult, juvenile, and resident fish migration, passage, rearing, and/or survival. Reduce greenhouse gas emissions in the Pacific Northwest.
Modeling System Configuration	Same as the No Action Alternative.
Canadian Treaty Projects	Same as the No Action Alternative.
Hydrologic Data Sets Used for Monte Carlo Evaluation	Same as the No Action Alternative.
Hydrologic Data Sets Used for Monte Carlo Evaluation	Same as the No Action Alternative.
Water Supply Forecast Used for Monte Carlo Evaluation	Same as the No Action Alternative.

Note: all elevations are in NGVD29

Changes to HydSim Assumptions (General)

- Increased flows to account for powerhouse surface passage routes constructed at John Day, McNary and Ice Harbor projects reflected by an increase of 8 kcfs, 8 kcfs and 4 kcfs, respectively, in "other spill" at those projects, with the same start and end dates as other fish passage spill.
- The powerhouse surface passage routes eliminate the need to install fish screens, resulting in an increase in turbine availability from the No Action Alternative for periods where there would have been fish screens installed.
- Upgrades to adjustable spillway weirs (ASW) assume ASW spill of 11 kcfs per weir in spring and 7 kcfs per weir in summer. If spill at the projects needs to be increased over that as called for by measure O1 to accommodate the new ASW, it was increased to cover the

required spill. The end of spring spill is June 15 in the lower Columbia projects, and June 20 on the lower Snake River projects.

- Fish passage spill is limited to 110 percent total dissolved gas (TDG), but is marginally higher where additional spill is required for powerhouse surface passage (PHSP), weirs, and/or adult ladder attraction. Spill starts April 3rd at lower Snake River projects and April 10th at lower Columbia River projects; fish passage spill ends July 31.
- Flow and pool elevation restrictions are lifted as outlined in individual projects.
- Restrictions to operate turbines within 1 percent of peak efficiency are eliminated, resulting in increased availability during fish passage season.
- Contingency reserves were held within fish passage spill on the lower Snake River and lower Columbia River projects. This reduced the reserve obligation held by other projects in the system, resulting in a higher availability at those projects.
- Changes to flood risk management were incorporated via the Corps-provided URCs and refill tables.
- The variable end-of-December draft target at Libby was replaced with a single draft target.
- Changes to the Upstream Storage Correction method were incorporated via an updated GCL URC shift algorithm, as described in the Grand Coulee section.
- Grand Coulee turbine availability was modified to reflect ongoing maintenance that is more accelerated than current outages.
- Summer elevation and draft targets were modified at Libby and Hungry Horse as described.
- *Updated John Day H/K tables based on estimates of 4.5 percent efficiency improvement after installation of new turbines was unintentionally omitted from the Plant Change file.*
- All other assumptions are unchanged from the No Action Alternative

Projects

Canadian Projects

Canadian Projects are unchanged from NAA

US Headwater

LIBBY
HydSim Considerations

- Change to Libby draft and refill operations incorporated via updated URCs and refill table provided from ResSim. They operate to local flood control needs below 6.9MAF and to system needs (same as NAA_FC by end of April) above 6.9 MAF.
- Changes to Libby VarQ incorporated in updated algorithm for setting summer flows and releases.

- End of December elevation target set to 2,400 ft in all years, with an extra 20 ft of draft for hydropower).
- Summer draft operation: Based on the local Libby water supply forecast, set end of September elevation target by interpolating from the following table :

Lib May A-A WSF		September Elev. Target	
Percentile	**kaf**	**feet**	**ksfd**
0	0	2,439	2,061.34
15	4,656.0	2,439	2,061.34
25	5,007.0	2,449	2,280.3
75	6,782.0	2,449	2,280.3
85	7,328.0	2,454	2,394.889
100	99,999	2,454	2,394.889

- All other operations and constraints are same as NAA.

HUNGRY HORSE

HydSim Considerations

- Summer draft operation: Based on the local Hungry Horse water supply forecast, set end of September elevation target by interpolating from the following table :

HGH April-Aug Volume		September Elev. Target	
Percentile	**kaf**	**feet**	**ksfd**
0	0	3,540	1,275.1
10	1,407.0	3,540	1,275.1
20	1,579.0	3,550	1,386.7
100	9,999	3,550	1,386.7

- Draft deeper for hydropower: Set April 10th target to 10 ft below URC; set January, February, and March lower limits to achieve a 90 percent probability of filling to the April 10th target. Set April 15, April 30 and May 31 targets to 10 ft below URC.
- All other operations are the same as No Action Alternative.

DWORSHAK

HydSim Considerations

- Draft deeper for hydropower: Set April 10th target to 10 ft below URC; set January, February, and March lower limits to achieve a 90 percent probability of filling to the April 10th target. Set April 15, April 30 and May 31 targets to 10 ft below URC.
- All other operations same as No Action Alternative.

BROWNLEE

No changes from No Action Alternative

GRAND COULEE
HydSim Considerations

- A new Grand Coulee Storage Reservation Diagram ("SRD") is implemented via updated URCs received from ResSim, and an updated refill percentage table. This new SRD was created using the planning draft rate of 0.8 ft/day. This draft rate does not affect operations planning. The SRD also represents increased space to protect against rain-induced flooding. *This increased space in December was inadvertently omitted from the HydSim runs; this space was included starting in January.*
- A new method was implemented to adjust the URCs for upstream storage. The new method used an unadjusted water supply forecast for The Dalles to determine the end of April target contents and then any correction (in terms of a lower target) for when upstream storage reservoirs are higher than flood control would dictate. The amount of the reduction in storage is calculated based on curves that weight the storage in upstream projects by relative flood risk benefits. This new algorithm is used in place of the No Action Alternative GCL URC shift algorithm.
- The Hydro availability file HYAVAIL has been updated to reflect increased limitations on hydraulic capacity through each power plant and spillway to represent maintenance activities at Grand Coulee that are more accelerated than those used in the No Action Alternative.
- Draft deeper for hydropower:
    - September target minimum is 1,277 ft; October minimum target is 1,283 ft. As both month-end targets are a hydropower operation, the end elevations are variable depending on the year's market conditions. A similar method to No Action Alternative correlates flow at The Dalles (as a proxy for market strength) with how deep Grand Coulee should be drafted in a year.
    - The April 10th target will be 10 ft below URC; the January, February and March minimums will be set to have a 90 percent probability of achieving the April 10th target.
    - Contents will be adjusted January and February for a hydropower operation.
- All other operations same as No Action Alternative.

LOWER SNAKE RIVER PROJECTS
HydSim Considerations

- An additional powerhouse surface passage ("PHSP") route to be constructed at Ice Harbor project is modelled by accounting for 4 kcfs flowing through this new structure via an incremental 4,000 cfs in the "other spill" category, April through the end of July.
- Spillway weirs are replaced with adjustable spillway weirs (ASWs), with flows of 11 kcfs in spring through June 20 and 7 kcfs in summer. LGS already has an ASW so this does not apply at that project.

- The spill operation is as close to 110 percent TDG as feasible given operational or structural minimums. Spill is April 3 through July 31.
    - IHR
        - 110 percent TDG spill: 10 kcfs
        - April-May 110 percent TDG spill will be overwritten with 11 for ASW.
    - LMN
        - April 110 percent TDG spill: 15 kcfs
        - May 110 percent TDG spill is 10 kcfs; will be overwritten with 11 for measure S4
        - June 110 percent TDG spill is 10 kcfs which is sufficient to cover the ASW with the June 20 end of 11 kcfs and June 21 start of 7 kcfs
    - LGS
        - April 110 percent TDG spill: 15 kcfs
        - May- July 110% TDG spill: 10 kcfs
    - LWG
        - 110 percent TDG spill: 15 kcfs
        - July is 110 percent TDG spill is 5 kcfs so will be overwritten with 7 kcfs for measure S4
- Using the full range of forebay operating range allows the lower Snake River projects to carry more reserves during fish passage season, and is reflected in the HYAVAIL file. Set lower Snake River projects' maximum elevations to full, and first code elevations at full to represent the larger operating range.
- Operate turbines across their full range of capacity (no longer restrict turbine operations to within 1 percent of peak efficiency during fish passage season). This will increase their capacity and therefore increase their availability.
- Contingency reserves may be carried within lower Snake River juvenile fish passage spill. This will reduce the amount of reserves needed to be held at other (non-spilling) projects, resulting in increased availability in the HYAVAIL file for those projects.

MID-COLUMBIA AND LOWER-COLUMBIA RIVER PROJECTS
HydSim Considerations

- Installation of high-efficiency/capacity turbines at John Day were unintentionally omitted from the H/K table (Plant change input file) and should have reflected a 4.5 percent increase in efficiency. The outage and availability values were appropriately updated in the HYAVAIL file.

- An additional powerhouse surface passage ("PHSP") route to be constructed at McNary and John Day projects is modelled by accounting for 8 kcfs flowing through this new structure via an incremental 8 kcfs in the "other spill" category from April through the end of July.
- With the PHSP route, fish screens will no longer be installed at McNary and John Day projects. This will result in an increase in the availability ratios in fish passage season, reflected in the HYAVAIL file.
- Spillway weirs at McNary and John Day projects are replaced with Adjustable spillway weirs (ASWs), with flows of 11 kcfs in spring through June 20 and 7 kcfs in summer. Spill at John Day (see below) is sufficient to include these flows but spill at McNary needs to be adjusted.
- Contingency reserves may be carried within lower Columbia juvenile fish passage spill. This will reduce the amount of reserves needed to be held at other (non-spilling) projects, resulting in increased availability in the HYAVAIL file for those projects.
- John Day may operate within the full reservoir operating range year round. Upper limits at John Day are set to full (as opposed to a lower seasonal max reflecting the minimum irrigation pool plus 1.5 ft in the No Action Alternative), and first-coded to 2/3 full to represent flexibility in the monthly time step model.
- The spill operation is as close to 110 percent TDG as feasible given operational or structural minimums. Spill is from April3 through July 31.
    - BON:
        - Spill at 110 percent TDG is only 5 kcfs; minimum spill to operate the corner collector is 50 kcfs. This is very close to the 115 percent TDG spill (45 kcfs), so spill is set to 50 kcfs from April 3 through July 31.
        - Corner collector spill is 5 kcfs, and is accounted for in the SO spill. The corner collector spill in March and August is removed, since spill is below 50 kcfs.
    - TDA
        - Spill 40 percent, with spill cap at 110 percent TDG spill levels.
    - JDA
        - 110 percent TDG spill at John Day is between 5 kcfs and 15 kcfs; however, when spill at John Day is below 30 percent of outflows, dangerous eddies form. Therefore spill at John Day is set to 30 percent of outflow and the 115 percent TDG spill is used as a cap. This will still result in some periods with spill below 30 percent when inflows are low, but overall far fewer dangerous spill-related eddies are expected to form.
    - MCN
        - 110 percent TDG spill at McNary is between 5 kcfs and 15 kcfs; however, Structural Measure 4 has the two spillway weirs upgraded to ASWs with flows of 11 kcfs each through June 15, so spill is 22 kcfs for the spring spill through June 15

- Summer spill (starting June 16) is set to 110 percent TDG which is enough to cover 2 ASWs at 7 kcfs each as outlined by Structural Measure 4.

OTHER US PROJECTS

SKQ

No change to SKQ from the No Action Alternative.

Albeni Falls

- No change to Albeni Falls from the No Action Alternative.

Post Falls

- No change to Post Falls from the No Action Alternative.

Modeling Data Sheet: Multi-Objective Alternative 3 (MO3)

Alternative Modeling Summary – Multiple-Objective 3

Table E4 - 6. Alternative Summary – MO3

Name:	**CRSO Multi Object Alternative 3**
CRSO Projects	Modified U.S. operations at multiple reservoirs
Flood Risk	Changes were made to the Grand Coulee and Libby upper rule curves for flood risk management. The changes in rule curves designed with an intent to maintain the current level of flood risk.
Power	Some modifications to generation practices that are designed to increase hydropower generation efficiency.
Biological and Water Supply Objectives	Fully meet existing water supply obligations and provide for authorized additional regional water supply. Improve adult, juvenile, and resident fish migration, passage, rearing, and/or survival. Reduce greenhouse gas emissions in the Pacific Northwest.
Modeling System Configuration	Same as the No Action Alternative.
Canadian Treaty Projects	Same as the No Action Alternative.
Hydrologic Data Sets Used for Monte Carlo Evaluation	Same as the No Action Alternative.
Hodrologic Data Sets Used for Monte Carlo Evaluation	Same as the No Action Alternative.
Water Supply Forecast Used for Monte Carlo Evaluation	Same as the No Action Alternative.

Note: all elevations are in NGVD 29

Changes to HydSim Assumptions (General)

- Lower Snake River dams are simulated as removed by designating them as non-generating reservoirs and passing inflow; in HydSim all inputs associated with generation, flow requirements, and content targets are removed.
- Increased flows to account for powerhouse surface passage routes (PHSP) to be constructed at McNary project are reflected by an 8 kcfs increase in "other spill" with the same start and end dates as other fish passage spill at the project.
- The powerhouse surface passage routes eliminate the need to install fish screens, resulting in an increase in turbine availability from the No Action Alternative for the duration in those periods where there would have been fish screens installed.
- Upgrades to adjustable spillway weirs (ASWs) assumed to be included in the spill totals already present.
- Spring fish passage spill is set to levels determined to cap at 120 percent total dissolved gas (TDG), or as close as possible while still maintaining minimum turbine flow requirements. Spring spill starts April 10 at all lower Columbia River projects, and ends June 15.
- Summer spill at the lower Columbia River projects is the same as the No Action Alternative but will end at midnight July 31.
- The state of Washington spill cap waiver is assumed to be 120 percent TDG during both spring and summer spill season (no 115 percent in the downstream forebay requirement) to accommodate the spring spill regime.
- Flow and pool elevation restrictions at John Day are lifted as outlined lower Columbia River projects section.
- Operation of turbines within and above 1 percent peak efficiency only increases turbine availability at relevant projects during the fish passage season. This change is represented in the HYAVAIL file.
- Summer elevation and draft targets were modified at Libby and Hungry Horse as described in the relevant project sections.
- Contingency reserves may be held within fish passage spill on the lower Columbia River projects. This reduced the reserve obligation held by other projects in the system, resulting in a higher availability at those projects. These changes are reflected in the HYAVAIL file.
- Changes to flood risk management were incorporated via Corps-provided URCs, SRDs, and refill tables.
- The end-of-December variable draft target at Libby was replaced with a single draft target.
- Changes to the Upstream Storage Correction method incorporated via an updated GCL URC shift algorithm, as described in the Grand Coulee section.
- Grand Coulee turbine availability was modified to reflect ongoing maintenance that is more accelerated than current outages.

- Water Supply measures (Increased water pumped from Lake Roosevelt and Increased Chief Joseph diversions, and increased Flathead River diversions) are incorporated via a negative adjustment to the flows into relevant projects.
- *Updated John Day H/K tables based on estimates of 4.5* percent *efficiency improvement after installation of new turbines was unintentionally omitted from the Plant Change file.*
- All other assumptions are unchanged from the No Action Alternative

Projects

Canadian Projects

Canadian Projects are unchanged from NAA

US Headwater

LIBBY
HydSim Considerations

- Change to Libby draft and refill operations incorporated via updated URCs and refill table provided from ResSim . They operate to local flood control needs below 6.9 MAF and to system needs (same as NAA_FC by end of April) above 6.9 MAF.
- Changes to Libby VarQ incorporated in updated algorithm for setting summer flows and releases.
- End of December elevation target set to 2,420 ft in all years, with allowance for additional draft of 20 ft.
- Summer draft operation: Based on the local Libby water supply forecast, set end of September elevation target by interpolating from the following table :

Lib May A-A WSF		September Elev. Target	
Percentile	**kaf**	**Feet**	**ksfd**
0	0	2,439	2,061.34
15	4,656.0	2,439	2,061.34
25	5,007.0	2,449	2,280.3
75	6,782.0	2,449	2,280.3
85	7,328.0	2,454	2,394.889
100	99,999	2,454	2,394.889

- All other operations and constraints are same as the No Action Alternative.

HUNGRY HORSE
HydSim Considerations

- Summer draft operation: Based on the local Hungry Horse water supply forecast, set end of September elevation target by interpolating from the following table :

HGH April-August Volume		September Elev. Target	
Percentile	**kaf**	**Feet**	**ksfd**
0	0	3,535.8	1,228.7
10	1,407.0	3,535.8	1,228.7
20	1,579.0	3,546	1,341.3
100	9,999	3,546	1,341.3

- This table accommodates the 3,540 ft and 3,550 ft targets of the original sliding scale draft less an adjustment for the additional irrigation for water supply flexibility.
- COLF minimum flows are increased by 493 cfs when the flow augmentation draft is 20 ft.
- All other operations and constraints are same as the No Action Alternative.

DWORSHAK

- Due to the conversion of all lower Snake River projects to non-generating reservoirs, all flow targets for them have been removed. All codes that require Dworshak to be drafted for lower Snake River projects flow requirements were also removed.

BROWNLEE

No changes from No Action Alternative

GRAND COULEE

HydSim Considerations

- A new Grand Coulee Storage Reservation Diagram ("SRD") is implemented via updated URCs received from ResSim, and an updated refill percentage table. This new SRD was created using the planning draft rate of 0.8 ft/day. This draft rate does not affect operations planning.
- A new method was implemented to adjust the URCs for upstream storage. The new method used an unadjusted water supply forecast for The Dalles to determine the end of April target contents and then any correction (in terms of a lower target) for when upstream storage reservoirs are higher than flood control would dictate. The amount of the reduction in storage is calculated based on curves that weight the storage in upstream projects by relative flood risk benefits. This new algorithm is used in place of the No Action Alternative GCL URC shift algorithm.
- The Hydro availability file HYAVAIL has been updated to reflect increased limitations on hydraulic capacity through each power plant and spillway to represent maintenance activities at Grand Coulee that are more accelerated than those used in the No Action Alternative.
- All other operations and constraints are same as the No Action Alternative.

LOWER SNAKE RIVER PROJECTS
HydSim Considerations

- All lower Snake River projects are reclassified to non-generating reservoirs that will pass inflow.
    - Deleted all codes that require Dworshak to be drafted for lower Snake River projects flow requirements.
    - Deleted all codes that required drafting for water budget for the lower Snake River projects.
    - Commented out all references to spill at the lower Snake River projects.
    - Deleted all upper rule curves for lower Snake River projects.
    - Deleted all availability ratios for lower Snake River projects from the HYAVAIL file.
    - Removed all lower Snake River projects from the Spill Allocation file for allocating over generation spill.
    - Removed other references as required (e.g. H/K tables, plant update information, rule curves, initial contents, first codes, and storage requirements).

MID- AND LOWER-COLUMBIA RIVER PROJECTS
HydSim Considerations

- Installation of high-efficiency/capacity turbines at John Day were unintentionally omitted from the H/K table (Plant change input file) and should have reflected a 4.5 percent increase in efficiency. The outage and availability values were appropriately updated in the HYAVAIL file.
- An additional powerhouse surface passage ("PHSP") route to be constructed at McNary is modelled by accounting for 8 kcfs flowing through this new structure via an incremental 8 kcfs in the "other spill" category, April through the end of July.
- With the PHSP route, fish screens will no longer be installed at McNary project. This will result in an increase in the availability ratios in fish passage season, reflected in the HYAVAIL file. (S4)
- The spring spill operation set to 120 percent TDG for all projects. Spring spill is April 10 through June 15.
- The summer spill operation is the same as the No Action Alternative, but ends July 31.
- The state of Washington spill cap waiver is assumed to be 120 percent TDG in the tailrace during both spring and summer spill season (not also restricting TDG in the downstream forebay to a maximum of 115 percent TDG).
- Contingency reserves may be carried within lower Columbia River juvenile fish passage spill. This will reduce the amount of reserves needed to be held at other (non-spilling) projects, resulting in increased availability in the HYAVAIL file for those projects.

- John Day may operate within the full reservoir operating range year round. Upper limits at John Day are set to full (as opposed to a lower seasonal max reflecting the minimum irrigation pool plus 1.5 ft in the No Action Alternative), and first-coded to 2/3 full (265 ft) to represent flexibility in the monthly time step model.
- All other operations and constraints are same as the No Action Alternative.

OTHER US PROJECTS

SKQ

No change to SKQ from the No Action Alternative.

Albeni Falls

No change to Albeni Falls from the No Action Alternative.

Post Falls

No change to Post Falls from the No Action Alternative.

Modeling Data Sheet: Multi-Objective Alternative 4 (MO4)

Alternative Modeling Summary – Multiple-Objective 4

Table E4 - 7. Alternative Summary – MO4

Name:	**CRSO Multi Object Alternative 4**
CRSO Projects	Modified U.S. operations at multiple reservoirs
Flood Risk	Changes were made to the Grand Coulee and Libby Dam upper rule curves for flood risk management. Additionally, winter flood space was included at Grand Coulee Dam. The changes in rule curves designed with an intent to maintain the current level of flood risk.
Power	Some modifications to generation and operation practices that are designed to increase hydropower generation efficiency.
Biological and Water Supply Objectives	Fully meet existing water supply obligations and provide for authorized additional regional water supply. Improve adult, juvenile, and resident fish migration, passage, rearing, and/or survival. Reduce greenhouse gas emissions in the Pacific Northwest.
Modeling System Configuration	Same as the No Action Alternative.
Canadian Treaty Projects	Same as the No Action Alternative.
Hydrologic Data Sets Used for Monte Carlo Evaluation	Same as the No Action Alternative.

Name:	CRSO Multi Object Alternative 4
Water Supply Forecast Used for Deterministic Evaluation	Same as the No Action Alternative.
Water Supply Forecast Used for Monte Carlo Evaluation	Same as the No Action Alternative.

Note: all elevations are in NGVD 29

Changes to HydSim Assumptions (General)

- The flows in powerhouse surface passage routes to be constructed at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, John Day, and McNary projects are reflected by a 4 kcfs (lower Snake River plants) or 8 kcfs (lower Columbia River plants) increase, in "other spill" at those projects, with the same start and end dates as other fish passage spill at the project.
- The additional structure for passage means that there will not be a need for the installation of fish screens, resulting in an increase in turbine availability from the No Action Alternative for the duration in those periods where there would have been fish screens installed.
- Additional 2 kcfs of spill October 1 – November 30 at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary and John Day dams for steelhead through a structural change in the spillway
- Fish passage spill is set to 125 percent total dissolved gas (TDG). Spill starts March 1 at all projects, and ends August 31 at all projects.
- Allow turbines to operate within and above 1 percent peak efficiency at lower Snake and lower Columbia projects during fish passage season
- Contingency reserves may be held within fish passage spill on the lower Snake River and lower Columbia River projects. This reduces the reserve obligation held by other projects in the system, resulting in a higher availability at those projects.
- Operations at Libby, Hungry Horse, Albeni Falls, and Grand Coulee projects have been altered to discharge an additional 2.0 MAF to support spring flow objectives at McNary dam. These changes are described in the relevant project sections.
- Reservoir drawdown to Minimum Operating Pool and associated changes are described in the relevant project sections.
- Changes for resident fish: Changes to summer draft at Libby and Hungry Horse described in the relevant project sections.
- Changes to flood risk management are incorporated via Corps-provided URCs, SRDs, and refill tables.
- Changes to Libby December draft described in the Libby project section.
- Changes to the Upstream Storage Correction method incorporated via an updated GCL URC shift algorithm, as described in the Grand Coulee section.

- Updated availability of Grand Coulee turbines reflects ongoing maintenance of power plants that is more accelerated than current outages to represent a broader range of possible hydraulic capacity during maintenance activities; represented in the HYAVAIL file.
- Water Supply measures (Increased water pumped from Lake Roosevelt and Increased Chief Joseph diversions, and increased Flathead River Diversions) are incorporated via a negative adjustment to the flows into relevant projects.
- *Updated John Day H/K tables based on estimates of 4.5* percent *efficiency improvement after installation of new turbines was unintentionally omitted from the Plant Change file.*
- All other assumptions are unchanged from the No Action Alternative

Projects

Canadian Projects

Canadian Projects are unchanged from NAA

US Headwater

LIBBY
HydSim Considerations

- Change to Libby draft and refill operations incorporated via updated URCs and refill table provided from ResSim. They operate to local flood control needs below 6.9 MAF and to system needs (same as NAA_FC by end of April) above 6.9 MAF.
- Changes to Libby VarQ incorporated in updated algorithm for setting summer flows and releases.
- End of December elevation target set to 2,420 ft in all years.
- Summer draft operation: Based on the local Libby water supply forecast, set end of September elevation target by interpolating from the following table :

Lib May A-A WSF		September Elev. Target	
Percentile	**kaf**	**feet**	**ksfd**
0	0	2,439	2,061.34
15	4,656.0	2,439	2,061.34
25	5,007.0	2,449	2,280.3
75	6,782.0	2,449	2,280.3
85	7,328.0	2,454	2,394.889
100	99,999	2,454	2,394.889

- Libby provides 26.69 percent of the required flow augmentation during May – July to meet the McNary flow target.
- All other operations and constraints are same as the No Action Alternative.
- A maximum downstream elevation of 1,753 ft at the Bonners Ferry gauge is not binding in HydSim.

HUNGRY HORSE

HydSim Considerations

- Summer draft operation: Based on the local Hungry Horse water supply forecast, set end of September elevation target by interpolating from the following table :

HGH April-August Volume		September Elev. Target	
Percentile	**kaf**	**feet**	**ksfd**
0	0	3,535.8	1,228.7
10	1,407.0	3,535.8	1,228.7
20	1,579.0	3,546	1,341.3
100	9,999	3,546	1,341.3

- This table accommodates the 3,540 ft and 3,550 ft targets of the original sliding scale draft less an adjustment for the additional irrigation for water supply flexibility.
- COLF minimum flows are increased by 493 cfs when the flow augmentation draft is 20 ft.
- Hungry Horse provides 11.6 percent of the required flow augmentation during May – July to meet the McNary flow target.
- All other operations and constraints are same as the No Action Alternative.

DWORSHAK

No changes from No Action Alternative

BROWNLEE

No changes from No Action Alternative

GRAND COULEE

HydSim Considerations

- A new Grand Coulee Storage Reservation Diagram ("SRD") is implemented via updated URCs received from ResSim, and an updated refill percentage table. This new SRD was created using the planning draft rate of 0.8 ft/day. This draft rate does not affect operations planning. The SRD also represents increased space to protect against rain-induced flooding. *This increased space in December was inadvertently omitted from the HydSim runs; this space was included starting in January.*
- A new method was implemented to adjust the URCs for upstream storage. The new method used an unadjusted water supply forecast for The Dalles to determine the end of April target contents and then any correction (in terms of a lower target) for when upstream storage reservoirs are higher than flood control would dictate. The amount of the reduction in storage is calculated based on curves that weight the storage in upstream projects by relative flood risk benefits. This new algorithm is used in place of the No Action Alternative GCL URC shift algorithm.
- The Hydro availability file HYAVAIL has been updated to reflect increased limitations on availably hydraulic capacity through each power plant and spillway to represent

maintenance activities at Grand Coulee that are more accelerated than those used in the No Action Alternative.

- Grand Coulee provides 50.0 percent of the required flow augmentation during May through July to meet the McNary flow target.
- All other operations and constraints are same as the No Action Alternative.

LOWER SNAKE RIVER PROJECTS
HydSim Considerations

- An additional powerhouse surface passage ("PHSP") route to be constructed at all four lower Snake River projects is modelled by accounting for 4 kcfs flowing through this new structure via an incremental 4 kcfs in the "other spill" category, March through the end of August for each project.
- With the PHSP route, fish screens will no longer be installed at the lower Snake River projects. This will result in an increase in the availability ratios in fish passage season, reflected in the HYAVAIL file.
- Additional spill of 2 kcfs for each lower Snake River project, October 1 to November 30 for the 'spillway notch' spill for steelhead.
- The spill operation set to 125 percent TDG for all projects. Spill is March 1 through August 31.
- Contingency reserves may be carried within lower Snake River juvenile fish passage spill. This will reduce the amount of reserves needed to be held at other (non-spilling) projects, resulting in increased availability in the HYAVAIL file for those projects.
- Lower Snake River projects are drawn down to MOP + 1.5 ft from March 15 to Aug 15. The project elevations are set to the middle of the operating range to represent within-month flexibility.
- Operate turbines within and above 1 percent peak efficiency only. This will increase their capacity and therefore increase their availability and is reflected in the availability ratios in the HYAVAIL file.
- All other operations and constraints are same as the No Action Alternative.

MID-COLUMBIA AND LOWER-COLUMBIA RIVER PROJECTS
HydSim Considerations

- Installation of high-efficiency/capacity turbines at John Day were unintentionally omitted from the H/K table (Plant change input file) and should have reflected a 4.5 percent increase in efficiency. The outage and availability values were appropriately updated in the HYAVAIL file.
- An additional powerhouse surface passage ("PHSP") route to be constructed at McNary and John Day projects is modelled by accounting for 8 kcfs flowing through this new structure via an incremental 8 kcfs in the "other spill" category for each project, March through the end of August.

- With the PHSP route, fish screens will no longer be installed at McNary and John Day projects. This will result in an increase in the availability ratios in fish passage season, reflected in the HYAVAIL file.
- The spill operation set to 125 percent TDG for all projects. Spill is March 1 through August 31.
- Contingency reserves may be carried within lower Columbia River juvenile fish passage spill. This will reduce the amount of reserves needed to be held at other (non-spilling) projects, resulting in increased availability in the HYAVAIL file for those projects.
- Lower Columbia River projects are drawn down to MOP + 1.5 ft for Bonneville, The Dalles and John Day and MOP + 1 ft at McNary from March 25 to Aug 15. The projects' elevations are set to the middle of their operating range to represent within-month flexibility.
- All other operations and constraints are same as the No Action Alternative.

OTHER US PROJECTS

SKQ

No change to SKQ from the No Action Alternative.

Albeni Falls

- Albeni Falls provides 11.71 percent of the required flow augmentation during May through July to meet the McNary flow target.

Post Falls

No change to Post Falls from the No Action Alternative.

Modeling Data Sheet: Preferred Alternative (PA)

Alternative Modeling Summary - PA

Table E4 - 8. Alternative Modeling Summary - PA

Name:	CRSO Preferred Alternative
CRSO Projects	Modified U.S. operations at multiple reservoirs.
Flood Risk	Changes were made to the Grand Coulee and Libby upper rule curves for flood risk management. The changes in rule curves are designed with an intent to maintain the current level of flood risk.
Power	Some modifications to generation practices that are designed to increase hydropower generation efficiency.
Biological and Water Supply Objectives	Fully meet existing water supply obligations, same as the No Action Alternative. Improve adult, juvenile, and resident fish migration, passage, rearing, and/or survival. Reduce greenhouse gas emissions in the Pacific Northwest.

Name:	CRSO Preferred Alternative
Modeling System Configuration	Same as the No Action Alternative.
Canadian Treaty Projects	Same as the No Action Alternative.
Hydrologic Data Sets Used for Monte Carlo Evaluation	Same as the No Action Alternative.
Hydrologic Data Sets Used for Monte Carlo Evaluation	Same as the No Action Alternative.
Water Supply Forecast Used for Monte Carlo Evaluation	Same as the No Action Alternative.

Note: all elevations are in NGVD 29

Changes to HydSim Assumptions (General)

- Increased forebay range flexibility for Lower Snake River and John Day projects. The reservoir pools gain operating flexibility from April 3 to August 31 to coincide with the juvenile fish passage season. The operating elevation range restriction at the lower Snake River projects is MOP +1.5 feet and at the John Day project MIP +2 feet, except during the period April 1 to May 31 when the John Day forebay operating range may occasionally be higher for Predation Disruption Operations.
- Updated John Day H/K tables based on estimates of 4.5% efficiency improvement after installation of new turbines are reflected in the Plant Change file.
- Spring and Summer spill designed to model the 2019-2021 Spill Operation Agreement.
- Contingency reserves may be held within fish passage spill on the lower Snake River and lower Columbia River projects. This reduces the reserve obligation held by other projects in the system, resulting in a higher availability at those projects.
- Eliminate restrictions to operate turbines within 1% of peak efficiency, resulting in increased availability during fish passage season.
- Changes to flood risk management are incorporated via USACE-provided URCs and refill tables.
- Changes to the Upstream Storage Correction method incorporated via an updated GCL URC shift algorithm, as described in the Grand Coulee section.
- Updated availability of Grand Coulee reflects ongoing maintenance of power plants that is more accelerated than current outages to represent a broader range of possible hydraulic capacity during maintenance activities are represented in the HYAVAIL file.
- An increase of approximately 45 kaf in water pumped from Lake Roosevelt is incorporated via a negative adjustment to the flows above Grand Coulee.
- Implements Variable Draft Limits at Dworshak, increasing winter draft while targeting a 95% probability of reaching the March 31st Upper Rule Curve.

- The Lake Roosevelt elevation objective of 1283 feet or higher by the end of September may be delayed to an elevation objective of 1283 feet or higher by the end of October.
- Changes for Resident fish: Changes to summer draft at Libby and Hungry Horse described in the relevant project sections.
- John Day change for Avian Predators described in Lower Columbia section.
- Cease installation of fish screens at Ice Harbor, McNary, and John Day projects, resulting in an increase in turbine availability from the No Action Alternative for the duration in those periods where there would have been fish screens installed.
- All other assumptions are unchanged from the No Action Alternative

Projects

Canadian Projects

Canadian Projects are unchanged from NAA

US Headwater

LIBBY
HydSim Considerations

- Change to Libby draft and refill operations incorporated via updated URCs and refill table provided from ResSim. They operate to local flood control needs below 6.9MAF and to system needs (same as NAA_FC by end of April) above 6.9 MAF.
- Changes to Libby VarQ incorporated in updated algorithm for setting summer flows and releases.
- Summer draft operation: Based on the local Libby water supply forecast, set end of September elevation target by interpolating from the following table:

Lib May A-A WSF		September Elev. Target	
Percentile	**kaf**	**feet**	**ksfd**
0	0	2,439	2,061.34
15	4,656.0	2,439	2,061.34
25	5,007.0	2,449	2,280.3
75	6,782.0	2,449	2,280.3
85	7,328.0	2,454	2,394.889
100	99,999	2,454	2,394.889

- All other operations and constraints are same as NAA.

HUNGRY HORSE
HydSim Considerations

- Summer draft operation: Based on the local Hungry Horse water supply forecast, set end of September elevation target by interpolating from the following table:

HGH April-Aug volume		September Elev. Target	
Percentile	**kaf**	**feet**	**ksfd**
0	0	3,540	1,275.1
10	1,407.0	3,540	1,275.1
20	1,579.0	3,550	1,386.7
100	9,999	3,550	1,386.7

- All other operations are the same as No Action Alternative.

DWORSHAK

Hydsim Considerations

- Implements Variable Draft Limits at Dworshak, increasing winter draft while targeting a 95% probability of reaching the URC on March 31st.
- All other operations same as No Action Alternative.

BROWNLEE

No changes from No Action Alternative

GRAND COULEE

Hydsim Considerations

- A new Grand Coulee Storage Reservation Diagram ("SRD") is implemented via updated URCs received from ResSim, and an updated refill percentage table. This new SRD was created using the planning draft rate of 0.8 ft/day. This draft rate does not affect operations planning. The SRD also represents increased space to protect against rain-induced flooding.
- A new method was implemented to adjust the URCs for upstream storage. The new method used an unadjusted water supply forecast for The Dalles to determine the end of April target contents and then any correction (in terms of a lower target) for when upstream storage reservoirs are higher than flood control would dictate. The amount of the reduction in storage is calculated based on curves that weight the storage in upstream projects by relative flood risk benefits. This new algorithm is used in place of the previous GCL URC shift algorithm.
- The Hydro availability file HYAVAIL has been updated to reflect increased limitations on availably hydraulic capacity through each power plant and spillway to represent maintenance activities at Grand Coulee that are more accelerated than those used in NAA.
- Increased pumping from Lake Roosevelt is modelled as a reduction of natural flows into Grand Coulee by 45 kaf.
- The end of September target minimum is 1277 feet; the end of October minimum target is 1283 ft. As both month-end targets are a hydropower operation, the end elevations are variable depending on the year's market conditions. A similar method to No Action Alternative correlates flow at The Dalles (as a proxy for market strength) with how deep Grand Coulee should be drafted in a year.

LOWER SNAKE RIVER PROJECTS
Hydsim Considerations

- An additional 0.5' of forebay operating range allows the Lower Snake River projects to carry some reserves during fish passage season, and is reflected in the HYAVAIL file.
- Contingency reserves may be carried within Lower Snake River juvenile fish passage spill. This will reduce the amount of reserves needed to be held at other (non-spilling) projects, resulting in increased availability in the HYAVAIL file for those projects.
- Spring and Summer spill designed to model the 2019-2021 Spill Operation Agreement.

MID-COLUMBIA AND LOWER-COLUMBIA RIVER PROJECTS
Hydsim Considerations

- Contingency reserves may be carried within Lower Columbia juvenile fish passage spill. This will reduce the amount of reserves needed to be held at other (non-spilling) projects, resulting in increased availability in the HYAVAIL file for those projects.
- John Day has an additional 0.5' of forebay operating range, though this does not impact the amount of reserves we attribute to that project.
- Maintain John Day reservoir elevations to disrupt juvenile salmonid predator reproduction via 1' higher minimum elevations (resulting in an operating range of 263.5-265.0') April 1 through May 31.
- Fish screens will no longer be installed at McNary project. This will result in an increase in the availability ratios reflected in the HYAVAIL file.
- Installation of high-efficiency/capacity turbines at John Day are reflected in an updated H/K table (Plant change input file) reflecting a 4.5% increase in efficiency and in an updated outage and availability values in the HYAVAIL file.

OTHER US PROJECTS
SKQ

No change to Kerr from the No Action Alternative.

Albeni Falls

No change to Albeni Falls from the No Action Alternative.

Post Falls

No change to Post Falls from the No Action Alternative.

Draft Columbia River System Operations Environmental Impact Statement

Appendix J
Hydropower

EXECUTIVE SUMMARY

Introduction

This appendix presents the hydropower analyses conducted for the Columbia River System Operations (CRSO) Draft Environmental Impact Statement (DEIS). The Bonneville Power Administration (Bonneville), U.S. Army Corps of Engineers (Corps), and U.S. Bureau of Reclamation (Reclamation) are co-lead agencies in developing the CRSO DEIS, which is required for the agencies' compliance with the National Environmental Policy Act (NEPA). This appendix is part of a larger set of CRSO DEIS documents that detail the efforts of the co-lead agencies in evaluating alternatives for the future operation and configuration of 14 major Federal hydropower projects of the Federal Columbia River Power System (FCRPS) collectively referred to as the Columbia River System (CRS).

This appendix focuses on hydropower effects of the CRSO DEIS alternatives. The hydropower studies were conducted by Bonneville in close coordination with the Corps. Bonneville analyses examined the effects of the alternatives on hydropower production, power system reliability, replacement resource needs, and other power obligations. Bonneville also reviewed the potential effects of climate change on the relative effects of the alternatives.

Hydropower results in this appendix contribute to other analyses in the CRSO DEIS, including analyses of socioeconomic, air quality, and water quality effects. The results of those other effects are detailed in the appropriate appendices. Modeling details for this hydropower assessment are presented in the *Hydroregulation Appendix* and *Hydrology and Hydraulics Appendix (H&H Appendix).*

Columbia River System Projects

The CRS consists of the 14 major projects operated in coordination with each other for several congressionally authorized purposes, including flood risk management (FRM), navigation, hydropower production, irrigation, fish and wildlife conservation, recreation, municipal and industrial water supply, and water quality. They are a subset of the FCRPS, a network of 31 multi-purpose dam and reservoir projects constructed in the Columbia River and its tributaries in the Pacific Northwest and operated by the Corps and Reclamation. The FCRPS also includes the transmission system built and operated by Bonneville to market and deliver electric power.

The 14 CRS projects examined in detail in the CRSO DEIS include six Federal storage projects: Libby, Hungry Horse, Albeni Falls, Grand Coulee, John Day, and Dworshak; and eight Federal run-of-river projects: Chief Joseph, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, The Dalles, and Bonneville.

Hydropower production at several non-Federal projects in the Columbia River basin is potentially affected by the CRSO DEIS alternative. These non-Federal dams include five Mid-Columbia River dams downstream of Grand Coulee Dam and Chief Joseph Dam; several

dams within the United States and Canada on the Flathead, Clark Fork, and Pend Oreille Rivers downstream of Hungry Horse and Albeni Falls Dams; and several Canadian dams on the Kootenay River downstream of Libby Dam. Notable non-Federal dams in the Columbia Basin that are not affected include three Columbia River Treaty (CRT) projects (Mica, Arrow, and Duncan) and Revelstoke Dam in Canada; and the Hells Canyon complex (Brownlee, Oxbow, and Hells Canyon Dams) on the Snake River.

The operation of these dams is coordinated for several purposes. The storage operation of the CRS storage projects, the Hells Canyon complex, and three CRT dams in Canada is coordinated for flood risk management to reduce flooding either locally or for the Columbia River reach below Bonneville Dam. United States and Canadian power production is coordinated per terms of the CRT. All the dams are connected to the Western Interconnection power system and contribute to ensuring transmission grid stability and reliability throughout the West. The 14 CRS projects are also operated to meet several objectives in Biological Opinions intended to reduce and mitigate the effects of the dams.

CRSO DEIS Alternatives

In 2016 the co-lead agencies implemented a public scoping process with the public, tribes, local and state governmental agencies, other Federal agencies, non-government entities, and other stakeholders to identify issues that addressed the general purpose and need of the EIS: to review the management of the CRSO projects. The co-lead agencies used the information to develop measures to address the issues. Then the agencies combined these measures into four multiple objective (MO) alternatives. A No Action Alternative (NAA) was also developed for comparing the effects of the alternatives. A draft Preferred Alternative (PA) was then created combining measures from the studied MOs. The following alternatives are evaluated for hydropower effects in this appendix:

- NAA – includes operating rules and structures in place or committed for construction when the Notice of Intent for the EIS was published in September 2016.
- MO1 – includes a number of measures to benefit fish survival, water management, water supply, and hydropower production.
- MO2 – includes measures that emphasize power production, renewable resource integration, and reduction of use of carbon-producing generation resources while also providing for water management and some measures to benefit fish survival.
- MO3 – includes breaching of four lower Snake River dams and adds other measures beneficial to anadromous and resident fish as well as some measures for water management, water supply, and hydropower production.
- MO4 – includes other measures to aid anadromous fish survival without breaching the Snake River dams as well as some measures for resident fish, water management, water supply, and hydropower production.

- PA – combines a number of measures as the preferred alternative to meet the purpose and need, EIS objectives, and environmental, economic, and sociological criteria. In addition, new information about spill operations from the 2018 and 2019 spring fish spill pilot operations that benefit downstream migration of juvenile anadromous fish became available after the range of alternatives was developed. Using this new information, the co-lead agencies modified the measure for juvenile fish spill operation for the preferred alternative using the analysis from the range of spill levels evaluated in the MOs.

Hydropower Analyses

Bonneville conducted several analyses of the effects of the alternatives using its HYDSIM, HOSS, and other regionally accepted models. Most involved simulations for each alternative of the monthly and daily operation of the Columbia River system of dams over an 80-year record of historically based streamflows. Analyses included:

- Energy generation – United States portion of the Columbia River system (NW-US), CRS, Mid-Columbia, and Canadian portion of the Columbia River system average, lowest 10th percentile (P10), and critical water (1937) generation.
- Peak generation – CRS 120-hour peak, Heavy Load Hour P10 peak (HLH P10), and Heavy Load Hour critical water peak (HLH critical water) generation.
- Qualitative assessment of NW-US system effects on integration of renewal resources.
- Hydropower generation for use in DEIS socioeconomics and air quality analyses.
- NW-US system reliability and loss-of-load probabilities (LOLP).
- Development and use of least-cost and least-carbon/least-cost resource portfolios needed for system reliability and meeting load growth.
- Hydropower generation effects on Colville tribal payment and Northwest Power Act 4(h)(10)(C) credits.

Summaries of the results follow.

Energy and Peak Generation Results

Energy results for the NW-US system are provided in this summary; results for the CRS, Mid-Columbia, and Canadian systems are in the appendix and its exhibits. Table ES - 1, Table ES - 2, and Table ES - 3 summarize the NW-US average, P10, and critical water generation.

Peak generation results were prepared only for the CRS (Federal) system due to modeling construct. Table ES - 4, Table ES - 5, and Table ES - 6 summarize the CRS (Federal) 120 peak, HLH P10, and HLH critical water peak generation.

The following summaries generally apply to all energy and peak generation metrics and all systems unless otherwise noted.

- The changes in CRS (Federal) are largely the same as for the NW-US system as it is the largest component of the NW-US system. Most of the NW-US generation changes occurred on the CRS system.
- Non-Federal Mid-Columbia system generation results are similar to the NW-US and CRS (Federal) systems because of their location below Grand Coulee. Changes in Federal operations above and at Grand Coulee directly affect the flow of water through the five Mid-Columbia projects, resulting in similar impacts.
- Little change from NAA generation occurred on the Canadian system as a result of the alternatives. All Canadian generation changes occurred at Waneta and Seven Mile Dams on the Pend d'Oreille River downstream of Hungry Horse and Albeni Falls Dams and several other projects on the Kootenay River downstream of Libby Dam.
- NW-US and CRS MO1 and the PA generation were slightly less than the NAA. Increases in CRS spill for fish passage and withdrawals for water supply resulted in NW-US and CRS average generation declines from the NAA during spring and summer months. Generation increases in January resulted from drafts at Grand Coulee and from Libby starting January at a higher elevation. Small changes were observed for the Mid-Columbia and Canadian systems.
- MO2 showed increased generation from the NAA for the NW-US system and CRS. Increased winter storage drafts and reduced amounts and duration of spill for fish passage contributed to United States and CRS increases. All other MO alternatives resulted in less NW-US and CRS generation than the NAA; NW-US and CRS reductions. Changes to the Mid-Columbia and Canadian systems were minimal as they were not affected by CRS fish passage spill measures
- NW-US and CRS MO3 generation is reduced year-round from the loss of CRS generation at the four lower Snake River dams, although this reduction from NAA generation is offset in August by lower Columbia River projects' generation increases. The greatest reductions from the NAA occur in spring and summer due to increased fish passage spill at the lower Columbia projects. The August NW-US and CRS generation increase results from terminating CRS fish passage spill earlier than the NAA. Small changes were observed for the Mid-Columbia and Canadian systems.
- NW-US and CRS MO4 generation is reduced from NAA generation nearly year-round from increased fish passage spill during the spring and summer and the effects of additional storage use for fish migration which impacts the fall and sometimes the winter. Changes in the storage operation at the upstream CRS projects influenced generation at the Mid-Columbia and Canadian systems.

Table ES - 1 through Table ES - 6 summarize the average, P10, and critical water (1937) generation for the NW-US, CRS (Federal), Mid-Columbia, and Canadian systems. CRS (Federal)

peak generation summaries are also provided for Peak Load (120 Hour), HLH P10, and HLH critical water generation; peak summaries were not prepared for the NW-US, Mid-Columbia, or Canadian systems.

Study results are summarized for several periods:

- The November to February (Nov – Feb) period is generally the time of greatest power demand due to colder winter temperatures; it is also a time when storage reservoir operations for FRM and refill adjust to the water supply forecast.
- The April 16 to July (Apr II – Jul) period is the annual spring runoff, system refill, and numerous measures for improving anadromous and resident fish survival.

The maximum and minimum loss periods identify those months during which the greatest generation changes occur for a specific alternative with respect to the NAA.

Table ES - 1. NW-US System Average Generation: Change from NAA

	Average U.S. Generation (aMW)				
	Nov - Feb	**Apr II - Jul**	**Max Loss Period**	**Max Gain Period**	**Annual**
NAA	14018	15672	Variable	Variable	13373
MO1	-4 (0%)	-341 (-2%)	-745 (-6%): AugI	228 (2%): Jan	-173 (-1%)
MO2	429 (3%)	728 (5%)	-380 (-3%): Mar	1574 (13%): AugI	453 (3%)
MO3	-823 (-6%)	-2059 (-13%)	-2786 (-17%): May	716 (7%): AugII	-1137 (-9%)
MO4	-73 (-1%)	-2389 (-15%)	-3549 (-26%): Mar	244 (2%): Jan	-1339 (-10%)
PA	110 (1%)	-706 (-5%)	-1370 (-8%): May	678 (7%): AugII	-162 (-1%)

Table ES - 2. NW-US System P10 Generation: Change from NAA

	P10 U.S. Generation (aMW)				
	Nov - Feb	**Apr II - Jul**	**Max Loss Period**	**Max Gain Period**	**Annual**
NAA	10676	11156	Variable	Variable	10144
MO1	13 (0%)	-645 (-4%)	-1284 (-10%): May	79 (1%): Dec	-280 (-2%)
MO2	444 (3%)	544 (3%)	-458 (-5%): AprI	1158 (12%): AugI	380 (3%)
MO3	-120 (-1%)	-1793 (-11%)	-2892 (-23%): May	573 (7%): AugII	-798 (-6%)
MO4	-34 (0%)	-1105 (-7%)	-2278 (-23%): Mar	17 (0%): Dec	-826 (-6%)
PA	2 (0%)	-678 (-4%)	-1593 (-13%): May	390 (5%): AugII	-176 (-1%)

Table ES - 3. NW-US System Critical Water Generation: Change from NAA

	1937 U.S. Generation (aMW)				
	Nov - Feb	**Apr II - Jul**	**Max Loss Period**	**Max Gain Period**	**Annual**
NAA	10475	11531	Variable	Variable	10297
MO1	12 (0%)	-889 (-8%)	-1390 (-12%): May	177 (2%): Jan	-385 (-4%)
MO2	168 (2%)	759 (7%)	-586 (-5%): Jan	1210 (14%): Feb	348 (3%)
MO3	-179 (-2%)	-1858 (-16%)	-2784 (-24%): May	263 (3%): AugII	-817 (-8%)
MO4	-187 (-2%)	-1456 (-13%)	-2768 (-26%): AugI	-48 (0%): Dec	-980 (-10%)
PA	-163 (-2%)	-953 (-8%)	-1596 (-14%): May	254 (3%): Oct	-354 (-3%)

Table ES - 4. CRS (Federal) Peak Load (120 Hour) Generation: Change from NAA

	Average Federal 120 Hour Generation (aMW)				
	Nov - Feb	Apr II - Jul	Max Loss Period	Max Gain Period	Annual
NAA	11220	12082	Variable	Variable	10784
MO1	-30 (0%)	-2 (0%)	-728 (-7%): AugI	179 (1%): Jun	-72 (-1%)
MO2	310 (3%)	1013 (8%)	-327 (-3%): Mar	1235 (10%): May	509 (5%)
MO3	-1078 (-10%)	-2004 (-17%)	-2660 (-21%): May	796 (9%): AugII	-1210 (-11%)
MO4	-70 (-1%)	-2383 (-20%)	-4146 (-36%): Mar	78 (1%): Jan	-1400 (-13%)
PA	65 (1%)	-610 (-5%)	-1213 (-10%): May	538 (6%): AugII	-132 (-1%)

Table ES - 5. CRS (Federal) HLH P10 Generation: Change from NAA

	P10 Federal 120 Hour Generation (aMW)				
	Nov - Feb	Apr II - Jul	Max Loss Period	Max Gain Period	Annual
NAA	8963	9805	Variable	Variable	8769
MO1	38 (0%)	-616 (-4%)	-1193 (-13%): AugI	103 (2%): AprI	-265 (-2%)
MO2	340 (2%)	704 (4%)	-399 (-5%): Mar	999 (13%): AugII	415 (3%)
MO3	-317 (-2%)	-1679 (-11%)	-2371 (-21%): May	670 (8%): AugII	-787 (-6%)
MO4	-25 (0%)	-1854 (-12%)	-3103 (-36%): Mar	44 (1%): Feb	-1153 (-9%)
PA	59 (0%)	-829 (-5%)	-1539 (-14%): May	394 (5%): Sep	-186 (-1%)

Table ES - 6. CRS (Federal) HLH Critical Water Generation: Change from NAA

	1937 Federal 120 Hour Generation (aMW)				
	Nov - Feb	Apr II - Jul	Max Loss Period	Max Gain Period	Annual
NAA	8981	9724	Variable	Variable	8842
MO1	10 (0%)	-837 (-9%)	-1717 (-16%): AugI	162 (2%): AprI	-371 (-4%)
MO2	224 (2%)	884 (9%)	-268 (-3%): Jan	1164 (10%): Jun	419 (5%)
MO3	-249 (-3%)	-1759 (-18%)	-2481 (-26%): May	485 (6%): AugII	-761 (-9%)
MO4	-102 (-1%)	-1480 (-15%)	-3948 (-37%): AugI	-30 (0%): Feb	-1070 (-12%)
PA	-27 (0%)	-783 (-8%)	-960 (-10%): May	319 (3%): Nov	-244 (-3%)

Energy and Peak Generation Summary

On an annual basis, MO1 and the draft preferred alternative have a 1 to 4 percent energy and peak reduction in generation from the NAA mostly on the CRS (Federal) system with little to no change on the Mid-Columbia and Canadian systems.

MO2 provides about 3 to 5 percent gains in energy and peak compared to the NAA. Most of this occurs on the CRS (Federal) system. Very little change occurs on the Mid-Columbia or Canadian projects.

MO3 and MO4 have 8 to 10 percent and higher reductions in energy and peak generation from the NAA, with MO4 having the largest. Again, little to no change in annual generation occurred on the Mid-Columbia and Canadian systems.

On an annual basis, the PA has energy and peak reductions in generation compared to the NAA between 1 and 3 percent.

CRS (Federal) Generation for Revenue Determination

Bonneville prepared CRS energy generation estimates for the CRSO DEIS socioeconomic analysts to estimate Federal revenues for each alternative. Revenue analyses and result details are provided in the *Power and Transmission (P&T) Socioeconomics Appendix* to the CRSO DEIS.

Bonneville forecasts the amount of Federal hydropower it expects to have supplied from the FCRPS to support its sale of firm power or firm requirements power[1] under long-term firm power sales contracts. Bonneville models the most adverse water year on record for the Columbia River system to determine the firm power amount of generation the FCRPS is expected to produce. The use of the water year that produced the least amount of usable power is often called critical water planning for which Bonneville uses the water-year 1937. The change in critical-year (1937) average generation of the CRS projects is the primary component in determining the change in the amount of federal hydropower that Bonneville can expect to have available for marketing long-term firm power. Generation amounts greater than critical water generation may be available for making sales of surplus power. The CRS (Federal) generation amount estimates for the socioeconomic analyses are provided in Table ES - 7.

The CRS generation estimates show the effect of each alternative on the two types of power sold by Bonneville: firm power and secondary (surplus) power.

Firm power is used to serve Bonneville's core statutory and contractual obligations, such as Bonneville's power obligation to its long-term firm requirements customers. A change in critical-water (1937) average firm generation from the CRS projects affects the amount of firm power Bonneville can expect to have available to support its long-term firm power sales contracts.

In addition to firm power, Bonneville also sells power when water conditions are above critical water conditions. This type of power, referred to as secondary or surplus power, is available when water conditions are at historical averages as opposed to critical water levels. Bonneville forecasts the availability of secondary power by averaging generation from 80 historical water years (80-year average generation). Generation amounts greater than critical water generation may be available for making sales of surplus power.

The CRS (Federal) generation amount estimates for the socioeconomic analyses for critical water year (firm power) and 80-year average are provided in Table ES - 7.

[1] Firm Requirements Power is Federal power that Bonneville makes continuously available to a customer to meet Bonneville's obligations to the customer under Section 5(b) of the Northwest Power Act (Bonneville 2018), 16 U.S.C. § 839c(b).

Table ES - 7. Average CRS (Federal) Generation for Revenue Determination: Change from NAA

Alternative	1937 Critical Water Average Generation (aMW / % change)	80-Year Average Generation (aMW / % change)
NAA	6,237	8,340
MO1	-297 / -4.8	-132 / -1.6
MO2	378 / 6.1	445 / 5.3
MO3	-748 / -12.0	-1,105 / -13.2
MO4	-888 / -14.2	-1,302 / -15.6
PA	-304 / -4.9	-157 / -1.9

System Reliability

Bonneville and other regional planning entities such as the NW Council use Loss-of-Load Probability (LOLP) as a fundamental metric of power system reliability. Bonneville and NW Council use a standard of 5 percent LOLP, which means that a power outage (or multiple outages) for lack of generation could occur in about one in 20 years. Hence, a lower LOLP means the system is more reliable. LOLP measures the frequency of a power outage; it does not capture the magnitude or duration of an outage. Bonneville developed the Conditional Value at Risk (CVaR) metric to assess the magnitude of average load not met for the outages.

Key reliability findings for the NW-US system are summarized in ES-8. Similar summaries for the CRS (Federal), Mid-Columbia, and Canadian systems are not provided as the LOLP analysis was performed only for the northwest region.

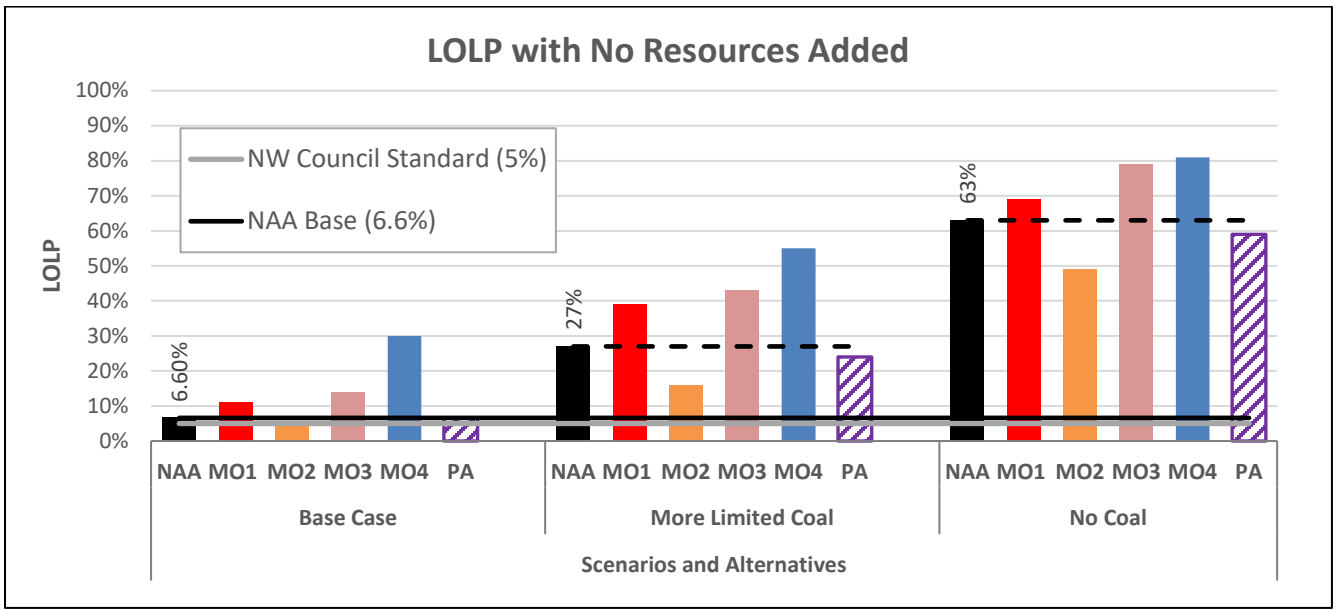
MO1 almost doubles the LOLP of the NAA due to increases in summer loss of load. Overall, MO2 impacts system loss of load the least and lowers the LOLP from 6.6 percent in the NAA coincidentally to meet the 5 percent LOLP standard. Major increases in loss of load occur in MO3 due to Snake River dam breaching. Loss of load in MO4 is even greater than in MO3 due to increased fish passage spill and the flow augmentation measures. The LOLP of the PA is 6.5 percent, near that of the NAA at 6.6 percent. Summarized observations by alternative follow in Table ES - 8.

Table ES - 8. NW-US System LOLP and CVaR Summary

Alternative	LOLP (%)	Notable CVaR Results
NAA	6.6	65.1 aMW @ 2.9% LOLP in January
MO1	11.2	58.3 aMW @ 2.8% LOLP in January 23.7 aMW @ 2.5% LOLP in August I
MO2	5.0	65.5 aMW @ 2.8% LOLP in January
MO3	13.9	98.7 aMW @ 4.1% LOLP in January 34.5 aMW @ 2.3% LOLP in June
MO4	29.6	63.9aMW @ 2.8% LOLP in January 725.3 aMW @ 23.8% LOLP in August I
PA	6.5	55.4 aMW @ 2.6% LOLP in January

When Bonneville prepared the CRSO EIS analysis in 2017, several coal-fired power plants in the region were scheduled to close. These closures were accounted for in the system reliability results in Table ES - 8. Since 2017, additional coal plant closures have been announced.

Removing additional coal-fired baseload generating resources raises the LOLP of NAA and all of the MOs. Bonneville performed an additional analysis of the effect of the coal-plant closures on the LOLP; results are displayed in Figure ES - 1. The base case represents the LOLPs for the DEIS using information available in 2017. The Limited Coal area represents the "updated view of the future" with 1,741 MW of coal remaining in the region. The No Coal area has no coal generation serving northwest loads.



Note: Gray line represents the NW Council's standard at 5.0%, and the black lines represents the LOLP of the NAA.

Figure ES - 1. NW-US LOLP with Removal of Coal Plants

The major increases in LOLP indicate the region needs major investments in resources to maintain the current levels of reliability.

Potential Replacement Power Portfolios and Carbon Emission Impacts

Bonneville prepared estimates of potential resource portfolios needed to be added to each CRSO DEIS alternative for the power system to achieve the 6.6 percent LOLP of the NAA. Because MO2 achieved 5 percent LOLP in the base case, Bonneville estimated a potential portfolio of avoided resource additions.

Portfolios were developed for conventional least-cost additions and zero-carbon/least-cost additions using information from NW Council sources. The conventional least-cost portfolios consisted of gas-fired single and combined-cycle generation. The zero-carbon portfolios consisted of the least-cost combinations of wind and solar generation and demand response (DR) measures. Portfolios for MO1, MO2, MO3, and MO4 are in Table ES - 9 and Table ES - 10.

Table ES - 9. NW-US System Conventional Least-Cost Replacement Portfolio and Associated Generation of Carbon-based Generation for the Base Case without Additional Coal-Plant Closures

Alternative	LOLP (percent)	CT capacity added to reach 6.6% LOLP (MW)	CT avg. added Generation (aMW)
MO1	11.2	560	163.1
MO2	5.0	-400 (avoided)	-244 (avoided)
MO3	13.9	1,120	607.0
MO4	29.6	3,240	708.2
PA	6.5	N/A	N/A

Note: Green font used when reduction is beneficial.

Table ES - 10. NW-US System Zero-Carbon Portfolio and Associated Change in Carbon-based Generation for the Base Case without Additional Coal-Plant Closures

Alternative	LOLP (percent)	Least carbon capacity added to reach 6.6% LOLP (MW)	Change in existing Carbon-producing Generation (aMW)
MO1	11.2	1,200 Solar/600 DR	-70
MO2	5.0	-600 DR (avoided) -660 Wind (avoided) -250 Solar (avoided)	-428
MO3	13.9	2,550 Solar/600 DR	457
MO4	29.6	5,000 Solar/600 DR	70
PA	6.5	N/A	142

Note: Green font used when reduction is beneficial.
1/ The increase in carbon-producing generation for MO3 when only zero-carbon resources are added stems from increased generation at existing carbon-producing power plants.

The carbon-based generation from the conventional least cost portfolio, the carbon-based generation changes from the least carbon, and the carbon generation avoided in MO2 amounts were provided to CRSO DEIS analysts for estimating the socioeconomic and air quality effects of the alternatives. Details are provided in the *P&T Socioeconomic* and *Air Quality* appendices of the DEIS.

Integration of Other Renewable Resources and Hydropower Flexibility

Flexibility in hourly and sub-hourly hydro operations is critical to the reliability of the power supply and its ability to adjust to changes in demand for electricity and changes in the output produced by other renewable resources. Power generation must equal load (demand) at all times. The hydropower system and natural gas plants in the region increase or decrease their generation output moment-to-moment to balance the changes in load and other generation, such as other renewable resources.

While some of the measures in the multi-objective alternatives would increase the flexibility of the hydrosystem to respond to these changes other measures would decrease the flexibility. As the amount of solar and wind power generation in the region increases, there will be more need for flexibility to respond to increasing magnitudes of solar generation variation between day and night or with changing cloud-cover and wind generation variation between calm and windy times.

Bonneville conducted a qualitative assessment of the effects of the alternatives on hydropower flexibility since its existing hydropower models do not model the short timeframes needed to assess changes in flexibility. Bonneville observed that several measures may lead to an increase in power system flexibility, including the ability to include reserves in fish passage spill, use of full operating range of run-of-river reservoirs, the expanded ability to reduce to zero generation, and the ability to operate below, within, or above the most efficient turbine operating range. Measures that reduce flexibility include minimum operating pools at the lower Snake and Columbia River projects, narrow and restricted turbine operating ranges, and large amounts of spill that reduce generation to minimum generation levels.

Bonneville concluded that MO2 has the most flexibility and improves flexibility over the NAA. MO1 has roughly the same flexibility as the NAA; MO3 and MO4 have reductions in flexibility compared to the NAA.

Colville Payments

Bonneville makes annual payments to the Confederated Tribes of the Colville Reservation as compensation for tribal lands inundated by Lake Roosevelt. The annual payment is based in part on actual generation at Grand Coulee. Effects of the alternatives are quantified in the CRSO using the distribution of forecasted annual average generation across the 80 water years. Overall, all alternatives show a reduction of Grand Coulee average 80-year annual generation compared to the NAA. Table ES - 11 summarizes the Grand Coulee generation changes. The determination of the payment is detailed in the *P&T Socioeconomics Appendix.*

Table ES - 11. Average Grand Coulee Generation for Colville Payment Determination

Alternative	aMW	Difference from NAA aMW (% change)
NAA	2,434	-
MO1	2,399	-35 (-1.4)
MO2	2,419	-15 (-0.6)
MO3	2,388	-46 (-1.9)
MO4	2,381	-52 (-2.2)
PA	2,426	-8 (-.3)

4(h)(10)(C) Credits

The Northwest Power Act requires Bonneville to make expenditures to mitigate fish and wildlife and their habitats in the Columbia River Basin affected by the development and operation of the Columbia River System.[2] Bonneville fulfills this mandate by making expenditures for: (1) direct fish and wildlife program operations and maintenance; (2) direct fish and wildlife program capital projects; and (3) power purchases made to replace the federal dam system's firm generating capability lost due to fish mitigation measures. While Bonneville incurs these costs as part of its section 4(h)(10)(A) mitigation duty, the actions funded also offset the impacts of the Columbia River System's non-power purposes such as navigation, irrigation, or flood risk management. Bonneville, however, is responsible for the power share of mitigation costs only, so it must therefore recover the non-power share of its fish and wildlife mitigation expenditures in some other way. Section 4(h)(10)(C) provides that vehicle. It requires the Administrator to allocate the expenditures incurred mitigating fish and wildlife and to recoup the non-power share of those expenditures from the U.S. Treasury. The system-wide weighted average of the non-power cost allocation is 22.3%. Bonneville thus takes a 22.3% credit annually against its obligations to the U.S. Treasury for the non-power share of mitigation it funds.

The annual amount of section 4(h)(10)(C) credit is expected to vary across CRSO EIS alternatives because the hydropower operations undertaken and mitigation expenditures that Bonneville would make to protect fish and wildlife under these alternatives would vary, and, in turn, affect the amount of credit received. The methodology for determining the amount of fish and wildlife costs for these categories consists of three distinct steps: (i) obtaining Direct Fish and Wildlife Program Expenditures from accounting records; (ii) estimating fish and wildlife related power purchases using HYDSIM, Bonneville's hydrosimulation model, and (iii) allocating these expenditures between power and non-power purposes to ascertain the credit value.

The credit for each alternative is estimated in Appendix H Power and Transmission Section 4.1.4. It is based in part on the estimates in this Appendix of the differences in additional power purchases Bonneville would need to make under each alternative to implement CRS operations to protect and mitigate fish and wildlife. The difference between the alternatives in the amount of additional purchase power, also called replacement power, needed to operate the CRS to protect and mitigate fish and wildlife is shown in Table ES - 12.

The 4(h)(10)(C) credit will generally increase or decrease in kind as the cost of CRS operations for fish and wildlife increase or decrease. The estimated mitigation expenditures and associated 4(h)(10)(C) credit are discussed Appendix H Power and Transmission Section 4.1.4.

[2] Section 4(h)(10)(A), 16 U.S.C. § 839b(h)(10)(A).

Table ES - 12. Annual Replacement Power Purchases (aMW)

Alternative	Eligible Purchase w/ F&W	Eligible Purchase w/o F&W	Additional Purchase	Change from NAA (%)
NAA	397	38	359	-
MO1	417	37	381	6.1
MO2	333	38	294	-18.1
MO3	814	37	777	116.4
MO4	846	37	809	125.3
PA	448	38	410	14.2

Bonneville Climate Change Assessments

The co-lead agencies are reviewing multiple scenarios to qualitatively evaluate the potential effects of climate change on the natural streamflows in the Columbia River Basin. Details about the development and use of these scenarios are presented in Chapter 4 of the CRSO DEIS.

Bonneville selected four scenarios for a quantitative hydropower assessment and assessed the relative generation changes between alternatives for each of the four climate scenarios. Bonneville concluded that climate change does not affect the overall conclusion regarding the net effect of any of the MO alternatives relative to NAA. MO2 is still the best alternative for hydropower production, system reliability, and carbon reduction compared with the NAA; MO1's generation remains the closest to NAA generation, and MO3 and MO4 generation and reliability are still much lower than the NAA.

Climate change, as represented by the four scenarios, is adding some uncertainty to the annual magnitude of generation and significant uncertainty to the monthly magnitude of the effect of the MO alternatives relative to NAA.

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631 # Abbreviations, Acronyms, and Glossary

aMW	Average Megawatts
AURORA	Electric Market Forecasting Model
BC Hydro	British Columbia Hydro and Power Authority
BiOp	Biological opinion
Bonneville	Bonneville Power Administration
Corps	U.S. Army Corps of Engineers
CO_2	carbon dioxide
CPO	Coordinated Plan of Operation
CRS	Columbia River System
CRSO	Columbia River System Operations
CRT	Columbia River Treaty
CT	Combustion Turbine
CVaR	Conditional value of risk (a measure of power outage magnitude)
DEIS	Draft Environmental Impact Statement
DR	demand response
Draft	To lower the elevation of a reservoir (more flow out than in)
EIS	Environmental Impact Statement
FCOP	Flood Control Operating Plan
FCRPS	Federal Columbia River Power System
F&W	fish and wildlife
FELCC	Firm Energy Load Carrying Capability
FERC	Federal Energy Regulatory Commission
FRM	Flood Risk Management
FWPO	Flexible Winter Power Operations
HLH	Heavy Load Hour (6 am to 10 pm, except Sundays and Holidays)
HLH P10	Heavy-Load-Period Federal Generation from Lowest 10th Percentile
HOSS	Hourly Operations Scheduling Simulator
HYDSIM	Hydrologic Simulator Model
kcfs	thousand cubic feet per second
LOLP	Loss-of-Load-Probability
Maf	million acre-feet
MIP	minimum irrigation pool
MO1	Multiple-Objective Alternative 1
MO2	Multiple-Objective Alternative 2
MO3	Multiple-Objective Alternative 3
MO4	Multiple-Objective Alternative 4
MOP	minimum operating pool

MW	Megawatt
NAA	No-Action Alternative
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NGVD29	National Geodetic Vertical Datum of 1929
NW Council	Northwest Power and Conservation Council
NW-US	Northwest portion of Columbia River System in the United States
P&T	Power and Transmission
PNCA	Pacific Northwest Coordination Agreement
PUD	Public Utility District
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
ResSim	Reservoir System Simulation Model
RMJOC	River Management Joint Operating Committee
SRD	storage reservation diagram
TDG	total dissolved gas
VarQ	Variable Flow Flood Risk Management Curves
WECC	Western Electricity Coordination Council

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CHAPTER 1 - INTRODUCTION TO COLUMBIA RIVER SYSTEM OPERATIONS EIS AND HYDROPOWER

This appendix presents the hydropower analyses conducted for the Columbia River System Operations (CRSO) Draft Environmental Impact Statement (DEIS). The Bonneville Power Administration (Bonneville), U.S. Army Corps of Engineers (Corps), and U.S. Bureau of Reclamation (Reclamation) are co-lead agencies in developing the CRSO DEIS, which is required for the agencies' compliance with the National Environmental Policy Act (NEPA). This appendix is part of a larger set of CRSO DEIS documents that detail the efforts of the co-lead agencies in evaluating alternatives for the future operation and configuration of 14 major projects of the Federal Columbia River Power System (FCRPS) collectively referred to as the Columbia River System (CRS).

This appendix focuses on hydropower effects of the CRSO DEIS alternatives and is supported by several other CRSO DEIS documents that provide additional details on the EIS processes, alternatives, system operation and modeling, and several other uses affected by the alternatives. Details about the NEPA process and development of alternatives are presented in the CRSO DEIS report. Modeling details for this hydropower assessment are presented in the *Hydroregulation Appendix* and *Hydrology and Hydraulics Appendix (H&H Appendix).* Hydropower results in this appendix contribute to other analyses in the CRSO DEIS, including analyses of socioeconomic, air quality, and water quality effects. The results of those other effects are detailed in the appropriate appendices.

1.1 COLUMBIA RIVER SYSTEM PROJECTS

As defined for this study, the CRS consists of the 14 major federal projects operated in coordination with each other. They are a subset of the FCRPS, a network of 31 multi-purpose Federal dam and reservoir projects constructed primarily in the Columbia River and its tributaries in the Pacific Northwest and operated by the Corps and Reclamation. The FCRPS also includes the Federal transmission system built and operated by Bonneville to market and deliver electric power.

The United States Congress authorized the Corps and Reclamation to construct, operate, and maintain the FCRPS projects to meet multiple specified purposes, including flood risk management (FRM), navigation, hydropower production, irrigation, fish and wildlife conservation, recreation, municipal and industrial water supply, and water quality. Although not every project is authorized for each of these purposes, all 14 CRS projects are authorized for hydropower.

The results of Bonneville's hydropower modeling are provided in system groupings: NW-US, CRS, Mid-Columbia, and Canadian. Exhibit 1 provides a list of the projects in these systems and indicates which projects are affected by the CRSO DEIS alternatives.

1.1.1 FCRPS Projects in the CRS

The 14 CRS projects on the Columbia River and its major tributaries are operated as a coordinated system. The CRSO DEIS focuses on these 14 CRS projects: Libby, Hungry Horse, Albeni Falls, Grand Coulee, Chief Joseph, Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and Bonneville. Figure 1-1 shows the geographic locations of the 14 projects. Table 1-1 summarizes the general characteristics of the 14 projects pertinent to hydropower.

The CRS projects examined in detail in the CRSO DEIS fall into two major categories: storage and run-of-river projects. There are five Federal storage projects in the CRS: Libby, Hungry Horse, Albeni Falls, Grand Coulee, and Dworshak. There are nine Federal run-of-river projects in the CRS: Chief Joseph, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and Bonneville.

Storage is key to operating the CRS for multiple uses. The total water storage available in the reservoirs on the Columbia River and its tributaries is approximately 55 million acre-feet (Maf). About 20 Maf of that storage capacity is in Canada. About 16 Maf is in the five CRS storage projects and the other 19 Maf is in several other Federal and non-Federal dams in the Snake River basin in southern Idaho and eastern Oregon, Yakima River Basin in Washington, and Willamette River Basin in Oregon. In general, the storage reservoirs capture streamflow during relatively high spring snowmelt flow periods. Refill is managed to reduce downstream flooding and store water for release for multiple objectives in times of relatively low streamflows during late summer and fall months.

Run-of-river projects have limited storage capacity. These projects release water at the dam at nearly the same rate it enters the reservoir. The reservoirs behind run-of-river projects often are operated for hydropower resulting in frequent, small fluctuations in water levels. Reservoir levels behind these projects typically vary only 3 to 5 feet in normal operations.

1.1.2 Other FCRPS Projects

The remaining 17 FCRPS projects are operated independently from the 14 CRS projects and are located in the upper Snake River basin in southern Idaho, the Yakima River basin in Washington, and the Willamette and Rogue River basins in Oregon. Their operation is replicated in the modeling of each alternative (i.e., project storage operations, outflows, and generation are the same in each CRSO DEIS alternative).

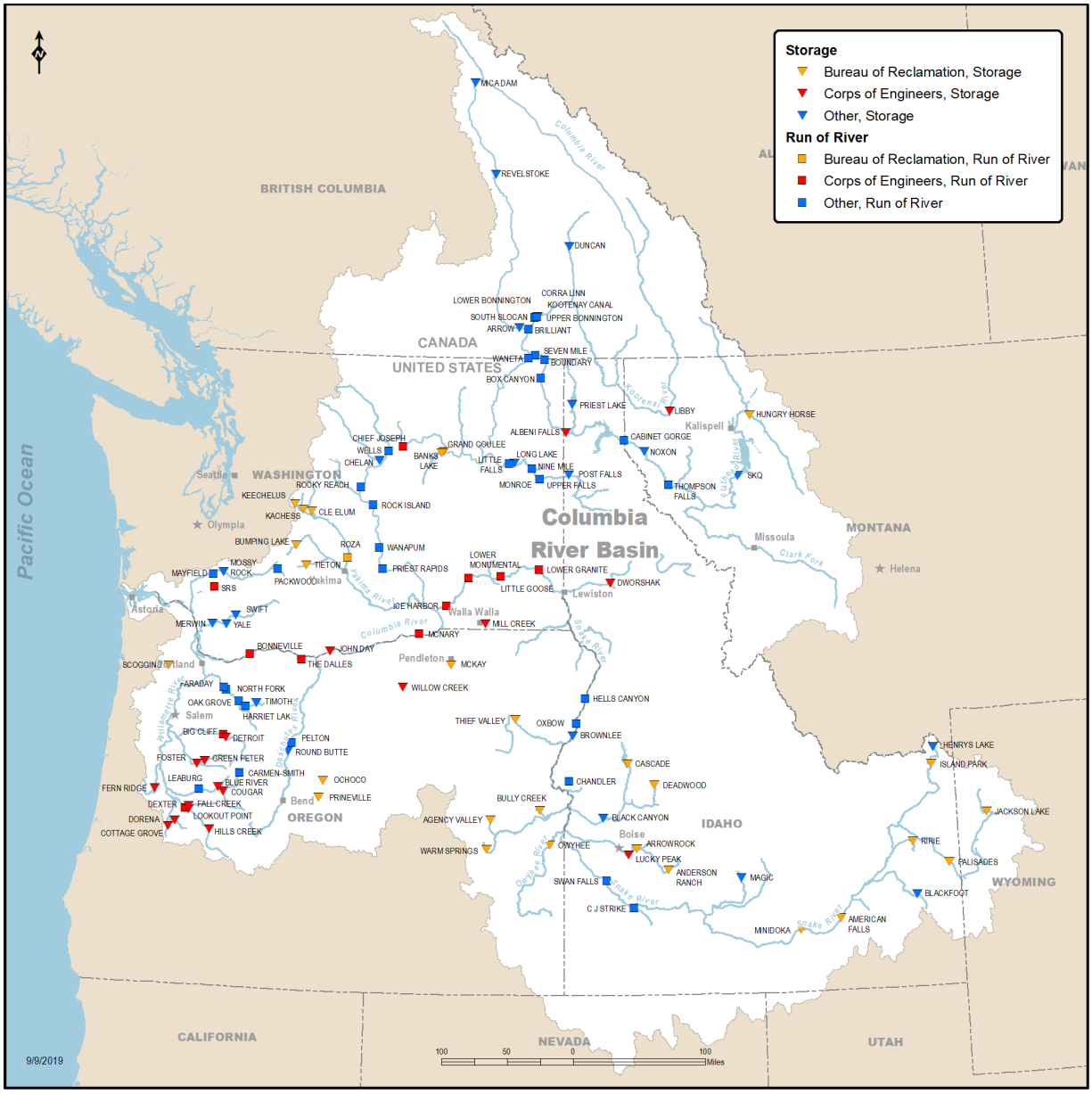


Figure 1-1. Geographic Location for the CRSO Projects

703 **Table 1-1. General Characteristics of the Columbia River System (CRS) Projects**

Project	Reservoir/ Lake	Project Type	Storage Volume (Maf)	Hydropower (no. of units – capacity)
Libby	Koocanusa	Storage	5.0	5 units – 525 MW
Hungry Horse	Hungry Horse	Storage	3.0	4 units – 428 MW
Albeni Falls	Pend Oreille	Storage	1.2	3 units – 42 MW
Grand Coulee	Roosevelt	Storage	5.4	24 units, 6 pump/generators – 7,015 MW
Chief Joseph	Rufus Woods	Run-of-river	-	27 units – 2,000
Dworshak	Dworshak	Storage	2.0	3 units – 400 MW
Lower Granite	Lower Granite	Run-of-river	-	6 units – 810 MW
Little Goose	Bryan	Run-of-river	-	6 units – 810 MW
Lower Monumental	Herbert G. West	Run-of-river	-	6 units – 810 MW
Ice Harbor	Sacajawea	Run-of-river	-	6 units – 603 MW
McNary	Wallula	Run-of-river	-	14 units – 980 MW
John Day	Umatilla	Run-of-river (with storage)	0.5	16 units – 2,480 MW
The Dalles	Celilo	Run-of-river	-	22 units – 2,080 MW
Bonneville	Bonneville	Run-of-river	-	18 units – 1,200 MW

704 Project information from http://www.crso.info/index.html

705 ### 1.1.3 Non-Federal Dams and Reservoirs

706 There are numerous other dam and reservoir projects in the Columbia River and its tributaries
707 that are operated by Federal and non-Federal entities in the United States and Canada. These
708 include both storage and run-of-river projects that can affect or be affected by CRS project
709 operations.

710 #### *1.1.3.1 Canadian Projects*

711 Mica, Arrow, and Duncan (Columbia River Treaty Projects[3] in Canada) are major storage
712 projects with 15.5 Maf of Treaty storage and 5 Maf of non-Treaty storage. The 15 Maf of Treaty
713 storage is operated by British Columbia Hydro and Power Authority (BC Hydro) for FRM and
714 hydropower in accordance with the terms of the Columbia River Treaty (CRT). In addition, there

[3] See Bonneville website for information on the Columbia River Treaty at:
https://www.bpa.gov/Projects/Initiatives/Pages/Columbia-River-Treaty.aspx

is a separate non-Treaty storage operation under separate mutual agreements between the United States Entity and the Canadian Entity[4] to provide resident fish benefits in Canada and anadromous fish benefits in the United States. Mica, Arrow, and Revelstoke power production is not affected by the CRSO DEIS alternatives. Duncan Dam does not have power facilities and its storage operation is not affected by the DEIS alternatives.

Several other projects are operated by BC Hydro and other entities in Canada on the lower Kootenay and Pend d'Oreille rivers, both tributaries to the Columbia River. Power production at these dams would be affected by the CRSO DEIS alternatives.

1.1.3.2 Mid-Columbia River Projects

Three Washington state Public Utility Districts (PUDs) operate the following five run-of-river dams in the Mid-Columbia River under licenses issued by the Federal Energy Regulatory Commission (FERC):

- Wells, operated by Douglas County PUD
- Rocky Reach and Rock Island, operated by Chelan County PUD
- Wanapum and Priest Rapids, operated by Grant County PUD

These projects are hydrologically affected by upstream Federal storage project operations, which influence flows through the PUD projects particularly from Grand Coulee Dam. Power production at the five PUD dams would be affected by the CRSO DEIS alternatives.

1.1.3.3 Middle Snake River Dams

The Idaho Power Company operates three FERC-licensed dams, collectively known as the Hells Canyon Complex, located on the middle Snake River on the Oregon/Idaho border. The Hells Canyon, Oxbow, and Brownlee projects are hydropower facilities that affect flows on the lower Snake River. Hells Canyon and Oxbow are run-of-river projects downstream of Brownlee Dam. Brownlee Dam is the most significant for CRSO, as it provides a total storage capacity of 1.4 Maf, of which 980,000 acre-feet are used jointly for FRM and power production. Brownlee also is operated for recreation, navigation below Hells Canyon, and provides flow augmentation for downstream fish migration. Power production at these dams would not be affected by the CRSO DEIS alternatives. Operation of these dams is replicated in all the CRSO DEIS alternatives.

1.1.3.4 Other Columbia River Non-Federal Dams in the United States

There are other non-Federal dams located below the Federal storage projects at Hungry Horse and Albeni Falls dams. They include Sèliš Ksanka Qĺispè (formerly Kerr Dam), Thompson Falls, Noxon Rapids, Cabinet Gorge, Box Canyon, and Boundary Dams. All are run-of river except Sèliš

[4] The Columbia River Treaty of 1964 designated Entities to implement the terms of the treaty. The U.S Entity is Administrator of Bonneville and the Commander of Corps Northwestern Division; the Canadian Entity is BC Hydro.

Ksanka Q́ispè Dam which regulates about 1.2 Maf storage at Flathead Lake in Montana and Noxon Rapids. Power production at these dams would be affected by the CRSO DEIS alternatives.

1.2 COLUMBIA RIVER SYSTEM MULTIPLE-USE OPERATIONS

Operation of the CRS results from the coordinated implementation of the numerous measures and objectives that comprise the CRT, biological opinions (BiOps), power system reliability, and several other authorized uses such as navigation, irrigation, and recreation. In coordinating system water management, the co-lead agencies generally prioritize FRM, environmental responsibilities (i.e., conservation actions for protected fish species), and other authorized uses such as navigation and irrigation before power generation to meet the daily and seasonal demand for electricity by Bonneville.

Coordinated CRS operation begins with planning. The co-lead agencies are involved in several processes pertinent to the annual, short-term, and real-time operation of the 14 CRSO projects. Major areas of involvement affecting hydropower include the planning and implementation of the CRT, development and implementation of BiOps issued by National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service, hydropower coordination under the Pacific Northwest Coordination Agreement (PNCA), and ongoing coordination discussions between the co-lead agencies and others for real-time operation.

The operating objectives of these various processes affecting hydropower are summarized in the following subsections. More operation details are provided in the CRSO DEIS and the No-Action Alternative (NAA) description in Section 1.4 of this appendix.

1.2.1 Columbia River Treaty

The CRT requires the United States Entity and the Canadian Entity to prepare operating plans each year that are the basis for the operating rule curves for CRT projects in Canada. These rule curves guide the annual storage and release of water from the three CRT projects in Canada to meet CRT flood risk and hydropower objectives. They also incorporate the CRT Flood Control Plan[5] prepared periodically by the Corps and BC Hydro.

Since 1977, the United States and Canadian entities have mutually agreed to annual and long-term operations of 5 Maf of non-Treaty storage space in Canada. While pursuing a long-term agreement, there were eight short-term agreements between Bonneville and BC Hydro for use of non-Treaty space in Canada during the period 1977-1983. The first long-term non-Treaty storage agreement was executed in April 1984 to benefit resident fish in Canada and anadromous fish in the United States. The current non-Treaty agreement was executed in 2012.

[5] Columbia River Treaty Flood Control Operating Plan (CRT FCOP), prepared by Corps for the United States Entity. May 2003.

Guidance provided by the CRT operating plans is incorporated into the CRSO DEIS alternatives modeling.

1.2.2 Biological Opinions

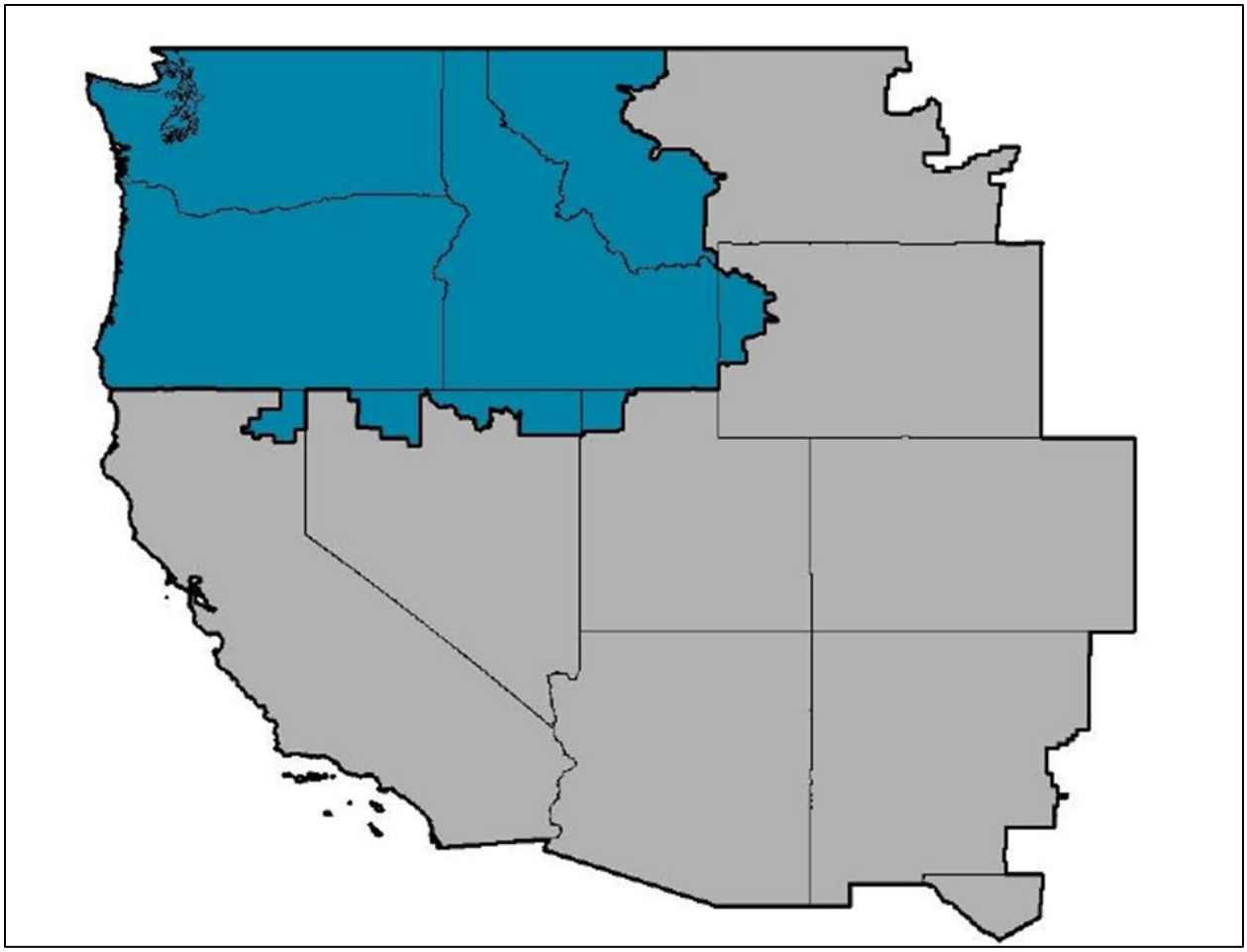
Annual plans also are developed for purposes other than power. In particular, operations to support anadromous fish are planned through a Coordinated Plan of Operation (CPO). The co-lead agencies work with federal and state fisheries agencies and tribes to develop the CPO. The Corps' annual fish passage plan is another key plan that specifies operations for juvenile and adult fish passage facilities on the lower Snake River and lower Columbia River projects, and operations at the Chief Joseph and Dworshak projects. There also are plans to implement several measures specified in BiOps for resident fish.

Collectively, measures in these BiOps and plans influence storage and water release from the five storage dams in the CRS. They also influence the amount of water spilled for juvenile fish passage at eight federal run-of-river projects on the lower Snake and Columbia rivers. These storage and spill operations affect hydropower generation and system reliability and are identified in the alternative descriptions (Section 1.4 and Chapter 3).

1.2.3 Power and Transmission System

The 14 CRS projects are the major producers of the federal power Bonneville sells on a long-term basis to regional power customers, such as public utilities (municipalities, PUDs, cooperatives, Federal agencies and tribal utilities), investor-owned utilities, and direct service industrial customers. Bonneville also operates and maintains 15,000 miles of high-voltage transmission lines within the Pacific Northwest. This system interconnects and integrates electric power that flows through the regional transmission system and interconnects with systems throughout the western United States and parts of Canada and Mexico. The CRSO DEIS alternatives have the potential to impact the power available for sale as well as the flow of power across the transmission system. Together, these changes could affect costs for both power and transmission services, which could affect rates and, ultimately, regional and local economies. The geographic areas for the analyses of effects of the CRSO DEIS alternatives on power and transmission are shown in Figure 1-2.

Bonneville regularly engages with other generating utilities and organizations such as the Northwest Power and Conservation Council (NW Council) Northwest Power Pool, Pacific Northwest Utilities Conferencing Committee, and the Western Electricity Coordination Council (WECC) to update and coordinate power resources capabilities and future needs to maintain overall system demand and reliability. Bonneville is also constantly engaged with other generating utilities and transmission grid operators on the real-time system operation.



Note: the blue shaded area bounded by the black outline is the Bonneville service area.
Source: Western Electricity Coordination Council (WECC 2018); Bonneville GIS (2018)

Figure 1-2. Power Area of Analysis – the U.S. Portion of the Western Interconnection and the Bonneville Service Area

The hydropower production and reliability information included in this appendix are used in the analyses of impacts of CRSO DEIS alternatives to transmission reliability, power and transmission rates, and their socioeconomics impacts. Details of the power and transmission analyses are provided in the CRSO DEIS *P&T Socioeconomics Appendix.*

1.2.3.1 Pacific Northwest Coordination Agreement

The Pacific Northwest Coordination Agreement (PNCA) is an agreement for planned operations among the utilities and other entities that operate the major electric generating facilities and systems in the Pacific Northwest. Coordination is achieved through exchanges of energy and capacity among the various parties to the agreement. Parties include Bonneville, Corps, Reclamation, U.S. Entity, eight public utility districts and municipalities, and six investor-owned utilities that have hydropower resources in the Columbia River basin. The PNCA was first signed in 1964 and coincided with the development of the CRT and the eventual construction of the

AC-DC Intertie to interconnect the Pacific Northwest with the Pacific Southwest. The PNCA was renewed in 1997. It will expire in 2024.

Annual planning for coordinated power system operations occurs pursuant to the PNCA. Although there are multiple hydropower producers in the Columbia River Basin, planning studies are conducted as if the total coordinated system had a single owner, synchronizing operations to maximize power production while meeting numerous non-power operating requirements.

Studies are conducted to estimate how much power can be produced from the whole system and by each PNCA party. These studies are updated throughout the operating year and guide reservoir operations that produce the planned power capability while meeting numerous multiple-use operating requirements.

The role of the PNCA has diminished since the mid-1990s as the non-federal Mid-Columbia projects' long-term output contracts[6] with various regional utilities expired and requirements for non-power uses increased in priority. Actions to improve flows for juvenile anadromous fish migration, protect adult spawning, and improve reservoir conditions for resident fish have reduced the opportunities of the PNCA parties to influence the operation of the coordinated system. In parallel, the increased use of the wholesale market has largely replaced PNCA transactions for transferring power between utilities.

1.2.4 Seasonal Operations

Seasonal operation of the CRS results from the coordinated implementation of the numerous measures and objectives that comprise the CRT, BiOps, power system reliability, and several other authorized uses. In coordinating system water management, the co-lead agencies generally prioritize FRM and environmental responsibilities (i.e., conservation actions for protected fish species) before power generation to meet the daily and seasonal demand for electricity by Bonneville. The amount of hydropower generated at most times of the year is generally dictated not by the demand for electricity but rather by the amount of water traveling down the river. However, in emergency and emergency avoidance situations, power system operations are prioritized to protect human health and safety as well as the safety and reliability of the power grid. These emergency situations are mostly short-term and would be within the monthly averages produced by Hydrologic Simulator Model (HYDSIM).

Monthly average generation is driven primarily by natural streamflows and operation of the five major CRS storage projects: Libby, Hungry Horse, Albeni Falls, Grand Coulee, and Dworshak. The greatest period of hydroelectric generation typically coincides with spring runoff. Much of

[6] Regional investor-owned utilities and some public utility customers purchased part of their long-term power supplies from the Mid-Columbia projects under 50-year contracts. When transmission opened up and the wholesale power markets became competitive, the Mid-Columbia project owners offered their hydro output to new market competitors and the region's utilities shifted their resource supplies away from Mid-Columbia projects.

the hydropower production at this time is also known as seasonal surplus and is the byproduct of the freshet impacting the Columbia River and its tributaries. The seasonal surplus often far exceeds the amount of firm power needed to meet Bonneville's firm power supply obligations under contract. The lowest generation generally occurs in late summer and fall.

The storage and release of water from the CRS storage projects affects hydropower production downstream at the other nine CRS dams and several non-Federal dams. The CRT projects in Canada also provide storage operations that affect downstream hydropower generation. The annual use of storage affecting generation is summarized in Figure 1-3 and the following subsections.

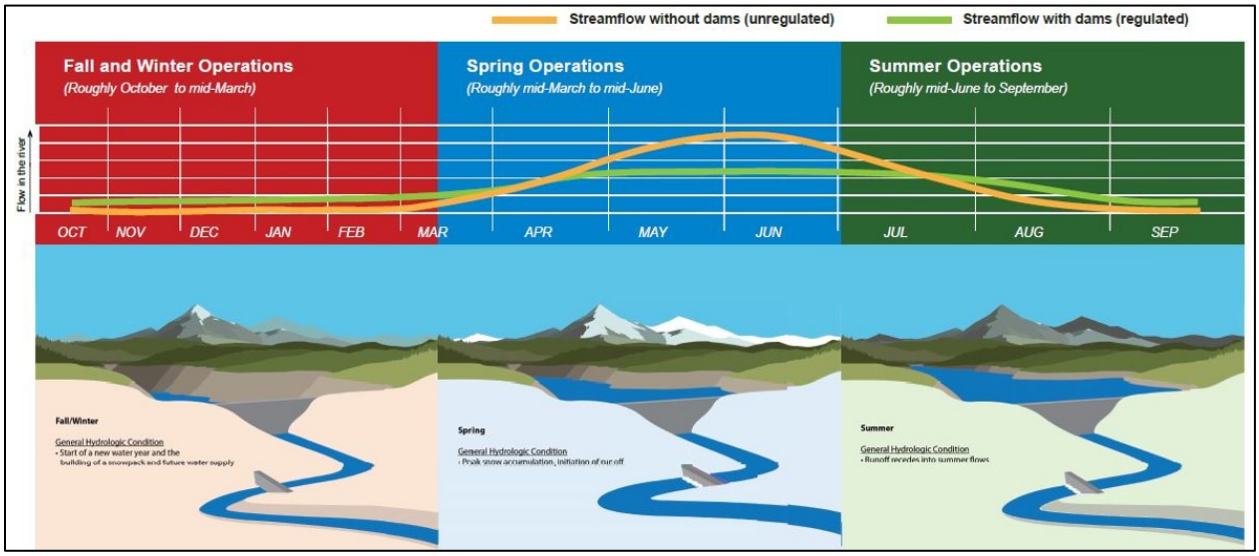


Figure 1-3. Seasonal Operations of CRS

1.2.4.1 Fall and Winter Operations

The fall-winter season generally runs from October to mid- to late-March. The previous year's snowpack melts by the start of the fall season and the seasonal snowpack begins to build. As snow accumulates in the headwaters through the fall and winter, reservoirs are drafted to provide space to capture the next spring's high flows. This draft supplements seasonally low flows and provides safe navigation corridors, generates power, benefits certain salmon spawning conditions, and helps protect wildlife habitat and cultural resources.

1.2.4.2 Spring Operations

The spring season generally runs from mid- to late-March through mid- to late-June. The snowpack usually reaches its peak snow accumulation sometime between mid-March and mid-May depending on elevation and location in the Basin. Water supply forecasts based on snowpack and other assumptions provide an indication of the spring runoff volume and timing anticipated and inform the space required for FRM operations and water supply for other uses. Once runoff begins, the Corps and Reclamation reduce the storage project outflows and begin refilling the reservoirs. The co-lead agencies balance FRM requirements, refill objectives, and

flows for juvenile fish migration in the lower Columbia and Snake rivers by attempting to operate no lower than the FRM elevation for April 10th. This provides space to moderate higher flows to reduce flood risk and the amount of stored water to be released for juvenile fish migration.

The co-lead agencies adjust reservoir storage releases through April, May, and June to minimize flooding, meet fish flow objectives, and refill the reservoirs for summer.

1.2.4.3 Summer Operations

The summer season runs from approximately mid-June through September. The spring runoff is generally receding from mid-May or early June through the remainder of the summer season. Storage reservoirs reach their highest elevation during the summer months, often reaching full pool. Water stored during the spring is released throughout the summer season to augment flows for fish in the lower Columbia and lower Snake Rivers. Flows also provide water for irrigation, recreation, and power production.

During summer months, the system balances providing additional flow for augmentation downstream to aid juvenile and adult fish migration, irrigation use, and power production.

1.2.5 Real-Time Operations

The co-lead agencies operate the system on a real-time basis. Many real-time operations are not modeled in a study due to the lack of precision in model input, processing, and outputs of monthly, daily, or even hourly generation and because real-time operations respond to changing loads, weather, market, and other conditions. Hydropower operation may change on a second-to-second or hourly basis, especially at the run-of-river projects that must adjust powerhouse generation with load. These changes are considered part of the average flows and generation in study outputs, but may be addressed qualitatively when necessary.

Examples of factors that cause short-term operational adjustments that are imprecisely captured in study output averages include:

- Specific extreme weather events (warmer or colder than average climatology) affect demand for power hour-to-hour and day-to-day.
- Increases or decreases in generation from other resources such as wind or solar power generation need to be offset by changes in hydropower generation.
- Short-term real-time flow conditions may not provide enough water at a dam to meet all fish bypass flows, leakage and lockage flows, and minimum or optimum flows for turbine operations; even though all these conditions were met in a study.
- Unplanned equipment outages may result in periods of extraordinary maintenance for generators or other project facilities that may require short-term departures from conditions in the study.

- Special operations may be required for installation or maintenance of structures associated with fish passage or with transmission infrastructure.
- Short-term rainfall may cause temporary higher flows in the fall or winter that differ from study conditions. This water can be used to produce surplus (non-firm or secondary) energy or left in storage for future use if storage space is available.
- There may be times when there is not enough water to provide power to meet Bonneville's power supply obligations. Bonneville might need to purchase power on the wholesale market to meet its obligations even though such purchases were not needed to meet demands in a study using period averages.
- There may be times of temporary high flows that result in unexpected project spills when there is no market for extra hydropower generation. These short-term spills may not occur in a study based on averages.
- Power system contingency affects the available capacity of hydrogenation for lower Snake and Columbia River projects. When contingency reserves are deployed, they can affect the overall spill and powerhouse operation of the projects.

These and other situations are addressed in real-time by the co-lead agencies as they consider making short-term adjustments to operations. This often involves consultations with other interests especially when it involves power outages or impacts that may be adverse to fish and wildlife species protected under the Endangered Species Act.

1.3 ALTERNATIVES DEVELOPMENT PROCESS

The CRSO EIS team of the co-lead agencies implemented a public scoping process in 2016 to inform the public about the EIS and identify issues to be addressed. Over 400,000 comments were received from members of the public, tribes, local and state governmental agencies, non-governmental organizations, and other stakeholders.

The CRSO EIS team analyzed the scoping input and identified more than 100 distinct project objectives that required more than 500 measures to achieve. The objectives and associated measures were then grouped into eight broad single-objective alternatives. Finally, to achieve multiple objectives, measures from the single objective alternatives were combined into four multiple-objective alternatives as shown in in Exhibit 2. In addition to these four alternatives, a No Action Alternative (NAA) is used as a point of comparison as required by NEPA. The resulting 5 alternatives are modeled, evaluated, and compared with one another to determine their benefits and impacts. Descriptions of the Alternatives

The CRSO DEIS contains four multiple-objective alternatives and the NAA. The NAA represents reservoir operations and dam structures in place when the Corps filed a Notice of Intent for the EIS in September 2016.

The four, multiple-objective alternatives contain different combinations of operational and structural measures to address issues identified in the CRSO DEIS public scoping meetings.

Operational measures include: differing storage operations at the Federal upstream storage projects and differing spill and powerhouse flow levels at the Federal downstream run-of river projects. Structural measures include: differing juvenile and adult fish passage system improvements; installation of more efficient turbines with improved fish passage at select projects; and dam breaches at the four lower Snake River dams.

Summary descriptions and effects of the NAA and four multiple-objective alternatives are provided in the following sections and limited to the measures pertinent to this hydropower assessment. More complete, detailed descriptions of the NAA and multiple-objective alternatives are provided in the CRSO DEIS. Specific details for how the alternatives were modeled for hydropower assessments are provided in the CRSO DEIS *Hydroregulation Appendix* narratives and modeling data sheet exhibits. Exhibit 2 of this appendix includes a matrix that lists all the measures in each multiple-objective alternative. Measures that do not affect hydropower production are not listed in the multiple-objective alternative descriptions below.

1.3.1 No-Action Alternative (NAA)

The NAA includes the operation and structures in place or committed for construction when the Notice of Intent for the EIS was published in the Federal Register in September 2016 and applied to forecast future years. In summary, those pertinent to this hydropower assessment include:

- FRM Operations per Corps current criteria for the five CRS storage projects, three CRT projects in Canada, and United States FERC-licensed projects (Brownlee and Sèliš Ksanka Qĺispè).
- Canadian Treaty project (Mica, Arrow, and Duncan) storage operations for FRM are as defined in the Flood Control Operating Plan[7]and power operations are as defined in the 2022 Assured Operating Plan. Also includes Canadian storage operations for non-power uses as defined in current agreements between the United States Entity and the Canadian Entity.
- Project operating criteria as specified in authorizing legislation and water control manuals including minimum and maximum discharge rates of change and minimum and maximum forebay elevations.
- Flow augmentation objectives consistent with the 2008 BiOp (as amended in 2010 and 2014) issued by NMFS for salmon and steelhead, including spring and summer flow targets at Lower Granite and McNary Dams, chum spawning operations below Bonneville Dam, and spawning and rearing operations below Priest Rapids Dam.

[7] See Columbia River Flood Control Operating Plan prepared by Corps of Engineers (May 2003) at: http://www.nwd-wc.usace.army.mil/cafe/forecast/FCOP/FCOP2003.pdf

- Spill operations for juvenile fish passage consistent with the 2008 BiOp (as amended in 2010 and 2014) issued by NMFS for salmon and steelhead, including fish passage spill operations at the eight lower Snake and Columbia River dams.
- Summer drafts at Libby and Hungry Horse dams to meet September 30 targets of 10 feet from full in most years or 20 feet from full in dry years.
- Loads/Resources for hydropower modeling are for 2022 forecasts.
- Turbine/generator maintenance for Federal projects is a generic future year based on 5-year maintenance averages and includes Grand Coulee turbine/generator overhaul plus forthcoming upgrades to McNary and Ice Harbor turbines.

1.3.2 Multiple-Objective 1 (MO1)

MO1 includes a number of measures to benefit fish as well some measures for water management, power production, and water supply. Not all measures in MO1 affect hydropower; MO1 contains the following departures from the NAA that affect the power assessment:

- Fish Passage Spill:
  - The amount of spill in MO1 is more than the NAA, but less than provided by flexible spill operations regional entities agreed to implement in 2019 and 2020.
  - Two spill blocks are used for spring fish passage. One block is spill to 120/115 percent of the total dissolved gas (TDG) cap level and the other is performance standard spill. Alternative years will have the different spill blocks first or second.
  - NAA summer spill levels are provided, but a fish-count trigger can potentially end summer spill earlier at the lower Snake River projects in August to benefit power when few juvenile fish are migrating.
  - Power contingency reserves can be carried within juvenile fish passage spill.
- Water Management:
  - Account for local runoff volumes in Libby variable discharge (VarQ)[8] draft and refill operations when the Libby water supply forecast is 6.9 Maf or less.
  - Replace Libby end-of-December variable draft target with single 2,420-foot target elevation.
  - Apply updated Upstream Storage Correction method to determine end of April draft requirement for Grand Coulee.

[8] The VARQ FRM procedure was developed to improve the multi-purpose operation of Libby and Hungry Horse dams while not reducing the level of flood protection in the Columbia River. VarQ details are available in the CRSO DEIS FRM Appendix.

- Update Grand Coulee storage reservation diagram (SRD) to account for a reduced planning draft rate limit of 0.8 feet/day and added FRM protection for winter rain-induced flooding below Bonneville Dam.
- Reduce limit on Grand Coulee maximum outflow to account for forecasted increase in outages. Use accelerated maintenance schedule for power plant and spillways instead of the NAA 5-year average.

- Water Supply
  - Increase water supply diversion from Lake Roosevelt, below Hungry Horse Dam, and from Chief Joseph.
- Storage
  - Sliding scale summer target elevation at Libby and Hungry Horse dams.
  - Dworshak cool water releases are made earlier (June and July) and later (September) with reduced flow in August.
  - Increase John Day target elevation in April and May by 1' to reduce avian predation.
- Run-of-River
  - Increased lower Snake Dam operating range (MOP[9] + 1.5 feet).
  - Increased John Day forebay operating range (MOP + 2 feet).
- Structural:
  - Use new higher-efficiency turbines with improved fish passage survival in place of older turbines at John Day.
  - Construct powerhouse surface passage routes at McNary and Ice Harbor dams, which increases the minimum spill relevant for MO1 and affects turbine availability.

1.3.3 Multiple-Objective 2 (MO2)

MO2 represents operations that might be implemented if climate change becomes the primary policy driver in the future. More emphasis is placed on hydropower production and flexibility to integrate other renewable resources to reduce carbon emissions from fossil fuel generating resources. Not all measures in MO2 affect hydropower; MO2 contains the following departures from the NAA that affect the power assessment:

- Fish Passage Spill
  - Fish passage spill amounts are reduced from the NAA, near 110 percent TDG at most projects except when minimum spill levels are higher for powerhouse surface passage routes, for the spillway weirs, and/or for adult attraction to fish ladders.

[9] MOP or minimum operating pool is the lowest forebay operating elevation for a run-of-river project.

- Fish passage spill is curtailed on August 1.
- Power contingency reserves are carried within fish passage spill.

- Water Management
  - Libby VarQ draft and refill operations are modified when water supply forecast is 6.9 Maf or less.
  - Libby end-of-December variable draft procedure replaced with a 2,420-foot target elevation. Implementation of this measure in MO2 is affected by the next measure for additional draft below FRM elevations.
  - Additional draft below FRM elevation for hydropower allowed at Libby, Hungry Horse, Albeni Falls, Grand Coulee, and Dworshak.
  - Updated upstream Storage Corrections Method is applied to the Grand Coulee SRD.
  - Update Grand Coulee SRD to account for a reduced planning draft rate limit of 0.8 feet/day and added FRM protection for winter rain-induced flooding below Bonneville Dam.
  - Reduced limit on Grand Coulee maximum outflow to account for forecasted increase in outages. Use accelerated maintenance schedule for power plant and spillways instead of NAA 5-year average.
- Water Supply
  - Water supply measures are unchanged from NAA in MO2.
- Storage
  - Sliding scale summer target elevation at Libby and Hungry Horse dams.
  - Storage projects are allowed to draft slightly deeper to meet power demand during the most valuable periods of high demand in the fall and winter allowing slightly more generation in the winter and slightly less during the spring.
- Run of River
  - Unrestricted forebay operations (i.e., no seasonal restrictions to MOP and minimum irrigation pool [MIP] provide more flexibility for power generation at the lower Snake and Columbia rivers run-of-river projects). This flexibility provides increased ability to serve peak load obligations, increased renewable resource integration capability, and energy market price effects.
  - Operate turbines across their full range of capacity year-round.
  - Zero generation operations may occur on lower Snake River projects November – February.
- Structural
  - New higher efficiency turbines with improved fish passage survival replaced older turbines at John Day.

- Added powerhouse surface passage at John Day, McNary, and Ice Harbor Dams, which increases the minimum spill relevant for MO2 and affects turbine availability.

1.3.4 Multiple-Objective 3 (MO3)

MO3 breaches the four lower Snake River dams and adds other measures beneficial to resident and mainstem anadromous fish. For power purposes, a generic future year after the dams are removed is being modeled. Not all measures in MO3 affect hydropower; MO3 contains the following departures from the NAA that affect the power assessment:

- Dam Breach
  - Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams are breached by removing earthen embankments.
- Fish Passage Spill
  - Spring spill for fish passage at the four lower Columbia River dams up to 120 percent TDG.
  - Reduced duration of summer juvenile fish passage spill (curtailed on August 1).
  - Power contingency reserves can be carried within fish passage spill.
- Water Management
  - Libby VarQ draft and refill operations are modified when water supply forecast is 6.9 Maf or less.
  - Libby end-of-December variable draft procedure replaced with a 2,420-foot target elevation but allow power drafts down to 20 feet lower.
  - Updated upstream Storage Corrections Method is applied to the Grand Coulee SRD.
  - Update Grand Coulee SRD to account for a reduced planning draft rate limit of 0.8 feet/day.
  - Reduced limit on Grand Coulee maximum outflow to account for forecasted increase in maintenance outages. Use accelerated maintenance schedule for power plant and spillways instead of NAA 5-year average.
- Water Supply
  - Increase water supply diversion from Lake Roosevelt, below Hungry Horse Dam, and from Chief Joseph Dam (Lake Rufus Woods).
- Storage
  - Sliding scale summer target elevation at Libby and Hungry Horse dams.
- Run of River
  - John Day allowed to operate up to full pool except as needed for flood risk management.

- Lower Columbia project turbines can be operated within and above 1 percent peak efficiency in juvenile fish passage season.

- Structural
  - New higher efficiency turbines with improved fish passage survival replaced older turbines at John Day.
  - Additional powerhouse surface passage at McNary Dam, to increase the minimum spill relevant for MO3 and affects the turbine availability.

1.3.5 Multiple-Objective 4 (MO4)

MO4 includes aggressive measures to aid anadromous fish survival without breaching the lower Snake River dams. Not all measures in MO4 affect hydropower; MO4 contains the following departures from the NAA that affect the power assessment:

- Fish Passage Spill
  - Spill through modified spillway weirs at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary and John Day projects during October and November for steelhead overshoots, overwintering steelhead, and kelt.
  - Spill to 125 percent TDG for juvenile anadromous fish passage is provided from March 1 to August 31.
  - Power contingency reserves may be carried within fish passage spill.
- Water Management
  - Libby VarQ draft and refill operations account for local runoff volumes when that same water supply forecast is 6.9 Maf or less.
  - Replace Libby end-of-December variable draft procedure with a 2,420-foot target elevation.
  - Apply updated upstream Storage Corrections Method to the Grand Coulee SRD.
  - Update Grand Coulee SRD to account for a reduced planning draft rate limit of 0.8 feet/day and added FRM protection for winter rain-induced flooding below Bonneville Dam.
  - Reduced limit on Grand Coulee maximum outflow to account for forecasted increase in maintenance outages. Use accelerated maintenance schedule for power plant and spillways instead of NAA 5-year average.
- Water Supply
  - Increase water supply diversion from Lake Roosevelt, below Hungry Horse Dam, and from Chief Joseph.

- Storage
    - Release up to 2 Maf of additional water from upstream federal storage projects to support 220 kcfs (thousand cubic feet per second) spring and 200 kcfs summer target flows at McNary.
    - Sliding scale summer target elevations at Libby and Hungry Horse dams.
    - Manage Libby outflow in November through March to limit Bonners Ferry stage to maximum of 1,753 feet National Geodetic Vertical Datum of 1929 (NGVD29) for riparian habitat protection.
- Run of River
    - The eight Lower Snake River and Lower Columbia River projects are operated within MOP+1.5 feet from mid-March to late August.
    - Operate lower Snake and Columbia River dam turbines within or above 1 percent peak efficiency during fish passage season.
- Structural
    - Construct additional powerhouse surface passage routes to meet system-wide PITPH[10] target at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, and/or John Day dams. This also increases the minimum spill relevant for MO4 and affects turbine availability.

1.3.6 Draft Preferred Alternative (PA)

The Preferred Alternative combines a number of measures to benefit fish as well some measures for water management, power production, and water supply. The PA contains the following departures from the NAA that affect the power assessment:

- Fish Passage Spill:
    - This measure is a revised juvenile fish passage spill operation based upon results of the spring 2019 Flexible Spill Test Operation and analysis of the four MO Alternatives.
    - In a 24-hour period, the Juvenile Fish Passage Spill measure would involve 16 hours of spill operations up to 125% TDG at most projects for juvenile outmigration. For the remaining 8 hours, the projects would spill at a lower level, up to 125% TDG. These spill levels are slightly variable, depending on the project (see DEIS Chapter 7). These operations would be implemented during the spring juvenile migration, April 3 – June 21, at the lower Snake River projects, and April 10 – June 16 at 5 the lower Columbia River projects. When Flex Spill ceases, the projects would transition to summer spill operations.

[10] PITPH is a metric that estimates the proportion of juvenile fish passing a dam via the powerhouse. It is based on the relationship between the proportion of juvenile fish that pass via spill and the proportion that pass via the turbines and bypass systems at the dam.

- PA summer spill levels are described in DEIS Chapter 7 with a late summer transition spill operation from August 15 - 31.
- Power contingency reserves can be carried within juvenile fish passage spill.

- Water Management:
  - Account for local runoff volumes in Libby variable discharge (VarQ)[11] draft and refill operations when the Libby water supply forecast is below 6.9 Maf. Revert to NAA operation for years with water supply forecasts above 6.9 Maf.
  - Apply updated Upstream Storage Correction method to determine end of April draft requirement for Grand Coulee.
  - Update Grand Coulee storage reservation diagram (SRD) to account for a reduced planning draft rate limit of 0.8 feet/day.
  - Reduce limit on Grand Coulee maximum outflow to account for forecasted increase in outages. Use accelerated maintenance schedule for power plant and spillways instead of the NAA 5-year average.
- Water Supply
  - Increase water supply diversion from Lake Roosevelt by 45,000 acre-feet of water above the NAA.
- Storage
  - Sliding scale summer target elevation at Libby and Hungry Horse dams.
  - Dworshak will be operated with a variable draft elevation target to increase hydropower generation in the winter and reduce non-fish passage spill in the spring, while protecting the refill of the reservoir.
  - Operate John Day pool between 264.5 – 266.5 feet during April 10 – June 15 to reduce avian predation.
- Run-of-River
  - Increased lower Snake Dam operating range (MOP[12] + 1.5 feet).
  - Increased John Day forebay operating range (MOP + 2 feet).
  - John Day full pool measure would allow for operation of the reservoir across the full range 262.0 – 266.5 feet elevation outside of fish passage season, except as needed for structural measures

[11] The VARQ FRM procedure was developed to improve the multi-purpose operation of Libby and Hungry Horse dams while not reducing the level of flood protection in the Columbia River. VarQ details are available in the CRSO DEIS FRM Appendix.
[12] MOP or minimum operating pool is the lowest forebay operating elevation for a run-of-river project.

1224 - Zero generation operations may occur on lower Snake River projects October 15 –
1225 February with revised timing of the measure to provide hydropower flexibility to integrate
1226 new renewable resources and while minimizing impacts to ESA-listed fish.

1227 • Structural:

1228 - Use new higher-efficiency turbines with improved fish passage survival in place of older
1229 turbines at John Day.

1230 - Construct powerhouse surface passage routes at McNary and Ice Harbor dams, which
1231 increases the minimum spill relevant for PA and affects turbine availability.

1232

CHAPTER 2 - HYDROPOWER SYSTEM OPERATIONS REVIEW UNDER NEPA

2.1 HYDROPOWER IN THE COLUMBIA RIVER SYSTEM MANAGEMENT AREA

The Columbia River and its tributaries provide the Pacific Northwest with some of the nation's cheapest and cleanest, carbon free electric power. The Columbia River produces more hydropower than any other river in the United States. While most of the nation is powered by coal, natural gas, and a growing number of renewable resources, the Pacific Northwest runs primarily on water. Hydropower is not without its potential faults as spills can increase TDG, reservoirs can increase water temperatures, dams present fish passage challenges, and projects can leak oil and other chemicals. Nevertheless, many consider them to be clean and economical due to their use of streamflows to produce carbon-free power. Federal and non-Federal dams in the Pacific Northwest produce 50 percent of the region's electric energy and have 54 percent of its electric capacity, primarily from the Columbia River and its tributaries[13]. Most Federal power is currently sold at cost to the region's consumer-owned utilities. Other regional utilities, such as investor owned utilities, also have statutory rights to purchase federal power from Bonneville. Thus, hydropower is vitally important to the Pacific Northwest's economy.

This appendix provides the power production results of the CRSO DEIS alternative for generation averages, generation peak capability, system reliability and flexibility, and carbon-fueled resource use. These hydropower results were used as input to the analyses provided in the *P&T Socioeconomic Appendix* and *Air Quality* Appendix of the CRSO DEIS.

2.2 HYDROPOWER INTERACTION WITH MULTIPLE USES

Hydropower is one of many authorized purposes of the CRS dams that affects and is affected by other authorized and incidental uses. This section summarizes how hydropower operations interact with the other uses.

2.2.1 Flood Risk Management

Hydropower and FRM are generally complimentary of each other. Columbia River flooding generally occurs with the rapid snowmelt of late spring, often in combination with spring rains. Storage reservoirs are drafted in the fall and winter months to create space to store runoff. This draft provides water used for power production during fall and winter months when streamflows are typically low to produce firm power to meet regional power customer load demands, which are typically higher than in the spring.

2.2.2 Anadromous Fish

Construction of certain Federal and non-Federal hydropower facilities without fish passage facilities blocked salmon and steelhead species' access to portions of the Columbia River and

[13] Pacific Northwest Hydropower for the 21st Century Power Grid. Accessed at https://www.nwcouncil.org/energy/energy-topics/hydropower

tributaries. The eight CRS run-of-river lower Snake and Columbia River dams have fish ladders to provide for upstream fish migration and juvenile fish bypass systems and spill programs for downstream fish migration. Grand Coulee Dam and then Chief Joseph Dam blocked access to the upper Columbia River. The Hells Canyon Complex (Idaho Power) blocked access to the upper Snake River. Dworshak blocked access to the North Fork Clearwater River. Implementation of several operational, structural, and mitigating actions to reduce the adverse effects of these projects on anadromous salmon and steelhead affect the hydropower analyses as provided herein. Flow augmentation actions are provided at different times of the year to improve in-stream conditions for juvenile fish migration in the mid and lower Columbia and lower Snake Rivers. Augmentation also is provided for spawning and rearing conditions in portions of these rivers. Flow augmentation measures that increase spring and early summer flows tend to reduce hydropower benefits. Operational measures that increase fall and winter flows can be beneficial to hydropower.

Juvenile fish passage spill operations are provided at the four lower Snake River and four lower Columbia River dams during spring and summer migration periods. Spill for juvenile fish passage generally reduces hydropower production, especially during times of normal or relatively low spring or summer flows. There are conditions during periods of relatively high spring flows when the effects of spill for passage on power are minimized from lack of need or available turbines for surplus generation.

Fish screens are installed at many powerhouses to direct juvenile fish to bypass systems. These improve fish survival, but limit power production by reducing efficiency, typically by 1 to 3 percent. In spite of efforts to provide passage through collection systems and spill, some juvenile fish migrate through the powerhouse turbines. Turbine generator units operate at ± 1 percent of their most efficient operating level, which may improve survival of fish passage through a turbine, but limits power flexibility.

John Day and the four lower Snake River dams operate at lower portions of their 3- to 5-foot operating ranges to help reduce juvenile fish reservoir migration time during the fish passage season. Power flexibility is reduced when the reservoir operating range is reduced.

There are several CRSO DEIS alternative measures, especially structural and offsite mitigation actions, which would benefit anadromous fish but do not affect the hydropower analysis in this appendix including improved surface passage facilities, improved fish ladder systems, fish transportation systems (barging), and habit improvements.

2.2.3 Resident Fish

Libby, Hungry Horse, Albeni Falls, Grand Coulee, and Dworshak dams all have operating measures to improve resident fish conditions in their reservoirs and river reaches below the dams. Operations that tend to increase minimum outflows often reduce benefits to hydropower. Operations that limit summer drafts to benefit resident fish can limit power production that may be offset by releasing retained water later in the fall or winter. Operations that limit fall and early draft (Albeni Falls) can reduce power benefits.

2.2.4 Water Quality

Water temperature and TDG are the two main water quality parameters affected by system operations. Water quality within the river system must be adequate to support aquatic life, municipal or industrial use, and water recreation. The co-lead agencies implement several temperature measures that help mitigate temperature and TDG effects and affect hydropower production.

2.2.4.1 Temperature

Minimum outflow requirements can help meet downstream temperature objectives. Libby, Hungry Horse, and Dworshak all have selective withdrawal structures for their powerhouses, which allow water to be released at different temperatures from stratified layers in their reservoirs. The release timing and amount affects power production.

2.2.4.2 Total Dissolved Gas

Spill at dams can result in increased levels of TDG, which can be harmful to fish. TDG generally increases with increased spill levels. Spills for fish passage at the Snake River and Columbia River dams is limited to state water quality standards. Waivers to the water quality standards have allowed targeting higher TDG levels for fish passage. Spill affects hydropower production by reducing the amount of water going through the turbines. During periods of particularly high flow, more water may also be spilled when there is not enough turbine capacity to route the excess water through the turbines and/or when there is a large surplus of power and no ability to market it (termed lack-of-market spill).

2.2.5 Irrigation and Water Supply

There are several federal and non-federal irrigation and water supply projects that withdraw surface water from the Columbia River and its tributaries. Irrigation withdrawals from the Columbia River and its tributaries reduce instream flows and consequently reduce the amount of water available for power production.

2.2.6 Navigation

Navigation locks provide commercial and recreational watercraft passage at the eight lower Snake River and lower Columbia River Corps-operated dams. A relatively small amount of water bypasses the powerhouses during filling and emptying the locks.

2.2.7 Recreation

Recreation facilities including parks, boat ramps, and docks have been constructed at all the federal reservoirs and in many river reaches below the dams. Reservoir recreation is generally best during warmer spring and summer months when the reservoir is full or near full and all facilities are operable. Reservoir operations are generally incidental to operations for FRM and Endangered Species Act purposes. Nevertheless, operations that promote early spring filling or

limit reservoir draft in late summer can affect power production. Occasionally short-term operations support recreation, which limit operations for power.

2.2.8 Transmission

The Pacific Northwest hydropower projects and numerous non-hydropower resources connect to the Bonneville high voltage transmission system and/or interconnected with the west coast power grid which is known as the Western Interconnection. Within the WECC, Bonneville operates the Federal Columbia River Transmission system in the northwest. Bonneville's Transmission Services is responsible for transmission reliability in its territory. This includes ensuring that transmission lines have sufficient capacity to transmit power from the generating resources to the locations where the electricity is used. As part of the CRSO EIS, Bonneville is analyzing the impact of the alternatives on its transmission reliability and assessing whether new transmission infrastructure may be needed for the alternatives. Bonneville's service area and major transmission lines are shown in Figure 2-1. The CRSO DEIS transmission analysis is described in *P&T Socioeconomic Appendix* document.

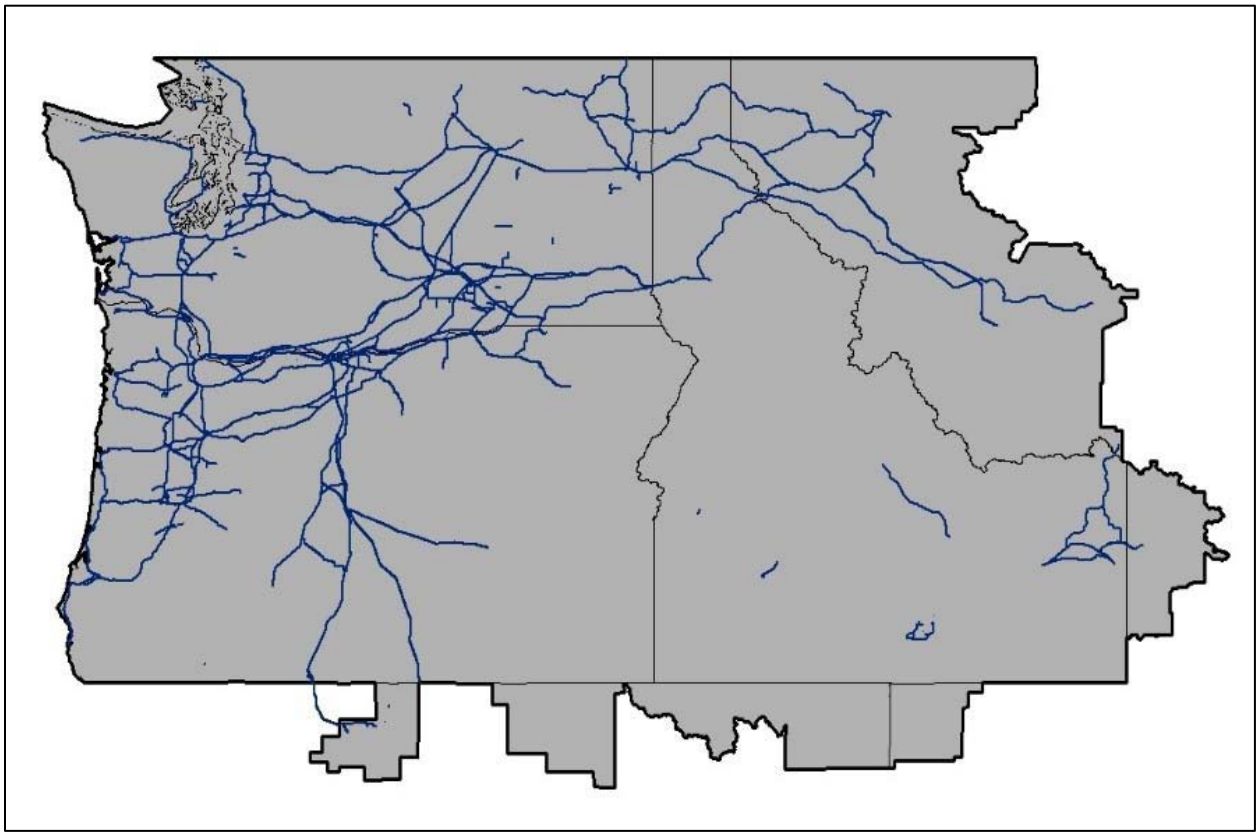


Figure 2-1. Bonneville Service Area and Transmission Lines

An important component of grid reliability is to ensure that electricity generation matches electricity demand at all times. Many of the hydropower resources on the grid can be operated to rapidly increase or decrease generation in response to fluctuating electrical demand needed

to meet load or fluctuations in the generation of wind and solar and other resources, providing power flexibility that maintains a safe, reliable transmission system. The standby capacity and the ability to decrease generation are called generating reserves. Bonneville's power operations provide this service to the transmission operations. A subset of generating reserves are capacity reserves. They are used to replace generation when another generating unit stops unexpectedly or a transmission line that is importing energy suddenly cannot import the power. Contingency reserves are provided for 30-90 minutes until Bonneville can purchase power on the next cycle of the hourly spot market (i.e., the wholesale power market). Hydropower dams are a valuable tool for providing power flexibility when needed. The need for resources that can quickly respond to changes in the system is increasing as more wind and solar generation resources – resources that can vary rapidly due to changes in wind and sun within hours, minutes, and even seconds – are added in the region and the broader Western Interconnection. Hydropower can usually respond to these sudden changes and help integrate wind and solar power to the grid when there is operational flexibility for hydropower.

2.2.9 System Generation and Loads

The Pacific Northwest hydropower system consists of different hydropower systems or groupings of hydropower projects. The hydropower effects from the CRSO DEIS alternatives are provided in the following groupings of projects:

- Columbia River System– includes generation from the 14 projects.
- Federal – includes the 14 CRS projects plus 17 others for a total of 31 Federal projects in the FCRPS
- Mid-Columbia projects – includes the 5 Mid-Columbia non-Federal projects which incur many of the hydropower effects from the CRSO alternatives due to their location directly downstream of Grand Coulee and Chief Joseph dams.
- NW-US system – includes Federal, Mid-Columbia projects, and other non-Federal generation.
- Canadian Treaty – includes generation from Mica and Keenleyside (Arrow) projects in Canada.
- Canadian Total – includes generation from Canadian Treaty projects and other projects in Canada on the Kootenay and Pend Oreille rivers.

To provide a safe and reliable source of electricity, Bonneville and other Northwest generating utilities must constantly match system generation to load. In addition to hydro, other resources producing firm power to meet load in the region include non-hydropower generation, such as nuclear and fossil-fueled or variable generation produced by renewable resource resources (wind and solar). Hydropower surpluses often result in opportunities to sell surpluses and thereby reduce power production at non-hydropower facilities. If such opportunities to sell excess power do not exist, surplus conditions may result in temporary storage of water in reservoirs if there is flexibility in the operation or spilling water at hydropower projects even

when powerhouse units could generate additional power. During times of water surplus, especially during spring runoff, hydropower surpluses can also be used to displace gas-fired and coal-fired power generation at a relatively low cost with zero carbon emissions. Measures that increase hydropower production and/or flexibility increase hydropower benefits.

When conducting hydropower studies such as those for the CRSO DEIS, the generation resulting from an alternative is often compared to a load forecast. These comparisons inform analysts of several factors including the need for additional resources, availability of surpluses, and reliability. Bonneville makes load/resource comparisons for its own loads and resources as well as comparing loads and resources for the region in various planning analyses.

Energy comparisons in the CRSO DEIS are generally made by comparing HYDSIM generation output resulting from a regional residual hydropower load. Analysts estimate this residual load by subtracting forecasted generation of non-hydropower resources (nuclear and fossil-fuel generation), renewable resource generation (wind and solar), and hydropower independent resource generation (e.g., the other 17 FCRPS projects) from the regional load forecast to arrive at the portion intended to be served by the CRS projects' generation in HYDSIM.

Hourly or peak load comparisons for the CRSO DEIS are made using Hourly Operations Scheduling Simulator (HOSS) output and only for the federal system; hourly studies become increasingly complex when adding the uncertainty of the forecasts and availability of resources of the entire region. Bonneville prepares a federal residual hydropower load by adjusting the Federal load forecast for Bonneville firm power sales contracts and resources not modeled in HOSS. However, for the purposes of this CRSO analysis, the ultimate metric of interest is whether or not one alternative produced more or less generation than another, so the results reported here do not include direct comparisons of generation against load.

Reliability comparisons are made for the CRSO DEIS using GENEration Evaluation SYStem (GENESYS), an hourly regional (Pacific Northwest) model that stochastically games temperature derived regional loads and stochastic variability of regional resources (i.e., streamflow, forced outages, variable wind, and solar). The data input set and assumptions for this analysis uses the NW Council 's 2022 Resource Adequacy Assessment.[14]

2.3 HYDROPOWER MODELS

Bonneville used the HYDSIM, HOSS, AURORA, and GENESYS models for most of its hydropower analyses in the CRSO DEIS. Details of Bonneville's modeling are provided in the CRSO DEIS *Hydroregulation Appendix*.

14 Details for load descriptions are provided in Northwest Power and Conservation Council's (NW Council's) Pacific Northwest Power Supply Adequacy Assessment for 2022 at https://www.nwcouncil.org/energy/energy-advisory-committees/resource-adequacy-advisory-committee

2.3.1 HYDSIM

HYDSIM has been in use at Bonneville for decades and is well-calibrated. HYDSIM is a monthly model, where April and August are split into half-months (e.g., April I and April II) giving 14 HYDSIM periods in each water year. The model has been used for years for hydropower planning at Bonneville and Treaty coordination with Canada and regional utilities. Project inflows, outflows, powerhouse flows, and spills calculated by HYDSIM are period averages. Reservoir elevations and storage contents calculated by HYDSIM are end-of-period. The model produced average generation for each of the 14 periods in 80 water years for each of the projects. Results were calculated for four project groupings: NW-US (Pacific Northwest Federal and non-Federal), Canadian, CRS (Federal), and Mid-Columbia. Summing the generation for all projects in a group for each period resulted in 14-period average generation for each of the 80 water years. The hydropower metrics were then calculated from the final generation data.

More detail on model runs can be found in the *Hydroregulation Appendix*. In the studies described here, the HYDSIM generation output was evaluated, generally using simple spreadsheets, to assess the impacts on metrics for average generation, lowest 10th percentile generation, and critical water generation.

2.3.2 HOSS

Bonneville has used HOSS for many years to study peak- and off-peak generation and reliability. HOSS uses monthly HYDSIM output data to calculate an hourly generation schedule for the Federal hydropower system. This provides generation results on a finer time scale for peak generation metrics. HOSS incorporates the same HYDSIM modeling objectives such as minimum flows, maximum flows, upper rule curves, fish operations, fish passage spill, and other measures pertinent to the CRSO DEIS alternatives.

HOSS results are summarized in the 14 HYDSIM periods for each of the 80 water years of the CRSO DEIS studies. Generation results are provided for the Federal system only. More model run details can be found in the *Hydroregulation Appendix*. The 120-Hour generation and HLH generation tables (14 periods by 80 water years) were then used to compute the 120-hour, 10th percentile HLH, and critical water year HLH metrics.

2.3.3 AURORA

AURORA is a production cost model, developed by Energy Exemplar, Ltd Pty., used by hundreds of utilities globally to forecast short- and long-term electricity prices. Given model inputs (resource build, load forecast, fuel cost, etc.), AURORA produces a price forecast by calculating the least cost solution of meeting system-wide load on an hourly basis, subject to a number of operating constraints. The cost of producing and delivering an additional unit of energy to a location in the system is assumed to approximate the price at that location.

Bonneville uses AURORA to create price distributions by using Monte Carlo sampling of projected loads, hydro generation, gas prices, transmission capacity, wind generation, and

Columbia Generating Station (CGS) capability. Given 80 years of month-average hydropower energy estimates provided by HYDSIM for each of the CRSO DEIS modeling studies, AURORA estimates month-average prices and month-average Lack of Market (LOM) spill MW quantities. LOM spill occurs in AURORA when available hydro generation exceeds transmission capabilities and system load net of lower cost or must-run generation. The AURORA LOM spill estimates are then included as LOM limits in a second pass of HYDSIM.

Energy revenue estimates are developed by applying AURORA prices to the energy differences between each alternative and the reference NAA case.

2.3.4 GENESYS

GENESYS is an economic dispatch model that uses Monte Carlo sampling to simulate short-term load uncertainty, and uncertainty in streamflows, wind, solar, and forced outages for thermal generation plants. The model performs a detailed constrained dispatch of the regulated hydropower projects in the watershed of the Columbia River and a simple dispatch of Pacific Northwest regional thermal plants against an extra-regional import market.

The model was developed by Northwest Power and Conservation Council (NWPCC), Bonneville, and other regional entities, and is used to perform studies requiring detailed hydropower dispatch for planning purposes. More specifically, NWPCC uses GENESYS for annual adequacy assessments, periodic regulated hydropower flow studies and periodic analysis of lost revenue due to hydropower dispatch change. The adequacy of the regional power supply is assessed probabilistically in GENESYS by evaluating any regional shortfall against NWPCC's adequacy standard. This standard was designed to assess whether the region has sufficient resources to meet growing demand for electricity in future years. Regulated hydropower flow studies have been performed for fish passage survival and life-cycle studies, and climate change scenarios.

For the CRSO DEIS alternatives, the GENESYS model was run by Bonneville staff. Datasets containing hydropower generation plant parameters and constraints (inputs similar to HYDSIM and Reservoir System Simulation [ResSim]), thermal generation plant parameters and constraints, and other generation sources and constraints (i.e., wind and solar power plants) were input into the model. Power demand loads and both long- and short-term generation commitments also were entered into the model.

2.4 HYDROPOWER METRICS

Six hydropower metrics were evaluated in three different categories. In general, Bonneville uses power generation metrics to determine the expected amount of power generated by the amount of water available through powerhouses, which varies because of differing CRSO DEIS alternative measures affecting total flow in the river and different allocations of the total flow between spill and generation. Reliability metrics provide the probability of a regional power outage from changes in hydropower availability and a measure to quantify generation resources system reliability restoration to a specified level. Metric details are provided in Section 2.4.2.

2.4.1 Hydropower Generation Overview

Hydropower modeling produces quantitative results for several metrics. Hydropower production changes generally improve or reduce system benefits in accordance with the following:

- Bonneville and other regional utilities generally experience higher energy demand during the winter months. Typically, there is higher spot (wholesale) market value (i.e., prices for energy) in the winter. Utilities that are short on power often face higher market prices when acquiring additional power during this time. The spring period is typically characterized by surplus generation, low energy demand, and low spot market energy values. Utilities that sell their surplus power into the market during this time generally receive smaller secondary revenues. Fall months are transitional. In the summer, demand for power is slightly less than demand for power in the winter. However, because there is generally less flow (especially later in the summer) and demand for power in the summer is increasing in the region, the summer is also a period of higher value for energy. Depending on whether a utility is long or short on power may expose them to higher spot market prices.
- Energy losses during periods of high energy demand and low flows such as winter can negatively affect the cost and ability of meeting demand. A similar loss during periods of low energy demand and high water such as spring would not have the same magnitude consequence.
- The Loss-of-Load-Probability (LOLP) presented in this analysis indicates a real consequence of generation losses during periods of high demand/low generation. Loss-of-load or curtailment are industry terms for the lights going out. Considering that most regional infrastructure depends on reliable power, an event that results in the loss of power is a human health and safety issue as well as an economic issue. Regional planning authorities and power industry standards demand that the likelihood of curtailments is held below certain levels. When the regional generating resources are determined to be inadequate to meet these standards, generating resources must be added at a significant cost to the ratepayers.
- Analysis of the tail events (such as the 10th percentile metrics) is a standard hydropower metric used to determine resource adequacy. Therefore, losses of any magnitude in this metric would directly affect future resource adequacy.
- The 120-hour capacity metric is a measure of a system's ability to meet monthly load peaks day-after-day under expected load conditions. Any decrement to this metric affects the system's ability to meet short-term peak loads.
- An average gas combustion turbine can produce about 364 MW and the Columbia Generating Station produces an average of 1,075 MW.

These factors provide some general context for quantitative and qualitative results in hydropower production and system reliability from the CRSO DEIS alternatives. There is

substantially more detail in the *P&T Socioeconomic Appendix* on the effects these hydropower generation changes have on regional power rates and other key factors.

2.4.2 Hydropower Generation Metrics

The hydropower generation metrics in this appendix are standards Bonneville uses in several types of studies involving the FCRPS including Bonneville rate cases, system reliability studies, CRT planning studies, and planning studies such as the CRSO DEIS. The *Hydroregulation Appendix* in the CRSO DEIS details how the metric values are quantified. In summary, the generation metrics include:

- Average generation: The average electric power created from an energy source in megawatts (MW). In this appendix, the average generation is reported either by year or by 14-period averages wherein April and August are split into two periods. It is calculated by HYDSIM as the annual average or the 14-period average for the 80 water-years studied.[15]
- 10th percentile average generation: The lowest 10th percentile average generation calculated by HYDSIM from the 80 water-years studied. This metric provides an indication of how much generation can be expected month by month under dry water conditions. The 10th percentile generation level is closely related to what Bonneville studies as part of its Federal System Needs Assessment, which evaluates the ability of the FCRPS to meet projected firm load obligations under various conditions.
- Critical water-year average generation: The generation for water year 1937 (October 1, 1936 – September 30, 1937) is calculated in HYDSIM. This dry water year is the lowest average CRS power generation of all years in the 80-year study period. Production of this amount of hydropower could reasonably be expected if the 1937 conditions repeated under modern system conditions. It is an important metric in determining the need for additional resources (power) to meet the Administrator's load supply obligations or replace aging and retired generating resources. Bonneville's long-term firm power sales to its regional power customers are tied to this metric.
- 120-Hour generation: Calculated by HOSS, it is the average of 120 hours (60 hours for the split months of April and August) with the highest demand for electricity and hence the highest generation averaged for all 80 water years (5 hours/day, 6 days a week for 4 weeks).
- 10th percentile Heavy Load Hour (HLH) generation: The lowest 10th percentile HLH generation average is for hours ending 0700 to 2200 (7 am to 10 pm) of all 80 water years. The Heavy Load Hours are a standard definition in the utility industry referring to blocks of time with relatively higher demand for power. Electric power is routinely traded in the wholesale power market in HLH blocks.
- Critical water year HLH generation: The HLH generation for water year 1937.

[15] The hydropower studies used 80 historic water years as proxies for the potential future water supply. The 80 water years are from the 2010 Modified Flow studies.

2.4.3 Hydropower Revenue Metrics

Estimates of hydropower revenue values are reported in millions of dollars for energy and capacity. Determining revenue value is complex and includes estimating hydropower generation, hydropower revenue, and the challenges of forecasting power prices. Power prices involve forecasts of regional and west-coast-wide power demand and supply and economic conditions historically uncertain. The *Hydroregulation Appendix* provides hydropower generation computation value details. This appendix provides the estimated amounts of hydropower average energy generation and critical water generation for the federal system in Chapter 3.6. The *P&T Socioeconomic Appendix* provides revenue value effects on Bonneville's rates and other economic factors.

2.4.4 System Reliability Metrics

The North American Electric Reliability Corporation (NERC) states there are two components of reliability: resource adequacy and security.[16]

Resource adequacy is the ability of the power system to meet aggregate energy and capacity demand at any time. While there is no regional resource adequacy standard, Bonneville is required by the Northwest Power Act to meet its long-term requirements customers' "firm power load", which means providing power on a continuous, uninterrupted, and on demand basis.[17] Measuring LOLP is a useful metric in evaluating the adequacy of the power supply in the region to meet the firm power needs of Bonneville and other utilities' loads. A high LOLP generally indicates that the power supply in the region is constrained, increasing the probability that a system event, such as an extreme weather event or the loss of a generator, could result in a power shortage or blackout.

Security is defined as the ability of the system to withstand sudden disturbances such as sudden losses of transmission lines or generators. The focus of this analysis is on resource adequacy. (Bonneville is required to carry reserves to be able to increase generation in the case of a disturbance. The required level of reserves was included in the modeling as a fixed input value.)

Bonneville and the NWPCC use LOLP as a fundamental metric of power system reliability. LOLP measures the frequency of a power outage; it does not capture the magnitude or duration of an outage. Bonneville and NWPCC use a standard of 5 percent LOLP (i.e., an adequate power supply should have a 5 percent or less likelihood of at least one load curtailment (power shortage or rolling blackouts) event occurring in 1 year).

[16] *See* 2019 State of Reliability, NERC, at 2, June 2019, *available* https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_SOR_2019.pdf.
[17] *See* 16 U.S.C. § 839c(b)(1); *see also* S. Rep. 96th Cong. 1st Sess. No. 272, 1980 at p. 26.

Bonneville uses the Conditional Value at Risk (CVaR) metric to provide this information. CVaR is expressed in megawatt-months of curtailments during months with the highest probability of an outage and represents the quantity of energy not served.

2.4.5 Integration of Renewable Resources in the System

The metric for resource integration is system generation flexibility. Bonneville models do not have an effective metric to accurately capture changes in flexibility, especially within an hour or from hour-to-hour. A qualitative assessment was prepared based on Bonneville real-time power scheduling experience.

2.4.6 Carbon Emission Metrics

The CRSO DEIS co-lead agencies measure carbon emissions in metric tons of carbon dioxide (CO_2) released into the atmosphere. The amount of CO_2 emitted results from changes to fossil-fueled power production due to hydropower production changes from the CRSO DEIS alternatives. When Bonneville determines it has surplus power (energy, capacity, or both), Bonneville often sells such power to purchasers that either operate or acquire fossil-fueled power. Such purchasers in turn may reduce or turn off their generating plants. Conversely, when there is less hydropower generation than needed to meet demand, fossil-fuel generation may increase to meet the demand. The fossil-fueled production effects of the alternatives are determined in Bonneville's development of potential replacement power resource portfolios and analysis of their potential use in this appendix (Chapter 4.2). The CRSO DEIS *Air Quality Appendix* and *P&T Socioeconomic Appendix* discuss the effects of the CO_2 changes resulting from the changes in fossil fuel production.

2.4.6.1 Methodology

There are numerous generating units supplying power to the Pacific Northwest power system. At any given time, some of these units will be hydroelectric, nuclear, and perhaps wind and solar generating units that do not emit CO_2 while others likely will be coal or natural gas-fired generating units that emit CO_2.

The NWPCC's 7th Power Plan has a conservation strategy for the region to acquire nearly 4,862 average megawatts (aMW) of conservation between 2010 and 2025. Even with this amount of conservation, loads will continue to grow, albeit at a lower rate. State renewable portfolio standards will require the development of approximately 6,100 MW of installed wind capacity by 2025 in addition to the 4,266 MW of wind capacity dedicated to serving regional loads. There are also plans to close several large coal plants in the region. With these changes to the power system, particularly the retirement of large coal plants, thousands of megawatts of additional generating resources in the region for both energy and capacity are needed. New gas-fired generation in addition to the nearly 7,500 MW currently operating plants would provide needed capacity because wind and solar resources are intermittent. However, the Northwest is trending toward reducing fossil-fuel emissions and may choose not to build new gas-fired generation.

Resources, acquired by Bonneville, must be cost effective in accordance with the Northwest Power Act. The Act sets out the following resource priority: conservation, renewable resources, generating resources using waste heat or high fuel conversion efficiency resources, and then all other resources. Resource requirements of entities other than Bonneville are not covered in this CRSO DEIS. However, the last resource dispatched to meet load is considered the marginal resource; it is likely to have higher operating costs than resources used before it. According to the NWPCC report, *Avoided Carbon Dioxide Production Rates of the Northwest Power System*, (NWPCC Report) typically marginal units (units that turn on/off the most in response to changes in demand) are gas-fired power plants now operating in the region and new plants forecasted to be constructed by 2025 (NWPCC 2018).

CHAPTER 3 - IMPACTS OF THE ALTERNATIVES ON HYDROPOWER

3.1 HYDROPOWER GENERATION IMPACTS

This chapter provides the values for hydropower energy and peak generation resulting from the NAA and four Multiple-Objective (MO) alternatives with comparisons to the NAA. Details on the metrics used for the comparisons are in Chapter 2.

3.1.1 Overview

Three metrics were evaluated specifically for hydropower energy generation: average generation, 10th percentile average generation (P10), and critical water year (1937) average generation. In addition, three metrics were evaluated specifically for hydropower peak generation: 120-Hour generation, 10th percentile Heavy Load Hour (HLH P10) generation, and critical water year (1937) Heavy Load Hour (HLH critical water) generation. Hydropower generation impact results for the metrics were produced for each of four systems including: the NW-US system, the 14-dam Federal system (CRS), the five-dam Mid-Columbia system, and the Canadian system (CRT and several non-Treaty projects). A list of the system dams in each system is provided in Exhibit 1.

The NW-US energy results for average, P10, and critical water generation are presented in this chapter. Generation changes from the NAA for all the systems generally reflect the changes observed for the NW-US system and discussed in Section 3.2. Exceptions for the CRS, Mid-Columbia, and Canadian systems are noted. The energy results for the CRS, Mid-Columbia, and Canadian systems are provided in Exhibit 4, Exhibit 5, and Exhibit 6.

The CRS (Federal) peak results are presented in Section 3.3; no NW-US, Mid-Columbia, or Canadian peak results were produced due to modeling limitations.

3.1.2 General Methodology

Bonneville and the Corps collaborated extensively on modeling the CRSO DEIS alternatives. The Corps used ResSim to model the CRSO DEIS alternatives. The resulting 80-year daily or Monte Carlo calculation values from ResSim for reservoir elevations, streamflows, and project spills were used for most of analyses performed for the CRSO DEIS. Because ResSim does not include power drivers in operations and ResSim output did not provide hydropower production values for the alternatives, Bonneville produced the hydropower generation results using HYDSIM. The reservoir and streamflow conditions for each alternative over the 80-year study period in HYDSIM and ResSim studies were closely coordinated to minimize differences. Bonneville also used the HOSS model to develop estimates of the hourly operations for use in estimating peak generation values that contribute to reliability and resource integration analyses. HYDSIM and HOSS modeling and ResSim coordination details are presented in the *Hydroregulation Appendix*. ResSim details are provided in the *Hydrology and Hydraulic Data Analysis Appendix*.

3.2 ENERGY GENERATION RESULTS

Energy generation results for each of the CRSO DEIS alternatives were produced for the U.S., CRS (Federal), Mid-Columbia, and Canadian systems. Generation results for each alternative are driven primarily by storage reservoir objectives for downstream flow measures and specified project spill measures for fish passage Section 1.4 in this document and Chapter 2 of the DEIS provide details about the measures in the alternatives.

This section also compares the energy generation results between the NAA and each alternative and provides the rationale for generation changes from the NAA.

3.2.1 Energy Generation Methodologies

Bonneville used the HYDSIM model output to estimate the average generation, P10 generation, and critical water year generation for each of the alternatives. The average generation is for each of the 14 periods in each year of the 80-year study record. P10 generation is for the lowest 10th percentile average for each of the 14 periods in each year of the 80-year study record. The P10 values for each period will be from different water years, not from the P10 water year. The critical water year generation is the generation from October 1936 through September 1937 from the 80-year study record.

Key study inputs include the measures listed in Section 1.4. Modeling details are provided in the *Hydroregulation Appendix*. After completing the HYDSIM runs, Bonneville noticed generation inadvertently did not account for new high efficiency turbines at John Day Dam in any of the MO alternatives. These new turbines will replace the existing turbines and increase power production efficiency by 4.5 percent at John Day. Time constraints did not permit model revisions for the DEIS. Consequently, the MO alternative 80-year average generation values in this appendix are low by about 45 aMW with a range of 20 to 60 aMW depending on the alternative, month, and water conditions. In addition, HYDSIM did not pick up the elevation limit in December for providing 650 thousand acre-feet of space at Grand Coulee to protect against rain-induced flooding in MO1, MO2, and MO4. Had this elevation constraint been in effect, December generation would have increased by about 450 aMW and January and February generation would have been lower. Annual average generation was not affected.

3.2.2 NW-US Energy Generation Summaries

NW-US system energy generation results are provided from HYDSIM output for average generation in Figure 3-1 and Table 3-1, P10 average generation in Figure 3-2 and Table 3-2, and critical water generation in Figure 3-3 and Table 3-3. Complete results for the NW-US, CRS (Federal), Mid-Columbia, and Canadian systems are provided in figures and tables in Exhibit 4.

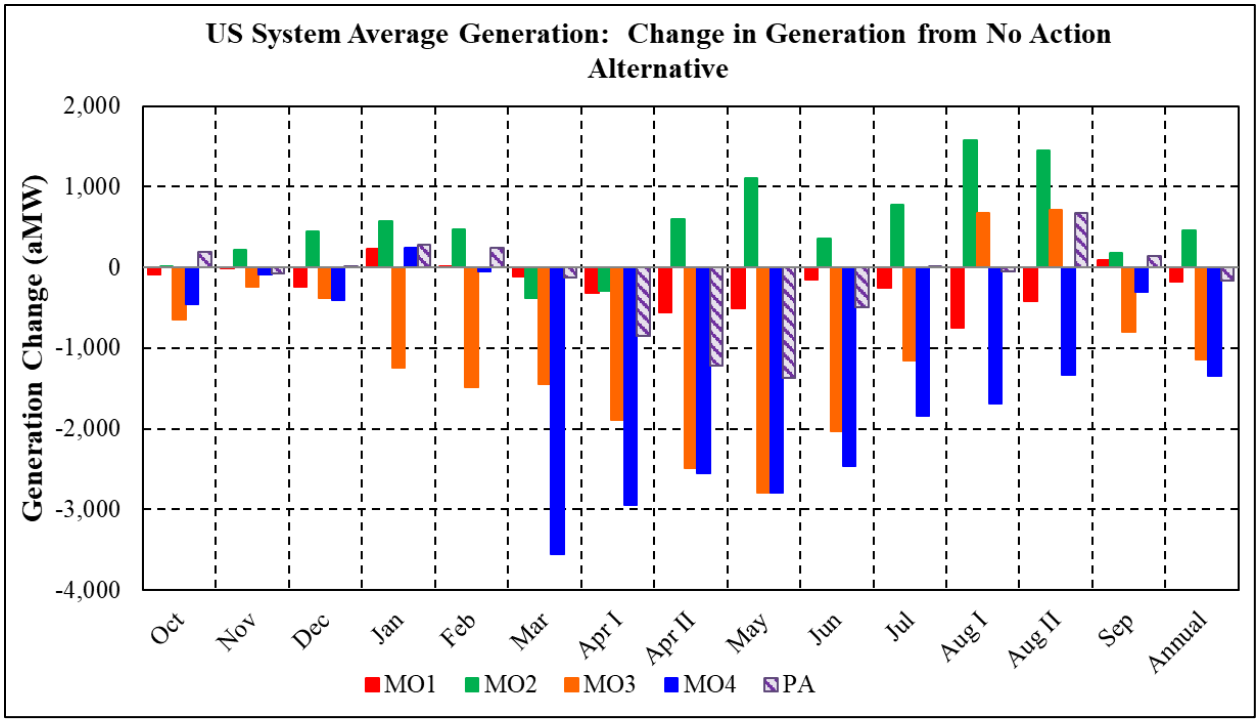


Figure 3-1. NW-US System Average Generation: Change from NAA

Table 3-1. NW-US System Average Generation: Change from NAA

US System Average Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
NAA	9,364	12,205	13,519	15,115	15,299	13,724	12,643	13,469	16,462	17,504	14,173	11,770	10,229	9,215	13,373
MO1	-83	-17	-242	228	16	-117	-317	-558	-506	-147	-258	-745	-416	92	-173
MO2	6	222	450	572	468	-380	-294	602	1,102	361	772	1,574	1,449	177	453
MO3	-646	-234	-380	-1,243	-1,481	-1,451	-1,889	-2,490	-2,786	-2,032	-1,151	678	716	-804	-1,137
MO4	-457	-83	-402	244	-49	-3,549	-2,938	-2,552	-2,793	-2,462	-1,834	-1,693	-1,336	-308	-1,339
PA	189	-78	1	281	244	-130	-855	-1,221	-1,370	-496	4	-53	678	137	-162

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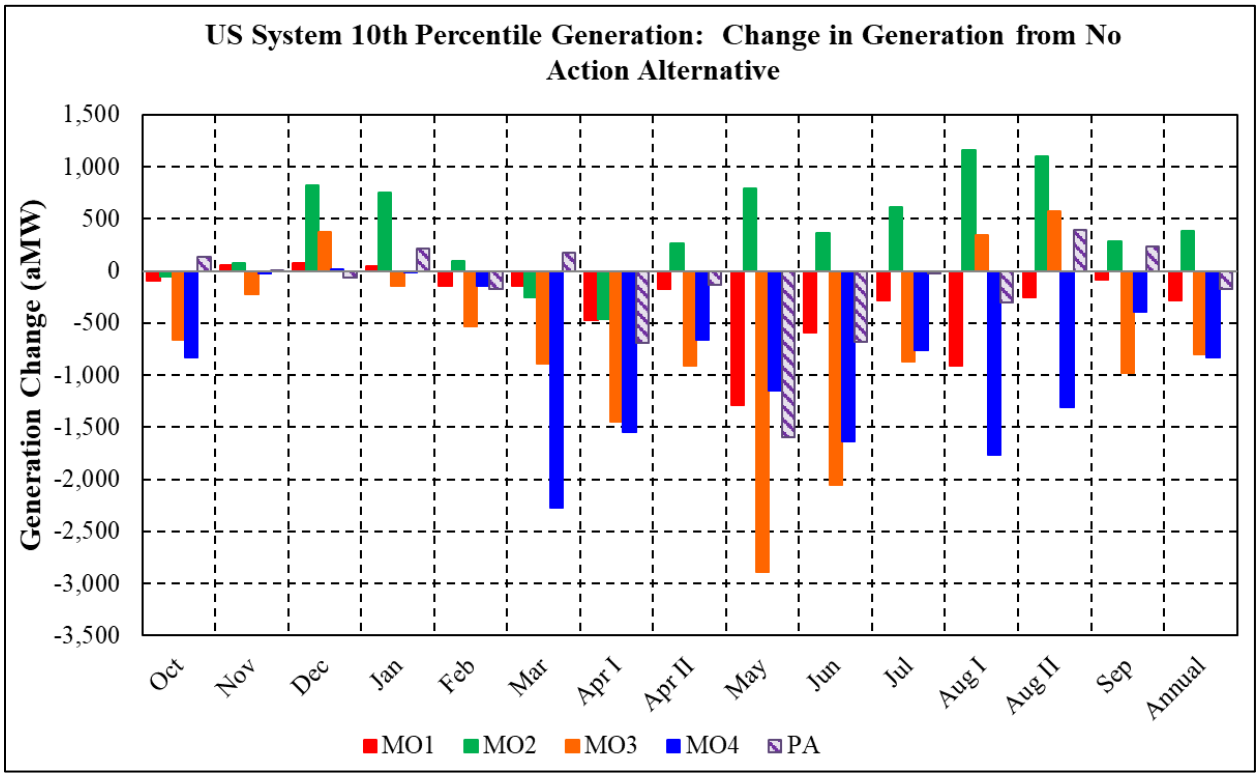

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1732 **Figure 3-2. NW-US System P10 Generation: Change from NAA**

1733 **Table 3-2. NW-US System P10 Generation: Change from NAA**

US System 10th Percentile Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
NAA	8,530	10,662	10,904	10,866	10,228	9,713	8,736	7,814	12,570	13,017	9,557	9,599	8,635	8,307	10,144
MO1	-92	53	79	49	-143	-140	-476	-177	-1,284	-591	-284	-912	-250	-85	-280
MO2	-50	73	818	747	91	-255	-458	263	794	360	609	1,158	1,095	285	380
MO3	-665	-221	374	-140	-536	-888	-1,449	-907	-2,892	-2,056	-867	339	573	-978	-798
MO4	-830	-20	17	-2	-143	-2,278	-1,551	-663	-1,150	-1,632	-766	-1,770	-1,313	-395	-826
PA	138	8	-60	215	-171	174	-694	-132	-1,593	-682	-21	-305	390	239	-176

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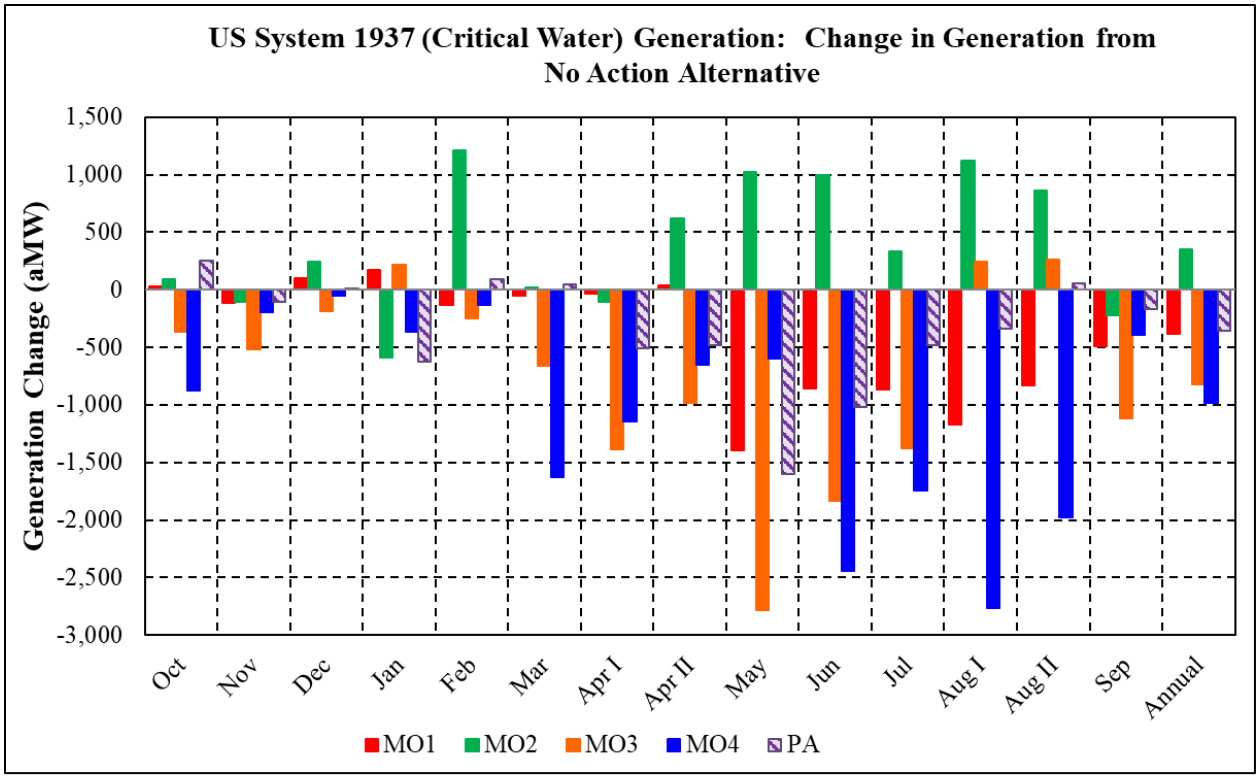


Figure 3-3. NW-US System Critical Water (1937) Generation: Change from NAA

Table 3-3. NW-US System Critical Water (1937) Generation: Change from NAA

US System 1937 (Critical Water) Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
Water Year 1937 (Critical Water)															
NAA	8,766	11,079	11,224	10,754	8,690	9,034	8,707	7,841	11,424	13,914	11,117	10,539	9,405	9,221	10,297
MO1	28	-117	99	177	-129	-50	-36	35	-1,390	-858	-864	-1,172	-829	-489	-385
MO2	90	-105	245	-586	1,210	17	-106	618	1,027	994	332	1,122	866	-224	348
MO3	-366	-520	-184	217	-247	-658	-1,388	-986	-2,784	-1,831	-1,378	246	263	-1,112	-817
MO4	-873	-197	-48	-369	-131	-1,627	-1,147	-653	-601	-2,442	-1,747	-2,768	-1,976	-388	-980
PA	254	-102	8	-622	93	46	-510	-479	-1,596	-1,017	-477	-338	55	-171	-354

3.2.3 NW-US System Energy Generation: MO Comparisons to NAA

The following average generation summary is provided for the NW-US system. Similar trends were observed for the CRS and Mid-Columbia systems, though the Mid-Columbia projects are not affected by spill changes at the CRS projects. Because the Treaty projects were operated the same for each of the CRSO DEIS alternatives, there was relatively little change in the Canadian system. There was no change in the Idaho Power projects because the Hells Canyon Complex and federal projects in the Upper Snake River basin as these also were operated the same for each of the CRSO DEIS alternatives and are upstream of the CRS projects and not impacted by changes in flows from the CRS projects.

3.2.3.1 Energy: NAA compared to MO1

Table 3-4, Table 3-5, and Table 3-6 provide the average, P10, and critical water year differences between NAA and MO1 for the NW-US system. Positive differences indicate an increase in average generation from the NAA.

Table 3-4. NW-US System Average Generation: NAA vs. MO1

NW-US System - Generation (Average MW)															
	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	9,364	12,205	13,519	15,115	15,299	13,724	12,643	13,469	16,462	17,504	14,173	11,770	10,229	9,215	13,373
MO1	9,280	12,188	13,277	15,343	15,315	13,607	12,326	12,911	15,956	17,358	13,915	11,025	9,813	9,306	13,200
Change	-83	-17	-242	228	16	-117	-317	-558	-506	-147	-258	-745	-416	92	-173

Table 3-5. NW-US System P10 Generation: NAA vs. MO1

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	8,530	10,662	10,904	10,866	10,228	9,713	8,736	7,814	12,570	13,017	9,557	9,599	8,635	8,307	10,144
MO1	8,438	10,715	10,983	10,915	10,085	9,573	8,260	7,637	11,286	12,426	9,274	8,687	8,385	8,222	9,865
Change	-92	53	79	49	-143	-140	-476	-177	-1,284	-591	-284	-912	-250	-85	-280

Table 3-6. NW-US System Critical Water (1937) Generation: NAA vs. MO1

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	8,766	11,079	11,224	10,754	8,690	9,034	8,707	7,841	11,424	13,914	11,117	10,539	9,405	9,221	10,297
MO1	8,794	10,962	11,323	10,931	8,560	8,984	8,671	7,876	10,034	13,056	10,252	9,366	8,576	8,732	9,912
Change	28	-117	99	177	-129	-50	-36	35	-1,390	-858	-864	-1,172	-829	-489	-385

Figure 3-4 and Figure 3-5 also illustrate the individual project differences for major individual NW-US system projects for average and critical year (1937) generation. The solid “Sys” line indicates the Federal plus Mid-Columbia generation difference from the NAA. (The Federal plus Mid-Columbia projects constitute the majority of changes between MO1 and NAA, but there would also be some changes at the other non-Federal projects comprising the NW US system.) The individual project blocks indicate the amount of change in project average generation from the NAA. Project blocks above the zero line indicate a project generated more than the NAA; blocks below the zero line indicate less generation than the NAA. Detailed information for the individual project differences is provided in Exhibit 3.

The individual projects in Figure 3-4 include the 14 CRS projects plus the 5 Mid-Columbia projects: Grand Coulee (GCL), Chief Joseph (CHJ), Wells (WEL), Rocky Reach (RRC), Rock Island (RKI), Wanapum (WAN), Priest Rapids (PRD), McNary (MCN), The Dalles (TDA), John Day (JDA), Bonneville (BON), Libby (LIB), Hungry Horse (HGH), Dworshak (DWR), Lower Granite (LWG), Little Goose (LGS), Lower Monumental (LMN), and Ice Harbor (IHR).

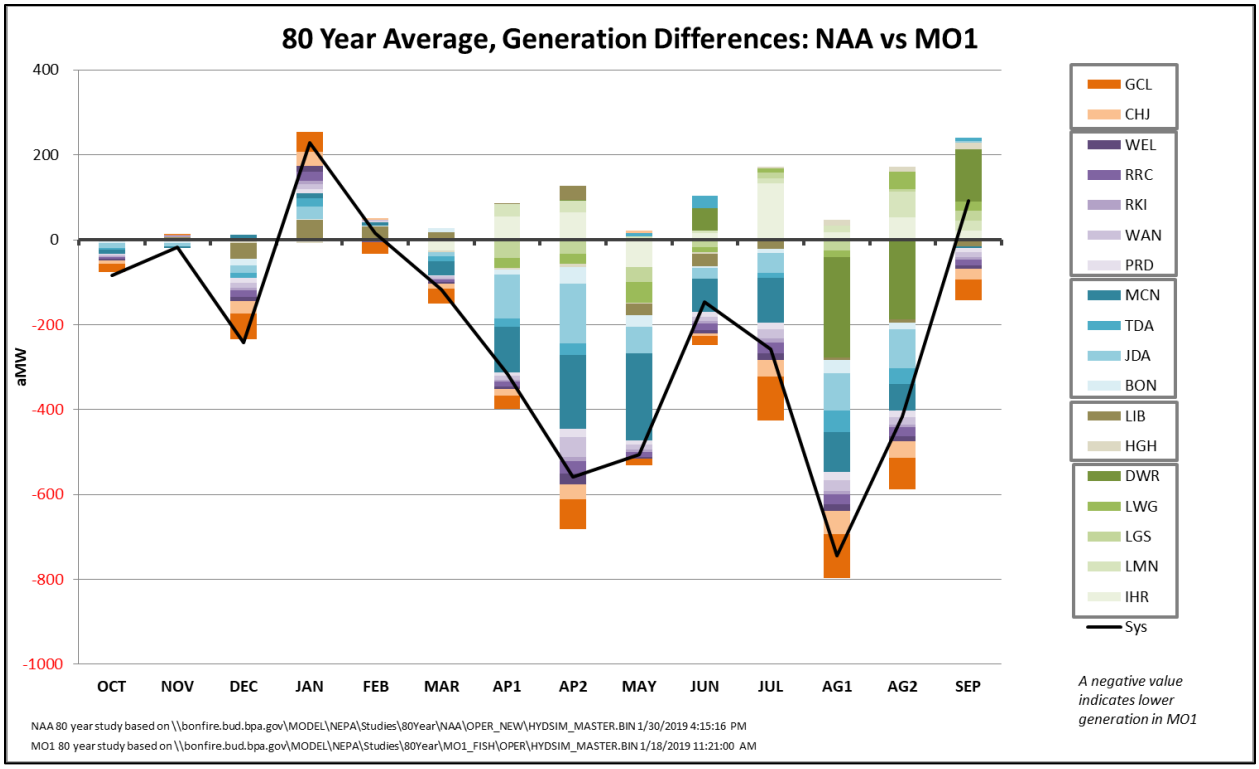


Figure 3-4. NW-US System and Project Average Generation: NAA vs. MO1

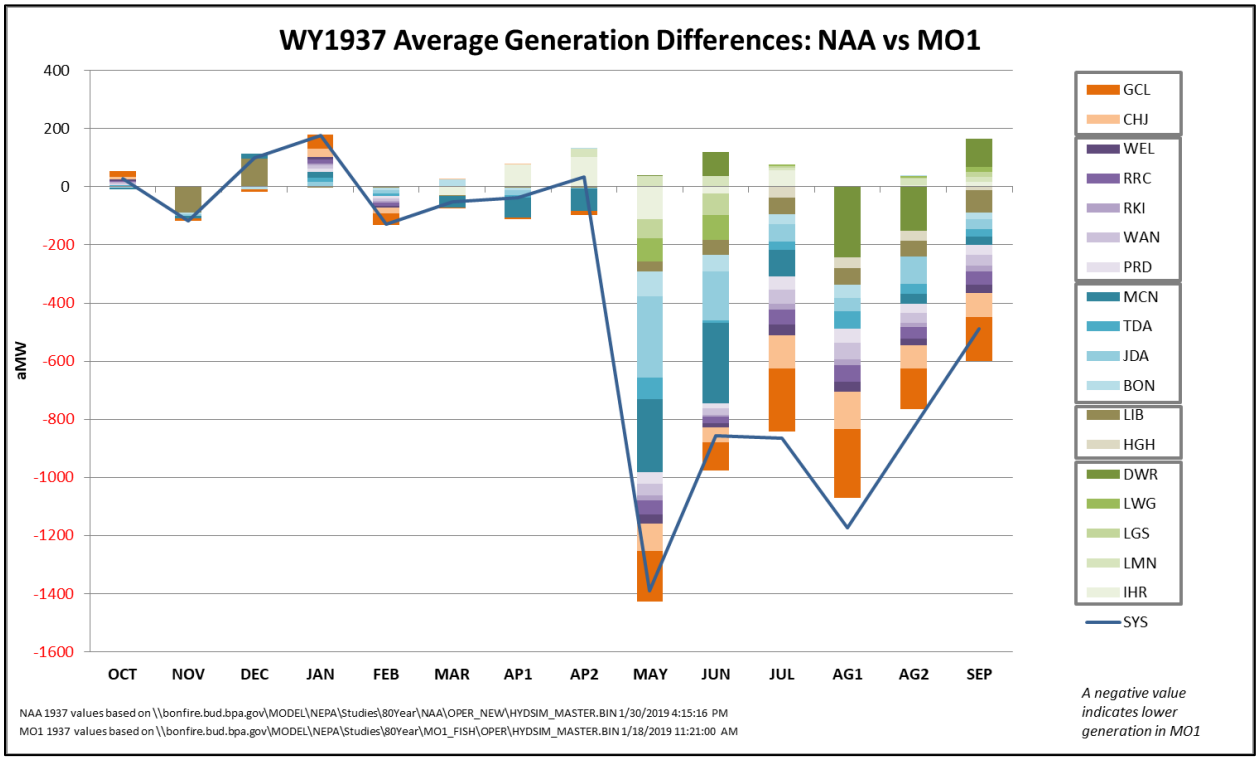


Figure 3-5. NW-US System and Project Critical Water Generation: NAA vs. MO1

Generation changes between NAA and MO1 primarily result from the following:

December: The reduction in generation in December is partially due to Libby ending December at a target of 2,420 feet NGVD29 (about 3.8 feet higher on average than the NAA variable target); the reduction in inflows to Grand Coulee, combined with essentially the same end of month elevation, means there is less generation both at the project and at all the projects downstream. However, the December operation at Grand Coulee for protection against rain-induced flooding that was inadvertently not picked up in HYDSIM would have offset this effect. This additional month of the operation would have increased December generation in years where an increase in flows was possible and decreased January generation by up to 450 MW in the years with the largest effect.

January: The largest portion of the increase in average generation in January is the result of Grand Coulee changes. In MO1, Grand Coulee ends December slightly higher, and ends January on average almost 2 feet lower, than NAA. This, in addition to changes from FRM (specifically winter flood operations that vacate additional space and maintain that space through March in case of rain events), increased generation at Grand Coulee (and therefore also the downstream projects).

March-June: Based on preliminary modeling, the hydro modelers initially expected to see an increase in spill and potentially flow constraints at Grand Coulee during the drawdown in late spring and possibly during refill if drawdown before run-off was not fully achieved in very large water years due to Grand Coulee maintenance operations measure. However, when the complete MOs were modeled together with the measure for a 0.8-foot planned draft rate, the Grand Coulee maintenance measure did not appear to have a significant effect on operations.

April-May: MO1 is generating less in the spring because MO1 greatly increased spring spill. Both blocks of the alternating block pattern have higher spill than the NAA spring spill levels. In alternating years, the block for the first half of spring spill (through May 11) is either to 120 percent TDG in the tailrace limited to 115 percent in the forebay or slightly higher spill levels than the overall spring spill in NAA and the 2017 Fish Passage Plan.

June-July: MO1 generates less power because its summer spill is slightly higher than in the NAA. Some of the decrease in generation is offset by higher releases from Dworshak in June and July. The higher Dworshak outflows also allow the lower Snake River projects that spill to a fixed amount to generate more than in the NAA; the additional outflows also offset some generation loss at the lower Snake River projects that have summer spill set to a greater percent of outflow than in the NAA.

August: The MO1 change in the operation at Dworshak moves some of the August outflow into June, July, and September resulting in less outflow from Dworshak and in the lower Snake River projects during August. This combined with higher MO1 summer spill results in less generation, which is somewhat offset in the second half of August due to MO1's end date for summer spill at the lower Snake River projects being earlier than NAA's. In some periods (primarily in August due to the reduced flows from Dworshak), HYDSIM modeling showed that not enough water

flows in the lower Snake River to meet minimum turbine flows, powerhouse surface passage spill, and flow needed for the navigation locks and fish ladders. This exemplifies how little water is flowing in the lower Snake River in August and matches the observation of very little generation in August.

September: The small generation increase in September is due to the slight increase in outflows at Dworshak and the projects downstream as part of the MO1 adult fish measure. This increase offsets the generation decreases at Grand Coulee and Chief Joseph resulting from lower inflow due to an ending elevation increase at Libby in many years (a result of the sliding scale measure).

MO1: P10 VS. AVERAGE GENERATION

As observed with the annual average of 80 years, the annual average generation for the P10 driest years in MO1 (Table 3-5) are lower than NAA. In the P10, the difference between generation in MO1 and NAA is larger than the difference calculated for the average of all water years. Looking at the specific months, this effect is strongest in May and June.

In turn, November and December have a slight increase in generation for the 10th percentile driest years compared to No Action unlike the month-average generation for all water years.

MO1: CRITICAL WATER VS. AVERAGE GENERATION

In the critical water (Table 3-6), MO1 loses more generation than P10 generation relative to NAA than in the 80-year average. The annual loss in critical year generation is a primary input to the agency's calculation of the minimum annual power it can depend on generating with the hydro-system even in a "bad year" which determined how much firm power (power guaranteed to be continuously available) from the FCRPS is available in meeting the Administrator's long-term firm power contract obligations. In order to be in a load/resource balance, any reductions in the amount of firm power produced by the FCRPS must be acquired from other resources. Taking the monthly view, the large losses in generation in July and August would likely lead to power shortages during this period as analyzed in Chapter 4 of the LOLP study.

3.2.3.2 Energy: NAA compared to MO2

Table 3-7 through Table 3-9 provide the average, P10, and critical water generation differences between NAA and MO2 for the NW-US system. Positive differences indicate an increase in average generation from the NAA. Figure 3-6 and Figure 3-7 also indicate the individual project differences for major individual United States projects for average and critical water year (1937) generation. Detailed information by project for the critical water differences is provided in Exhibit 3.

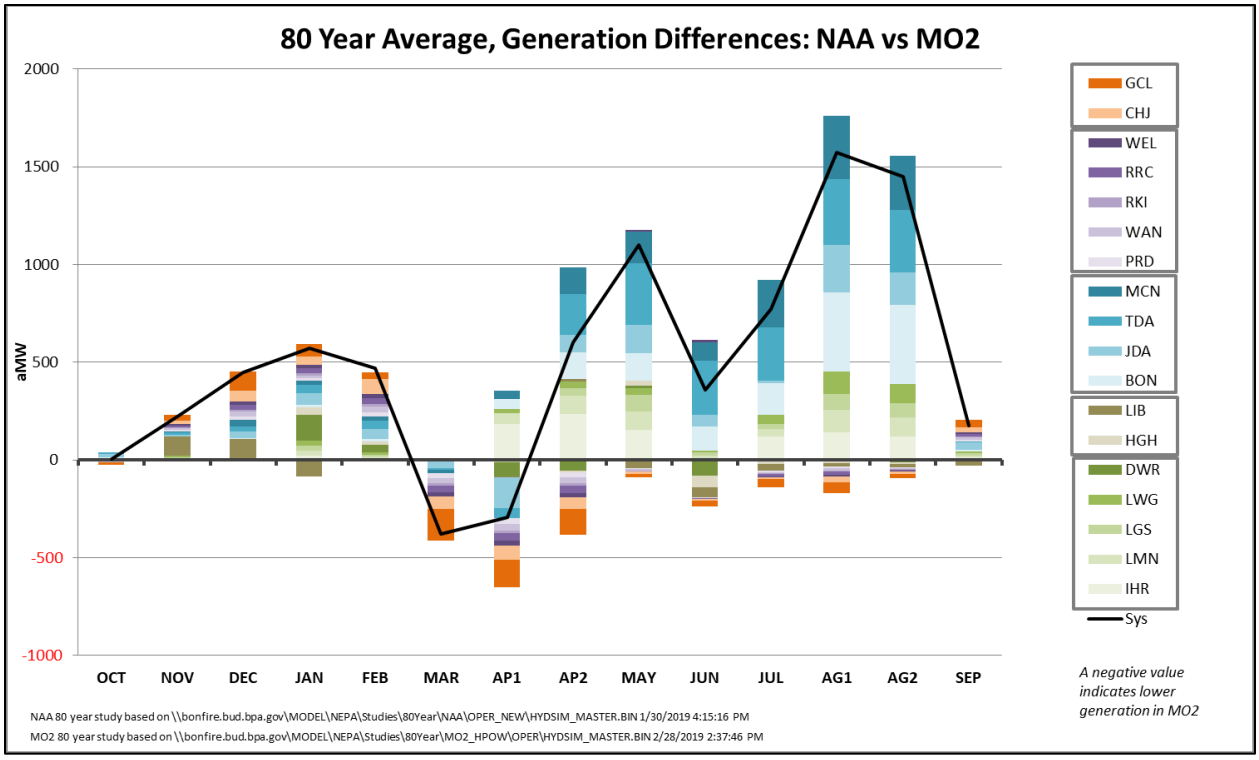


Figure 3-6. NW-US System and Project Average Generation: NAA vs. MO2

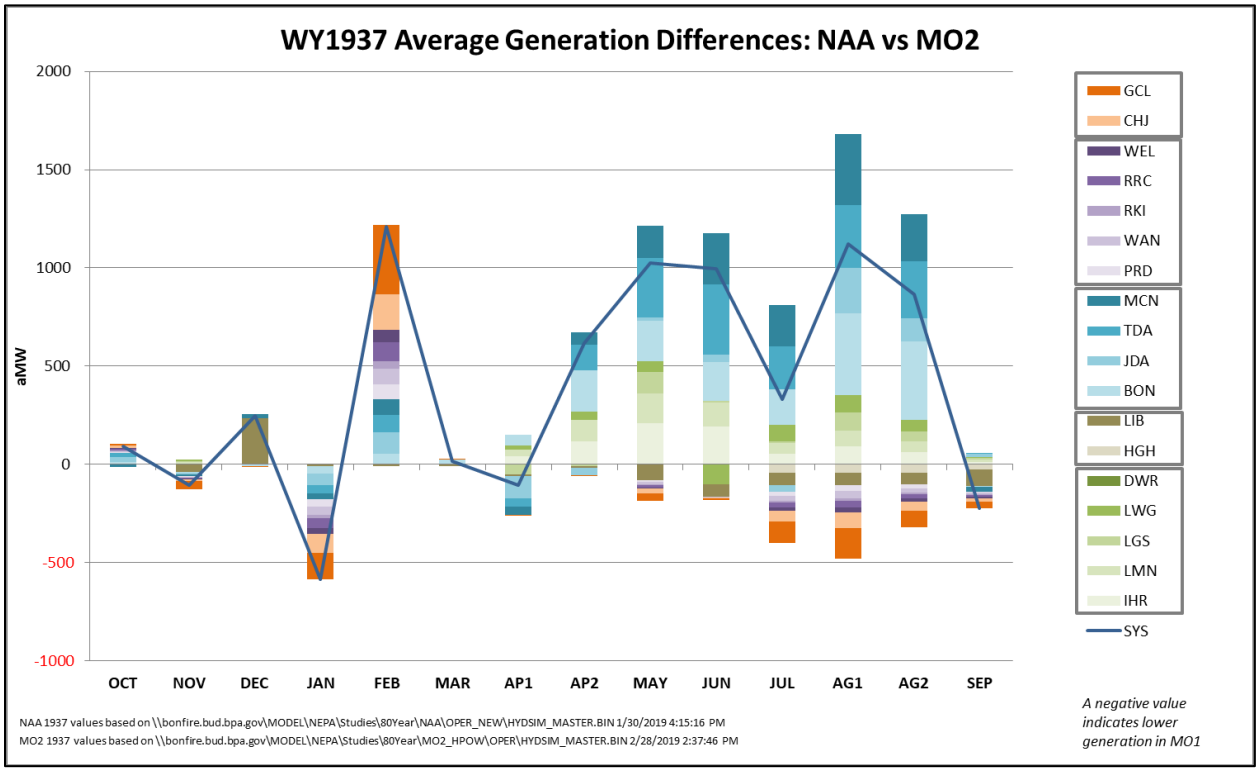


Figure 3-7. NW-US system and Project Critical Water Generation: NAA vs. MO2

Generation differences between NAA and MO2 primarily result from the following:

Table 3-7. NW-US System Average Generation: NAA vs. MO2

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	9,364	12,205	13,519	15,115	15,299	13,724	12,643	13,469	16,462	17,504	14,173	11,770	10,229	9,215	13,373
MO2	9,370	12,428	13,970	15,686	15,768	13,344	12,349	14,071	17,564	17,865	14,945	13,344	11,678	9,392	13,826
Change	6	222	450	572	468	-380	-294	602	1,102	361	772	1,574	1,449	177	453

Table 3-8. NW-US System P10 Average Generation: NAA vs. MO2

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	8,530	10,662	10,904	10,866	10,228	9,713	8,736	7,814	12,570	13,017	9,557	9,599	8,635	8,307	10,144
MO2	8,480	10,736	11,722	11,613	10,319	9,458	8,278	8,077	13,364	13,377	10,166	10,757	9,729	8,592	10,524
Change	-50	73	818	747	91	-255	-458	263	794	360	609	1,158	1,095	285	380

Table 3-9. NW-US System Critical Water Generation: NAA compared to MO2

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	8,766	11,079	11,224	10,754	8,690	9,034	8,707	7,841	11,424	13,914	11,117	10,539	9,405	9,221	10,297
MO2	8,856	10,973	11,470	10,168	9,900	9,051	8,601	8,459	12,451	14,908	11,449	11,661	10,270	8,997	10,645
Change	90	-105	245	-586	1,210	17	-106	618	1,027	994	332	1,122	866	-224	348

October – December: The generation increase from NAA is due to deeper drafts and lower end-of-month elevation targets at Libby; 2,428 feet NGVD29 at the end of November and 2,400 feet NGVD29 at the end of December. The additional draft and higher releases from Libby increase generation at the site and several projects downstream through Bonneville Dam. Had the Winter System FRM Space measure been included in December as intended, the December generation would have been even higher, by up to 450 aMW in years with the largest effect.

January – February: The generation increase from NAA is due to deeper drafts of Hungry Horse, Grand Coulee, and Dworshak in January and February. The additional draft and higher releases from all three projects increase generation at the site and several projects downstream through Bonneville Dam. Had the Winter System FRM Space measure been included in December, generation in January, and possibly February, would have been lower.

March – April I: The generation reduction is a consequence of deeper drafts of storage projects (Hungry Horse, Grand Coulee, and Dworshak) in January and February resulting in less water released in March and April I. Decreased flow lowers power production at the storage and downstream projects.

April I – August II: The generation increases from the NAA are the result of reduced spills for fish passage at the eight lower Snake River and Columbia River projects.

MO2 fish passage spill is near 110 percent TDG at most projects, except when minimum spill levels are higher for powerhouse surface passage routes, spillway weirs, and/or for adult attraction to fish ladders, which is less than NAA spill. In addition, the MO2 spill duration is shorter ending on July 31 whereas the NAA spill ends on August 31. Both MO2 actions result in generation increases, especially in August.

September: The generation increase in September results from MO2 having a slower, later reservoir fill target of October 31 rather than September 30 in the NAA. Because the refill is slower, more flow is released from Grand Coulee in September, increasing generation at the site and several projects downstream through Bonneville Dam. The flow then decreases from Grand Coulee in October as the refill is increased to meet the same end of October target elevation.

MO2: P10 AND CRITICAL WATER VS. AVERAGE GENERATION

Generation in the 10th percentile driest years and in the critical water year followed the same trend as the average generation over the 80 water years. In the critical water, MO2 gains about 350 aMW relative to NAA. The annual gain in critical year generation is a primary input to the agency's calculation of the minimum annual power. It can depend on generating with the hydro-system even in a "bad year," which determines how much firm power produced by the FCRPS is available to Bonneville to meet its long-term Regional Dialogue firm power sales contracts. The differences in generation between January and February might be adjustable in real-time generation.

3.2.3.3 Energy: NAA compared to MO3

Table 3-10 through Table 3-12 provide the average, P10, and critical water generation differences between NAA and MO3 for the NW-US system. Positive differences indicate an increase in average generation from the NAA. Figures 3-8 and 3-9 also illustrate the individual project differences for major individual United States projects. Detailed information for the differences is provided in Exhibit 3.

Table 3-10. NW-US System Average Generation: NAA vs. MO3

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	9,364	12,205	13,519	15,115	15,299	13,724	12,643	13,469	16,462	17,504	14,173	11,770	10,229	9,215	13,373
MO3	8,718	11,971	13,139	13,872	13,819	12,273	10,754	10,980	13,676	15,473	13,022	12,448	10,945	8,410	12,236
Change	-646	-234	-380	-1,243	-1,481	-1,451	-1,889	-2,490	-2,786	-2,032	-1,151	678	716	-804	-1,137

Table 3-11. NW-US System P10 Average Generation: NAA vs. MO3

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	8,530	10,662	10,904	10,866	10,228	9,713	8,736	7,814	12,570	13,017	9,557	9,599	8,635	8,307	10,144
MO3	7,865	10,441	11,279	10,725	9,692	8,825	7,287	6,908	9,678	10,960	8,691	9,938	9,208	7,329	9,347
Change	-665	-221	374	-140	-536	-888	-1,449	-907	-2,892	-2,056	-867	339	573	-978	-798

Table 3-12. NW-US System Critical Water Generation: NAA vs. MO3

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	8,766	11,079	11,224	10,754	8,690	9,034	8,707	7,841	11,424	13,914	11,117	10,539	9,405	9,221	10,297
MO3	8,400	10,558	11,040	10,971	8,443	8,376	7,318	6,855	8,640	12,083	9,738	10,785	9,668	8,109	9,480
Change	-366	-520	-184	217	-247	-658	-1,388	-986	-2,784	-1,831	-1,378	246	263	-1,112	-817

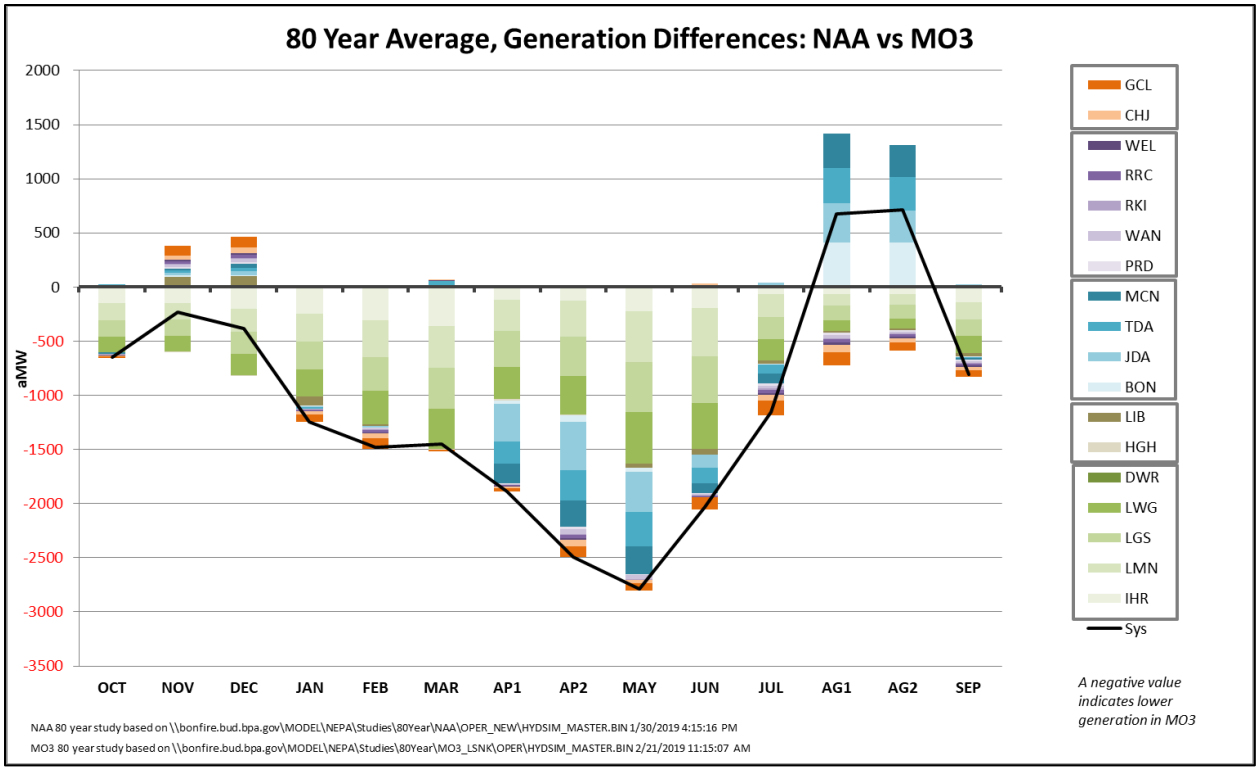


Figure 3-8. NW-US System and Project Average Generation: NAA vs. MO3

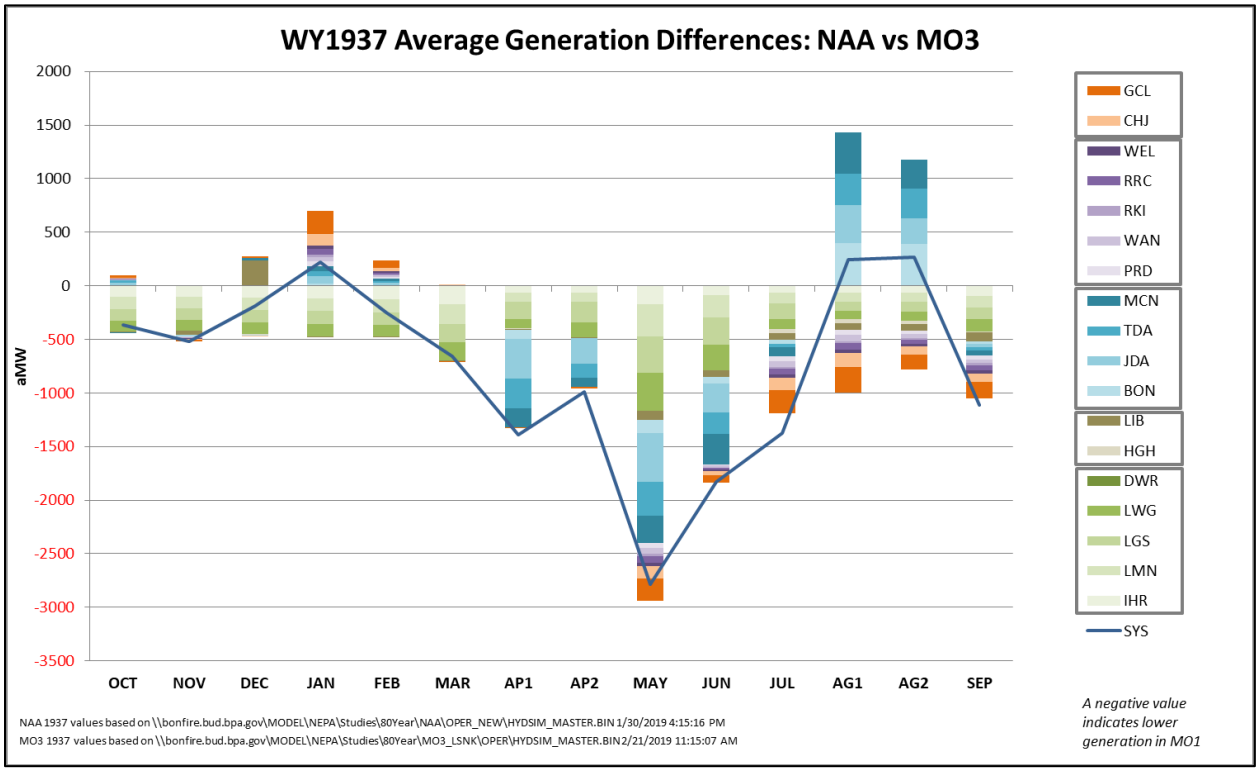


Figure 3-9. NW-US System and Project Critical Water Generation: NAA vs. MO3

Generation differences between NAA and MO3 are explained as follows:

October – September: Breaching of the four lower Snake River dams results in reduced NW-US system generation in all months except August when the lost Snake River dam generation is offset by generation increases on the Lower Columbia projects from ending spill July 31 (AG1 and AG2).

November – December: Deeper drafts to lower end-of-month elevation targets at Libby (2,428 feet NGVD29 at the end of November and 2,400 feet NGVD29 at the end of December) result in the generation increases from the NAA. The additional draft and higher releases from Libby increase generation at the site and several projects downstream through Bonneville Dam. Because these increases do not fully offset the generation losses from the removal of the four lower Snake River dams, the overall NW-US system average generation in November and December is lower than the NAA generation for the same period.

January – March: Loss of generation from the lower Snake projects is the primary driver for reduced generation.

April – July: MO3 average generation is less than NAA primarily due to the removal of the four lower Snake River dams and additional lower Columbia River spill for fish passage. MO3 spills the Lower Columbia projects to 120 percent TDG, which is higher than spill in NAA.

August: MO3 NW-US system average generation is greater than NAA primarily due to fish passage spill ending July 31, whereas NAA spill ends on August 31, offsetting the loss of Lower Snake River dam generation.

MO3: P10 AND CRITICAL WATER VS. AVERAGE GENERATION

Generation is significantly lower in MO3 compared to NAA in the 80-year average. The same trend holds true for generation in the lowest 10th percentile and critical water generation, though the loss is not quite as much. This may be because there is simply less power generated at the lower Snake River dams during drier water years, so increasing spill to 125 percent has a slightly smaller effect in the drier years. However, it is these driest years when the loss in generation would be most critical to meeting system reliability.

SENSITIVITY ASSESSMENT FOR SNAKE RIVER DAM BREACHING

Snake River dam breaching is included as one of several measures in MO3. The generation effects of dam breaching were difficult to distinguish from the total effects of the measures in MO3. Bonneville prepared a separate hydropower analysis of the impact of dam breaching because of the high-profile nature of this measure. The average annual and critical generation loss was estimated to be 1,030 aMW and 538 aMW, respectively. Details of this sensitivity analysis are in Exhibit 7.

3.2.3.4 Energy: NAA compared to MO4

Table 3-13 through Table 3-15 provide average, P10, and critical water generation differences between NAA and MO4 for the NW-US system. Positive differences indicate an increase in

average generation from the NAA. Figure 3-10 and Figure 3-11 also illustrate the individual project differences for major individual United States projects for average and critical year (1937) generation. Detailed information for the project differences is provided in Exhibit 3.

Table 3-13. NW-US System Average Generation: NAA vs. MO4

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	9,364	12,205	13,519	15,115	15,299	13,724	12,643	13,469	16,462	17,504	14,173	11,770	10,229	9,215	13,373
MO4	8,906	12,122	13,117	15,358	15,250	10,175	9,705	10,918	13,669	15,042	12,339	10,077	8,893	8,906	12,034
Change	-457	-83	-402	244	-49	-3,549	-2,938	-2,552	-2,793	-2,462	-1,834	-1,693	-1,336	-308	-1,339

Table 3-14. NW-US System Average P10 Generation: NAA vs. MO4

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	8,530	10,662	10,904	10,866	10,228	9,713	8,736	7,814	12,570	13,017	9,557	9,599	8,635	8,307	10,144
MO3	7,700	10,643	10,921	10,864	10,085	7,435	7,185	7,151	11,420	11,385	8,792	7,829	7,322	7,912	9,319
Change	-830	-20	17	-2	-143	-2,278	-1,551	-663	-1,150	-1,632	-766	-1,770	-1,313	-395	-826

Table 3-15. NW-US System Critical Water Generation: NAA vs. MO4

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	8,766	11,079	11,224	10,754	8,690	9,034	8,707	7,841	11,424	13,914	11,117	10,539	9,405	9,221	10,297
MO4	7,894	10,882	11,176	10,385	8,558	7,407	7,560	7,188	10,823	11,472	9,370	7,770	7,429	8,833	9,317
Change	-873	-197	-48	-369	-131	-1,627	-1,147	-653	-601	-2,442	-1,747	-2,768	-1,976	-388	-980

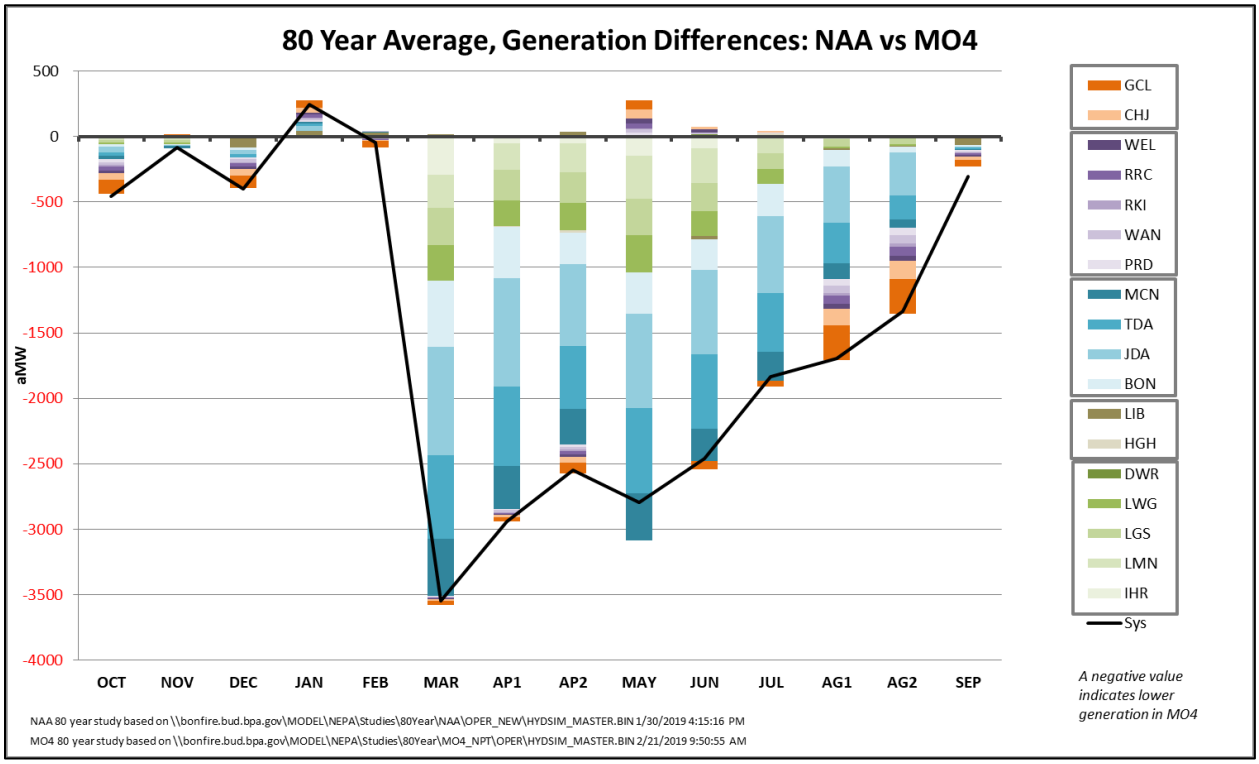


Figure 3-10. NW-US System and Project Average Generation: NAA vs. MO4

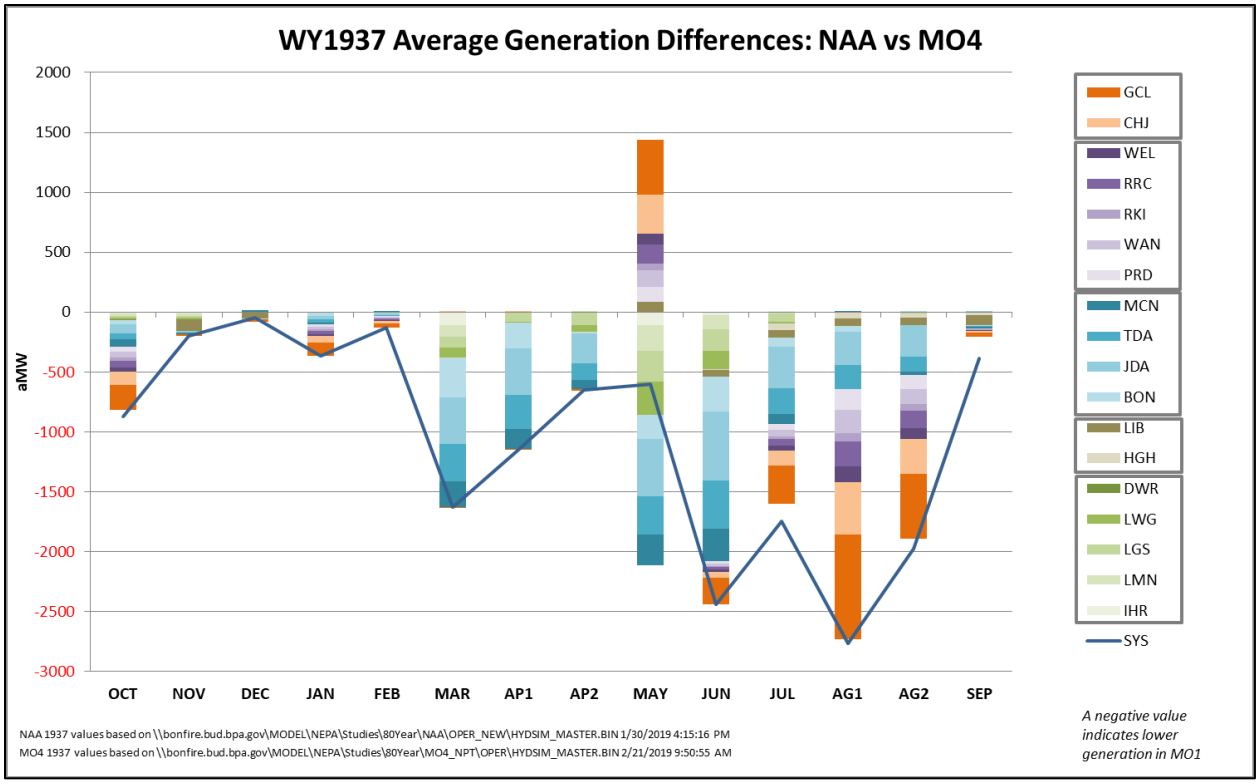


Figure 3-11. NW-US system and Project Critical Water Generation: NAA vs. MO4

Generation differences between NAA and MO4 primarily result from the following:

October: MO4 provides up to an additional 2 Maf from Grand Coulee, Libby, Hungry Horse, and Albeni Falls to meet the 220 kcfs spring and 200 cfs summer flow targets at McNary. Refilling this space in October results in an average generation reduction from the NAA.

MO4 provides lower Columbia River project spill which is not in the NAA for steelhead overshoots (adults that migrate too far up the Columbia River, overshoot their entry to a tributary, and come back down the river to swim up the tributary).

December – January: Limit Libby discharge in winter to help establish vegetation for resident fish habitat (November – March) and increase the end-of-December elevation at Libby (2,420 feet NGVD29 msl) compared to NAA, which is often at 2,411 feet NGVD29, but can be as high as 2,426.7 feet NGVD29. This releases less water in December and more in January. However, had the Winter System FRM Space measure been included in December as intended, the December generation would have been higher by up to 450 MW in the years with the largest effect, which could lead to a slight net positive December value for MO4 compared to NAA. Conversely, January and perhaps February would have had less generation, potentially resulting in both months with a reduction in generation in MO4 compared to NAA.

March – August: MO4 has significant average generation reductions from NAA during this period: Juvenile fish passage spill is raised to 125 percent TDG at all eight lower Snake and Columbia River projects; and the spill period is extended to March 1 through August 31, versus

the NAA period of early April through August 31. Most of the eight fish-passage projects are generating only at their minimum generation levels during this period and spilling the remainder of the water in all water years. In March and August, all eight projects are generating only at their minimum generation in all years.

MO4 strives to meet the 220 kcfs spring flow objective at McNary by drafting upstream storage reservoirs to provide up to 2 Maf additional flow in drier years. If not all of the 2 Maf were used in the spring, flow augmentation may continue into the summer to help meet the McNary summer flow target of 200 kcfs. This measure results in incremental generation during May-June in drier years and sometimes additional generation in July. Half of the water for the flow augmentation comes from Grand Coulee and the rest comes from Hungry Horse, Libby, and Albeni Falls. By August, the storage projects are not able to sustain this discharge and flows are reduced compared to NAA, leading to a significant reduction in generation at the storage projects, plus Chief Joseph in August. The reduction in generation at these projects due to reduced flow, together with the reduced generation from 125 percent TDG spill at the fish-passage projects, leads to a significant energy deficit in August and large impacts to the LOLP for MO4 discussed in Section 4.1.2.5. Reduced flows and generation from the flow augmentation persists into September as the storage projects refill. In drier years, the project may not be able to refill, causing these projects to operate at minimum flow/generation for longer, though that condition would also be the case in some of the same years in the NAA.

MO4: P10 and Critical Water vs. Average Generation

Generation is significantly lower in MO4 compared to NAA in the 80-year average. The same trend holds true for generation in the lowest 10th percentile, though the loss is not quite as much. This may be because there is simply less power generated at the lower Snake River dams during drier water years, so removing these dams has a slightly smaller effect in the drier years. However, it is these driest years when the loss in generation would, of course, be most critical to meeting system reliability. For example, in 1937 all eight fish passage projects are generating only at their minimum generation levels and spilling the rest of the project flows.

In the critical water, the roughly 800 aMW loss in generation in MO4 compared to NAA would result in a large decrease in the amount of energy Bonneville could provide to its preference customers through long-term contracts.

3.2.3.5 Energy: NAA compared to PA

Table 3-16 through Table 3-18 provide average, P10, and critical water generation differences between NAA and PA for the NW-US system. Positive differences indicate an increase in average generation from the NAA. Figure 3-12 and Figure 3-13 also indicate the individual project differences for major individual United States projects for average and critical year (1937) generation. Detailed information for the project differences is provided in Exhibit 3.

2008 **Table 3-16. NW-US System Average Generation: NAA vs. PA**

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	9,364	12,205	13,519	15,115	15,299	13,724	12,643	13,469	16,462	17,504	14,173	11,770	10,229	9,215	13,373
PA	9,552	12,128	13,521	15,395	15,544	13,594	11,788	12,249	15,093	17,008	14,177	11,718	10,907	9,352	13,211
Change	189	-78	1	281	244	-130	-855	-1,221	-1,370	-496	4	-53	678	137	-162

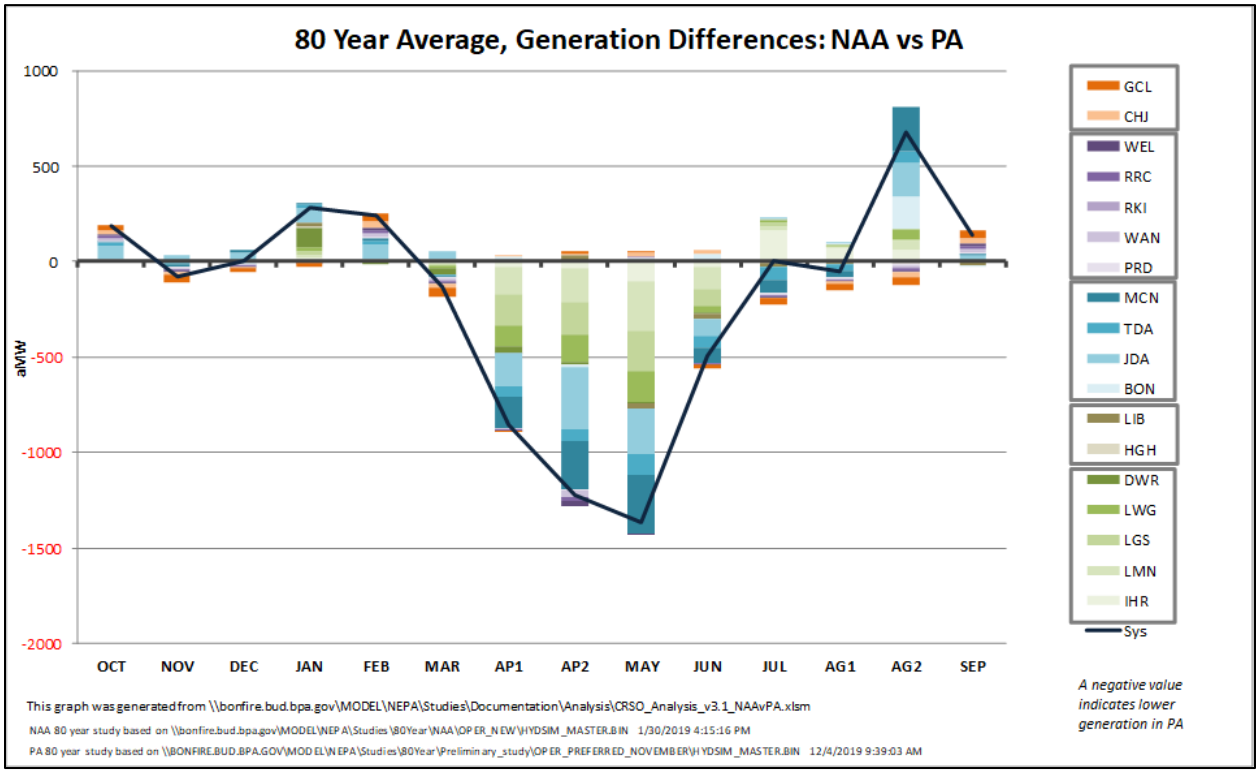
2009 **Table 3-17. NW-US System Average P10 Generation: NAA vs. PA**

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	8,530	10,662	10,904	10,866	10,228	9,713	8,736	7,814	12,570	13,017	9,557	9,599	8,635	8,307	10,144
PA	8,668	10,670	10,844	11,081	10,057	9,887	8,042	7,682	10,977	12,335	9,536	9,295	9,025	8,546	9,969
Change	138	8	-60	215	-171	174	-694	-132	-1,593	-682	-21	-305	390	239	-176

2010 **Table 3-18. NW-US System Critical Water Generation: NAA vs. PA**

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	8,766	11,079	11,224	10,754	8,690	9,034	8,707	7,841	11,424	13,914	11,117	10,539	9,405	9,221	10,297
PA	9,021	10,977	11,232	10,132	8,782	9,080	8,196	7,362	9,828	12,897	10,639	10,201	9,459	9,051	9,943
Change	254	-102	8	-622	93	46	-510	-479	-1,596	-1,017	-477	-338	55	-171	-354

2011



2012

2013 **Figure 3-12. NW-US System and Project Average Generation: NAA vs. PA**

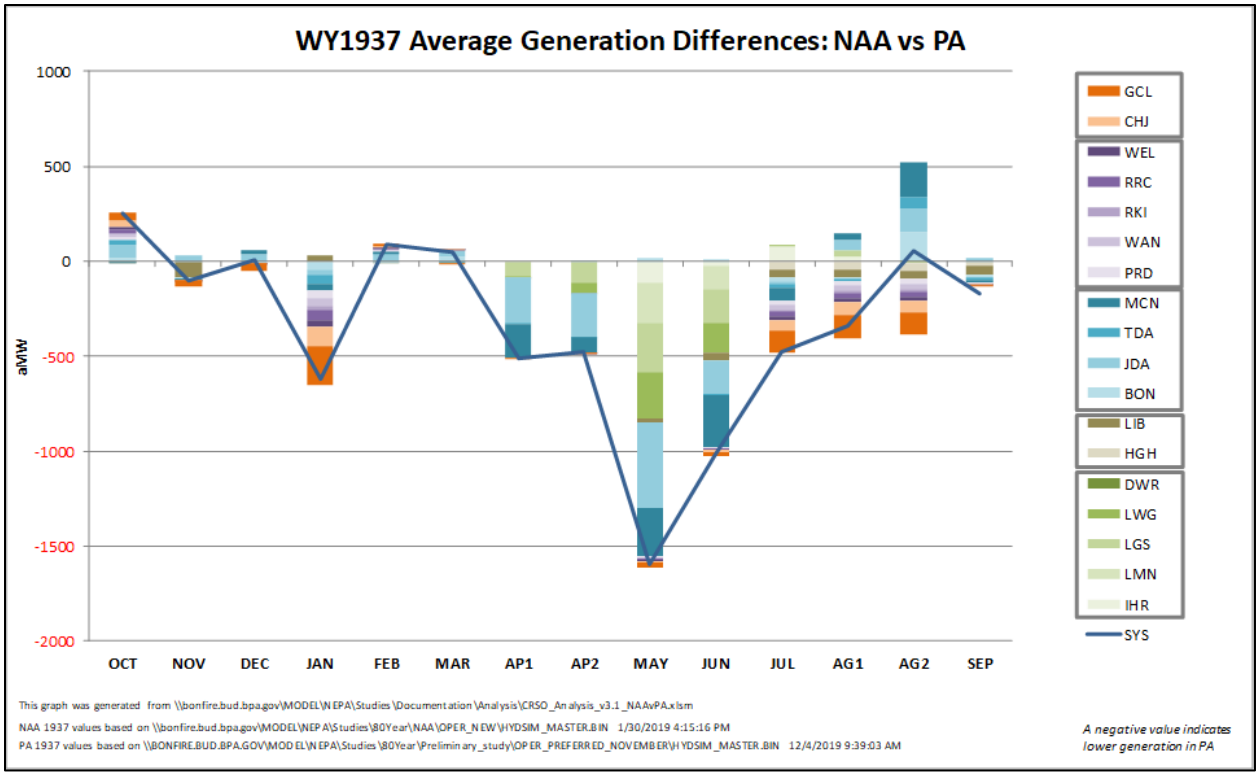


Figure 3-13. NW-US system and Project Critical Water Generation: NAA vs. PA

Generation differences between NAA and PA primarily result from the following:

September-October: The increase in average generation is the result of the flexibility to shift timing of fill at Grand Coulee as the system sets up for winter chum operations.

January-February: The increase in generation from NAA is due to deeper drafts of Dworshak in January and February. The additional draft and higher releases from Dwarshak increases generation at the site and several projects downstream through Bonneville Dam.

March-August I: The decrease in generation from NAA is due to the implementation of the flex spill agreement. The flex spill agreement increases spill at the lower Columbia River projects and the Lower Snake River projects over that which is modeled in NAA.

August II: The increase in generation from NAA is due to the shift to the Late Summer Transition Spill operation. The Late Summer Transition Spill operation represents a reduction in spill at the lower Columbia River projects and the Lower Snake River projects compared to NAA.

PA: P10 AND CRITICAL WATER VS. AVERAGE GENERATION

Generation in the 10th percentile driest years and in the critical water year followed the same trend as the average generation over the 80 water years. The sliding scale measure reduced the summer draft at Libby and Hungry Horse compared to NAA, thus further reducing at site and downstream generation July to September.

The annual loss in critical year generation is a primary input to the agency's calculation of the minimum annual power it can depend on generating with the hydro-system even in a "bad year" which determined how much firm power (power guaranteed to be continuously available) from the FCRPS is available in meeting the Administrator's long-term firm power contract obligations. In order to be in a load/resource balance, any reductions in the amount of firm power produced by the FCRPS must be acquired from other resources.

3.3 PEAK CRS (FEDERAL) GENERATION

The peak generation results for each of the CRSO DEIS alternatives are provided only for the CRS (Federal) system because HOSS is not configured to model the total NW-US or the non-Federal Mid-Columbia projects. This section provides summaries and comparisons of the CRS Peak-Load-Period (120 Hour) average generation, HLH P10, and HLH critical water between the NAA and each alternative. The rationales for 120 Hour generation changes from the NAA also are provided.

3.3.1 Federal Peak Generation Methodologies

Bonneville used its HOSS model to shape the HYDSIM period averages into hourly averages, and examined 120 peak hours each month (60 hours for the split months of April and August) with the highest demand for electricity and highest generation averaged for all 80 water years (5 hours/day, 6 days/week for 4 weeks). Bonneville also computed the HLH P10 generation for each period from HLH results independently in the 80-year study. Consequently, the HLH P10 generation results do not correspond to a single 10th lowest water year, but instead reflect the 10th lowest periods within the set of historical water years. The HLH critical water results are the HLHs in the October 1936 through September 1937 critical water. Key study inputs include the measures listed in Section 1.4. Modeling details are provided in the *Hydroregulation Appendix.*

3.3.2 CRS (Federal) Peak Generation Summary

CRS (Federal) Peak-Load-Period (120 Hour) average generation HOSS results for the CRSO DEIS alternatives are provided with comparisons in Figure 3-14 and Table 3-19, and CRS (Federal) HLH P10 generation for the alternatives compared to the NAA are provided in Figure 3-15 and Table 3-20. Comparisons of CRS HLH critical water generation for the alternatives and NAA are provided in Figure 3-16 and Table 3-21. Comparisons of the effects of the alternatives follow in Section 3.3.3.

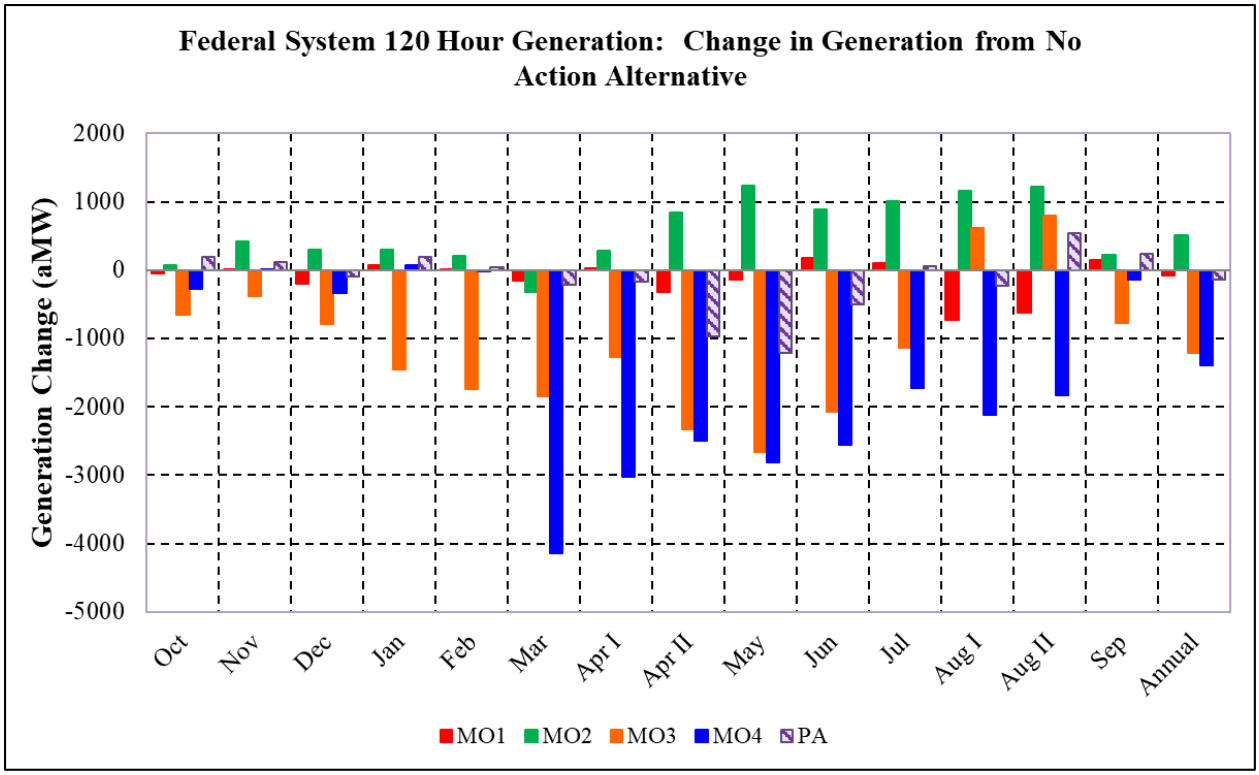


Figure 3-14. CRS (Federal) Peak-Load-Period (120 Hour) Generation: Change from NAA

Table 3-19. CRS (Federal) Peak-Load-Period (120 Hour) Generation: Change from NAA

Federal System 120 Hour Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
NAA	7,719	9,822	11,038	11,888	12,181	11,540	9,798	10,218	12,438	13,145	11,599	10,890	9,241	8,058	10,784
MO1	-51	6	-206	73	11	-156	23	-322	-134	179	109	-728	-625	155	-72
MO2	75	424	292	304	213	-327	287	835	1,235	880	1,006	1,162	1,215	224	509
MO3	-657	-375	-787	-1,455	-1,735	-1,843	-1,279	-2,324	-2,660	-2,071	-1,129	612	796	-776	-1,210
MO4	-270	9	-334	78	-25	-4,146	-3,021	-2,500	-2,818	-2,551	-1,729	-2,118	-1,833	-147	-1,400
PA	188	118	-92	186	49	-208	-168	-977	-1,213	-498	63	-230	538	234	-132

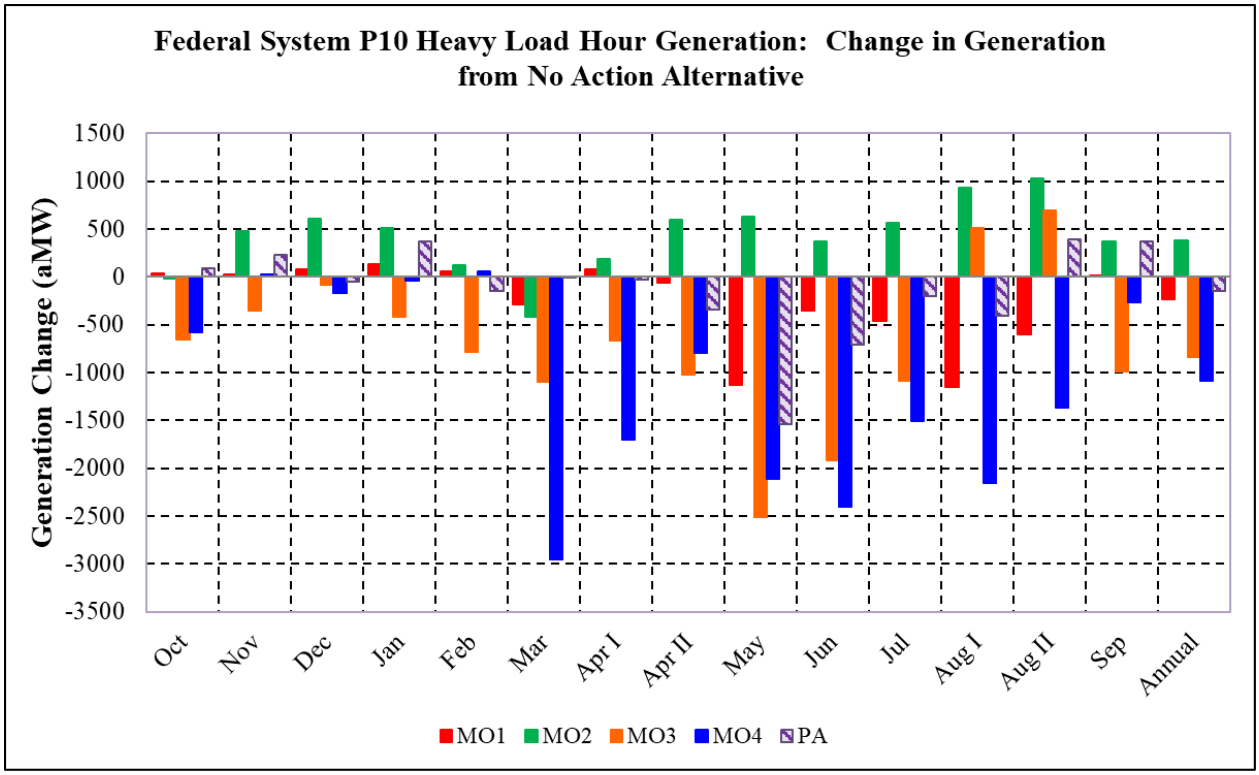


Figure 3-15. CRS (Federal) HLH P10 Generation: Change from NAA

Table 3-20. CRS (Federal) HLH P10 Generation: Change from NAA

Federal System P10 Heavy Load Hour Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
NAA	6,159	7,872	7,956	7,681	7,265	7,376	6,005	5,437	10,113	10,097	7,885	8,318	7,099	6,383	7,688
MO1	34	27	81	135	61	-283	77	-66	-1,132	-350	-455	-1,148	-601	2	-232
MO2	-16	477	607	511	123	-421	188	601	631	374	562	931	1,027	372	385
MO3	-654	-347	-85	-416	-779	-1,091	-667	-1,018	-2,513	-1,914	-1,080	513	690	-990	-841
MO4	-577	27	-169	-35	59	-2,955	-1,696	-797	-2,115	-2,405	-1,509	-2,152	-1,368	-263	-1,088
PA	85	229	-49	369	-145	-5	-25	-339	-1,537	-711	-201	-409	397	370	-148

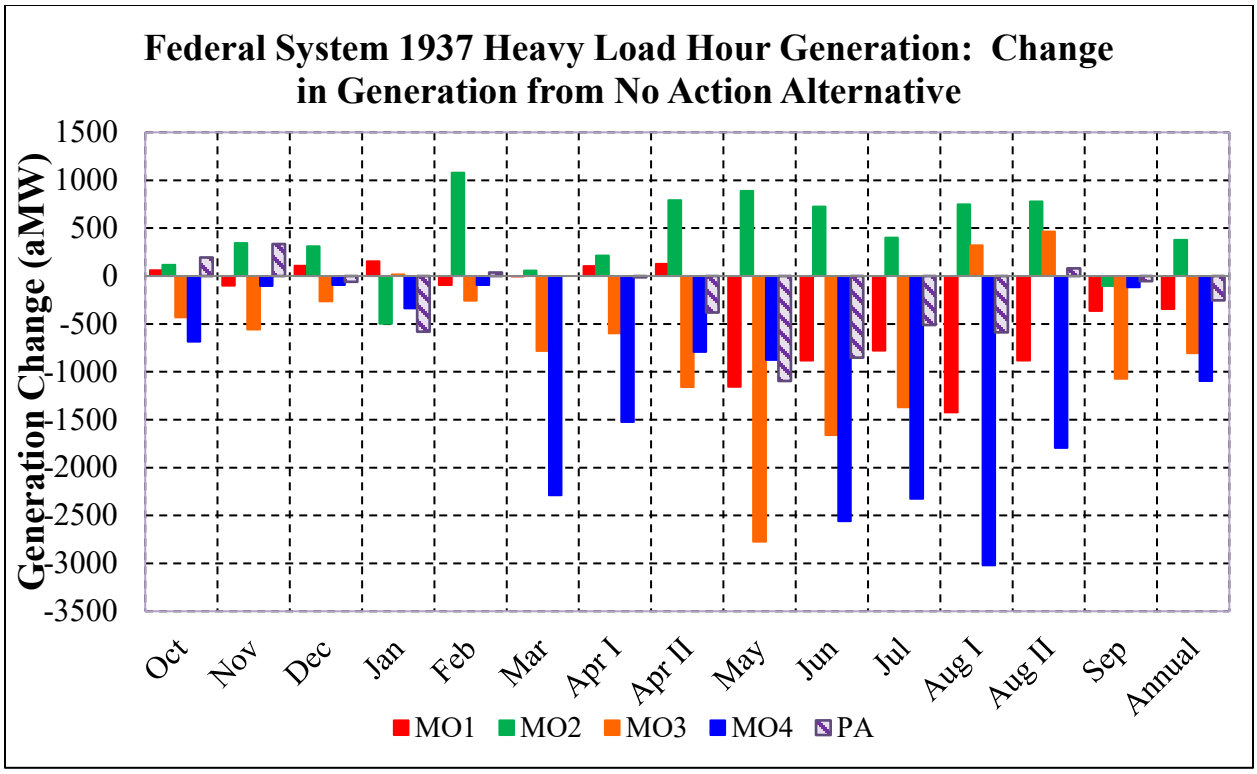


Figure 3-16. CRS (Federal) HLH Critical Water Generation: Change from NAA

Table 3-21. CRS (Federal) HLH Critical Water Generation: Change from NAA

Federal System 1937 Heavy Load Hour Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
Water Year 1937 (Critical Water)															
NAA	6,457	8,625	8,106	7,681	6,110	6,673	5,981	5,399	8,797	10,251	8,847	9,309	7,633	7,036	7,738
MO1	59	-101	106	152	-94	-1	104	126	-1,156	-881	-778	-1,422	-882	-363	-343
MO2	116	343	311	-498	1,079	55	214	792	890	724	400	747	779	-104	376
MO3	-431	-558	-265	15	-258	-783	-599	-1,160	-2,773	-1,659	-1,371	319	464	-1,073	-805
MO4	-684	-105	-94	-339	-95	-2,290	-1,525	-793	-877	-2,559	-2,325	-3,019	-1,793	-117	-1,095
PA	195	335	-59	-582	36	0	-12	-380	-1,097	-852	-511	-588	81	-55	-255

3.3.3 CRS (Federal) Peak Generation: Comparisons to NAA

The following CRS peak generation comparisons are provided for the CRS (Federal) system. CRS generation results for each alternative are driven primarily by its storage reservoir objectives for downstream flow measures and specified project spill measures for fish passage. It is likely that the total NW-US, Mid-Columbia, and Canadian systems would have similar generation trends for flow-related effects of the alternatives. The fish passage spill effects would be limited to the CRS projects.

3.3.3.1 Peak Generation: NAA compared to MO1

Table 3-22 through Table 3-24 provide the CRS Peak-Load-Period (120 Hour), HLH P10, and HLH critical water generation differences between NAA and MO1 for the CRS (Federal) system. Positive differences indicate larger generation in MO1 than the NAA.

Table 3-22. CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA vs. MO1

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	7,719	9,822	11,038	11,888	12,181	11,540	9,798	10,218	12,438	13,145	11,599	10,890	9,241	8,058	10,784
MO1	7,668	9,828	10,832	11,960	12,192	11,384	9,821	9,896	12,304	13,324	11,708	10,162	8,616	8,212	10,712
Change	-51	6	-206	73	11	-156	23	-322	-134	179	109	-728	-625	155	-72

Table 3-23. CRS (Federal) HLH P10 Generation: NAA vs. MO1

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	6,159	7,872	7,956	7,681	7,265	7,376	6,005	5,437	10,113	10,097	7,885	8,318	7,099	6,383	7,688
MO1	6,193	7,899	8,037	7,815	7,326	7,093	6,082	5,371	8,980	9,747	7,430	7,170	6,498	6,384	7,456
Change	34	27	81	135	61	-283	77	-66	-1,132	-350	-455	-1,148	-601	2	-232

Table 3-24. CRS (Federal) HLH Critical Water Generation: NAA vs. MO1

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	6,457	8,625	8,106	7,681	6,110	6,673	5,981	5,399	8,797	10,251	8,847	9,309	7,633	7,036	7,738
MO1	6,516	8,524	8,212	7,833	6,016	6,672	6,085	5,525	7,641	9,370	8,069	7,887	6,751	6,673	7,395
Change	59	-101	106	152	-94	-1	104	126	-1,156	-881	-778	-1,422	-882	-363	-343

The differences in energy results from HYDSIM discussed in Section 3.2.3 and the HOSS peak results here highlight how the MOs change the ability of the hydro system to increase generation during periods of higher demand, as exemplified by the heavy-load hour generation and the 120-hour generation, and to reduce generation during periods of lower demand, the light-load hours, especially the middle of the night.

For MO1, the most noteworthy result is that the 120-hour generation reduction for MO1 vs NAA did not decrease as much as the average generation for MO1 vs NAA. This indicated that the hydropower system in MO1 did not have quite as much ability as the NAA to increase generation for brief periods (around 6 hours per day) compared to the overall loss in generation. However, the ability to sustain the increased generation for 16 hours (during the HLHs) did decrease nearly as much as the overall loss in generation.

September to February: Though there is a reduction in generation in some months as shown in the average generation results described in Section 3.2.3.1, the HOSS results indicate that there is no reduction in HLH generation, indicating that the system generally has enough flexibility to shape flows into the daytime in MO1 as it did in NAA by reducing generation even further during light load hours (LLH).

May to August: MO1 is generating less primarily because of the increased spill as described in Section 3.2.3.1. This reduction in period-average generation also results in a reduction in HLH generation because there is not enough flexibility in the hydropower system for all of the reductions to be during LLH.

MO1: HLH Critical Water Generation: The change in HLH critical water generation for MO1 compared to the change in period-average critical water generation for MO1 in Table 3-6 is remarkably similar. This indicates that the ability of the system to shape generation into the

HLH during a critical year is not appreciably changed by the measures in MO1. The impacts to HLH critical water generation in MO1 are about the same as the impacts to critical water generation described in Section 3.2.3.1.

3.3.3.2 CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA vs. MO2

Table 3-25 through Table 3-27 provide the CRS Peak-Load-Period (120 Hour), HLH P10, and HLH critical water generation differences between NAA and MO2 for the CRS (Federal) system. Positive differences indicate an increase in average Peak-Load-Period (120 Hour) generation from the NAA.

Table 3-25. CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA vs. MO2

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	7,719	9,822	11,038	11,888	12,181	11,540	9,798	10,218	12,438	13,145	11,599	10,890	9,241	8,058	10,784
MO2	7,794	10,246	11,330	12,192	12,394	11,214	10,085	11,053	13,673	14,025	12,605	12,051	10,456	8,281	11,293
Change	75	424	292	304	213	-327	287	835	1,235	880	1,006	1,162	1,215	224	509

Table 3-26. CRS (Federal) HLH P10 Generation: NAA vs. MO2

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	6,159	7,872	7,956	7,681	7,265	7,376	6,005	5,437	10,113	10,097	7,885	8,318	7,099	6,383	7,688
MO2	6,143	8,349	8,563	8,191	7,388	6,955	6,193	6,038	10,744	10,470	8,447	9,249	8,126	6,755	8,073
Change	-16	477	607	511	123	-421	188	601	631	374	562	931	1,027	372	385

Table 3-27. CRS (Federal) HLH Critical Water Generation: NAA vs. MO2

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	6,457	8,625	8,106	7,681	6,110	6,673	5,981	5,399	8,797	10,251	8,847	9,309	7,633	7,036	7,738
MO2	6,573	8,968	8,417	7,183	7,189	6,728	6,195	6,191	9,687	10,975	9,247	10,056	8,412	6,932	8,114
Change	116	343	311	-498	1,079	55	214	792	890	724	400	747	779	-104	376

Load shaping in the HOSS studies generally follows the same trend as the HYDSIM energy data. For the 120-hour period, MO2 increases generation relative to NAA slightly more than the average generation, indicating that there may be a slight increase in shorter-term (roughly 6 hour) flexibility to shape generation. The unusual trend between January (large loss) and February (large increase) in the critical water year mirrors that seen with HYDSIM energy and may be able to be adjusted in actual operations to smooth generation across the two months.

With the exception of October (where the system does not change much) and March (when there is less flow and generation in the river), the system has the ability to increase overall generation and to increase generation during the HLH periods. This effect is from a combination of the flow and spill changes described earlier as well as the increased flexibility such as the increased forebay and turbine operating range of the lower Snake and lower Columbia River projects relative to NAA.

In almost all periods, the ability of the hydropower system to shape energy into HLHs is greater in MO2 compared to NAA. This can be seen by comparing the difference in period-average critical water year generation for MO2 compared to NAA in Table 3-9 with the difference in HLH

critical water generation shown in Table 3-27. This effect is attributable to the increase in hydro-system flexibility in MO2 compared to NAA. Additional flexibility stems from the increase in operating range at the lower Snake and John Day projects during the fish passage season, the increased period during which the lower Snake River projects may operate with zero generation, the allowance for carrying contingency reserves within fish passage spill, having more water available for generation in winter storage projects drafted deeper, and more water during the fish passage spill season from reduced spill. January is the one month with less shaping ability, perhaps due to Libby releasing little water after drafting very low in December.

3.3.3.3 CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA compared to MO3

Table 3-28 through Table 3-30 provide the CRS Peak-Load-Period (120 Hour), HLH P10, and HLH critical water generation differences between NAA and MO3 for the CRS (Federal) system. Positive differences indicate larger average generation in MO3 than the NAA.

Table 3-28. CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA vs. MO3

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	7,719	9,822	11,038	11,888	12,181	11,540	9,798	10,218	12,438	13,145	11,599	10,890	9,241	8,058	10,784
MO3	7,062	9,447	10,251	10,433	10,446	9,697	8,519	7,894	9,778	11,075	10,470	11,501	10,037	7,282	9,573
Change	-657	-375	-787	-1,455	-1,735	-1,843	-1,279	-2,324	-2,660	-2,071	-1,129	612	796	-776	-1,210

Table 3-29. CRS (Federal) HLH P10 Generation: NAA vs. MO3

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	6,159	7,872	7,956	7,681	7,265	7,376	6,005	5,437	10,113	10,097	7,885	8,318	7,099	6,383	7,688
MO3	5,506	7,525	7,871	7,265	6,486	6,285	5,338	4,419	7,600	8,183	6,805	8,831	7,790	5,393	6,847
Change	-654	-347	-85	-416	-779	-1,091	-667	-1,018	-2,513	-1,914	-1,080	513	690	-990	-841

Table 3-30. CRS (Federal) HLH Critical Water Generation: NAA vs. MO3

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	6,457	8,625	8,106	7,681	6,110	6,673	5,981	5,399	8,797	10,251	8,847	9,309	7,633	7,036	7,738
MO3	6,026	8,067	7,841	7,696	5,852	5,890	5,382	4,239	6,024	8,592	7,476	9,628	8,097	5,963	6,932
Change	-431	-558	-265	15	-258	-783	-599	-1,160	-2,773	-1,659	-1,371	319	464	-1,073	-805

The HLH and 120-hour results for MO3 are fairly similar to the average generation changes discussed in Section 3.2.3.3, except that MO3 decreases 120-hour generation even more than the average generation decrease in the winter months with less loss in April. The same is seen for the HLH generation at the P10 compared to the generation averaged over all hours in the P10 years as well as the HLH generation at critical water over all hours

November – March: In months where the difference between MO3 and NAA is larger for the P10 HLH than for the P10 period-average, the system has less flexibility to shape power into the daytime. In the winter months, the larger loss in the HLH hours compared to the period-average is likely the result of the loss of generation from the lower Snake River projects. In the winter in NAA, these projects have the most flexibility to shape generation during the day. During winter months typically flows allow generation above the minimum generation but are not so high

that the projects must run at full capacity all hours of the day. Thus, they are able to reduce generation during LLH and store some water for higher generation during the day in NAA.

April – August: There are two opposing influences on the ability of the hydrosystem to shape flows into the HLHs: On the one hand, in MO3 the lower Snake River projects no longer contribute to shaping. On the other hand, John Day has a larger forebay operating range than in the NAA, which gives it more room to store and release water to shape flows and generation within the day. Between April and August, a comparison of Table 3-10and Table 3-28 shows that these two effects alternate in which one is larger, likely depending on the amount of water available in each stretch of the river.

Breaching of the four lower Snake River dams not only eliminated the period-average generation from these days but also reduced their contribution to shaping generation into peak-load-periods.

Furthermore, in periods where flows are reduced (as explained above for period-average impacts), reduced flows generally reduce the ability of the remaining dams to shape generation into the peak-load periods (except in the highest flow periods when excess flow would be spilled and reducing flows does not initially reduce generation).

3.3.3.4 CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA compared to MO4

Table 3-31 through Table 3-33 provides the CRS Peak-Load-Period (120 Hour), HLH P10, and HLH critical water generation differences between NAA and MO4 for the CRS (Federal) system. Positive differences indicate lager average generation for MO4 than the NAA.

Table 3-31. CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA vs. MO4

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	7,719	9,822	11,038	11,888	12,181	11,540	9,798	10,218	12,438	13,145	11,599	10,890	9,241	8,058	10,784
MO4	7,449	9,831	10,704	11,966	12,156	7,395	6,777	7,718	9,620	10,594	9,870	8,772	7,408	7,911	9,384
Change	-270	9	-334	78	-25	-4,146	-3,021	-2,500	-2,818	-2,551	-1,729	-2,118	-1,833	-147	-1,400

Table 3-32. CRS (Federal) HLH P10 Generation: NAA vs. MO4

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	6,159	7,872	7,956	7,681	7,265	7,376	6,005	5,437	10,113	10,097	7,885	8,318	7,099	6,383	7,688
MO4	5,582	7,899	7,787	7,646	7,324	4,421	4,309	4,640	7,998	7,691	6,376	6,166	5,731	6,120	6,600
Change	-577	27	-169	-35	59	-2,955	-1,696	-797	-2,115	-2,405	-1,509	-2,152	-1,368	-263	-1,088

Table 3-33. CRS (Federal) HLH Critical Water Generation: NAA vs. MO4

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	6,457	8,625	8,106	7,681	6,110	6,673	5,981	5,399	8,797	10,251	8,847	9,309	7,633	7,036	7,738
MO4	5,773	8,520	8,012	7,342	6,015	4,383	4,456	4,606	7,920	7,692	6,522	6,290	5,840	6,919	6,643
Change	-684	-105	-94	-339	-95	-2,290	-1,525	-793	-877	-2,559	-2,325	-3,019	-1,793	-117	-1,095

The HLH and 120-hour results for MO4 are fairly similar to the average generation changes, with slight variations across the months, but no major patterns. On an annual basis, the

120-Hour, HLH, and HLH critical water generation decrease slightly more than the corresponding generation for the day-average as measured by HYDSIM (Table 3-13).

March – August: The loss in generation for HLH P10 in MO4 (Table 3-32) compared to NAA is larger than the loss in P10 period-average generation (Table 3-14). This results from the loss of generation flexibility at the lower Snake and lower Columbia River projects. In MO4, in the water conditions represented in the driest 10th percentile, these projects are all generating at their minimum generation level all hours of the day. This means that there is no ability for them to store any water during the LLHs to increase generation during the HLHs.

The change in HLH critical water generation for MO4 (Table 3-33) is remarkably similar compared to the change in period-average critical water generation for MO4 in Table 3-15. This indicates the ability of the system to shape generation into the HLHs during a critical year is not appreciably changed by the measures in MO4. The impacts to HLH critical water generation in MO4 are about the same as the impacts to critical water generation described in Section 3.2.3.4. Thus, the reduction in generation for all hours of the critical water year translated directly to a reduction in the ability to shape generation between heavy-load hours and light-load hours. In MO4, the four lower Snake River and the four lower Columbia River projects are all or mostly operating at minimum generation with little ability to shape generation into the heavy load hours.

3.3.3.5 CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA compared to PA

Table 3-34 through Table 3-36 provide the CRS Peak-Load-Period (120 Hour), HLH P10, and HLH Critical Water generation differences between NAA and PA for the CRS (Federal) system. Positive differences indicate an increase in generation from the NAA

Table 3-34. CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA vs. PA

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	7,719	9,822	11,038	11,888	12,181	11,540	9,798	10,218	12,438	13,145	11,599	10,890	9,241	8,058	10,784
PA	7,907	9,940	10,947	12,074	12,230	11,333	9,630	9,241	11,226	12,647	11,662	10,659	9,779	8,292	10,651
Change	188	118	-92	186	49	-208	-168	-977	-1,213	-498	63	-230	538	234	-132

Table 3-35. CRS (Federal) HLH P10 Generation: NAA vs. PA

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	6,159	7,872	7,956	7,681	7,265	7,376	6,005	5,437	10,113	10,097	7,885	8,318	7,099	6,383	7,688
PA	6,244	8,100	7,907	8,050	7,120	7,371	5,980	5,098	8,576	9,386	7,684	7,909	7,496	6,753	7,540
Change	85	229	-49	369	-145	-5	-25	-339	-1,537	-711	-201	-409	397	370	-148

Table 3-36. CRS (Federal) HLH Critical Water Generation: NAA vs. PA

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	6,457	8,625	8,106	7,681	6,110	6,673	5,981	5,399	8,797	10,251	8,847	9,309	7,633	7,036	7,738
PA	6,652	8,960	8,047	7,099	6,146	6,673	5,969	5,019	7,700	9,399	8,336	8,721	7,714	6,981	7,482
Change	195	335	-59	-582	36	0	-12	-380	-1,097	-852	-511	-588	81	-55	-255

For PA, the decreases in peak load and the ability to sustain the increased generation for 16 hours (during the HLHs) for PA vs NAA was nearly as much as the decrease in the average generation for PA vs NAA.

September to February: With the exception of December, the system has the ability to slightly increase average generation results and similarly HLH generation, indicating that the system generally has enough flexibility to shape flows into the daytime in PA as it did in NAA by reducing generation even further during light load hours (LLH).

March to June: PA has a large decrease in generation primarily because of the increased spill as described in Section 3.2.3.5. This reduction in period-average generation also results in a reduction in HLH generation because there is not enough flexibility in the hydropower system for all of the reductions to be during LLH.

July to August: PA is generating more primarily because of the decreased spill from Aug 15 – 31 as described in Section 3.2.3.5. This increase in period-average generation also results in an increase in HLH generation because there is flexibility in the hydropower system during August.

3.4 OVERALL GENERATION RESULTS

Table 3-37 through Table 3-39 summarize the average, P10, and critical water (1937) generation for the NW-US, CRS (Federal), Mid-Columbia, and Canadian systems. CRS (Federal) peak generation summaries are also provided for Peak Load (120 Hour), HLH P10, and HLH critical water generation; peak summaries were not prepared for the NW-US, Mid-Columbia, or Canadian systems.

Study results are summarized for several periods:

- The November to February period is generally the time of greatest power demand due to colder winter temperatures; it is also a time of water-supply-forecast-based adjustments of storage reservoir operations for FRM and refill.
- The April 15 (April I) to July period is the annual spring runoff, system refill, and numerous measures for improving anadromous and resident fish survival.

The maximum and minimum loss periods identify those months during which the greatest generation changes occur for an MO alternative with respect to the NAA.

3.4.1 NW-US System

NW-US system HYDSIM results are provided for average generation, P10 generation, and critical water generation. Positive values are increases from the NAA value. Results for the NW-US system are unavailable for peak generation metrics due to HOSS modeling limitations. Summaries generally apply to all generation metrics.

MO1 generation was slightly less than the NAA. Increases in spill for fish passage and withdrawals for water supply resulted in average generation declines from the NAA during spring and summer months. Generation increases in January resulted from drafts at Grand Coulee. August generation decreases resulted from the reduced flow from Dworshak in August.

MO2 showed increased generation from the NAA for the NW-US system. Increased winter storage drafts and reduced amounts and duration of spill for fish passage contributed to increases. All other MO alternatives resulted in less generation than the NAA.

MO3 generation is reduced year-round from removal of generation at the four lower Snake River dams. The greatest reductions from the NAA occur in spring and summer due to increased fish passage spill at the lower Columbia projects. The August generation increase results from terminating fish passage spill earlier than the NAA.

MO4 generation is reduced from NAA generation nearly year-round from increased fish passage spill during the spring and summer and the effects of additional storage water use for fish migration flow augmentation. The January increase results from increased releases from Libby because the reservoir was held at a higher elevation at the end of December.

PA generation is reduced in the spring, most significantly April through mid-June from the higher spill for juvenile fish passage relative to the NAA. Generation is higher in the second half of August as juvenile fish passage spill ends earlier than in NAA. There are smaller increases in generation in September, October, January, and February from a combination of measures including the Sliding Scale at Libby and Hungry Horse, Planned Draft Rate at Grand Coulee, Modified Draft at Libby, and Deeper Draft at Dworshak.

Table 3-37. NW-US System Average Generation: Change from NAA

	Average U.S. Generation (aMW)				
	Nov - Feb	**Apr II - Jul**	**Max Loss Period**	**Max Gain Period**	**Annual**
NAA	14018	15672	Variable	Variable	13373
MO1	-4 (0%)	-341 (-2%)	-745 (-6%): AugI	228 (2%): Jan	-173 (-1%)
MO2	429 (3%)	728 (5%)	-380 (-3%): Mar	1574 (13%): AugI	453 (3%)
MO3	-823 (-6%)	-2059 (-13%)	-2786 (-17%): May	716 (7%): AugII	-1137 (-9%)
MO4	-73 (-1%)	-2389 (-15%)	-3549 (-26%): Mar	244 (2%): Jan	-1339 (-10%)
PA	110 (1%)	-706 (-5%)	-1370 (-8%): May	678 (7%): AugII	-162 (-1%)

Table 3-38. NW-US System P10 Generation: Change from NAA

	P10 U.S. Generation (aMW)				
	Nov - Feb	**Apr II - Jul**	**Max Loss Period**	**Max Gain Period**	**Annual**
NAA	10676	11156	Variable	Variable	10144
MO1	13 (0%)	-645 (-4%)	-1284 (-10%): May	79 (1%): Dec	-280 (-2%)
MO2	444 (3%)	544 (3%)	-458 (-5%): AprI	1158 (12%): AugI	380 (3%)
MO3	-120 (-1%)	-1793 (-11%)	-2892 (-23%): May	573 (7%): AugII	-798 (-6%)
MO4	-34 (0%)	-1105 (-7%)	-2278 (-23%): Mar	17 (0%): Dec	-826 (-6%)
PA	2 (0%)	-678 (-4%)	-1593 (-13%): May	390 (5%): AugII	-176 (-1%)

Table 3-39. NW-US System Critical Water (1937) Generation: Change from NAA

	1937 U.S. Generation (aMW)				
	Nov - Feb	Apr II - Jul	Max Loss Period	Max Gain Period	Annual
NAA	10475	11531	Variable	Variable	10297
MO1	12 (0%)	-889 (-8%)	-1390 (-12%): May	177 (2%): Jan	-385 (-4%)
MO2	168 (2%)	759 (7%)	-586 (-5%): Jan	1210 (14%): Feb	348 (3%)
MO3	-179 (-2%)	-1858 (-16%)	-2784 (-24%): May	263 (3%): AugII	-817 (-8%)
MO4	-187 (-2%)	-1456 (-13%)	-2768 (-26%): AugI	-48 (0%): Dec	-980 (-10%)
PA	-163 (-2%)	-953 (-8%)	-1596 (-14%): May	254 (3%): Oct	-354 (-3%)

3.4.2 CRS (Federal) System

CRS (Federal) system results are provided for average generation, P10 generation, and critical water generation; and for Peak Load (120 Hour), HLH P10, and HLH critical water peak generation averages. Summaries generally apply to all generation metrics. The trend seen for the Federal System is largely the same as for the NW-US system. The Federal system is the largest component of the NW-US system. Most of the NW-US P10 generation loss occurred on the CRS system.

MO1 generation was slightly less than the NAA. Increases in spill for fish passage and additional withdrawals for water supply resulted in average generation declines from the NAA during spring and summer months. Generation increases in January resulted from drafts at Grand Coulee and Libby beginning January at a higher elevation. August generation decreases resulted from the reduced flow from Dworshak in August.

MO2 showed increased generation from the NAA for the CRS (Federal) system. Increased winter storage drafts and reduced amounts and duration of spill for fish passage contributed to increases. All other MO alternatives resulted in less generation than the NAA; reductions in MO3 and MO4 were substantial.

MO3 generation is reduced year-round from loss of the four lower Snake River dams. The greatest reductions from the NAA occur in spring and summer due also to increased fish passage spill at the four lower Columbia River projects. The August generation increase results from terminating fish passage spill earlier than the NAA.

MO4 generation is reduced from NAA generation year-round from increased fish passage spill during the spring and summer and the effects of additional storage use for fish migration flow augmentation. The January increase results from increased releases from Libby because the reservoir was held at a higher elevation at the end of December.

PA generation is reduced in the spring, most significantly April through mid-June from the higher spill for juvenile fish passage relative to the NAA. Generation is higher in the second half of August as juvenile fish passage spill ends earlier than in NAA. There are smaller increases in generation in September, October, January, and February from a combination of measures

including the Sliding Scale at Libby and Hungry Horse, Planned Draft Rate at Grand Coulee, Modified Draft at Libby, and Deeper Draft at Dworshak.

Table 3-40. CRS (Federal) Average Generation: Change from NAA

	Average Federal Generation (aMW)				
	Nov - Feb	Apr II - Jul	Max Loss Period	Max Gain Period	Annual
NAA	8712	9746	Variable	Variable	8339
MO1	4 (0%)	-269 (-3%)	-656 (-9%): Augl	183 (2%): Jan	-132 (-2%)
MO2	326 (4%)	763 (8%)	-282 (-3%): Mar	1641 (22%): Augl	445 (5%)
MO3	-843 (-10%)	-1985 (-20%)	-2749 (-27%): May	801 (11%): Augl	-1105 (-13%)
MO4	-56 (-1%)	-2435 (-25%)	-3535 (-40%): Mar	192 (2%): Jan	-1303 (-16%)
PA	109 (1%)	-685 (-7%)	-1373 (-13%): May	731 (11%): AugII	-156 (-2%)

Table 3-41. CRS (Federal) P10 Generation: Change from NAA

	P10 Federal Generation (aMW)				
	Nov - Feb	Apr II - Jul	Max Loss Period	Max Gain Period	Annual
NAA	6499	6880	Variable	Variable	6237
MO1	60 (1%)	-603 (-6%)	-1223 (-15%): May	83 (1%): Jan	-228 (-3%)
MO2	296 (3%)	565 (6%)	-303 (-5%): Mar	1310 (21%): Augl	354 (4%)
MO3	-338 (-4%)	-1706 (-18%)	-2785 (-35%): May	705 (13%): AugII	-804 (-10%)
MO4	-30 (0%)	-1515 (-16%)	-2232 (-36%): Mar	42 (1%): Feb	-855 (-10%)
PA	65 (1%)	-860 (-9%)	-1751 (-22%): May	506 (9%): AugII	-214 (-3%)

Table 3-42. CRS (Federal) Critical Water Generation: Change from NAA

	1937 Federal Generation (aMW)				
	Nov - Feb	Apr II - Jul	Max Loss Period	Max Gain Period	Annual
NAA	6430	6815	Variable	Variable	6237
MO1	8 (0%)	-726 (-11%)	-1215 (-17%): May	125 (2%): Jan	-297 (-5%)
MO2	137 (2%)	824 (12%)	-408 (-6%): Jan	1341 (20%): Augl	378 (6%)
MO3	-241 (-4%)	-1706 (-25%)	-2727 (-38%): May	655 (10%): Augl	-748 (-12%)
MO4	-156 (-2%)	-1517 (-22%)	-2357 (-30%): Jun	-65 (-1%): Dec	-888 (-14%)
PA	-116 (-2%)	-890 (-13%)	-1574 (-22%): May	253 (4%): AugII	-304 (-5%)

Table 3-43. CRS (Federal) Peak Load (120 Hour) Generation: Change from NAA

	Average Federal 120 Hour Generation (aMW)				
	Nov - Feb	Apr II - Jul	Max Loss Period	Max Gain Period	Annual
NAA	11220	12082	Variable	Variable	10784
MO1	-30 (0%)	-2 (0%)	-728 (-7%): Augl	179 (1%): Jun	-72 (-1%)
MO2	310 (3%)	1013 (8%)	-327 (-3%): Mar	1235 (10%): May	509 (5%)
MO3	-1078 (-10%)	-2004 (-17%)	-2660 (-21%): May	796 (9%): AugII	-1210 (-11%)
MO4	-70 (-1%)	-2383 (-20%)	-4146 (-36%): Mar	78 (1%): Jan	-1400 (-13%)
PA	65 (1%)	-610 (-5%)	-1213 (-10%): May	538 (6%): AugII	-132 (-1%)

Table 3-44. CRS (Federal) HLH P10 Generation: Change from NAA

	P10 Federal 120 Hour Generation (aMW)				
	Nov - Feb	Apr II - Jul	Max Loss Period	Max Gain Period	Annual
NAA	8963	9805	Variable	Variable	8769
MO1	38 (0%)	-616 (-6%)	-1193 (-13%): AugI	103 (2%): AprI	-265 (-3%)
MO2	340 (4%)	704 (7%)	-399 (-5%): Mar	999 (13%): AugII	415 (5%)
MO3	-317 (-4%)	-1679 (-17%)	-2371 (-21%): May	670 (8%): AugII	-787 (-9%)
MO4	-25 (0%)	-1854 (-19%)	-3103 (-36%): Mar	44 (1%): Feb	-1153 (-14%)
PA	59 (1%)	-829 (-9%)	-1539 (-14%): May	394 (5%): Sep	-186 (-2%)

Table 3-45. CRS (Federal) HLH Critical Water Generation: Change from NAA

	1937 Federal 120 Hour Generation (aMW)				
	Nov - Feb	Apr II - Jul	Max Loss Period	Max Gain Period	Annual
NAA	8981	9724	Variable	Variable	8842
MO1	10 (0%)	-837 (-9%)	-1717 (-16%): AugI	162 (2%): AprI	-371 (-4%)
MO2	224 (2%)	884 (9%)	-268 (-3%): Jan	1164 (10%): Jun	419 (5%)
MO3	-249 (-3%)	-1759 (-18%)	-2481 (-26%): May	485 (6%): AugII	-761 (-9%)
MO4	-102 (-1%)	-1480 (-15%)	-3948 (-37%): AugI	-30 (0%): Feb	-1070 (-12%)
PA	-27 (0%)	-783 (-8%)	-960 (-10%): May	319 (3%): Nov	-244 (-3%)

3.4.3 Mid-Columbia Non-Federal Projects

The Mid-Columbia non-Federal projects results are provided for average generation, P10 generation, and critical water generation for Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids Dams. Positive values are increases from the NAA value. Results are unavailable for peak generation metrics due to HOSS modeling limitations. Summaries generally apply to all generation metrics.

Mid-Columbia system generation results are in part similar to the NW-US and CRS (Federal) systems because of their location below Grand Coulee. Changes in Federal operations above and at Grand Coulee directly affect the flow of water through the five Mid-Columbia projects, resulting in similar impacts. However, changes in fish passage spill at the Federal projects and changes in flow on the lower Snake River would not affect the Mid-Columbia projects.

MO1 average generation was nearly the same as the NAA. December generation losses from draft reductions at Libby were offset by generation increases in January and February resulting from drafts at Libby and Grand Coulee.

MO2 showed no change in annual average generation from the NAA. Generation increased in the winter from increased storage drafts, which contributed to offsetting generation reductions in the spring, especially during below normal water supply conditions such as the P10 and critical water scenarios.

MO3 average generation was nearly the same as the NAA. Fall generation gains in November and December were offset by winter and spring reductions. Snake River dam breaching did not substantially affect Mid-Columbia flows and generation.

MO4 average generation was nearly the same as the NAA. Generation increased in the spring and early summer from fish migration flow augmentation. Those increases were offset with August flow reductions after termination of fish augmentation flows.

PA average generation was slightly increased in September, October, and February from a combination of measures including the Sliding Scale at Libby and Hungry Horse, Planned Draft Rate at Grand Coulee, including Modified Draft at Libby. Conversely, there are slight reductions in generation primarily in November, December, March, April, July, and August, largely from the same measures that moved water flow and generation between months. The net generation decrease may result from irrigation withdrawals for additional water supply.

Table 3-46. Mid-Columbia Average Generation: Change from NAA

	Average Mid-C Generation (aMW)				
	Nov - Feb	**Apr II - Jul**	**Max Loss Period**	**Max Gain Period**	**Annual**
NAA	2759	3075	Variable	Variable	2644
MO1	5 (0%)	-71 (-2%)	-129 (-5%): AprII	65 (2%): Jan	-35 (-1%)
MO2	83 (3%)	-30 (-1%)	-141 (-6%): AprI	116 (4%): Feb	3 (0%)
MO3	28 (1%)	-71 (-2%)	-124 (-5%): AprII	103 (4%): Dec	-27 (-1%)
MO4	-6 (0%)	32 (1%)	-253 (-10%): AugII	124 (4%): May	-30 (-1%)
PA	1 (0%)	-23 (-1%)	-86 (-3%): AprII	53 (2%): Feb	-5 (0%)

Table 3-47. Mid-Columbia P10 Generation: Change from NAA

	P10 Mid-C Generation (aMW)				
	Nov - Feb	**Apr II - Jul**	**Max Loss Period**	**Max Gain Period**	**Annual**
NAA	2106	2227	Variable	Variable	2018
MO1	47 (2%)	-70 (-2%)	-158 (-7%): AugI	146 (8%): Feb	-31 (-1%)
MO2	110 (4%)	-14 (0%)	-138 (-8%): Mar	347 (20%): Feb	18 (1%)
MO3	136 (5%)	-74 (-2%)	-158 (-7%): AugI	194 (11%): Feb	6 (0%)
MO4	18 (1%)	101 (3%)	-389 (-18%): AugI	291 (12%): May	-21 (-1%)
PA	27 (1%)	4 (0%)	-64 (-3%): AugI	182 (10%): Feb	12 (0%)

Table 3-48. Mid-Columbia Critical Water Generation: Change from NAA

	1937 Mid-C Generation (aMW)				
	Nov - Feb	**Apr II - Jul**	**Max Loss Period**	**Max Gain Period**	**Annual**
NAA	2272	2263	Variable	Variable	2133
MO1	4 (0%)	-133 (-6%)	-218 (-9%): AugI	52 (2%): Jan	-65 (-3%)
MO2	31 (1%)	-42 (-2%)	-178 (-8%): Jan	350 (20%): Feb	-12 (-1%)
MO3	61 (3%)	-138 (-6%)	-218 (-9%): AugI	192 (8%): Jan	-47 (-2%)
MO4	-35 (-2%)	79 (3%)	-775 (-32%): AugI	574 (27%): May	-63 (-3%)
PA	-46 (-2%)	-40 (-2%)	-194 (-8%): Jan	67 (4%): Oct	-32 (-1%)

3.4.4 Canadian System

The Canadian system results are provided for average generation, P10 generation, and critical water generation for the CRT dams and several non-Treaty dams on the lower Kootenay and Pend Oreille Rivers. Positive values are increases from the NAA value. Canadian results are unavailable for peak generation metrics due to HOSS modeling limitations.

Little change from NAA generation occurred on the Canadian system as a result of the alternatives. The major projects at Mica, Revelstoke, and Arrow were unaffected as their operation was replicated identically in all the alternatives. All generation changes occurred at Waneta and Seven Mile Dams on the Pend d'Oreille River downstream of Hungry Horse and Albeni Falls Dams and several smaller projects on the Kootenay River downstream of Libby Dam.

Table 3-49. Canadian Average Generation: Change from NAA

	Average Canadian Generation (aMW)				
	Nov - Feb	Apr II - Jul	Max Loss Period	Max Gain Period	Annual
NAA	3142	4114	Variable	Variable	3401
MO1	1 (0%)	-10 (0%)	-56 (-2%): Dec	36 (1%): Jan	-2 (0%)
MO2	46 (1%)	-19 (0%)	-61 (-3%): Jan	139 (4%): Dec	7 (0%)
MO3	30 (1%)	-19 (0%)	-102 (-4%): Jan	129 (3%): Dec	2 (0%)
MO4	-13 (0%)	20 (0%)	-108 (-3%): Sep	34 (1%): Jul	-6 (0%)
PA	14 (0%)	-6 (0%)	-19 (-1%): Sep	34 (1%): Jan	1 (0%)

Table 3-50. Canadian P10 Generation: Change from NAA

	P10 Canadian Generation (aMW)				
	Nov - Feb	Apr II - Jul	Max Loss Period	Max Gain Period	Annual
NAA	2452	3086	Variable	Variable	2615
MO1	27 (1%)	-61 (-1%)	-117 (-4%): Jul	74 (2%): AugII	-6 (0%)
MO2	106 (3%)	-99 (-2%)	-223 (-7%): Jul	242 (7%): Dec	7 (0%)
MO3	88 (3%)	-108 (-3%)	-220 (-7%): Jul	242 (7%): Dec	-2 (0%)
MO4	29 (1%)	63 (2%)	-106 (-4%): Sep	158 (5%): Jul	24 (1%)
PA	22 (1%)	-60 (-1%)	-115 (-4%): Jul	74 (2%): AugII	-7 (0%)

Table 3-51. Canadian Critical Water Generation: Change from NAA

	1937 Canadian Generation (aMW)				
	Nov - Feb	Apr II - Jul	Max Loss Period	Max Gain Period	Annual
NAA	3128	3149	Variable	Variable	2989
MO1	5 (0%)	-43 (-1%)	-137 (-5%): Jul	118 (3%): Dec	-32 (-1%)
MO2	70 (2%)	-41 (-1%)	-123 (-4%): Jul	307 (8%): Dec	-8 (0%)
MO3	70 (2%)	-44 (-1%)	-135 (-5%): Jul	307 (8%): Dec	-11 (0%)
MO4	-40 (-1%)	1 (0%)	-213 (-7%): Sep	183 (5%): May	-44 (-1%)
PA	-16 (-1%)	-34 (-1%)	-110 (-4%): Jul	38 (1%): Jan	-30 (-1%)

3.5 OTHER POWER AND NON-POWER OPERATIONS NOT INCLUDED IN HYDSIM AND HOSS MODELING

There are many project operations of the CRS that are not distinguishable or fully captured in the HYDSIM and HOSS modeling described above. Some of these happen on timescales that are shorter than the resolution of the models. Some are operations that are not included in models used in planning but are decided and implemented on an *ad hoc* basis during real-time operations if and when there are appropriate conditions and system flexibilities. Several examples are provided below and others are discussed in Section 1.2.5 and in the CRSO DEIS.

These operations are considered to be part of the NAA and many of the MOs, and would likely be part the preferred alternative. This section provides a discussion of some of these operations and a qualitative assessment their effects and the ability of the CRSO EIS alternatives ability to implement or accommodate some of the more significant ones.

3.5.1 Operations Not Distinguishable in HYDSIM or HOSS

The following operations are considered as part of the NAA and may have short-term system effects that are not fully captured or distinguishable in HYDSIM and HOSS modeling:

- **Albeni Falls, the Flexible Winter Power Operations (FWPO):** Between December 15 and March 31, Albeni Falls can be operated to use a larger portion of its authorized operation range to meet power needs more effectively. FWPO is not implemented in the CRSO DEIS studies, though the operations will continue. The Albeni Falls Dam FWPO Environmental Assessment published in 2011 covers this operation and is not superseded by the CRSO EIS[18].
- **Power shaping for demand**: CRS power operations provide weekly daily, hourly, and moment-to-moment shaping of generation in response to firm power customer load demands, variability in generating resources within Bonneville's balancing area, weather variations, and market conditions. The average variations in demand for power from month-to-month are incorporated in the HYDSIM modeling. Similarly, average variations in demand across the week such as lower demand on weekends as well as typical variations across the day with lighter demand at night are included the HOSS modeling. Similarly, average generation from wind and solar generation are included as reductions in demand. During real-time operations, changes in weather and many other factors affect demand for power. Changes in weather affect power generation from wind and solar projects. The hydropower system responds to these fluctuations on a daily, hourly, and faster time frames and will continue to do so, regardless of which alternative is selected as the preferred alternative

[18] See Albeni Falls Dam Flexible Winter Power Operations Final EA (October 2011) at https://www.bpa.gov/efw/Analysis/NEPADocuments/Pages/Albeni-Falls-Dam.aspx.

- **Power shaping for economic marketing:** In times of flexibility in power operations, Bonneville may buy power when wholesale prices are low or sell when prices are high. This could result in daily or hourly shaping of project releases within established ramp rates.
- **Power emergencies:** Power system emergencies can result from a loss of generating resources on or off the Bonneville system, loss of transmission, or other unexpected event. Through the Technical Management Team (a regional forum of federal agencies, states, and tribes) there is an established protocol for altering operations in the event of a power emergency to increase power generation.
- **Power contingency reserves:** An important component of grid reliability is to ensure that electricity generation matches electricity demand at all times. Many of the hydropower resources on the grid can be operated to rapidly increase or decrease generation in response to fluctuating electrical demand or fluctuations in wind and solar generation providing power flexibility when needed to meet load and maintain a safe, reliable transmission system. The standby capacity and the ability to decrease generation are called generating reserves. Bonneville's power operations provide this service to its transmission operations. A subset of generating reserves are capacity reserves. They are used to replace power when another generating unit within the Bonneville balancing area stops unexpectedly or a transmission line that is importing energy suddenly cannot import the power. Contingency reserves are provided for 30 to 90 minutes until power can be purchased on the next cycle of the hourly wholesale spot market. The flexibility of hydropower resources are a valuable tool for providing reserves.
- **Fish passage spill averaging**: In Bonneville modelling of MO1, MO3, and MO4, the spill is averaged over 12 or 24-hour periods as consistent with the water quality criterion and with the expectation that a similar approach would be in new criteria at the higher spill levels. Averaging spill would enable brief periods of slightly lower spill and higher generation to be balanced with other periods of the reverse conditions. Such an operational decision would be made during the course of the operating day. The increase in the ability to shape power generation across the day through spill averaging increases Bonneville's ability to shape generation to meet load, for marketing, and to support integration of wind and solar generation.
- **Libby December Draft:** In MO2 and MO3, Libby may draft 20 feet below the December target elevation for power. In CRSO modeling, Libby was always modeled as exercising this option. However, the exact operation would be decided based on any given year's conditions such as a warm December with less demand for power with an expectation for a colder January or February.
- **Grand Coulee Winter FRM Space:** In HYDSIM modeling of MO1, MO2, and MO4, Grand Coulee draft a few feet below full by mid-December to create space that can be filled in the event of a heavy winter rain event. In HYDSIM, this space at Grand Coulee is kept empty for the duration of the winter. However, if such a rain event were to occur, the space would be filled during the rain event and emptied again following the event.

- **Miscellaneous:** Several other operations are implemented in-season such as special elevations for Tribal fishing under their Treaty rights, weekend recreational events, reservoir elevations for loading or unloading special cargo, and maintenance work. These are described in the DEIS for NAA and are expected to continue.

3.5.2 Qualitative Effects of the MO Alternatives

The following discussions provide a qualitative assessment of the power effects of measures that are considered parts of the CRSO DEIS alternatives and are not distinguishable or fully captured in HYDSIM or HOSS modeling.

3.5.2.1 All Multiple-Objective Alternatives

Power contingency reserves are carried within juvenile fish passage spill for all MO alternatives. This increases the available capacity of hydro generation at the lower Snake and Columbia River projects. Holding the contingency reserves within the fish passage spill rarely affects fish passage spill amounts because the reserves are rarely used. Furthermore, contingency reserves can usually be deployed without reducing fish passage spill. In high flow conditions, this measure will reduce the incidence of spill stemming from lack-of-turbine capacity (which may lead to TDG above the water quality criterion) because the powerhouse will not need to reserve as much capacity outside fish passage spill.

HYDSIM does not shape powerhouse flows to meet weekly, daily, hourly, and real-time demands. All alternatives are considered to have shaping within the historic range of operations and impacts should be within historical flow changes.

MO1 ALTERNATIVE

In MO1 the forebay operating range at the Lower Snake River and John Day projects is increased by 0.5 feet during fish passage season. This flexibility is the same range being used in 2019 and is still smaller than the historic range of operations during the fall and winter time frame.

MO2 ALTERNATIVE

MO2 includes the operation of the lower Snake and Columbia River and projects at full reservoir operating range year-round except at John Day when it is operated for FRM. This type of flexibility is within the historic range of operations and impacts would be similar to historical elevation impacts during the fall and winter time frames when the projects operate at the full reservoir range.

Lower Snake and Columbia turbines can operate across their full range of capacity all year in MO2. This measure will increase generation and turbine flow capacities to reduce the amount of lack-of-turbine spill. The increased full-range use of turbine capacity was included in the CRSO DEIS modeling. The increased use of turbine range would increase slightly the amount of

within-day shaping to meet fluctuations in demand and would be within the historic range of operations and impacts would be similar to historic impacts.

MO2 also includes a measure that allows the Lower Snake River projects to shut off generation unless limited by grid stability requirements from September through March. This allows the projects to reduce generation when there is little demand and store the water for use at a later time when generation is in peak demand. This operation and its effects are within the historic range of operations typically observed in the mid-December through February winter months. Although the generation reduces the project flow to zero, the tailwater below the dam does not dry out because the downstream reservoir extends to the base of the upstream dam.

In both MO2 and MO3, the ramping rate limitations at all projects are defined for safety or geotechnical concerns such as erosion. More flexibility in ramping rates does not increase the total generation but increases the ability to shape flows and power generation within-day to meet fluctuations in demand.

ResSim models at the daily time step so within-day ramping was not captured. In power operations, projects would be shaped to the extent feasible to maximize generation during peak demand and minimize generation during low demand, while passing the necessary water across the day. For example, in the winter the project would pass the day average flow in a shape where the project was ramped down to minimum generation at night and ramp up over the morning peak demand. If the ramp rates allowed, another ramp down during midday to save water for the evening peak demand would likely occur, with an additional ramp down to minimums again for the overnight low demand period. The ramping limitations for safety or geotechnical concerns would need to be provided to calculate how much within day shaping of the flow would be allowed. If ramping rates are too restrictive for much within-day ramping, the projects would shape to have higher generation during the weekdays and lower generation on the weekends as allowed. Within-hour shaping would not be utilized on the headwater projects.

MO3 ALTERNATIVE

As stated above, MO3 includes no flow and ramping restrictions except those defined for safety or geotechnical concerns such as erosion. It also includes expanded John Day reservoir ranges similar to MO2.

MO3 also includes allowance for the Lower Columbia projects to operate turbines within and above the 1 percent peak efficiency range. This expands the turbine range on the upper end of the operating range which increases the turbine capacity to reduce the amount of lack-of-turbine spill. The increased turbine capacity would increase slightly the amount of within-day shaping to meet fluctuations in demand for electricity and fluctuations in generation from wind and solar power in the region, but is within the historic range of operations. Impacts should be similar to the historical impacts during the winter time frames when the projects operate at the full turbine range.

MO4 ALTERNATIVE

MO4 also includes the allowance for the Lower Columbia and Lower Snake River projects to operate turbines within and above the 1 percent range around peak efficiency. This expands the turbine range on the upper end of the operating range, which increases the turbine capacity to reduce the amount of lack-of-turbine spill. The increased turbine capacity would increase the amount of within-day shaping to meet fluctuations in demand, but is within the historic range of operations. Impacts should be similar to the historical impacts during the winter time frames when the projects operate at the full turbine range.

MO4 includes additional reservoir drawdowns to the Lower Columbia River projects. This will restrict the ability of those projects to meet fluctuations in power demand and to respond to fluctuations in wind and solar power generation. Though Lower Snake River projects are allowed to operate within MOP+1.5', which provides some offset to this, Grand Coulee and Chief Joseph will need to absorb more of the fluctuations in generation to meet power demand and obligations to integrate renewable energy.

PREFERRED ALTERNATIVE

In the PA the forebay operating range at the Lower Snake River and John Day projects is increased by 0.5 feet during fish passage season. This flexibility is the same range being used in 2019 and is still smaller than the historic range of operations during the fall and winter time frame.

PA includes the operation of John Day at full reservoir operating range year-round except at when it is operated for FRM. This type of flexibility is within the historic range of operations and impacts would be similar to historical elevation impacts during the fall and winter time frames when the projects operate at the full reservoir range.

PA also includes a measure that allows the Lower Snake River projects to shut off generation unless limited by grid stability requirements from October through February with revised timing to provide hydropower flexibility while minimizing impacts to ESA-listed fish. This allows the projects to reduce generation when there is little demand and store the water for use at a later time when generation is in peak demand. This operation and its effects are within the historic range of operations typically observed in the mid-December through February winter months. Although the generation reduces the project flow to zero, the tailwater below the dam does not dry out because the downstream reservoir extends to the base of the upstream dam.

3.6 HYDROPOWER GENERATION FOR REVENUE IMPACT ANALYSES

Bonneville prepared CRS energy generation estimates for the NAA and each CRSO EIS action alternative. The CRSO DEIS socioeconomic analysis used generation amounts to estimate Federal revenues for each alternative. Revenue analyses and result details are provided in the *P&T Socioeconomics Appendix* to the CRSO DEIS.

Bonneville markets firm power (power that is made continuously available expect for reasons of force majeure) under long-term firm power sales contracts. The FCRPS constitutes the largest system of resources that produce firm power, which is determined using the critical water year (1937). The change in annual average generation of the CRS projects is the primary component in determining the change in the amount of the Federal Base System Bonneville uses to support its long-term firm power sales contracts.

Bonneville used the HYDSIM model to estimate energy generation for each period during the 80-year study period. The average critical water (1937) generation was used to estimate the amount of firm power that the FCRPS is expected to produce. Bonneville is currently selling firm power through September 2028 under long-term Regional Dialogue firm power sales contracts. The contract and Bonneville's current priority firm power rate design (the Tiered Rates Methodology) is based on the Tier 1 System Firm Critical Output, which is the amount of firm power produced by the federal hydroelectric dams, Columbia Generating Station, and the non-federal resources Bonneville has acquired to meet its firm power supply contractual obligations. In the event the Tier 1 System Firm Critical Output decreases, such as through a reduction in the CRS's firm power capability, the resulting reduction would likely lead to a change in the supply of federal power to Bonneville's customers at the Tier 1 system rate. Customers that elected to serve their own loads above the Tier 1 System Firm Critical Output would be have to find other sources of supply to meet their load needs.[19] Generation amounts greater than the Tier 1 System Firm Critical Output may be available for surplus sales if not first needed to meet Bonneville's firm power obligations. The CRS generation amount estimates for the socioeconomic analyses are provided in Table 3-52.

Table 3-52. Average CRS (Federal) Generation for Revenue Determination

Alternative	1937 Average Generation Change from NAA (aMW / %)	80-Year Average Generation Change from NAA (aMW / %)
NAA	6,237	8,340
MO1	-297 / -4.8	-132 / -1.6
MO2	378 / 6.1	445 / 5.3
MO3	-748 / -12.0	-1,105 / -13.2
MO4	-888 / -14.2	1,302 / -15.6
PA	-304 / -4.9	-157 / -1.9

[19] Bonneville may sell power to these customers to meet their power needs if Bonneville has surplus power available. The availability of this power, however, is uncertain.

CHAPTER 4 - SYSTEM RELIABILITY

4.1 OVERVIEW

The Loss of Load Probability (LOLP) studies for the CRSO DEIS evaluate the NW-US system's ability to meet forecasted electric load in 2022. Generation amounts for each CRSO DEIS alternative plus other resources from the NWPCC's 2017 Resource Adequacy Assessment (NWPCC 2017a) are compared to the forecasted load for 2022. The analyses involve Pacific Northwest generating resources, assumptions of power imports and exports, regional loads, temperature correlated wind generation profiles, planned generating resource retirements, power conservation expectations, and new generating resource additions. Conservation and new resource assumptions are from the NWPCC's 7th Power Plan (NWPCC 2016).

It is important to note that since the analysis for LOLP in the CRSO EIS was launched in 2017, utilities in the Pacific Northwest have announced the retirement of additional coal generation plants. Therefore, the analysis described here may be viewed as "the 2017 view of the future." BPA is performing additional analyses to evaluate how these results would differ with fewer coal plants serving northwest loads.

Bonneville and other regional planning entities such as the NWPCC use LOLP as a fundamental metric of power system reliability. LOLP measures the frequency of years with one or more power outages in a Monte Carlo analysis or multiple operating years and conditions; it does not capture the magnitude or duration of an outage. Bonneville and NWPCC use a standard of 5 percent LOLP.

4.1.1 Methodology

Bonneville used the NWPCC's GENESYS model to conduct the studies and ran 6,160 Monte Carlo simulations for each CRSO DEIS alternative involving hydropower, wind, and solar energy variability; forced outages on thermal plant generation; and hourly historical temperature variations (1929 to 2006). This provided the LOLP frequency, how many games out of 6,160 had instances of insufficient resources to meet the demand, but did not measure the magnitude or duration of an outage. Bonneville prepared a CVaR analysis to assess the magnitude and seasonality of the outages.

CVaR techniques evaluate the amount of monthly average energy not served in the worst 5 percent (308 games) of the GENESYS games in which load was not met. For example, the NAA results in Figure 4-1 and Table 4-1 indicate there was an average load loss of 65.1 aMW in 2.9 percent of the worst 5 percent of the games (about nine games).

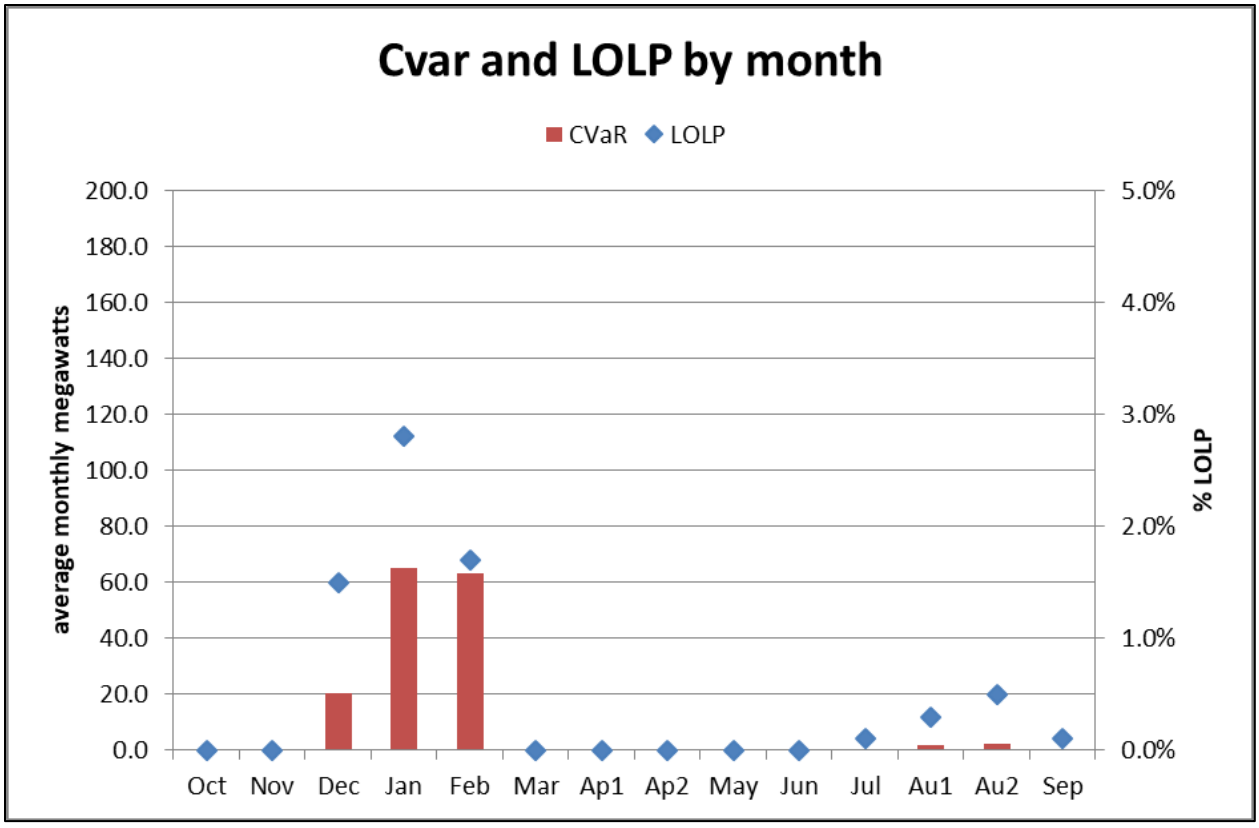


Figure 4-1. NW-US System CVaR and LOLP by Month for NAA

Table 4-1. NW-US System LOLP and CVaR by Month for NAA

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
LOLP (%)	0.0	0.0	1.5	2.9	1.8	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.6	0.2
CVaR (aMW)	0.0	0.0	21.2	67.3	64.3	0.0	0.0	0.0	0.0	0.0	0.5	2.3	2.5	0.2

The reliability analyses were regional (NW-US) and were not performed for the CRS (Federal), Mid-Columbia, or Canadian systems. Because the utilities in the region can buy and sell power bilaterally with one another that is surplus to their retail load needs, the loss of generation by one entity can have adverse consequences to utilities relying on such generation. If the Federal system loses generation, BPA may be obligated to acquire resources to replace losses in the Federal Base System consistent with Bonneville's long-term firm power sales contracts or its customers may do so. Therefore, this analysis focused on what resources would need to be acquired by Bonneville to serve its firm power load obligations. The socioeconomic analysis in the CRSO DEIS *P&T Socioeconomic* Appendix examines the two cases of whether Bonneville or non-Bonneville entities acquire replacement resources.

4.1.2 Lost-of-Load Probability Results

4.1.2.1 No-Action Alternative

Bonneville's analysis of the LOLP for the NAA is 6.6 percent for the Pacific Northwest, which means there was at least one outage in 6.6 percent of the simulation games. An LOLP of 6.6 percent means that the region would experience a significant power shortage (or recurring power shortages) in roughly one in every 15 years. These are power shortages because loads are greater than the power system's ability to generate electricity and are not power outages on the distribution system such as when a tree hits a power line and blacks out a neighborhood for a few hours. An LOLP event could result in rolling blackouts lasting up to several days.

Because the 6.6 percent LOLP value is above the regional standard, regional utility planners (and potentially Bonneville is requested by its customers) should be building or acquiring new generating resources with firm capacity. Only wind and solar are currently planned, and they do not have firm generation capacity. However, the region has accepted this higher level of LOLP over the past 5 years, and it has become the status quo. This does not meet the 5 percent LOLP standard, but the 6.6 percent LOLP of the NAA will serve as the measure of comparison for the effects of the other CRSO DEIS alternatives.

Bonneville estimates that the monthly CVaR varies from 0 to 67.2 aMW before any replacement resources are added. Load loss was highest in the winter months peaking at 2.9 percent in January. Summer months had considerably smaller events, but were not free of loss-of-load events. The Pacific Northwest has traditionally focused on winter as the period of reliability concern. However, with increasing population and an increasing use of air conditioning, summer months are emerging as reliability concerns as well. Detailed results are provided in Figure 4-1 and Table 4-1.

Note that the sum of the 14-period LOLP results do not add up to the annual LOLP results because some games had loss-of-load events in more than one month. Each year counts only once in the annual LOLP.

4.1.2.2 MO1: Change from NAA

Bonneville estimates the LOLP for MO1 is 11.2 percent for the Pacific Northwest, which means there was an outage (or multiple outages) in 11.2 percent of the simulation games or approximately one every 9 years. Bonneville and/or Bonneville's public power customers would need to build or acquire new firm resources to meet the 5 percent LOLP standard or the 6.6 percent level of NAA.

Bonneville estimates the monthly CVaR varies from 0 to 60.8 aMW. Load loss was its highest during the winter months peaking at 2.8 percent in February. Though smaller than the winter outages, in MO1 significantly more outages occurred in August compared to NAA where there were relatively few. Detailed results are provided in Figure 4-2 and Table 4-2.

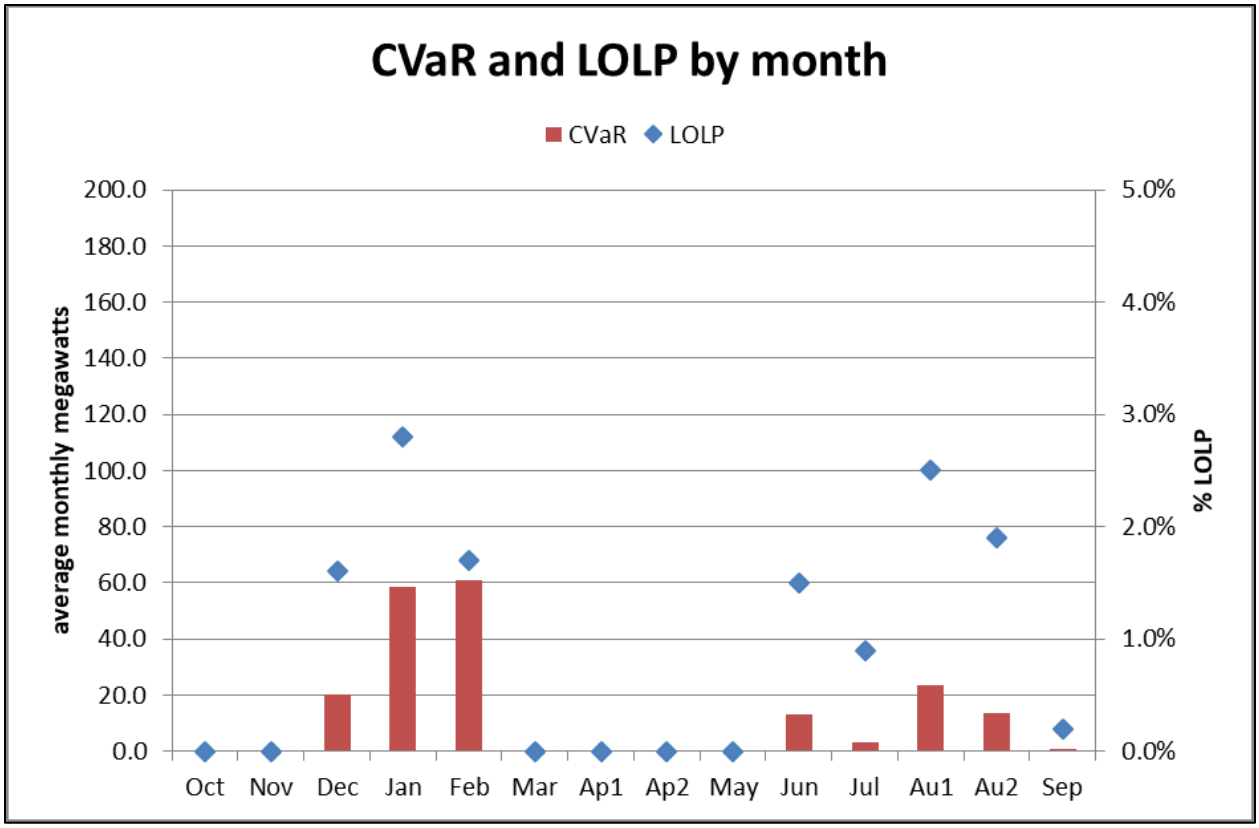


Figure 4-2. NW-US System CVaR and LOLP by Month for MO1

Table 4-2. NW-US System LOLP and CVaR by Month for MO1

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
LOLP (%)	0.0	0.0	1.6	2.8	1.7	0.0	0.0	0.0	0.0	1.5	0.9	2.5	1.9	0.2
CVaR (aMW)	0.0	0.0	20.2	58.3	60.8	0.0	0.0	0.0	0.0	12.9	3.0	23.7	13.4	0.5

The LOLP changes from the NAA (6.6 percent) to MO1 (11.2 percent) primarily result from:

- Less fall draft from Libby through December affected December through February water supply at Grand Coulee and below.
- Reduced flows in August from Dworshak affected flows in the lower Snake and Columbia Rivers.
- An increase in fish passage spill compared to NAA in the spring.

4.1.2.3 MO2: Change from NAA

Bonneville estimates the LOLP for MO2 is 5.0 percent for the Pacific Northwest, which means there was one or more outages in 5.0 percent of the simulation periods or approximately in one of every 20 years. This alternative improves the NW-US system LOLP coincidentally to the

Council standard without Bonneville and/or Bonneville's public power customers adding or acquiring new generating resources by increasing the capability of the hydropower system.

Bonneville estimates the monthly CVaR varies from 0 to 65.5 aMW. Load loss was highest during the winter months, peaking at 2.8 percent in January. This was the only alternative without an August outage. Detailed results are provided in Figure 4-3 and Table 4-3.

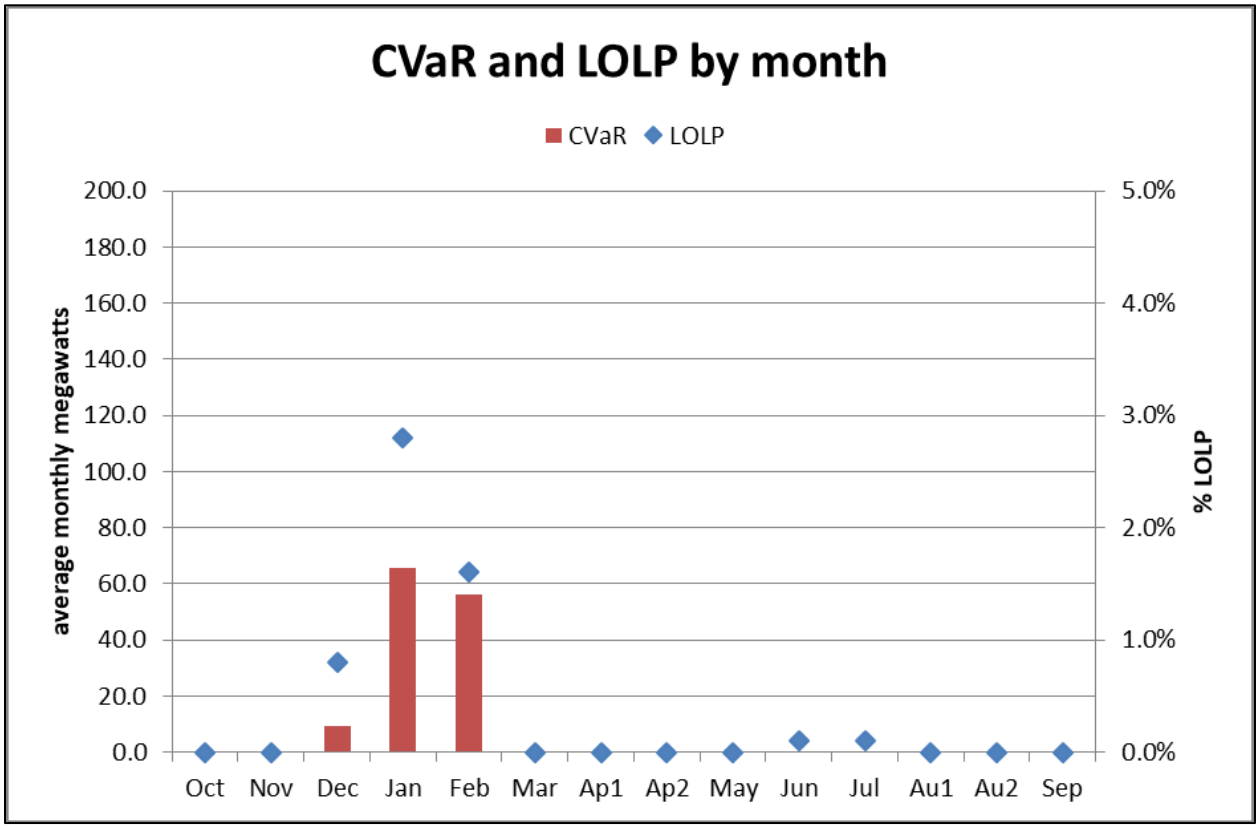


Figure 4-3. NW-US System CVaR and LOLP by Month for MO2

Table 4-3. NW-US System LOLP and CVaR by Month for MO2

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
LOLP (%)	0.0	0.0	0.8	2.8	1.6	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
CVaR (aMW)	0.0	0.0	9.1	65.5	56.3	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0

The LOLP changes from the NAA (6.6 percent) to MO2 (5.0 percent) primarily result from:

- Summer fish passage spill was limited to near 110 percent TDG and ends in August.
- Storage projects drafted slightly deeper in winter and early spring providing more water supply to the Columbia and Snake River projects for winter generation.
- After Grand Coulee's summer draft, refill to 1,283 feet NGVD29 was extended to the end of October (MO2) versus September (NAA).

4.1.2.4 MO3: Change from NAA

Bonneville estimates the LOLP for MO3 is 13.9 percent for the Pacific Northwest, which means there was one or more outages in 13.9 percent of the simulation periods or in nearly one in every 7 years. Bonneville and/or Bonneville's public power customers would need to build or acquire new firm resources to meet the 5 percent LOLP standard or to meet the 6.6 percent LOLP of NAA.

Bonneville estimates that the monthly CVaR varies from 0 to 98.7 aMW. Load loss was highest during the winter months peaking at 4.1 percent in January. Though smaller than the winter event, appreciable outages also occurred from June through August. Detailed results are provided in Figure 4-4 and Table 4-4.

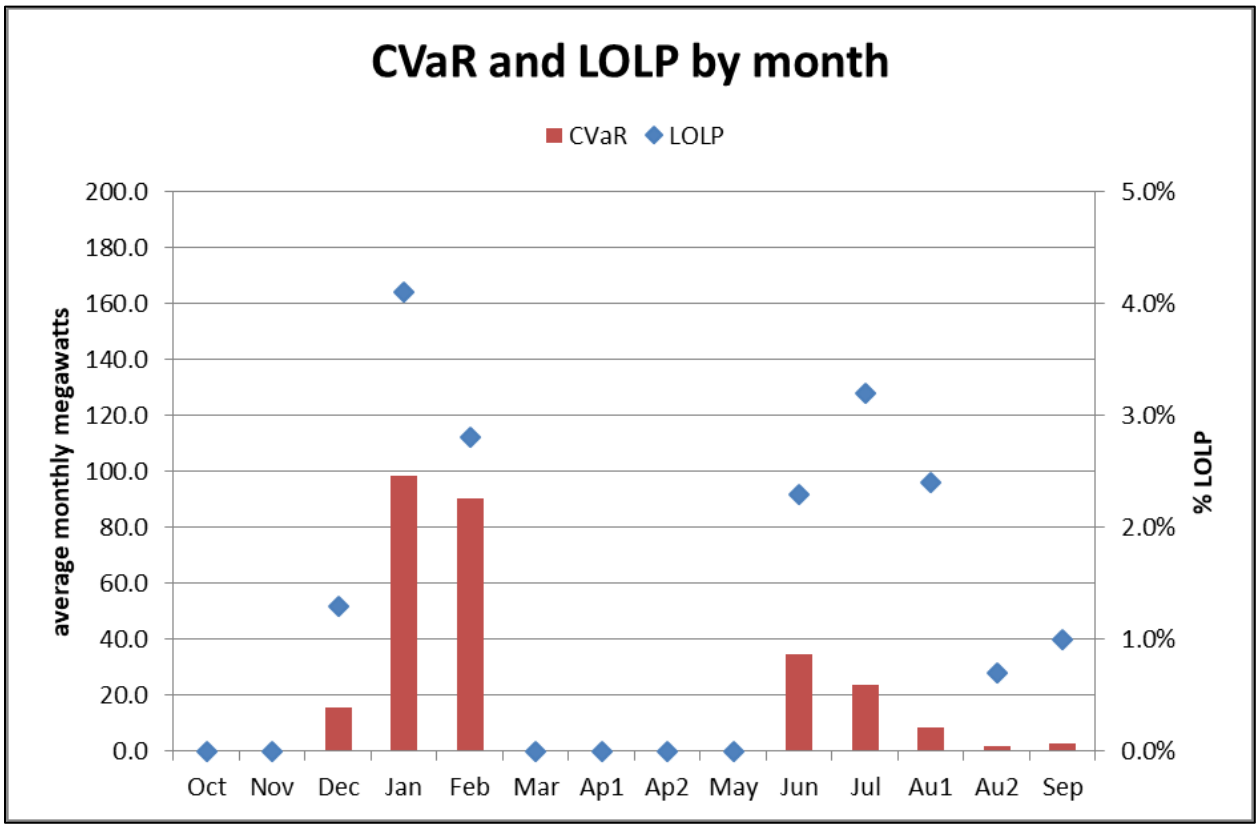


Figure 4-4. NW-US System CVaR and LOLP by Month for MO3

Table 4-4. NW-US System LOLP and CVaR by Month for MO3

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
LOLP (%)	0.0	0.0	1.3	4.1	2.8	0.0	0.0	0.0	0.0	2.3	3.2	2.4	0.7	1.0
CVaR (aMW)	0.0	0.0	15.8	98.7	90.2	0.0	0.1	0.0	0.0	34.5	23.7	8.7	1.9	3.0

The LOLP changes from the NAA (6.6 percent) to MO3 (13.9 percent) primarily result from:

- Breaching the four lower Snake River dams reduced year-round generation.
- Spring spill for fish passage at lower Columbia dams was raised to 120 percent TDG, which reduced generation at the four projects.
- Summer spill for fish passage was ended on August 1, which increased August power production at the lower Columbia dams.
- Deeper draft from Libby in December provided more flow at Grand Coulee and below in December but reduced the January flows.

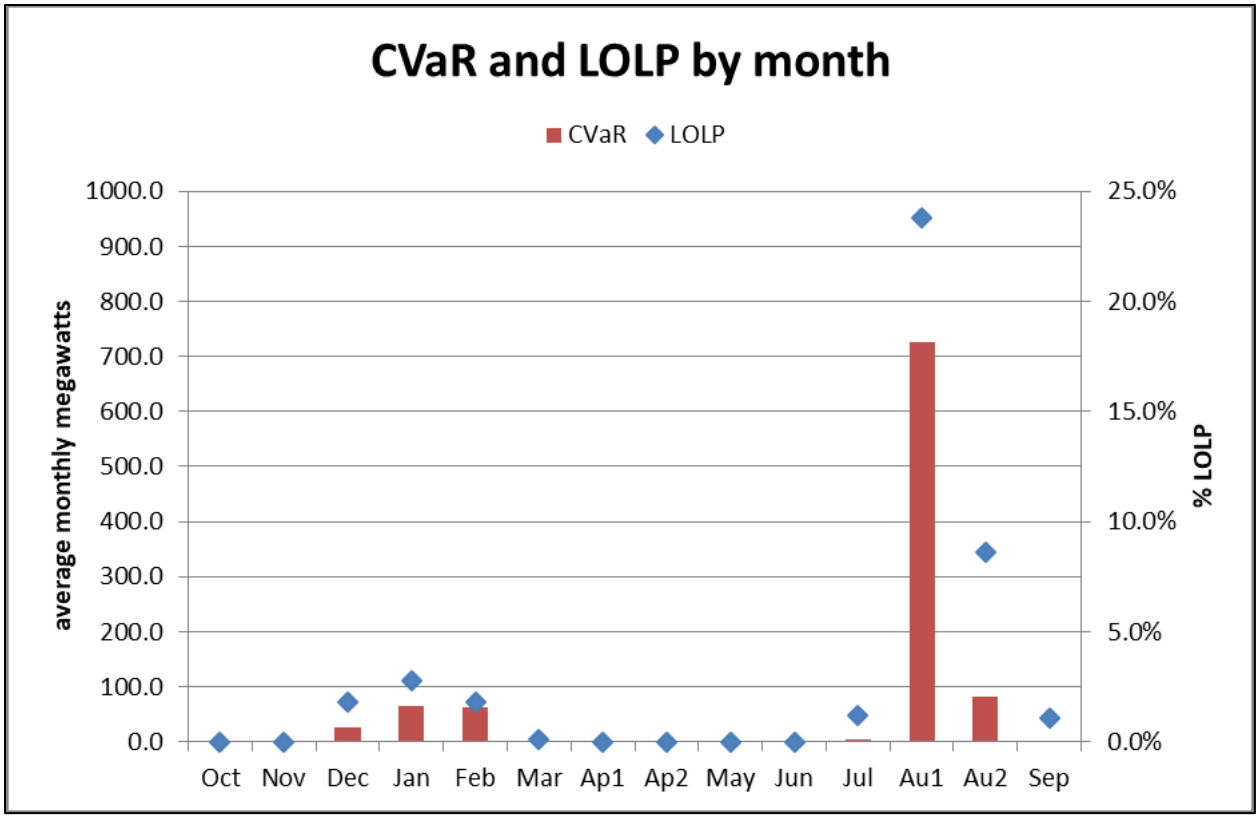
4.1.2.5 MO4: Change from NAA

Bonneville estimates the LOLP for the NAA is 29.6 percent for the Pacific Northwest, which means there was an outage in 29.6 percent of the simulation games meaning that the northwest region might experience significant power outages roughly in one of every 3 years. Bonneville and/or Bonneville's public power customers would need to build or acquire new firm resources to meet the 5 percent LOLP standard or to meet the 6.6 percent LOLP of NAA.

Bonneville estimates the monthly CVaR varies from 0 to 725.3 aMW. Load loss was highest during the summer months peaking at 23.8 percent in the first part of August. This would mean that roughly in one of every 4 years there would be extensive rolling blackouts in the region in early August. Because the CVaR is very high at 725.3 aMW, the rolling blackouts would require significant portions of the northwest to lose power. Detailed results are provided in Figure 4-5 and Table 4-5. Note the scale change for CVaR in Figure 4-5; zero to 1,000 aMW versus zero to 200 aMW in the other alternatives in this section.

The LOLP changes from the NAA (6.6 percent) to MO4 (29.6 percent) primarily result from:

- Fish passage spills at lower Columbia dams were raised to 125 percent TDG from March through August, which reduced generation to minimum generation at the four lower Snake and four lower Columbia River projects in most years.
- Flow augmentation of up to 2 Maf from upstream storage projects that support spring and sometimes early summer flows on the lower Columbia River reduce flows in August to October, sometimes even longer.



Note that the graph for MO4 is on a different scale compared to the graph for NAA and the other MOs.

Figure 4-5. NW-US System CVaR and LOLP by Month for MO4

Table 4-5. NW-US System LOLP and CVaR by Month for MO4

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
LOLP (%)	0.0	0.0	1.8	2.8	1.8	0.1	0.0	0.0	0.0	0.0	1.2	23.8	8.6	1.1
CVaR (aMW)	0.0	0.0	26.1	63.9	61.5	0.4	0.1	0.0	0.0	0.0	3.9	725.3	81.1	2.9

4.1.2.6 PA: Change from NAA

Bonneville estimates the LOLP for the PA is 6.5 percent for the Pacific Northwest, which means there was an outage in 6.6 percent of the simulation games. This is essentially the same as the 6.6 percent LOLP of the NAA. Less fall draft from Libby is affecting December through February inflows at Grand Coulee and downstream. Bonneville estimates the monthly CVaR varies from 0 to 60 aMW. Load loss was highest during the winter months, peaking at 2.6 percent in January. Detailed results are provided in Figure 4-6 and Table 4-6.

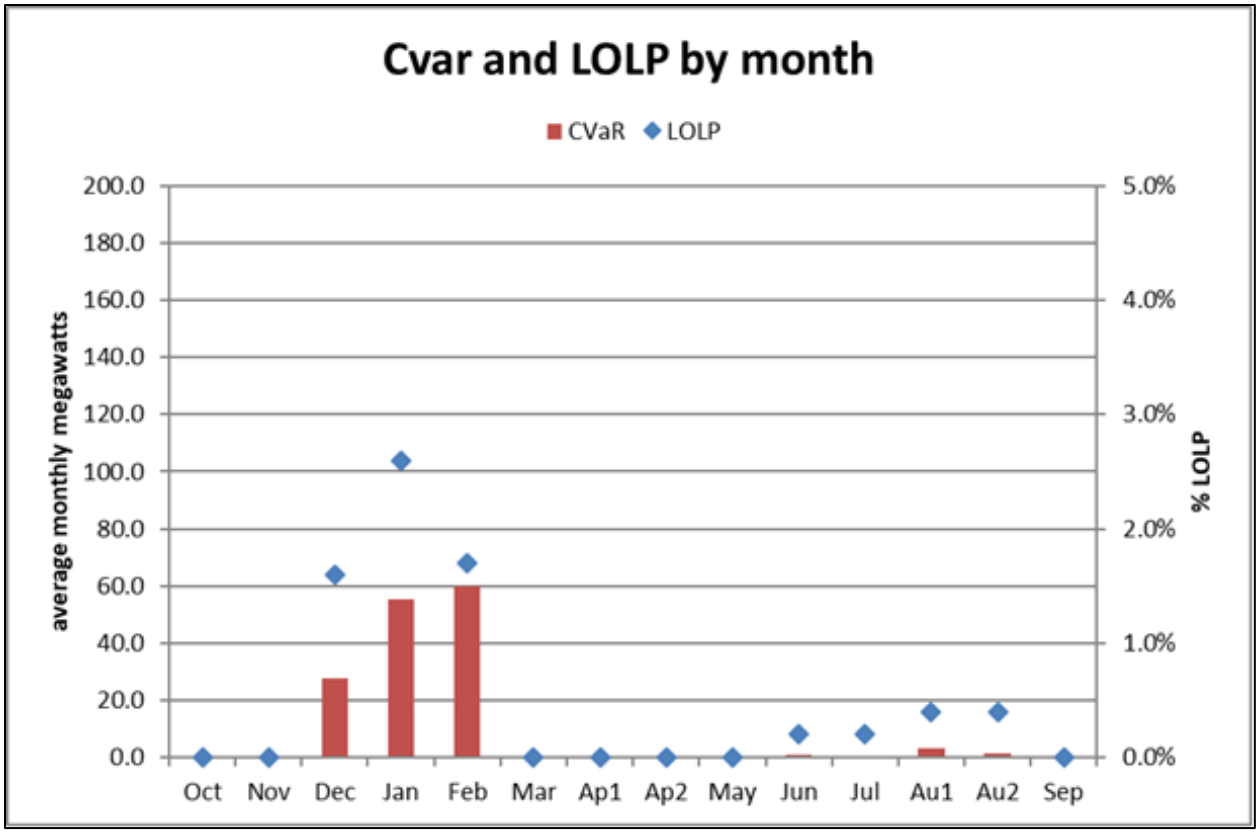


Figure 4-6. NW-US System CVaR and LOLP by Month for PA

Table 4-6. NW-US System LOLP and CVaR by Month for PA

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
LOLP (%)	0.0	0.0	1.6	2.6	1.7	0.0	0.0	0.0	0.0	0.2	0.2	0.4	0.4	0.0
CVaR (aMW)	0.0	0.0	27.7	55.4	60.0	0.0	0.0	0.0	0.0	1.0	0.5	3.1	1.3	0.0

4.1.3 Summary of Key Findings

Key reliability findings for the NW-US system are summarized in Table 4-7. Similar summaries for the CRS (Federal), Mid-Columbia, and Canadian systems are not provided.

MO1 almost doubles the LOLP of the NAA due to increases in summer loss of load. Overall, MO2 impacts system loss-of-load the least and lowers the LOLP from 6.6 percent in the NAA coincidentally to meet the 5 percent industry standard. Major increases in loss of load occur in MO3 due to Snake River dam breaching. Loss of load in MO4 is even greater than in MO3 due to increased fish passage spill and the flow augmentation measure. The PA essentially has the same LOLP as the NAA. Each alternative's key reliability findings are described briefly below.

Table 4-7. NW-US System LOLP and CVaR Summary

Alternative	LOLP (%)	Notable CVaR Results
NAA	6.6	65.1 aMW @ 2.9% LOLP in January
MO1	11.2	58.3 aMW @ 2.8% LOLP in January 23.7 aMW @ 2.5% LOLP in August I
MO2	5.0	65.5 aMW @ 2.8% LOLP in January
MO3	13.9	98.7 aMW @ 4.1% LOLP in January 34.5 aMW @ 2.3% LOLP in June
MO4	29.6	63.9aMW @ 2.8% LOLP in January 725.3 aMW @ 23.8% LOLP in August I
PA	6.5	55.4 aMW @ 2.6% LOLP in January

NAA

The system 6.6 percent LOLP does not meet the 5 percent industry standard which is an indication that Bonneville and/or Bonneville's public power customers the region should be building or acquiring generating resources with firm capacity to meet the 5 percent LOLP standard. Loss of load is most likely to occur in the winter months with a little loss of load occurring during the summer months.

NAA COMPARED TO MO1

Changing the timing of flows from Dworshak and increased fish passage spill raised the overall NAA LOLP from 6.6 percent to 11.2 percent in MO1. Unserved winter load was similar to the NAA. There was a moderate increase from the NAA in unserved load in the summer months due to fish passage spill.

NAA COMPARED TO MO2

MO2's increased hydropower operations total generation and flexibility lowered the overall LOLP coincidentally to the 5 percent industry standard. Reduced fish passage spill levels and duration eliminated almost all spring and summer loss of load. Winter load loss was just slightly better than the NAA.

NAA COMPARED TO MO3

MO3 removal of the lower Snake River power production raised the LOLP from 6.6 percent in the NAA to 13.9 percent. There were substantial increases in winter and summer load losses.

NAA COMPARED TO MO4

MO4 increased spill and flow measures raised the overall system LOLP from 6.6 percent in the NAA to 29.6 percent. The increased spill to 125 percent TDG and additional storage releases to

meet McNary flow targets resulted in major increases in loss of load in the summer compared to the NAA. Winter loss of load was similar to the NAA.

PA

The PA results were similar to the NAA. Similarly, loss of load is most likely to occur in the winter months with a little loss of load occurring during the summer months.

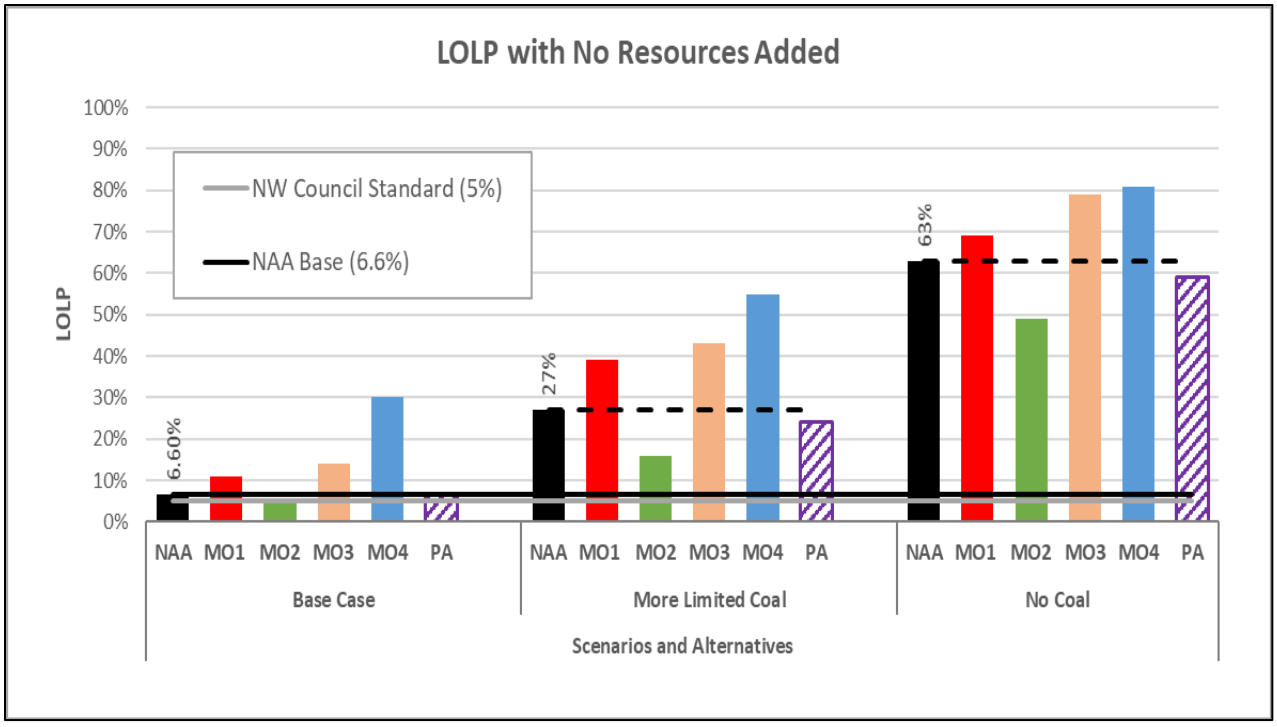
4.1.4 LOLP in the Context of Additional Coal-Plant Retirements

When Bonneville prepared the CRSO EIS analysis in 2017, several coal-fired power plants in the region were scheduled to close. These closures were accounted for in the system reliability analyses discussed in Chapter 4. Since 2017, additional and accelerated coal plant closures have been announced. These closures were not accounted for in the reliability analyses in Chapter 4.

The CRSO DEIS reliability studies include 4,246 MW of combined regional coal plant generation, including Centralia Coal plant in Washington (owned by Transalta, an Independent Power Producer) and the remaining coal plants owned and/or used by the region's investor-owned utilities to serve their retail load demand: Colstrip, Hardin, and Montana 1 in Montana; Jim Bridger in Wyoming; and North Valmy in Nevada. These coal plants all contributed to meeting the regional 6.6 percent LOLP for the NAA. Recent closure announcements are providing an "updated view of the future" with only 1,741 MW of coal plant availability by the end of the 2020s that is provided at the partially closed Colstrip and Jim Bridger plants.

Further, the state of Washington recently passed the *Washington Clean Energy Transformation Act* (Senate Bill 5116) to eliminate coal generation by 2025 and be carbon neutral by 2045. If other states in the Pacific Northwest follow Washington and commit to removing coal-fired power plants with a goal of achieving carbon neutrality or better, it is unlikely that new gas plants would be built in the region.

Removing coal-fired baseload generating resources and replacing them with new renewable resources instead of replacing them with gas-fired generation raises the LOLP of NAA and all of the MOs. Consequently, Bonneville supplemented the original analysis with a reassessment of the LOLP results with two scenarios of future coal- fired generation without new gas-fired generation. Results are displayed in Figure 4-7. The base case represents the LOLPs for the DEIS with the original information available in 2017. The Limited Coal area represents the "updated view of the future" with 1,741 MW of coal remaining in the region. The No Coal area has no coal generation.



Note: The gray line represents the NW Council's standard at 5.0%, and the black lines represent the LOLP of the NAA.

Figure 4-7. NW-US LOLP with Removal of Coal Plants

The "conventional least cost" analysis in Section 4.2.3 with gas-fired replacement resources is still valuable in giving a price range for replacement resources considering that some renewable resource technology would continue to fall in price. The major increases in LOLP indicate the region's utilities serving load need major investments in carbon-free resources to maintain the current levels of reliability. Bonneville did not carry the analysis of limited coal and no coal all the way through the DEIS because such an analysis would involve substantial assumptions about how investor-owned utilities would choose to replace their coal and because it did not have the tools to extrapolate the market that far into new conditions. However, Bonneville did carry forward qualitative assessments that are added to the base case analysis to document the potential effect of the additional coal closures.

4.2 POTENTIAL REPLACEMENT POWER PORTFOLIOS AND CARBON EMISSION IMPACTS

In Section 4.1, Bonneville provided estimates of the system reliability for the NAA and each of the MO alternatives. This section provides information on the development of two sets of potential resource portfolios needed to increase the reliability of MO1, MO3, and MO4 to the 6.6 percent LOLP of the NAA. This chapter also provides information on the development of each portfolio and the estimated amount of generation and carbon production from those portfolios when they are combined with the hydropower production of each MO.

The CO_2 estimates from the fossil fuel generation from the conventional least-cost portfolio are available in the air quality assessments in the CRSO EIS *Air Quality Appendix.* The resource

portfolios and their potential costs and future uses also impact utility revenues and power rates; these are discussed in the CRSO DEIS *P&T Socioeconomic Appendix.*

4.2.1 Overview

During any given time, there are numerous generating units supplying power to the Pacific Northwest power system. Some power will be produced by hydroelectric, wind, solar power, and nuclear resources, which do not emit CO_2; other power will likely be produced by coal or natural gas-fired generating units that emit CO_2. Increases in generation from hydropower and other renewables will often reduce or even eliminate the need to meet power loads with higher marginal-cost, carbon-emitting resources. Conversely, reducing hydropower can increase the need to operate existing gas and coal-fired generators even if other renewable generation is increased because wind and solar power are not able to meet demand at all times; hydropower reductions can also result in a need to build new carbon-producing generators. Hydroelectric, wind, and other renewables are generally the first used to meet demands before natural gas and coal fired units, due to their lower marginal cost, i.e., low "fuel" costs.

The last resource that is used or dispatched to meet load is considered the marginal resource. Bonneville studies dispatched the lowest cost marginal resource to meet the gap between hydro generation and loads.

4.2.2 Potential Replacement Power Portfolio Methodology

The regional standard for the LOLP as set by the NW Council is 5.0 percent, though the NW Council model currently shows an LOLP of 6.6 percent. To evaluate the impact of each alternative, Bonneville assessed what new resources would be needed in the region to lower the LOLP of MO1, MO3, and MO4 to the 6.6 percent LOLP of the NAA. For MO2, which had a lower LOLP than NAA, Bonneville determined what resource builds could be avoided with MO2 compared to NAA. Further, for each alternative, the analysis identified two different potential portfolios of resources for each alternative. One portfolio consisted of the least-cost resources and the other consisted of zero-carbon emitting, least-cost resources.

Bonneville developed screening studies for MO1, MO3, and MO4 to find the lowest cost portfolio for resources[20] relative to their contribution to lowering the LOLP to the NAA LOLP of 6.6 percent. Screened resources included gas-fired resources[21] (both single and combined cycle), solar, wind in the Columbia River Gorge (Gorge Wind), Montana wind (capped at 660 MW as this will be the transmission capability available after Colstrip 1 and 2 coal-fired generation units are retired), demand response (DR) at the Council's 7th Power Plan target

[20] Note if Bonneville acquires long term (greater than 5 years) or major resources such resources must be "cost effective" as that term is defined by the Northwest Power Act.
[21] According to the NW Council report *Marginal Carbon Dioxide Production Rates of the Northwest Power System*, the lowest cost marginal units are typically gas-fired power plants until 2025 (NW Council 2008).

(600 MW), and batteries. Resource characteristics (i.e., hourly capacity profiles) were sourced from the NW Council's Resource Adequacy Advisory Committee.

Resources costs were sourced from the 6th Power Plan, the 7th Power Plan, the 7th Power Plan Mid-Term Assessment, or staff experts at the NW Council except battery costs (sourced from recent integrated resource plans) as they were not updated in the Mid-Term assessment. Resource cost portfolios included:

- Variable costs of the resources including fuel costs.
- Variable cost of the power system changes due to inclusion of a new resource (i.e., adding solar into the power system usually reduced the need to burn gas and coal, and all portfolios have changes in power purchases and export sales).
- Capital costs of those resources amortized over their expected life span at the weighted cost of capital in the region.
- Only larger quantity resources that are commercially available were evaluated. Other resources may reach commercial scale viability in the coming years, but they are currently too speculative, so this analysis did not include them in potential replacement resource portfolios. For example, battery storage currently is limited to a few hours, and the potential replacement resource portfolios did not include long-duration battery storage. Similarly, while new pumped storage operations are being explored in the Northwest, these too would have limited duration. And both batteries and pumped storage provide capacity on a short-term basis; energy losses during discharge and recharging make them net energy consuming. Small modular nuclear power was not considered either as it is an untested source of power.

These portfolio costs were divided by the LOLP benefit (the drop-in percent of LOLP from the alternative without added resources) to calculate the lowest cost replacement resources per unit of the reduction in LOLP.

The lowest cost portfolio included gas-fired combustion turbine (CT) resources. The zero-carbon portfolio included Montana wind, solar, and DR resources. Once portfolios were selected, resources were added into the study until the LOLP of the alternative was equivalent to the NAA (6.6 percent).

These portfolios of resources were added to the GENESYS model, and they were dispatched to meet regional loads. The addition of these resources also impacted how much the region had to rely on independent power producers and exports and imports from out-of-region markets. The portfolios that included renewable resources also reduced the need to burn fossil fuels such as natural gas and coal, except in MO3 where there was a significant need for additional generation in the winter.

For each MO, two portfolios of potential replacement resources were identified. The conventional least-cost portfolios turned out to be only gas-fired generation. The zero-carbon, least cost portfolios were a combination of demand response, solar, and Montana wind.

MO2 achieved the five percent LOLP standard without the need to add additional resources. An "avoided resource" portfolio was developed by determining the portfolio needed to reduce the NAA LOLP from 6.6 percent to 5.0 percent.

4.2.3 Potential Replacement Power Portfolios and Carbon-based Generation Results

Bonneville prepared aMW generation estimates from carbon producing CT resources for the NW-US only. The generating resources could be financed and used by Bonneville or by other entities in the northwest. For the conventional least-cost portfolio, the results include the amount of gas and coal power capacity and average generation needed to reach the NAA LOLP of 6.6 percent. The results for least-cost resource additions are in Table 4-8.

Table 4-8. NW-US System Conventional Least-Cost Replacement Portfolio and Associated Generation of Carbon-based Generation

Alternative	LOLP (percent)	CT Capacity Added to Reach 6.6% LOLP (MW)	CT Avg. Added Generation (aMW)
MO1	11.2	560	163.1
MO2	5.0	avoided build: 440	-244
MO3	13.9	1,120	607.0
MO4	29.6	3,240	708.2
PA	6.5	N/A	N/A

Note: Green font used when reduction is beneficial.

For the zero-carbon portfolios, a mix of solar and DR resources were added to achieve the NAA LOLP of 6.6 percent. In these cases, the existing fossil-fuel generating resources would change their generation, decreasing when solar and/or wind are abundant and increasing when the system needs more capacity. The results for least-cost resource additions are in Table 4-8.

Bonneville also determined that the increased hydropower production in MO2 resulted in the NW-US system meeting the 5.0 percent LOLP industry standard without adding new resources. If resources are built for the NAA in the future, MO2 would reduce the amount of new resources need. Thus, MO2 results in avoided addition of new gas-fueled resources. Bonneville estimated the "avoided build" by developing a least-cost resource portfolio that improved the NAA LOLP from 6.6 percent to 5.0 percent. Similarly, Bonneville developed a zero-carbon resource portfolio to estimate the avoided cost of adding renewable resources.

The increase in hydropower generation from the NAA to MO2 resulted in the avoidance of adding 440 MW of gas CT capacity, which would have generated about 244 aMW annually, using the conventional least-cost portfolio. In the zero-carbon portfolio, the hydropower increases would have avoided the need to acquire about 1,510 MW of renewable energy resources. MO2 avoided resource builds are also included in Table 4-8 and Table 4-9.

Table 4-9. NW-US System Zero-Carbon Portfolio and Associated Change in Carbon-based Generation

Alternative	LOLP (percent)	Low Carbon Capacity Added to Reach 6.6% LOLP (MW)	Change in Existing Carbon-producing Generation (aMW)
MO1	11.2	1,200 Solar/600 DR	-70
MO2	5.0	1,510 avoided build: 250 Solar 600 DR 660 Montana Wind	-428
MO3	13.9	2,550 Solar/600 DR	457
MO4	29.6	5,000 Solar/600 DR	70
PA	6.5	N/A	142

Note: Green font used when reduction is beneficial.

Bonneville used the GENESYS model to develop the conventional least cost and no carbon resource portfolios and estimated the amount of generation produced by those portfolios for each alternative. This information provided input to the air quality analysis in the CRSO DEIS *Air Quality Appendix.*

POWER RATES MODELING

The capital and operating costs of the resource portfolios are important components for analyzing the power rate impacts of the alternatives. Bonneville used the AURORA model to estimate the operating costs of the resource portfolios for rate impacts. Details are provided in the CRSO DEIS *P&T Socioeconomic Appendix.*

4.2.4 Summary of Potential Replacement Resource Portfolios and Results

Bonneville prepared two replacement resource portfolios: a conventional least cost portfolio and a least carbon portfolio to estimate what would be required to restore the LOLP of the alternatives to the LOLP of NAA. Both portfolios relied on information in the NWPPC Seventh Power Plan (NWPPC 2016).

The conventional least cost portfolio is composed of gas-fired combustion turbines that are currently identified as having the least construction and operating costs. The gas-fired turbines emit carbon to the atmosphere, but at a lesser rate than the existing regional coal-fired generation.

The zero carbon portfolio is also a conventional least-cost portfolio with respect to renewable resources. It is composed of load reduction, wind, and solar generation.

MO1, MO3, and MO4 result in increased generation from carbon-fueled resources in the least-cost and zero-carbon scenarios. The increased generation in MO3 and MO4 is more than MO1

because of the need to add more resources for the reduced generation from breaching the Snake River dams (MO3) or additional fish passage spill and flow augmentation measures (MO4).

MO2 results in less carbon producing generation than the other MO alternatives and NAA; it also achieves the 5 percent LOLP industry standard. MO2 improved the reliability of the NAA to the 5 percent LOLP standard and increased hydropower availability and avoided the need to add 440 MW of gas-fired or 1,510 MW of renewable resources in the region.

4.2.5 Potential Replacement Resource Portfolios in the Context of Coal-Plant Retirements

Additional retirements of existing regional coal-fired generating plants used primarily by investor-owned utilities to serve their retail loads have been announced since the development of the CRSO EIS replacement portfolios. As mentioned in Section 4.1.4, more coal plants are slated to be retired and the LOLP of NAA and the MOs will go up significantly.

Updated reliability studies by Bonneville reveal that substantial generating resources will be needed to replace these plants to keep the region at the current LOLP of about 6.6 percent. If regional utilities choose to replace the coal generation with solar and wind, not gas-fired generation, then there will be fewer baseload resources in the region. As coal-fired generation is removed the amount of solar and wind that will need to be added to each MO to get to the NAA LOLP will increase more rapidly as there is a diminishing value for solar and wind when trying to meet power needs at all hours, not just during periods of ample wind and/or ample solar power. Because of the diminishing benefit of wind and solar as larger amounts are needed to replace baseload coal-fired generation, Bonneville estimated that storage (battery or pumped-storage hydropower) would become cost-effective.

Table 4-10 shows the amount of additional resources that would return each case to the current NAA LOLP of 6.6 percent. In this analysis, the amount of wind that can be imported from Montana is higher than that assumed in Section 4.3.2 because more transmission capacity from Montana will be freed up as more coal-plants are retired.

Table 4-10. Additional NW-US Resources Required to Meet 6.6% LOLP

MW of:	DR	MT Wind	Solar	Storage
NAA (base case)	0	0	0 + 0	0
Preferred	Same Reliability as NAA			
MO1 (base case)	600	0	0 + 1,200	0
MO2 (base case)	More Reliable than NAA (base case)			
MO3 (base case)	600	0	0 + 2,550	0
MO4 (base case)	600	0	0 + 5,000	0
NAA (p/c)	600	1696	4,000 + 0	2,500 + 0
Preferred	600	1696	4,000 - 200	2,500 + 0
MO1 (p/c)	600	1696	4,000 + 500	2,500 + 0

MW of:	DR	MT Wind	Solar	Storage
MO2 (p/c)	600	1696	4,000 - 2,900	2,500 + 0
MO3 (p/c)	600	1696	4,000 + 3,200	2,500 + 1,000
MO4 (p/c)	600	1696	4,000 + 3,200	2,500 + 0
NAA (no coal)	600	1696	22,000 + 0	4,000 + 0
Preferred	600	1696	22,000 - 1,000	4,000 + 0
MO1 (no coal)	600	1696	22,000 - 1,000	4,000 + 0
MO2 (no coal)	600	1696	22,000 - 6,100	4,000 + 0
MO3 (no coal)	600	1696	22,000 + 6,000	4,000 + 1,000
MO4 (no coal)	600	1696	22,000 + 1,400	4,000 + 0

The CRSO is concerned more with a decision on selection of the future preferred operation of the CRS and not directly with the retirement of coal-fired plants owned by investor-owned utilities in the region. However, regional reliability depends on all utilities, and the loss of baseload generation in the region affects the value of the hydropower produced by the CRS.

The figures below show the marginal resources needed for each MO to return its LOLP to the NAA LOLP for each coal-retirement scenario.

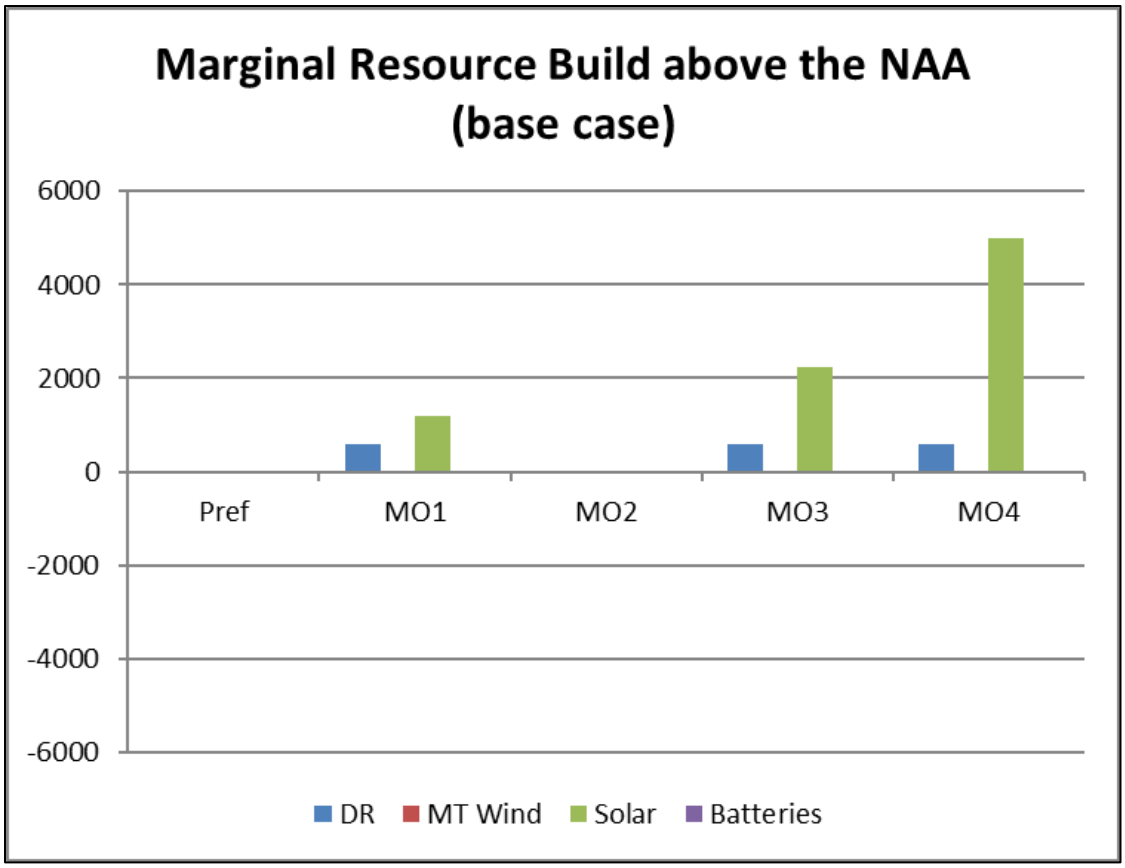


Figure 4-8. Marginal Resources to Build above the NAA (Base Case)

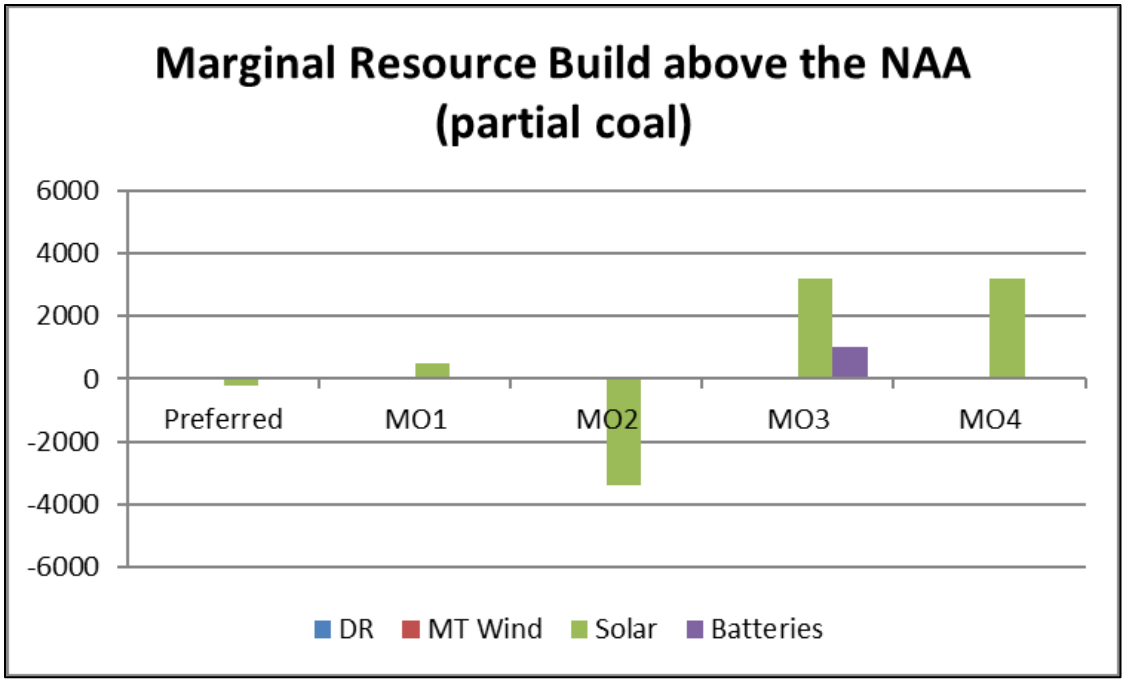


Figure 4-9. Marginal Resources to Build above the NAA (Limited Coal)

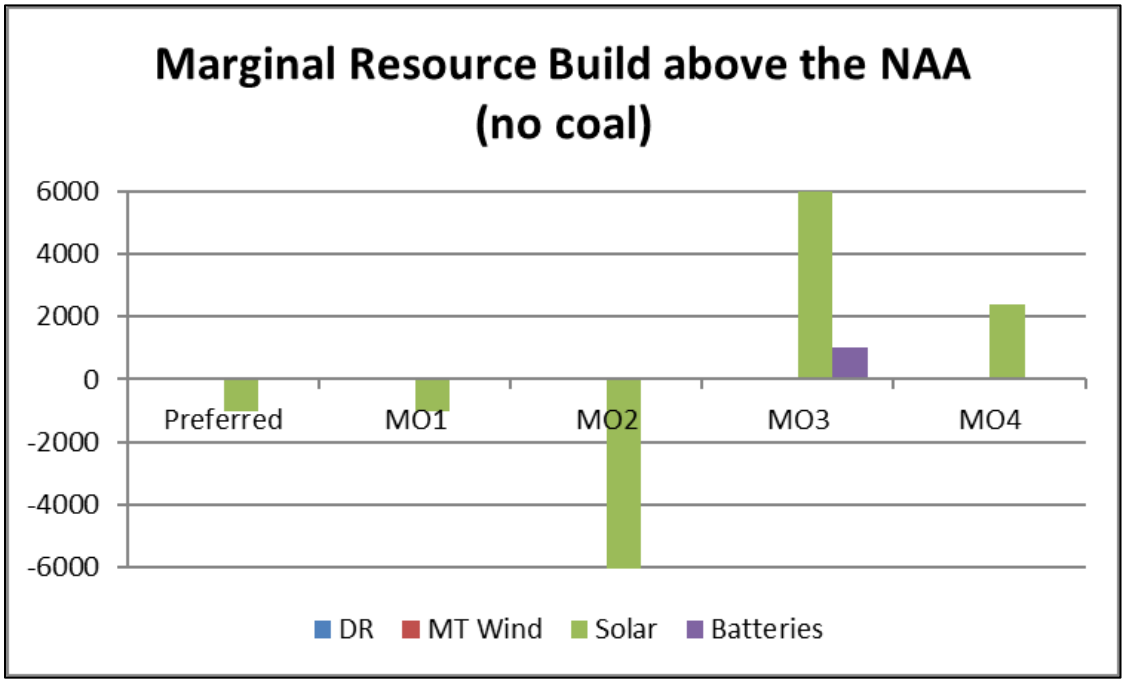


Figure 4-10. Marginal Resources to Build above the NAA (No Coal)

As more coal-plants are removed from the northwest system, the amount of additional resources needed for MO3 increases relative to NAA because fewer baseload resources are available, and solar and storage show diminishing returns. Similarly, the "avoided build" value of MO2 increases as the region retires coal plants. Less intuitively, as the region adds renewable resources to replace increasing amounts of retired coal, the additional resource needs for MO1

and MO4 compared to NAA decrease. This is likely to occur because NAA adds so much solar to meet demand year-round that there would more energy produced by solar available in the summer, the period when MO1 and MO4 have more LOLP events than NAA. For MO1 and MO4, if resources are added to replace the lost hydropower from changes in CRS operations, then there is the potential that these resources could reduce the amount of resources needed by the region to replace coal-based generation as plants are retired in coming years. Conversely, for MO3, as more coal plants retire, the amount of resources needed to maintain reliability attributable to changes in CRS operations increases.

4.3 INTEGRATION OF OTHER RENEWABLE RESOURCES AND HYDROSYSTEM FLEXIBILITY ANALYSIS

BPA maintains operating reserves on the hydropower system for responding to load fluctuations and for integrating the existing fleet of wind and solar. Operating reserves are provided by generating units that are connected to the transmission system and can rapidly increase or decrease to respond to changing demands. The current operating reserves are included in NAA and the MOs.

Flexibility in hourly and sub-hourly operations is critical to the reliability of the power supply. Power generation must equal load (demand) at all times. But load fluctuates as people operate appliances or businesses and industries operate their facilities. On the generation side, wind and solar generation changes throughout the day. Occasionally and often unexpectedly, traditional power plants experience a sudden outage or a transmission interruption changes the import or export of power. The hydropower system and natural gas plants in the region increase or decrease generation moment-to-moment to balance the changes in load and other generation.

Some of the measures in the multi-objective alternatives would increase the flexibility of the hydrosystem to respond to these changes; some measures would decrease the flexibility. As the amount of solar and wind generation output in the region increases, there will be more need for flexible generation to follow such increases. However, because there are no new gas plants being constructed in the region, it may be that the hydrosystem is called upon to supply the flexible generation to support increasing wind and solar output.

When there is no fish passage spill requirement on the four lower Columbia River and four lower Snake River projects, these projects, plus Grand Coulee and Chief Joseph, all can adjust generation as needed to balance loads and resources. During the fish passage spill season and when lower Snake River and John Day operating ranges are restricted to MOP and MIP operations, the operational flexibility for the lower Columbia River and lower Snake River projects to supply this generation response is diminished.

The following is a qualitative assessment of how the MO alternatives change the flexibility of the hydrosystem.

4.3.1 MO1 Compared to NAA

Overall some increase, some decrease in flexibility:

- Slightly larger forebay ranges for MOP and MIP will double the usable forebay range and increase the flexibility to store or release water and increase or decrease hourly generation at the lower Snake River projects and John Day from April through July.
- Counting contingency reserves within fish passage spill increases allows the hydrosystem to increase generation and increases the system's flexibility.
- Averaging spill over 24-hour blocks would enable brief periods of slightly lower spill and higher generation to be balanced with other periods of the reverse conditions.
- Increased spring spill, increased water supply withdrawals, and reduced flows in August on the lower Snake River decrease flexibility slightly.

4.3.2 MO2 Compared to NAA

Overall, significant increase in flexibility:

- Less spill plus moving some water from the spring into winter increase generation considerably and increases flexibility particularly during low-flow periods.
- Having the full forebay range (no MOP or MIP restriction during the fish passage season) on the lower Snake projects and John Day permits use of the full 3- to 5-foot forebay operating ranges year-round, which greatly enhance the ability to store/release water in the run-of-river projects over the course of a day to decrease/increase generation on an hourly basis. With this increase in operating range, the projects will be able to adjust generation much more to changing load and to help integrate other renewable resources like wind and solar.
- Under high flow conditions in April and May, less spill will mean turbines are fully loaded more often, reducing flexibility slightly in April and May. This is a trade-off between more generation in MO2 versus flexibility under these conditions.
- Counting contingency reserves within fish passage spill allows the hydrosystem to increase generation and increases the system's flexibility.
- The ability to reduce to zero generation more often would increase the ability for the regional grid to use wind and solar when they are generating. It also increases the ability of the projects to reduce generation during periods of low demand, perhaps reducing spill for lack-of-market or sales of power at a time of low economic value.

4.3.3 MO3 Compared to NAA

Overall, significant decrease in flexibility:

- Breaching the lower Snake River dams will reduce hydrosystem flexibility compared to NAA, except in the lowest-flow conditions when the dams would also not have had much flexibility in NAA.
- Because spring fish passage spill is higher in MO3 than in NAA on the lower Columbia River projects, these projects will also lose flexibility. Generation at McNary, in particular, will be at minimum generation more often than in NAA and have less flexibility to respond to changes in load or changes in wind and solar generation.
- Conversely, allowing turbines to operate within and also above the 1 percent efficiency range during the fish passage season will increase the flexibility at the lower Columbia River projects except during very high flows when the project is operating continuously at maximum available turbine generation.
- Having the full forebay range (no MIP restriction during the fish passage season) at John Day gives the project a 4.5 foot forebay operating range, which enhances the ability to store/release water over the course of a day to decrease/increase generation on an hourly basis. With this increase in operating range, the project will be able to adjust generation more to changing load and obligations and to help integrate other renewable resources like wind and solar.
- Counting contingency reserves within fish passage spill increases allows the hydrosystem to increase generation and increases the system's flexibility.
- Averaging spill over 12- or 24-hour periods would enable brief periods of slightly lower spill and higher generation to be balanced with other periods of the reverse conditions. Such an operational decision would be made during the course of the operating day.
- Stopping fish passage spill in August will also give the lower Columbia River projects more flexibility.

4.3.4 MO4 Compared to NAA

Overall, significant decrease in flexibility:

- Spilling to 125 percent TDG diverts most of the water from the turbines to the spillways. March-July, the lower Columbia and lower Snake River projects are generating only at minimum generation levels in most water years. Thus, they only rarely have any flexibility for load following and integrating other renewable sources. In all water years, all eight projects are on minimum generation in August and cannot provide any load shaping, renewables integration, or operating reserves.

- Having all of the lower Columbia and Snake River projects operate at or near MOP with a restricted forebay operating range during the fish passage season further removes flexibility at McNary, The Dalles, and Bonneville dams in those rare periods when there might be enough water available for power generation above the minimum. While the increased forebay operating ranges on the Lower Snake River projects might provide some offset, these projects are largely at minimum generation levels continuously as well and do not have any flexibility despite the larger operating range.

4.3.5 PA Compared to NAA

Overall some increase with spring months showing a decrease in flexibility:

- Slightly larger forebay ranges for MOP and MIP will double the usable forebay range and increase the flexibility to store or release water and increase or decrease hourly generation at the lower Snake River projects and John Day from April through July.
- Counting contingency reserves within fish passage spill increases allows the hydrosystem to increase generation and increases the system's flexibility.
- Increased spring spill and increased water supply withdrawals decrease flexibility. Flexible spill hours and decreased spill in August increase flexibility.
- The ability to reduce to zero generation more often would increase the ability for the regional grid to use wind and solar when they are generating. It also increases the ability of the projects to reduce generation during periods of low demand, perhaps reducing spill for lack-of-market or sales of power at a time of low economic value.

4.3.6 Flexibility Summary for the CRS

Because the emphasis on system flexibility is relative new due to the recent increased penetration of wind and solar resources, Bonneville does not have modeling tools to assess hour-to-hour and within-hour flexibility quantitatively which made it difficult to quantify the range of flexibility.[22] The results show a similarity in flexibility and the ability to meet changing loads and obligations and to integrate renewable resources in the NAA, MO1, and MO2, with MO2 having slightly more flexibility. There are definite reductions in flexibility in MO3 and MO4.

The qualitative discussion from Bonneville points to key measures that increase flexibility based on their experience with the existing system and renewable resources already in place. Those measures include:

- Increases in the forebay operating ranges beyond MIP and MOP at run-of-river projects.

[22] Assuming flexibility is implemented, Bonneville would do so in accordance with the statutory preference and priority given to public bodies and cooperatives prior to offering such power as a flexible integration product.

- Inclusion of system operating reserves in fish passage spills.
- Increases in turbine efficiency operating ranges beyond ±1 percent of best efficiency.
- The ability to operate at zero generation more often, outside the fish passage season, at the lower Snake River Projects

Operations that decrease flexibility include:

- Decreases in the forebay operating ranges to MOP at all run-of-river projects.
- Increases in fish passage spill that reduce the amount of water available for generation.

CHAPTER 5 - OTHER BONNEVILLE POWER OBLIGATIONS

5.1 COLVILLE PAYMENTS

Since Fiscal Year 1995, Bonneville has been making annual payments to the Confederated Tribes of the Colville Reservation as compensation for tribal lands inundated by Lake Roosevelt, which is formed by Grand Coulee Dam. The Spokane Tribe will likely also be receiving payments in the future. The annual payment is based on actual generation at Grand Coulee. The effects of the alternatives are being estimated by the use of average annual generation as modeled with 80 water years. Table 5-1 provides a summary of the annual values for Grand Coulee generation for each of the CRSO DEIS alternatives.

The monetary value of the payment considers several terms in addition to Grand Coulee generation including Bonneville's power sales revenues and sales price escalators. Details of the monetary value are provided in the *P&T Socioeconomic Appendix*. Table 5-1 summarizes the generation amounts used in the socioeconomic analysis.

Table 5-1. Average Grand Coulee Generation for Colville Payment Determination

Alternative	aMW	Difference from NAA aMW (% change)
NAA	2,434	-
MO1	2,399	-35 (-1.4)
MO2	2,419	-15 (-0.6)
MO3	2,388	-46 (-1.9)
MO4	2,381	-52 (-2.2)
PA	2,426	-8 (-.3)

All MO alternatives produced less generation at Grand Coulee than the NAA, but they were relatively minor changes from the NAA averages. Analyses of the payment revenue for the CRSO DEIS alternatives are provided in the *P&T Socioeconomic Appendix.*

5.2 4(H)(10)(C) CREDITS FOR REPLACEMENT POWER

The Northwest Power Act requires Bonneville to make expenditures to mitigate fish and wildlife and their habitats in the Columbia River Basin affected by the development and operation of the Columbia River System.[23] Bonneville fulfills this mandate by making expenditures for: (1) direct fish and wildlife program operations and maintenance; (2) direct fish and wildlife program capital; and (3) power purchases made to replace the federal dam system's firm generating capability lost due to fish mitigation measures. While Bonneville incurs these costs as part of its section 4(h)(10)(A) mitigation duty, the actions funded also offset the impacts of the Columbia River System's non-power purposes such as navigation, irrigation, or flood risk management. Bonneville, however, is responsible for the

[23] Section 4(h)(10)(A), 16 U.S.C. § 839b(h)(10)(A).

power share of mitigation costs only, so it must therefore recover the non-power share of its fish and wildlife mitigation expenditures in some other way. Section 4(h)(10)(C) provides that vehicle. It requires the Administrator to allocate the expenditures incurred mitigating fish and wildlife and to recoup the non-power share of those expenditures from the U.S. Treasury. The system-wide weighted average of the non-power cost allocation is 22.3%. Bonneville thus takes a 22.3% credit annually against its obligations to the U.S. Treasury for the non-power share of mitigation it funds.

The annual amount of section 4(h)(10)(C) credit is expected to vary across CRSO EIS alternatives because the hydropower operations undertaken and mitigation expenditures that Bonneville would make to protect fish and wildlife under these alternatives would vary, and, in turn, affect the amount of credit received. The methodology for determining the amount of fish and wildlife costs for these categories consists of three distinct steps: (i) obtaining Direct Fish and Wildlife Program expenditures from accounting records; (ii) estimating fish and wildlife related power purchase costs using HYDSIM, Bonneville's hydrosimulation model, and (iii) allocating these expenditures between power and non-power purposes to ascertain the credit value.

This appendix addresses only the power purchase or replacement power costs element of the methodology. The direct fish and wildlife program expenditures allocable under section 4(h)(10)(C) are described in Appendix H, Power and Transmission Section 4.1.4.

5.2.1 Methodology

Each year, the 4(h)(10)(C) credit results in part from the operations to protect and mitigate fish and wildlife by providing spill to aid fish passage at the lower Snake River and lower Columbia River dams and reservoir storage operations to improve flows and reservoir elevations for fish migration, spawning, incubation, and rearing throughout the Columbia River Basin. The cost of power purchased to replace the firm hydroelectric system capability lost due to these fish mitigation measures is eligible for credit under 4(h)(10)(C). There is no simple way to account for the energy differences due to operations for fish and wildlife based solely on actual operation data. Instead, hydroregulation modeling is used to estimate how much energy could have been produced without fish and wildlife operations.

Bonneville purchases power for a number of reasons, including purchases to replace generation lost due to fish mitigation measures. The 4(h)(10)(C) methodology was developed in 1995 (using models that historically have been used in Bonneville's rate cases) to conservatively capture the replacement power purchases required as a result of changes in hydro system operations to benefit fish and wildlife. The 4(h)(10)(C) credit calculation includes the effect of replacement power purchases attributable to fish measures. The methodology Bonneville uses identifies purchase amounts (relative to the same presumed load) for operations both with fish measures and without them in order to estimate the difference. This method avoids including the impacts of Bonneville's marketing decisions in the amount of fish credits Bonneville earns.

First, it is necessary to determine the total costs associated with operating the Federal Columbia River Power System in a manner that mitigates the impacts on fish and wildlife, and then to assign a portion of those costs to non-power purposes. This involves comparing how

the hydro system actually operated while providing mitigating operations for fish against how the hydro system would have operated without any fish constraints or considerations.

More specifically, the need to purchase electricity to meet Bonneville load due to changes in river operations to benefit fish arises from: 1) operations that store water for later release to increase flow; 2) operations that spill water over a dam's spillway rather than use it to generate electricity; and 3) operations which maintain water at certain elevations in order to protect spawning habitat or aid juvenile emigration.

For each year, actual hydro conditions and market prices were used to develop the credits. To start, the quantity of replacement power necessitated by fish operations must be identified. To do this, the actual/historical water available this year is used to assess power production with a computer model, the hydroregulation model, using the current hydro system configuration. Two hydroregulation studies are necessary. The first study, with fish, models the river operation for fish mitigation. The second study, without fish, models what river operations would be like without any consideration or water constraints for the benefit of fish.

Following this, Bonneville's surplus/deficit situation under each of these studies is assessed. In order that Bonneville's surplus/deficit situation not be a function of Bonneville marketing decisions, the calculation uses the Bonneville load that could have been served with certainty under conditions in the worst water year, without fish mitigation requirements. This is known as the Firm Energy Load Carrying Capability (FELCC) of the hydro system – a concept developed for use in the Pacific Northwest Coordination Agreement planning process in the 1960s and in continuous use under those agreements from 1964 to the current year. FELCC is an estimate of the generation guaranteed to be available from the federal hydro system under the worst water conditions and therefore is the amount of firm power that Bonneville would have been entitled to sell. The use of the FELCC, as an estimate of Bonneville's firm load, results in a fair and replicable calculation.

Bonneville's surplus/deficit situation using FELCC as load and the actual/historical water conditions given the without fish hydro study was compared to the surplus/deficit situation using FELCC as load and the actual/historical water conditions given the with fish hydro study. Situations that led to an increase in purchases were netted with situations that led to a reduction in purchases and were summed across the monthly periods to provide the amount of incremental energy in megawatt hours (MWhs) purchased as a result of fish mitigation for the year. Using a published price index of actual month average historical market prices, the prices were multiplied by the estimate of the change in purchased MWhs to determine the replacement power cost for the year. The price index utilized aligns with Bonneville's trading floor practices. Figure 5-1 illustrates the process of determining the 4(h)10(C) power purchase amounts.

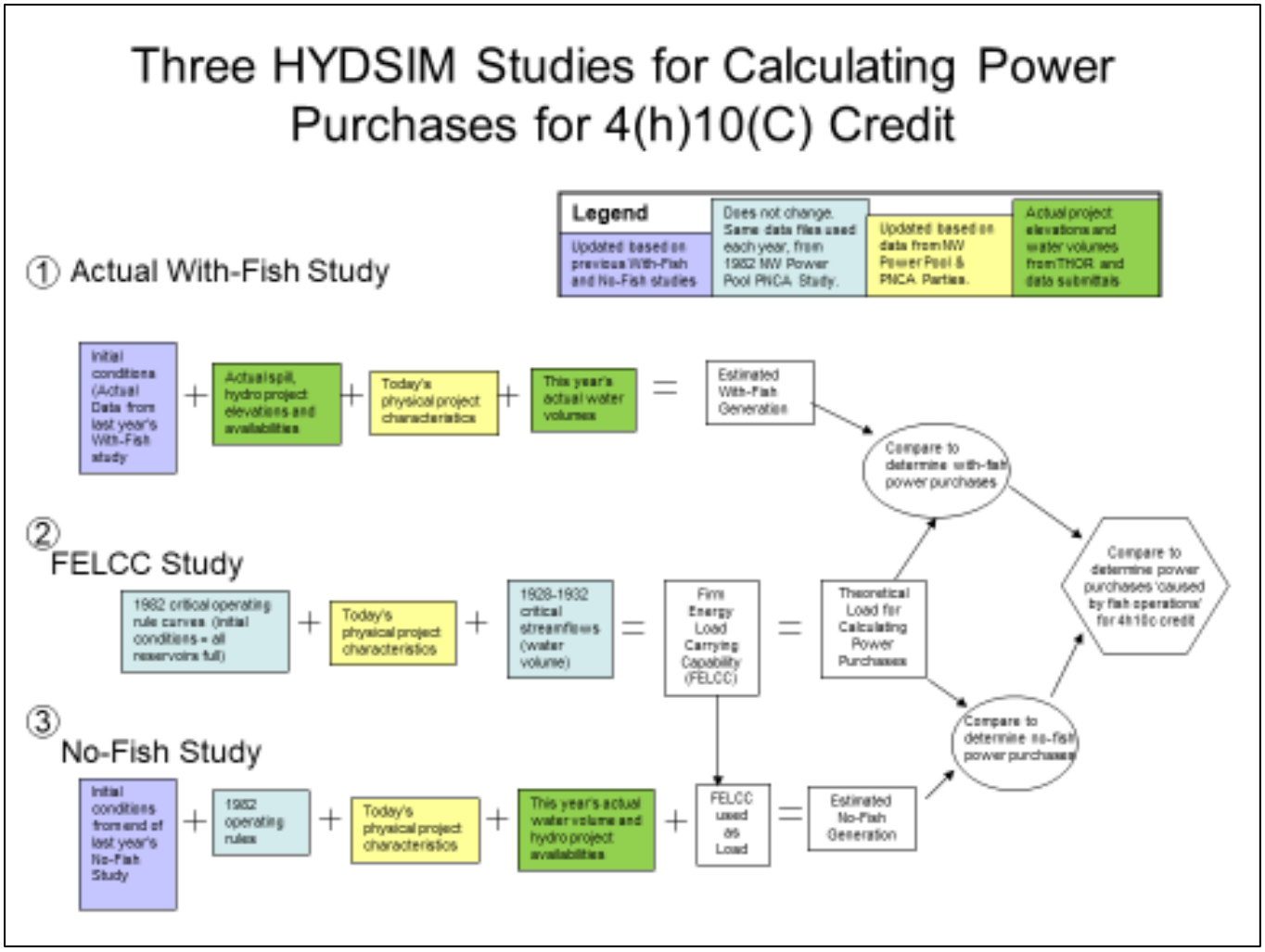


Figure 5-1. HYDSIM Studies for Calculating 4(h)(10)(C) Credit

5.2.2 Results

The estimated average annual replacement power purchases and associated 4(h)(10)(C) credits for each alternative with and without fish and wildlife measures are provided in Table 5-2.

Table 5-2. Annual Replacement Power Purchases (aMW)

Alternative	Eligible Purchase w/ F&W	Eligible Purchase w/o F&W	Additional Purchase	Change from NAA (%)
NAA	397	38	359	-
MO1	417	37	381	6.1
MO2	333	38	294	-18.1
MO3	814	37	777	116.4
MO4	846	37	809	125.3
PA	448	38	410	14.2

The average purchase results directly reflect the level of measures implemented for the benefit of Columbia and Snake River salmonids. The replacement power costs and associated credit tend to increase as those measures are added to the NAA.

5.2.2.1 MO Comparisons to the NAA

- MO1 has a moderate increase in purchases from the NAA primarily due to increased fish passage spill.
- MO2 purchases are lower than the NAA as there are fewer spill measures that reduce hydropower production.
- MO3 purchases are higher than the NAA because of the generation loss from total loss of generation at the four lower Snake River dams.
- MO4 purchases are higher due to increased fish passage spill and additional flow augmentation.

5.2.2.2 Summary of 4(h)(10)(C) Credits

The 4(h)(10)(C) credit will generally increase or decrease in kind as Bonneville's expenditures for fish and wildlife measures increase or decrease. The estimated expenditures and associated 4(h)(10)(C) credit are discussed Appendix H Power and Transmission Section 4.1.4.

CHAPTER 6 - POTENTIAL IMPACTS OF CLIMATE CHANGE ON HYDROPOWER

The methodology, analyses, and conclusions in this section do not comply with the policies or technical guidance of the Corps or Reclamation for evaluating the preparedness and resilience of water resource systems using climate change affected hydrology. Bonneville required a quantitative analysis of power generation and revenue to include in this appendix of the CRSO DEIS. It was not possible for Bonneville to use an approach that would meet the policies or technical guidance of the Corps or Reclamation under the time frame of the EIS. The technical approach and findings contained in this section are those of the Bonneville and should not be construed as an official Department of the Army or Department of Interior position, policy, or decision.

6.1 OVERVIEW

The River Management Joint Operating Committee (RMJOC) of the co-lead agencies is continuously evaluating climate change to identify potential vulnerabilities, risk, and resiliency of the FCRPS. The co-lead agencies used the unregulated (naturalized) streamflow scenarios developed by the University of Washington for Part 1 of the RMJOC-II study[24] to assess potential climate-related impacts for the CRSO DEIS. The 160 unregulated streamflow projections in this study provide a wide range of projected climate change impacts on CRS streamflows. The full range of 160 unregulated scenarios is considered in a qualitative sense for the other resources evaluated in the CRSO DEIS, Chapter 4.

Additionally, Bonneville selected four 30-year scenarios from the RMJOC-II projections to substitute for the 80-year Modified Flows (1929–2008) that were used in HYDSIM modeling of the NAA and MO alternatives. Each climate scenario has a 30-year projection (2020–2049) of flows based on temperature and precipitation assumptions of the scenario.

The hydrologic changes from these projections resulted in changes to the CRS reservoir elevations, streamflows, and hydropower generation. The effects of these changes were assessed quantitatively for potential climate-related impacts on power generation in the CRS. Having a quantifiable understanding of how future climate may impact DEIS alternatives was important to Bonneville's understanding of impacts to generation and revenue in the future. For the other multiple uses, climate change effects are being derived qualitatively from the RMJOC-II unregulated streamflow projections. These assessments are presented in Chapter 4 of the CRSO EIS.

Projected future changes in temperature, precipitation, snowpack, and streamflow will impact hydropower generation in the basin. While these changes may be significant, there is uncertainty about the magnitude of monthly and annual impacts to power generation given the uncertainties in the degree of warming and changes in precipitation trends. For this analysis,

[24] [https://www.bpa.gov/p/Generation/Hydro/hydro/cc/RMJOC-II-Report-Part-I.pdf]

Bonneville focused on understanding whether projected changes in climate would result in differences in the impacts of a given alternative on hydropower relative to the NAA.

6.2 GENERAL METHODOLOGY

Bonneville used HYDSIM to produce generation results to assess impacts to hydropower under four different RMJOC-II climate scenarios for the 2030s (2020-2049), substituting the four 30-year climate scenarios for the historic 80-year Modified Flows (1929-2008) for each of the DEIS alternatives. For this analysis, Bonneville selected a set of climate change scenarios that roughly represented a range of annual streamflow volumes and resulting hydropower impacts for the United States system of the Northwest (NW-US). The scenarios Bonneville selected are all projections based on the RCP 8.5 emissions scenario. The four scenarios represent a reasonable range of potential climate change impacts and provide a quantifiable basis for understanding how future changes in climate may impact generation. These four scenarios do not represent all possible future climate outcomes, nor do they represent a statistical sampling of all of the scenarios studied for the RMJOC-II report.

As noted in the CRSO DEIS *Hydroregulation Appendix*, Bonneville selected the following climate scenarios for the hydropower analyses:

- CC1: CanESM2-MACA-PRMS-P1.

  CC1 is the warmest on all RMJOC-II scenarios, with a basin average temperature increase of 5.3°F between the historical period (1970-1999) and the 2030s (2020-2049). It was also one of the wetter scenarios on a basin-average perspective, with a precipitation increase between the historical period and the 2030s of about 7 percent (warmest/wettest scenario). Although other scenarios in the set of 160 showed even higher future precipitation and annual volume, this scenario was on the high end of projected annual runoff compared to the other 160 scenarios (around 161 million acre feet by the 2030s, compared to the historical annual runoff of around 132 million acre feet). It also projected highest annual average volume runoff into Grand Coulee in the 2030s. The PRMS hydrologic model results tended to project higher winter flows than the other hydrologic model iterations used for RMJOC-II, but also lower summer flows.

- CC2: MIROC5-BCSD-VIC-P3

  CC2 indicates little less warming (about 4.4°F) and a little less of a precipitation increase (about 5 percent) than CC1 between the historical period and the 2030s. This yielded an annual volume of about 155 Maf at The Dalles. One interesting characteristic of this scenario was that the MIROC5 tended to concentrate future precipitation increases above Grand Coulee, with some decrease in precipitation in the Snake River Basin. The VIC hydrologic model parameterization used for this scenario (P3) tended to show lower flows in the winter and spring periods, but higher and slightly later spring peak flows compared to the other hydrologic model iterations.

- CC3: HadGEM2-CC-MACA-VIC-P1

  CC3 is similar to CC2 in that it projects about 4.5°F of warming by the 2030s, on average, and about a 7 percent precipitation increase. The difference in this scenario, though, is that more of the precipitation and annual volume increases tended to be larger in the Snake Basin compared to the upper Columbia. This VIC hydrologic model parameterization (P1) was the most closely calibrated hydrologic model used in RMJOC-II, and thus tended to perform best in the historical period, but with a tendency for higher winter flows compared to the other VIC parameterizations.

- CC4: GFDL-ESM2M-BCSD-VIC-P2

  CC4 projects are still significant, but less warming across the Columbia Basin, with an average temperature increase around 2.5°F by the 2030s relative to the historical period. However, it is also the driest climate model projection used for RMJOC-II for the 2030s, with a slight decrease in annual precipitation (about 2 percent). As a result, it projects the lowest average annual volume for the Columbia Basin at around 138 Maf – similar to what is currently experienced in the Columbia Basin in the historical period. The VIC hydrologic model parameterization (P2) also tended to have lower winter and spring flows compared to the PRMS and VIC-P1 parameterizations, but higher and earlier spring runoffs, with lower summer flows.

Bonneville assessed the relative changes between the alternatives for each climate change scenario. The NAA average and P10 generation was estimated for the 80-year streamflow record and each of the four 30-year climate scenarios. The average and P10 generation was also estimated for each of the MO alternatives. Those results are provided in tables for each of the MO discussions in Section 6.3. The MO changes in generation were then compared to see how the changes under the climate change scenarios compared to the changes with the 80-year streamflows. These comparisons are provided for each MO in Section 6.3.

Unlike the analysis performed with the 80-year streamflow records, these studies did not include lack-of-market spill because Aurora, the model that calculates the lack-of-market spill, models generation across the whole western interconnection but does not have information on other changes in the west that might occur with climate change. Consequently, the 80-year average and tenth percentile (P10) generation climate scenario amounts will not exactly match amounts in the CRSO DEIS alternatives for the historic 80-year Modified Flows.

6.3 POWER IMPACT ASSESSMENT OF THE CLIMATE CHANGE SCENARIOS

These assessments compare the generation of each of the CRSO DEIS alternatives for the historic 80-year Modified Flows with the four climate change scenarios. Monthly and annual generation production estimates were developed for average annual generation and the tenth percentile lowest generation in each set (P10) for the NW-US." This section describes the impacts in generation for each MO as compared to the NAA changes for each of the four climate scenarios. The purpose is to understand whether, under a reasonable sampling of

projected changes in climate, there is a difference in the impacts of a given alternative on hydropower relative to the NAA.

This section describes how the change in generation for each MO compared to NAA changes with the different streamflow scenarios evaluated for climate change. Thus, this is a comparison of the deltas for the purpose of observing whether the climate assumptions affect the relative differences between the NAA and the MO alternatives.

Figure 6-1, Figure 6-2, Table 6-1 and Table 6-2 show the differences between the NAA generation for the historical streamflow modeling and the four climate change scenarios. Figure 6-1 and Table 6-1 show the NW-US system average monthly generation for the 80 water years for the historical streamflows and the 30 water years for the climate change scenarios. Table 6-2 shows the generation for the 10th percentile lowest generation conditions within each of the respective streamflow sets.

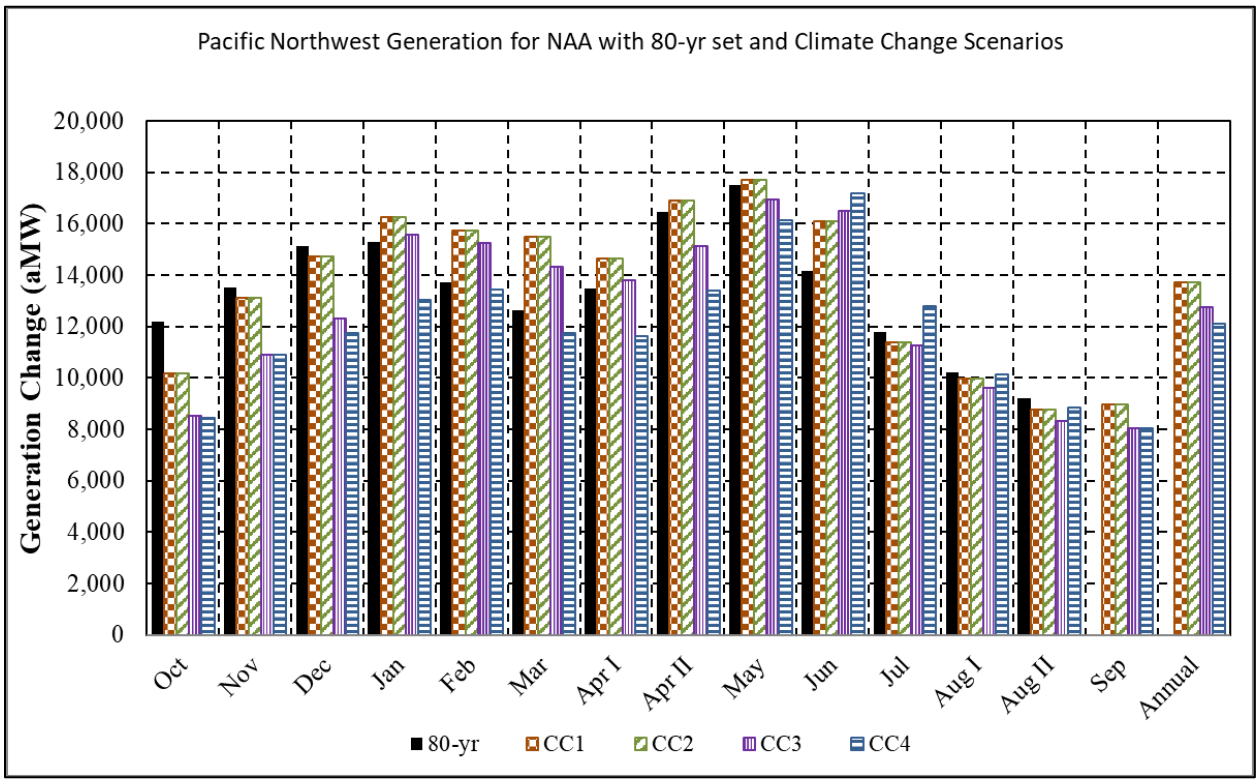


Figure 6-1. Pacific Northwest United States Average Generation Changes for Historic and Climate Change Scenarios for the NAA

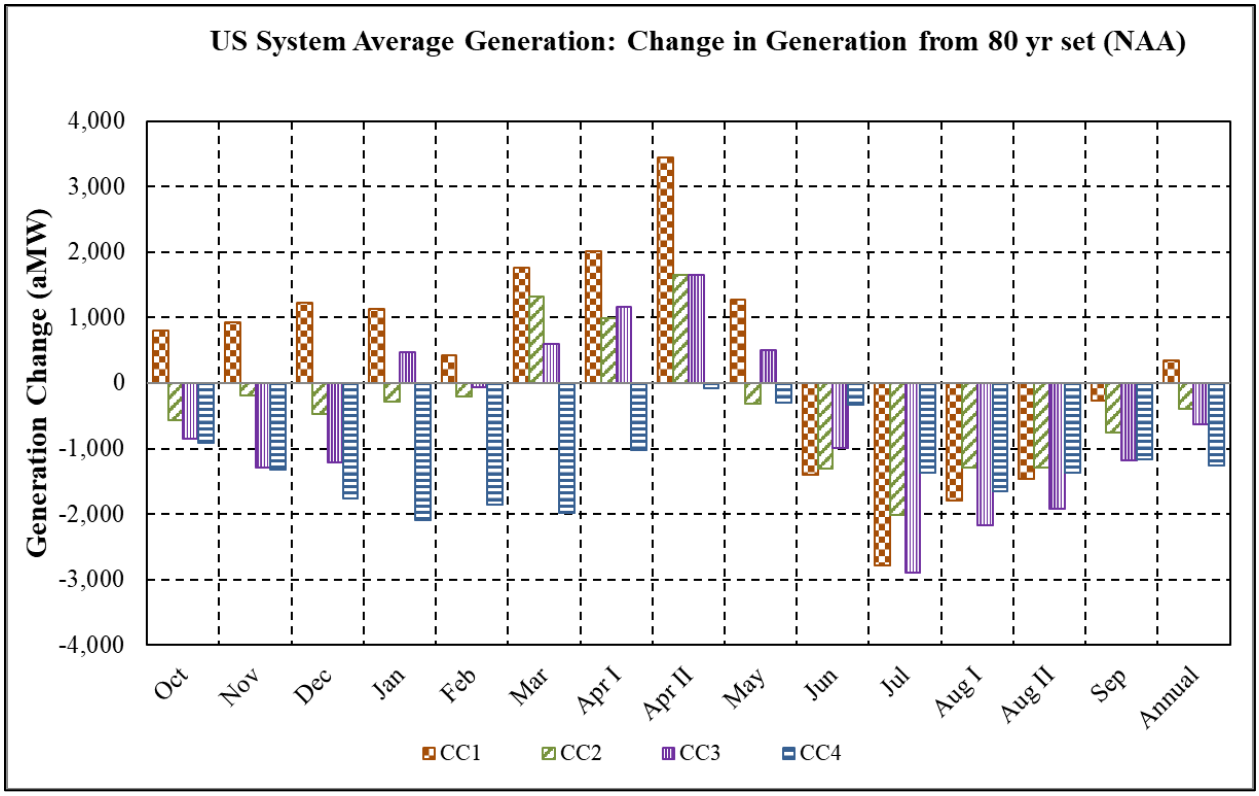


Figure 6-2. Difference in Generation for the NAA for four Climate Change Scenarios compared to the historical 80-yr historical for the NW-US system

Table 6-1. NAA Average Generation for Climate Change Scenarios

US System Average Generation: No Action Alternative Generation Results															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
Historical 80 Yr	9,365	12,207	13,524	15,138	15,341	13,799	12,774	13,599	16,744	17,877	14,247	11,740	10,233	9,216	13,455
CC1	10,162	13,130	14,743	16,245	15,718	15,483	14,655	16,914	17,727	16,109	11,391	9,982	8,772	8,949	13,720
CC2	8,804	12,017	13,046	14,830	15,086	15,038	13,632	15,119	16,148	16,205	12,156	10,482	8,935	8,461	12,973
CC3	8,508	10,918	12,300	15,582	15,234	14,314	13,809	15,123	16,961	16,516	11,273	9,605	8,315	8,037	12,737
CC4	8,448	10,881	11,763	13,025	13,448	11,743	11,625	13,396	16,155	17,173	12,808	10,122	8,865	8,057	12,113

Table 6-2. NAA P10 Generation for Climate Change Scenarios

US System 10th Percentile Generation: No Action Alternative Generation Results															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
Historical 80 Yr	8,531	10,662	10,904	10,866	10,228	9,713	8,740	7,814	12,626	13,047	9,557	9,365	8,635	8,307	10,142
CC1	7,243	9,909	11,747	12,740	11,687	11,608	9,635	12,969	15,750	13,092	7,876	8,011	7,667	6,939	10,639
CC2	7,666	10,110	11,183	11,367	10,837	9,713	9,180	10,181	12,013	10,879	7,449	8,080	7,419	7,292	9,653
CC3	6,946	9,629	10,858	12,062	11,522	10,779	10,505	11,140	13,450	11,545	8,165	8,259	7,371	6,169	9,971
CC4	7,327	9,909	9,912	10,369	9,784	8,832	8,523	9,265	13,163	14,032	8,992	8,370	7,718	6,860	9,672

On an annual average basis, the climate change scenarios did not change the overall conclusions of how much each alternative differed from the NAA. The impacts to hydropower generation of an MO compared to the NAA changed by 50 to 250 aMW under the four climate scenarios, which is generally smaller than the differences between each MO and the NAA under the 80-year Modified Flows. Thus, while climate change impacts the overall generation of the system and adds additional uncertainty to the impact each MO has on hydropower relative to the NAA, it does not change the power analysis conclusions of the relative impact of one MO

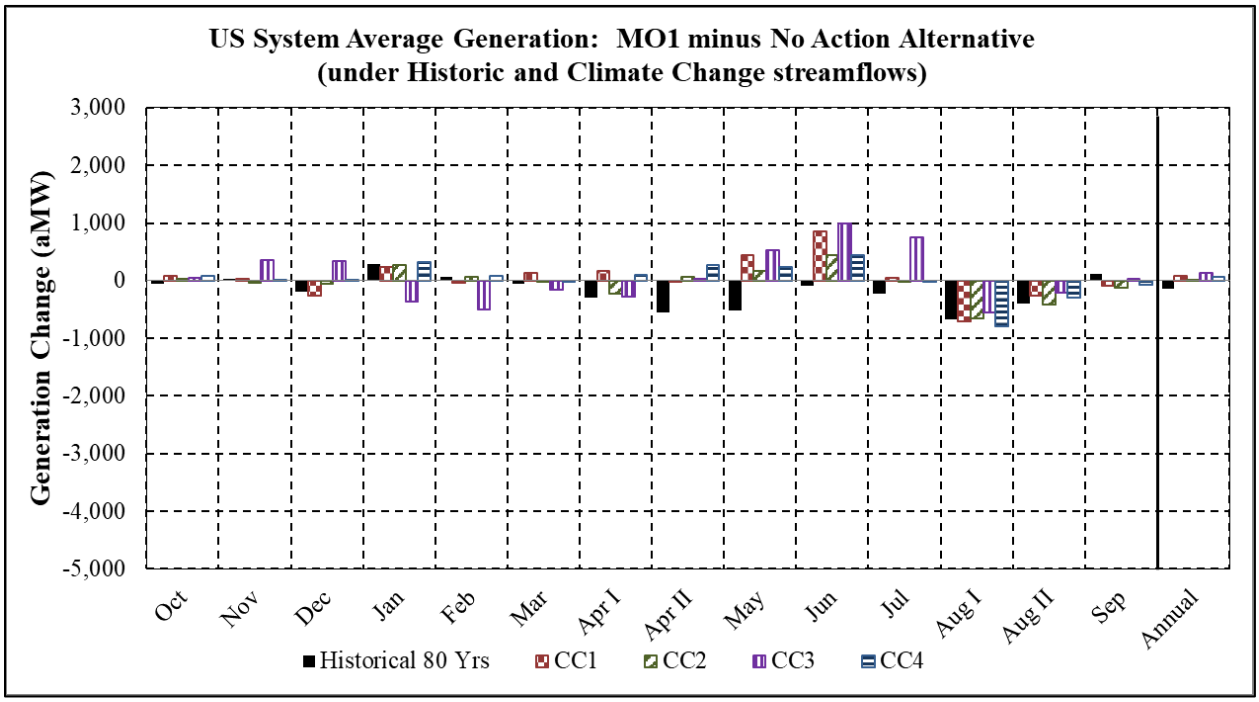
versus another. The results indicate that climate change is affecting generation in all alternatives roughly the same, especially on an annual average basis. While there are some notable differences described below, particularly on a monthly basis, the overall impacts of the MOs are not changing relative to the NAA. The one exception is MO1 which differs from NAA modestly, with the climate change scenarios indicating MO1 may result in slightly (only about 130 aMW) more energy than the NAA.

These results do not measure the projected impact climate change will have on operations, which may be large overall. Bonneville, the Corps, and Reclamation are separately studying the projected magnitude of the impact climate change will have on the operation of the hydro-system through the RMJOC-II study.

6.3.1 Assessment of MO1 with Historic and Climate Change Scenarios

6.3.1.1 MO1 Average Generation

The changes in the NW-US system average generation between the NAA and MO1 are provided in Figure 6-3 and Table 6-3. The MO1 average generation differences in Table 6-3 are the differences between NAA average generation in Table 6-1 and the average MO1 generation.



Note: The scale on the y-axis is chosen so that the graphs for all four MOs have the same scale.

Figure 6-3. NW-US Average Generation Changes for Historic and Climate Change Scenarios for MO1 Relative to NAA

Table 6-3. NW-US Average Generation Changes for Historic and Climate Change Scenarios for MO1 and the Differences Relative to NAA

US System Average Generation: MO1 minus No Action Alternative (under Historic and Climate Change streamflows)															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
Historical 80 Yr	-51	26	-195	283	67	-58	-298	-548	-514	-88	-223	-680	-390	124	-134
CC1	90	24	-262	238	-29	133	162	-6	444	855	41	-713	-259	-91	86
CC2	31	-34	-55	265	65	-24	-218	70	163	437	-15	-649	-413	-130	8
CC3	55	354	347	-369	-496	-160	-281	24	535	986	760	-560	-201	26	131
CC4	80	4	10	324	75	-16	93	274	239	451	-25	-792	-299	-69	59

MO1 produces less energy than the NAA in the average of the 80 water-years of the historical streamflows. In the four climate change scenarios, MO1 produces slightly more energy than the NAA on average. These results indicate that under climate change MO1 may produce more annual energy than the NAA. The largest increase in generation as compared to the NAA in these scenarios is in the spring (April II to June). August I (which was a large contributor to reliability concerns) remains significantly lower than the NAA even with climate change, indicating that there are still reliability concerns in this time period with climate change. Other months show minimal or mixed changes in generation for the different climate scenarios, underscoring that the additional uncertainty of climate change increases the uncertainty of future generation.

6.3.1.2 MO1 P10 Generation

The changes in NW-US P10 generation between the NAA and MO1 are provided in Figure 6-4 and Table 6-4. The MO1 P10 generation differences in Table 6-4 are the differences between NAA P10 generation in Table 6-2 and the MO1 P10 generation.

For P10 generation, MO1 produces less energy than the NAA in the average of 80 water-years of the historical streamflows. In three of the four climate change scenarios MO1 still produces less energy than the NAA, but the decrease is smaller than that in the average historical generation. In one climate change scenario, MO3 produces slightly more energy than the NAA. The variation in monthly impact from climate change on the difference between MO1 and the NAA is even larger for the P10 set than it is for the differences in average generation portrayed in Figure 6-3 and Table 6-3. This underscores that additional uncertainty is introduced by climate change, particularly in lower generation situations

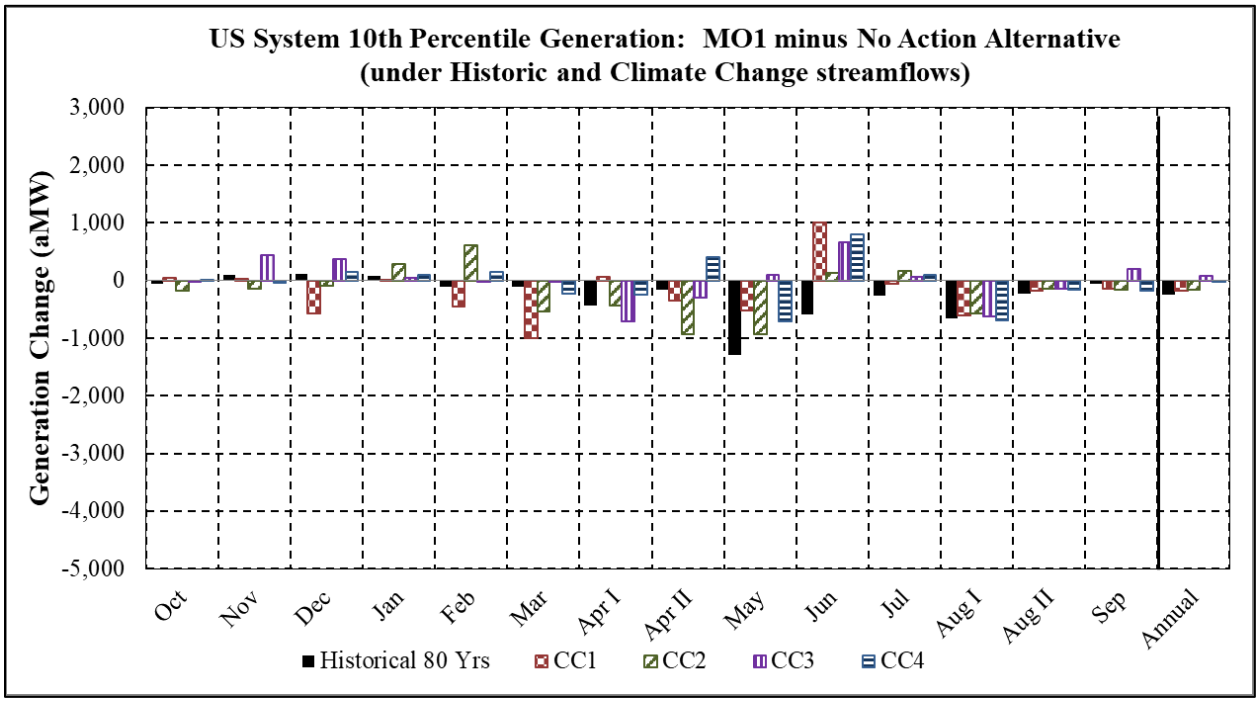


Figure 6-4. NW-US P10 Generation Changes for Historic and Climate Change for MO1 Relative to NAA

Table 6-4. NW-US P10 Generation Changes for Historic and Climate Change for MO1 and the Differences Relative to NAA

US System 10th Percentile Generation: MO1 minus No Action Alternative (under Historic and Climate Change streamflows)															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
Historical 80 Yrs	-62	92	119	88	-107	-101	-440	-151	-1,291	-580	-256	-653	-225	-56	-242
CC1	48	30	-575	18	-448	-1,006	59	-349	-522	1,000	-64	-605	-184	-143	-185
CC2	-171	-137	-91	290	618	-544	-435	-927	-940	136	169	-563	-135	-160	-160
CC3	-1	444	373	40	-16	-12	-707	-291	101	659	69	-620	-144	198	81
CC4	10	-38	154	102	149	-224	-245	407	-704	797	96	-696	-156	-184	-18

6.3.2 Assessment of MO2 with Historic and Climate Change Scenarios

6.3.2.1 MO2 Average Generation

The changes in NW-US system average generation between the NAA and MO2 are provided in Figure 6-5 and Table 6-5. The MO2 average generation differences in Table 6-5 are the differences between NAA average generation in Table 6-1 and the average MO2 generation.

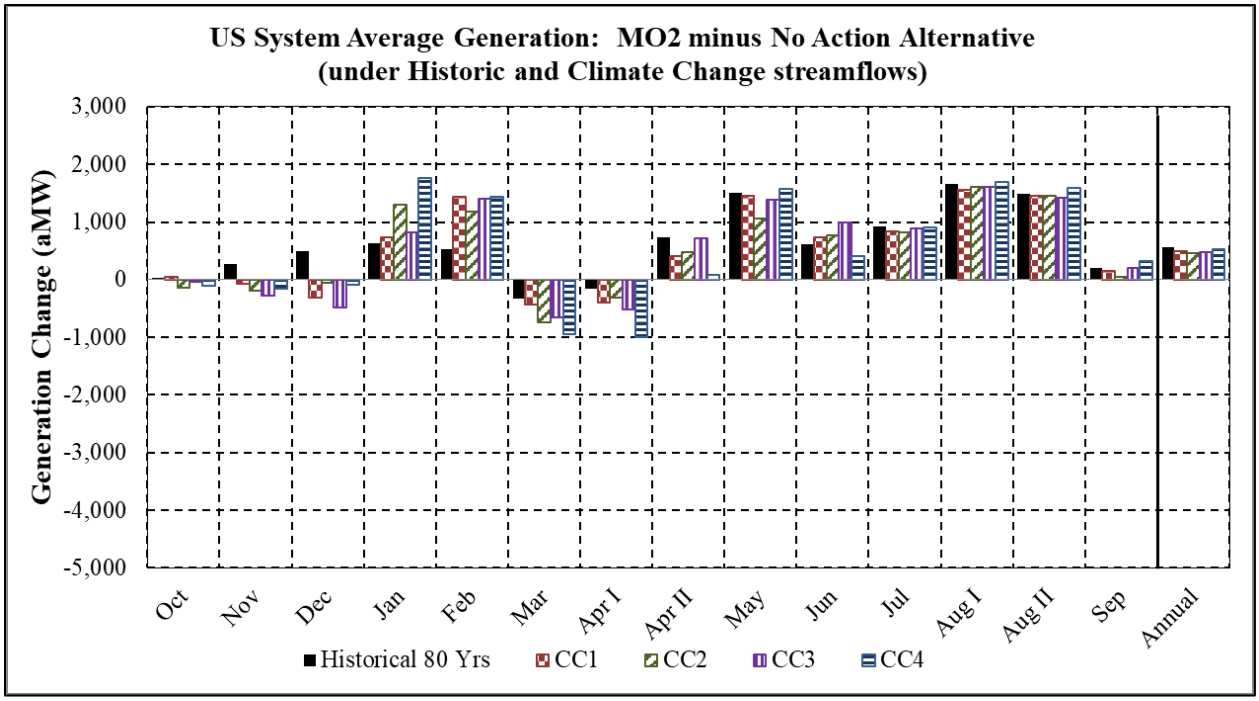


Figure 6-5. NW-US Average Generation Changes for Historic and Climate Change Scenarios for MO2 Relative to NAA

Table 6-5. NW-US Average Generation Changes for Historic and Climate Change Scenarios for MO2 and the Differences Relative to NAA

US System Average Generation: MO2 minus No Action Alternative (under Historic and Climate Change streamflows)															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
Historical 80 Yr	39	267	500	632	525	-333	-165	740	1,501	617	917	1,662	1,494	205	564
CC1	41	-74	-317	731	1,443	-432	-404	405	1,449	737	837	1,560	1,457	145	501
CC2	-137	-192	-60	1,293	1,182	-745	-316	477	1,057	768	817	1,609	1,450	53	468
CC3	-45	-273	-477	816	1,405	-648	-512	718	1,386	996	889	1,610	1,414	208	484
CC4	-100	-162	-88	1,766	1,439	-949	-1,003	91	1,569	415	901	1,695	1,584	323	523

MO2 produces more energy than the NAA over all 80 water years of the historical streamflows. In the four climate change scenarios, MO2 also produces more energy than the NAA, but the difference is slightly less than with the historical streamflows. These results indicate that under climate change, MO2 would also produce more annual energy than the NAA. Thus, the conclusion from the studies that MO2 is beneficial for power remains unchanged. On a monthly basis, the climate change scenarios indicate that January and February gain generation relative to the NAA while December, March and April may lose generation. The gains in hydropower in the winter months to serve peak loads are more valuable than changes in the spring months. Other months show minimal or mixed changes in generation for the different climate scenarios, underscoring the additional uncertainty about generation under future climate scenarios.

6.3.2.2 MO2 P10 Generation

The changes in NW-US P10 generation between the NAA and MO2 are provided in Figure 6-6 and Table 6-6. The MO2 P10 generation differences in Table 6-6 are the differences between NAA P10 generation in Table 6-2 and the MO2 P10 generation.

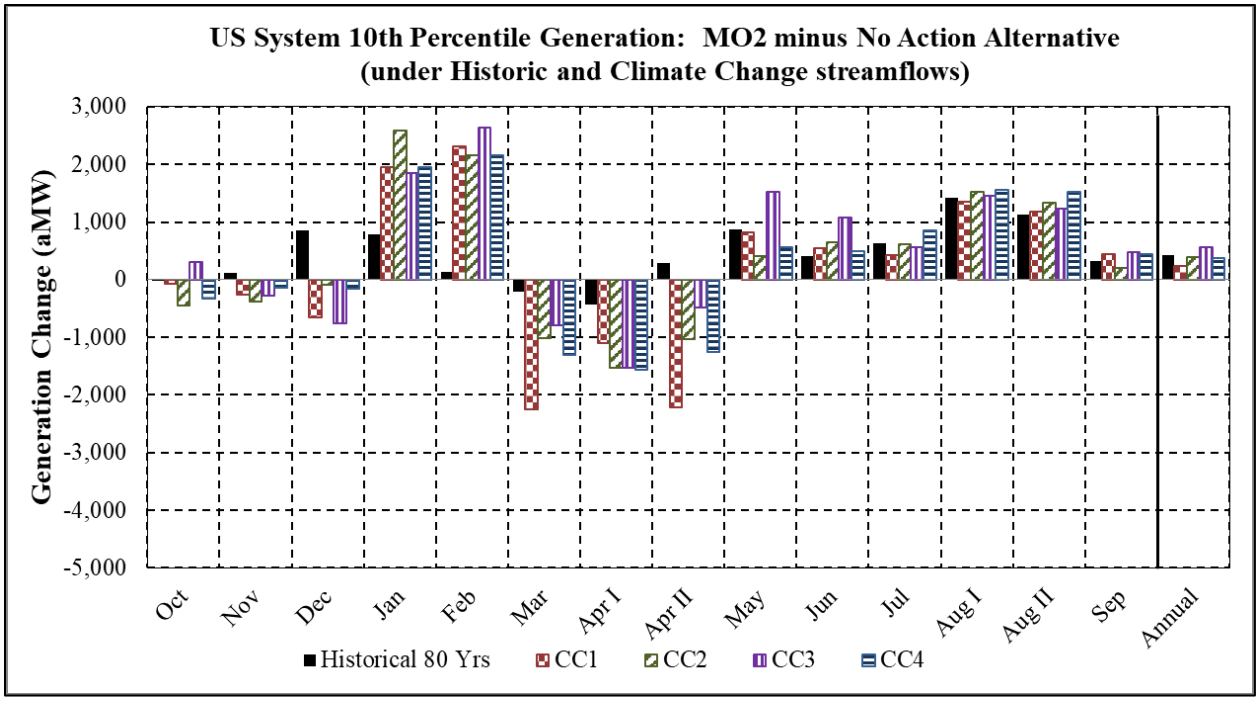


Figure 6-6. NW-US P10 Generation Changes for Historic and Climate Change Scenarios for MO2 Relative to NAA

Table 6-6. NW-US P10 Generation Changes for Historic and Climate Change Scenarios for MO2 and the Differences Relative to NAA

US System 10th Percentile Generation: MO2 minus No Action Alternative (under Historic and Climate Change streamflows)															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
Historical 80 Yr	-21	111	861	790	130	-217	-431	287	876	409	637	1,429	1,127	315	429
CC1	-69	-257	-654	1,954	2,321	-2,247	-1,103	-2,219	819	554	431	1,349	1,178	441	229
CC2	-443	-387	-93	2,581	2,154	-1,014	-1,522	-1,041	414	648	615	1,515	1,337	198	394
CC3	300	-280	-754	1,856	2,645	-797	-1,527	-478	1,527	1,080	571	1,461	1,232	484	570
CC4	-322	-132	-155	1,952	2,165	-1,307	-1,562	-1,263	563	489	846	1,558	1,521	437	380

For P10 generation, MO2 produces more energy than the NAA in the average of 80 water years of the historical streamflows. In the climate change scenarios, MO2 still produces more P10 energy than the NAA. In three of the climate scenarios the increase is smaller than that in the average historical generation and in one climate change scenario MO2 produces even more energy relative to the NAA. The variation in monthly impact from climate change on the difference between MO2 and the NAA is even larger for the P10 set than it is for the differences in average generation portrayed in Figure 6-5 and Table 6-5.

6.3.3 Assessment of MO3 with Historic and Climate Change Scenarios

6.3.3.1 MO3 Average Generation

The changes in NW-US system average generation between the NAA and MO3 are provided in Figure 6-7 and Table 6-7. The MO3 average generation differences in Table 6-7 are the differences between NAA average generation in Table 6-1 and the average MO3 generation.

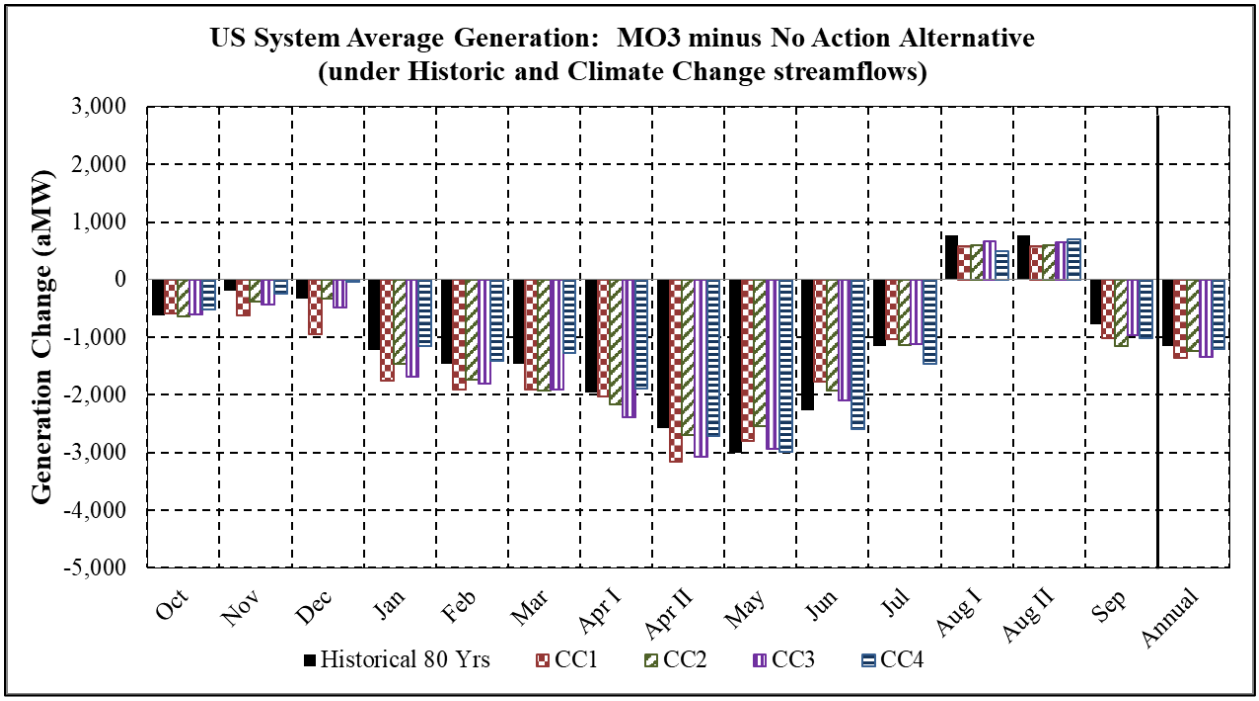


Figure 6-7. NW-US Average Generation Changes for Historic and Climate Change Scenarios for MO3 Relative to NAA

Table 6-7. NW-US Average Generation Changes for Historic and Climate Change Scenarios for MO3 and the Differences Relative to NAA

US System Average Generation: MO3 minus No Action Alternative (under Historic and Climate Change streamflows)															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
Historical 80 Yr	-614	-191	-332	-1,214	-1,466	-1,458	-1,951	-2,570	-3,002	-2,263	-1,148	764	761	-772	-1,158
CC1	-591	-627	-955	-1,749	-1,907	-1,914	-2,032	-3,156	-2,791	-1,776	-1,024	575	576	-1,016	-1,358
CC2	-631	-389	-327	-1,456	-1,739	-1,920	-2,166	-2,688	-2,545	-1,919	-1,129	601	596	-1,153	-1,247
CC3	-595	-430	-491	-1,687	-1,800	-1,899	-2,386	-3,075	-2,943	-2,088	-1,112	674	654	-956	-1,333
CC4	-525	-242	-45	-1,153	-1,417	-1,270	-1,896	-2,708	-2,994	-2,597	-1,469	495	708	-1,008	-1,196

MO3 produces less average energy than NAA over all 80-water years of the historical streamflows. In the four climate change scenarios, MO3 produces even less energy than NAA. These results indicate that under climate change, MO3 would likely produce even less annual energy than the NAA compared to the analysis with the historical streamflows. Thus, the conclusion in the studies that MO3 has significant negative impacts to power remains unchanged. Many of the months show even larger trends in decreases in power generation with climate change. Other months show slight increases, or a mix of increases and decreases.

6.3.3.2 MO3 P10 Generation

The changes in NW-US P10 generation between the NAA and MO3 are provided in Figure 6-8 and Table 6-8. The MO3 P10 generation differences in Table 6-8 are the differences between NAA P10 generation in Table 6-2 and the MO3 P10 generation.

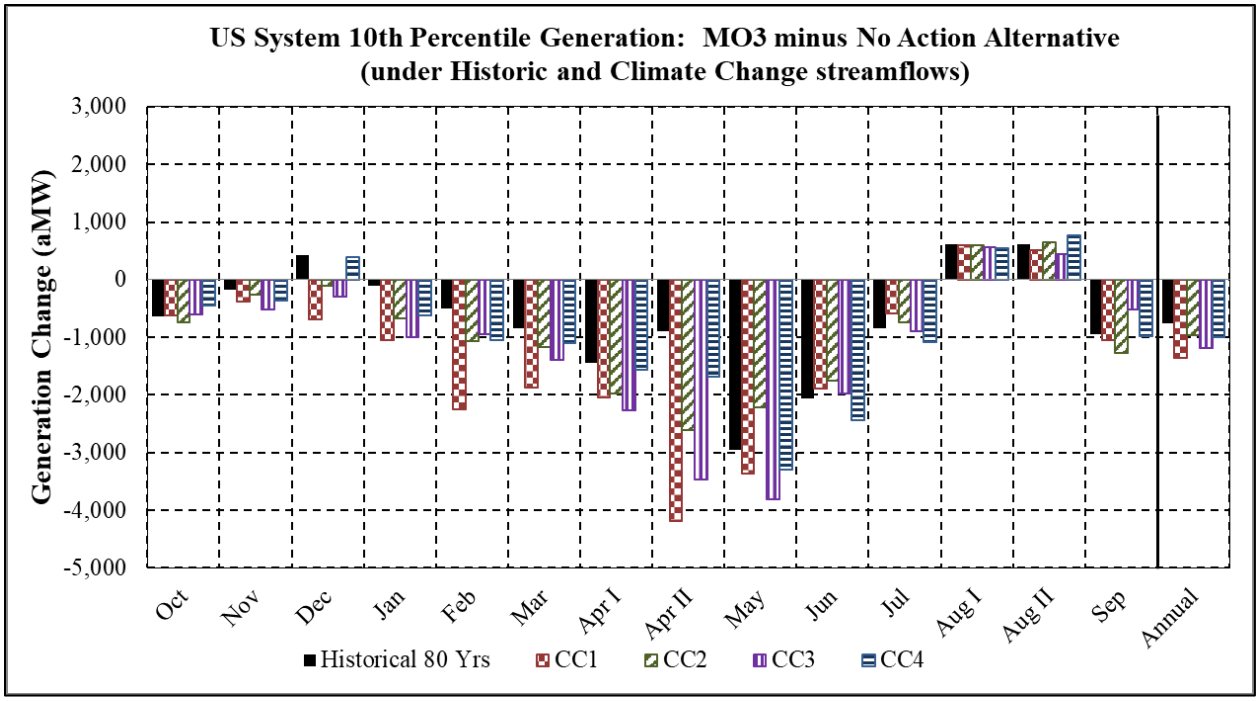


Figure 6-8. NW-US P10 Generation Changes for Historic and Climate Change Scenarios for MO3 Relative to NAA

Table 6-8. NW-US P10 Generation Changes for Historic and Climate Change Scenarios for MO3 and the Differences Relative to NAA

US System 10th Percentile Generation: MO3 minus No Action Alternative (under Historic and Climate Change streamflows)															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
Historical 80 Yr	-635	-181	418	-100	-495	-838	-1,436	-889	-2,946	-2,060	-835	615	611	-951	-763
CC1	-624	-383	-695	-1,050	-2,251	-1,879	-2,051	-4,182	-3,358	-1,896	-579	593	509	-1,048	-1,351
CC2	-743	-262	-108	-670	-1,063	-1,178	-1,979	-2,609	-2,221	-1,760	-746	603	646	-1,279	-970
CC3	-606	-525	-289	-998	-955	-1,398	-2,266	-3,467	-3,815	-1,969	-901	571	440	-526	-1,194
CC4	-450	-361	398	-620	-1,049	-1,109	-1,572	-1,680	-3,295	-2,435	-1,090	552	771	-983	-992

For P10 generation, MO3 produces less energy than the NAA in the average of 80 water years of the historical streamflows. In all four climate change scenarios, MO3 produces even less energy compared to the NAA. This trend is especially evident from November through April, with some months and some climate change scenarios showing very large reductions in generation relative to the NAA. In one instance (April II) the variation between climate change scenarios is over 3,000 MW. Thus, MO3 could have a greater negative impact on power generation compared to the NAA in the future, but the magnitude of this effect is considerably uncertain.

6.3.4 Assessment of MO4 with Historic and Climate Change Scenarios

6.3.4.1 MO4 Average Generation

The difference in NW-US system average generation between the NAA (Table 6-1) and MO4 are provided in Figure 6-9 and Table 6-9.

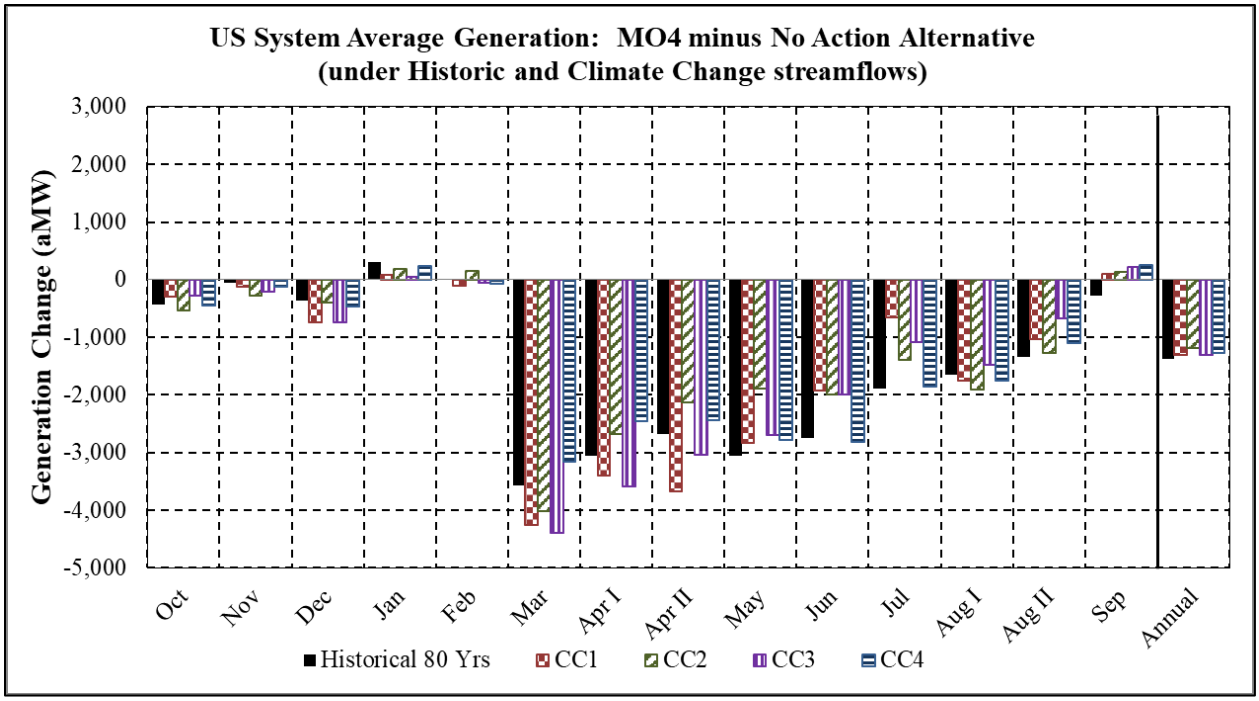


Figure 6-9. NW-US Average Generation Changes for Historic and Climate Change Scenarios for MO4 Relative to NAA

Table 6-9. NW-US Average Generation Changes for Historic and Climate Change Scenarios for MO4 and the Differences Relative to NAA

US System Average Generation: MO4 minus No Action Alternative (under Historic and Climate Change streamflows)															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
Historical 80 Yr	-432	-49	-360	299	1	-3,575	-3,059	-2,673	-3,056	-2,741	-1,890	-1,646	-1,334	-284	-1,380
CC1	-303	-128	-737	76	-108	-4,249	-3,392	-3,667	-2,830	-1,916	-663	-1,759	-1,024	93	-1,315
CC2	-535	-279	-395	184	145	-4,019	-2,677	-2,122	-1,881	-1,992	-1,385	-1,910	-1,278	131	-1,179
CC3	-284	-212	-744	48	-62	-4,387	-3,590	-3,033	-2,694	-1,988	-1,090	-1,473	-677	214	-1,308
CC4	-457	-118	-460	244	-67	-3,159	-2,449	-2,438	-2,778	-2,820	-1,854	-1,756	-1,106	258	-1,266

MO4 produces significantly less energy than NAA over all 80 water years of the historical streamflows. In the four climate change scenarios, MO4 produces less energy than NAA, though the loss is slightly less. These results indicate that under climate change, MO4 would produce significantly less annual energy than the NAA. Thus, the conclusion from the studies that MO4 has significant negative impacts to power remains unchanged. On a monthly basis, November through January have slightly greater decreases in energy in MO4 compared with the NAA with climate change, and May, June, July, August II, and September generally have slightly smaller decreases in energy with the climate change streamflows. Other results are more uncertain. August I, the period with the most significant reliability concern (based on hydropower impact assessments with the historical streamflows (discussed in Section 3.2 of this document and in the CRSO EIS), shows the potential for either slightly smaller or slightly larger losses depending on the climate change scenario. March and April show large variation and mixed results between climate change scenarios.

6.3.4.2 MO4 P10 Generation

The difference in NW-US P10 generation between the NAA (Table 6-2) and MO4 are provided in Figure 6-10 and Table 6-10.

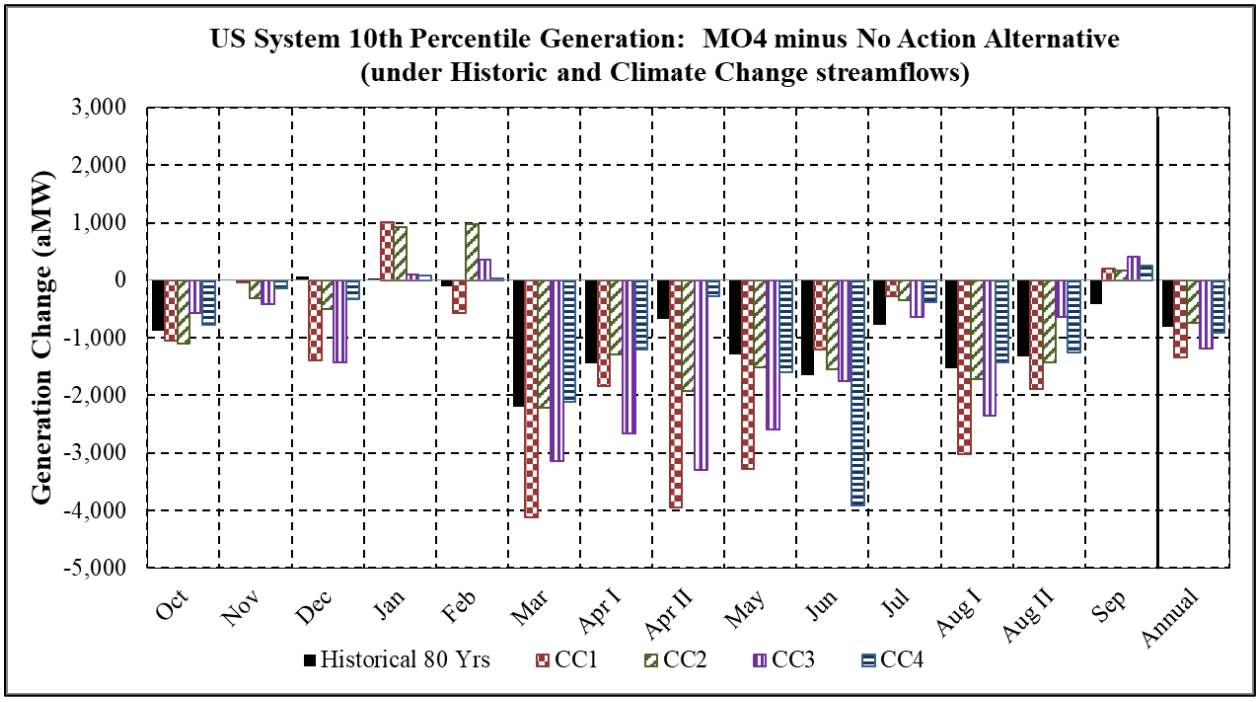


Figure 6-10. NW-US P10 Generation Changes for Historic and Climate Change Scenarios for MO4 Relative to NAA

Table 6-10. NW-US P10 Generation Changes for Historic and Climate Change Scenarios for MO4 and the Differences Relative to NAA

US System 10th Percentile Generation: MO4 minus No Action Alternative (under Historic and Climate Change streamflows)															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
Historical 80 Yrs	-871	19	63	37	-107	-2,204	-1,449	-676	-1,292	-1,648	-771	-1,525	-1,317	-410	-811
CC1	-1,048	-37	-1,397	1,005	-561	-4,127	-1,845	-3,955	-3,282	-1,201	-272	-3,021	-1,898	208	-1,348
CC2	-1,099	-310	-499	921	972	-2,224	-1,296	-1,927	-1,518	-1,550	-347	-1,723	-1,422	175	-734
CC3	-574	-410	-1,426	100	362	-3,145	-2,654	-3,302	-2,592	-1,751	-640	-2,346	-640	401	-1,189
CC4	-783	-139	-324	88	23	-2,120	-1,199	-285	-1,597	-3,908	-384	-1,428	-1,253	256	-919

For P10 generation, MO4 produces less energy than the NAA in the average of 80 water years of the historical streamflows. In three of the four climate change scenarios, MO4 produces even less energy compared to the NAA on an annual basis. The monthly differences between MO4 and the NAA are more pronounced than the annual average effect with significant variation between climate change scenarios. The scenarios show the potential of over 1,000 MW losses in December, 1,000 MW less loss in January and February, and possibly 1,000 to over 3,000 MW additional losses March to June and August. This again highlights the uncertainty of projected climate change impacts on generation. Regardless, these four climate scenarios do not change the conclusion that MO4 has a large negative impact on hydropower compared to the NAA, but climate change is another factor that makes the magnitude of this impact considerably uncertain.

6.4 ENERGY DEMAND (LOADS)

Warming regional temperatures are expected to impact energy demand (load) as well. For this analysis (both in the 80-year Modified Flows and for the four climate change scenarios), loads were held constant between alternatives.[25] However, by the 2030s, loads are likely to increase in the June through August period, and possibly into September as well, due to increasing air conditioning demand and longer air conditioning season. In the winter months (roughly December through February), loads are likely to decrease as increasing regional temperatures lower the need for heating. This has important potential implications for reliability.

The power shortages (Section 4.1.2) in December through February under the NAA and MO alternatives could be reduced into the 2030s as loads in those months decrease. Conversely, the summer shortages that increase in MO1, MO3, and MO4 as compared to the NAA are likely to be further exacerbated as temperatures and load in those months increase. The four climate scenarios do not alter those conclusions and add additional uncertainty given the variability between climate scenarios in monthly average and P10 generation amounts. Recent research supports these conclusions. An NW Council and Pacific Northwest National Laboratories study found that combined climate change impacts on loads and hydropower may lead to decreases in winter shortfalls and increases in summer shortfalls as increases in peak loads for cooling coincide with decreases in hydropower generation (NW Council 2018).

6.5 SUMMARY OF NW-US GENERATION CHANGES FOR HISTORIC AND CLIMATE CHANGE SCENARIOS

Climate change adds uncertainty to the annual magnitude of generation, and significant uncertainty to the monthly magnitude of the effect of the MO alternatives relative to the NAA. It does not change the general conclusions from the power analysis of the relative impact of one MO versus another. The results indicate that while climate change is very likely to impact hydropower generation in the future, it is likely to affect generation in all alternatives relative to the NAA roughly the same: MO2 is still the best alternative for hydropower and system reliability compared with the NAA; MO1 still produces the smallest change relative to the NAA; and MO3 and MO4 still have significant decreases in generation and reliability as compared to the NAA. Additionally, rising temperatures will likely decrease winter and increase summer energy demand in the region, which is likely to decrease winter shortfalls and increase summer shortfalls. This exacerbates reliability concerns in the summer period, particularly for MO1, MO3, and MO4 which already showed increased concerns as compared to the NAA.

There is much more detail on the overall effects of climate change on multiple uses in the CRSO EIS.

[25] There are some indirect effects of changes in load on operations through the Columbia River Treaty, but for the CRSO studies, the operations of the Canadian Treaty projects was kept constant.

CHAPTER 7 - REFERENCES

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Exhibit 1. Project List for NW-US, CRS (Federal), Mid-Columbia, and Canadian Systems

This exhibit provides a list of projects Bonneville modelled for the CRSO DEIS. The projects highlighted with an asterisk (*) are affected by the CRSO DEIS alternatives. The remaining projects are not affected by the alternatives but are part of the Bonneville hydropower models; their operation is replicated in each alternative.

Identification of Hydropower Projects within each Group

	Hydro Project Grouping			
Projects	**US System**	**Canadian System**	**Mid-Columbia**	**Federal System (CRS)**
Cushman 1	✓			
Cushman 2	✓			
Alder	✓			
Lagrand	✓			
Ross	✓			
Diablo	✓			
Gorge	✓			
Upper Baker	✓			
Lower Baker	✓			
Mica		✓		
Revelstoke		✓		
Arrow		✓		
Libby*	✓			✓
Bonners Ferry *	✓			
Duncan				
Corra Linn*		✓		
Canal Plant*		✓		
Upper Bonnington*		✓		
Lower Bonnington*		✓		
South Slocan*		✓		
Brilliant*		✓		
Hungry Horse*	✓			✓
Columbia Falls*	✓			
SQT (Kerr)*	✓			
Thompson Falls*	✓			
Noxon Rapids*	✓			
Cabinet Gorge*	✓			
Priest Lake				

	Hydro Project Grouping			
Projects	**US System**	**Canadian System**	**Mid-Columbia**	**Federal System (CRS)**
Albeni Falls*	✓			✓
Box Canyon*	✓			
Boundary*	✓			
Seven Mile*		✓		
Waneta*		✓		
Coeur d'Alene Lake				
Post Falls	✓			
Upper Falls	✓			
Monroe Street	✓			
Nine Mile	✓			
Long Lake	✓			
Little Falls	✓			
Grand Coulee*	✓			✓
Chief Joseph*	✓			✓
Wells*	✓		✓	
Chelan	✓			
Rocky Reach*	✓		✓	
Rock Island*	✓		✓	
Wanapum*	✓		✓	
Priest Rapids*	✓		✓	
Brownlee				
Oxbow				
Hells Canyon				
Dworshak*	✓			✓
Lower Granite*	✓			✓
Little Goose*	✓			✓
Lower Monumental*	✓			✓
Ice Harbor*	✓			✓
McNary*	✓			✓
John Day*	✓			✓
Round Butte	✓			
Pelton	✓			
Pelton Rereg	✓			
The Dalles*	✓			✓
Bonneville*	✓			✓
Timothy	✓			
Oak Grove	✓			

	Hydro Project Grouping			
Projects	**US System**	**Canadian System**	**Mid-Columbia**	**Federal System (CRS)**
North Fork	✓			
Faraday	✓			
River Mill	✓			
Swift 1	✓			
Swift 2	✓			
Yale	✓			
Merwin	✓			
Packwood Lake				
Mossyrock	✓			
Mayfield	✓			

(* indicates project may be directly affected by CRSO DEIS Alternatives)

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3648 # Exhibit 2. CRSO Alternative Crosswalk

	Measure Category	CRSO Measure Name	Multi-Objective #1 (MO1)	Multi-Objective #2 (MO2)	Multi-Objective #3 (MO3)	Multi-Objective #4 (MO4)	Preferred Alternative (PA)
Structural	Structural	Additional Powerhouse Surface Passage	X	X	X	X	
		Upgrade to Adjustable Spillway Weirs	X	X	X		
		Lower Granite Trap Modifications	X			X	X
		Modify Bonneville Ladder Serpentine Weir	X		X		X
		Lower Snake Ladder Pumps	X	X		X	
		Spillway Weir Notch Inserts				X	
		Fewer Fish Screens		X	X		X
		Improved Fish Passage Turbines at John Day	X	X	X	X	X
		Lamprey Passage Structures	X	X	X	X	X
		Turbine Strainer Lamprey Exclusion	X	X	X	X	X
		Bypass Screen Modifications for Lamprey	X	X	X	X	X
		Closeable Floating Orifice Gates					X
		Lamprey Passage Ladder Modifications	X	X	X	X	X
	Dam Breach	Breach Snake Embankments			X		
		Lower Snake Infrastructure Drawdown			X		
		Drawdown Operating Procedures			X		
		Drawdown Contingency Plans			X		
Operational	Fish Passage	Block Spill Test (Base + 120/115%)	X				
		Summer Spill Stop Trigger	X				
		Early Start Transport	X				X
		Contingency Reserves within Juvenile Fish Passage Spill	X	X	X	X	X
		Spill to 110% TDG		X			
		Spring & Fall Transport				X	
		No Summer Transport				X	
		Reduced Summer Spill			X		
		Spill to 125% TDG				X	
		Spring Spill to 120% TDG			X		
		Juvenile Fish Passage Spill Operations					X
		Spill for Adult Steelhead				X	
		Increase Juvenile Fish Transportation		X			
	Water Management	Modified Draft at Libby	X	X	X	X	X
		December Libby Target Elevation	X	X	X	X	
		Update System FRM Calculation at Grand Coulee	X	X	X	X	X
		Planned Draft Rate at Grand Coulee	X	X	X	X	X
		Grand Coulee Maintenance Operations	X	X	X	X	X
		Winter System FRM Space	X	X		X	
	Water Supply	Lake Roosevelt Additional Water Supply	X		X	X	X
		Hungry Horse Additional Water Supply	X		X	X	
		Chief Joseph Dam Project Addt'l Water Supply	X		X	X	
	Hydropower	Increased Forebay Range Flexibility	X				X
		Slightly Deeper Draft for Hydropower		X			
		Slightly Deeper Draft for Hydropower (Dworshak)					X
		Fall Operational Flexibility for Hydropower (Grand Coulee)					X
		Ramping Rates for Safety		X	X		
		John Day Full Pool		X	X		X
		Full Range Reservoir Operations		X			
		Full Range Turbine Operations		X			
		Above 1% Turbine Operations			X	X	X
		Zero Generation Operations		X			X
	Other Operational Measures	McNary Flow Target				X	
		Drawdown to MOP				X	
		Predator Disruption Operations	X				X
		Modified Dworshak Summer Draft	X				
		Sliding Scale at Libby and Hungry Horse	X	X	X	X	X
		Winter Stage for Riparian				X	

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Exhibit 3. Average and Critical Water Generation Effects on U.S. Projects

This exhibit provides detailed average and critical water generation data by project for several major NW-US system projects. The generation details supplement the graphs in Section 3.1.

Negative numbers indicate an alternative produced less hydropower than the NAA.

80 Year Average Generation Differences: NAA vs MO1

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
SYS	-83	-17	-242	228	16	-117	-317	-558	-506	-147	-258	-745	-416	92
GCL	-18	2	-60	47	-28	-34	-31	-72	-16	-22	-104	-104	-73	-48
CHJ	-9	1	-30	33	4	-13	-16	-35	6	-5	-40	-53	-40	-25
WEL	-3	1	-9	13	1	-4	-7	-25	-4	-8	-15	-16	-13	-9
RRC	-4	1	-15	22	-2	-6	-11	-29	-13	-16	-26	-25	-20	-13
RKI	-2	0	-6	8	-0	-3	-4	-9	-5	-6	-9	-8	-7	-6
WAN	-4	1	-12	11	3	-4	-9	-48	-11	-9	-20	-24	-18	-11
PRD	-3	1	-11	11	3	-4	-8	-18	-11	-11	-17	-21	-16	-10
MCN	-9	-4	10	11	8	-33	-108	-175	-205	-79	-105	-93	-62	-4
TDA	-4	1	-13	20	-3	-11	-20	-26	8	29	-12	-51	-36	7
JDA	-11	-6	-18	29	0	-10	-103	-142	-62	-25	-47	-88	-92	4
BON	-8	-5	-14	2	1	10	-12	-39	-26	-4	-8	-30	-16	0
LIB	2	5	-38	44	28	15	1	34	-29	-30	-22	-7	-7	-16
HGH	-1	-4	-8	-7	0	-4	-5	-7	-1	-3	4	13	13	16
DWR	0	0	1	2	2	-0	0	1	1	52	1	-237	-188	122
LWG	0	0	0	0	0	0	-23	-24	-49	-12	10	-15	40	22
LGS	0	0	0	0	0	1	-42	-33	-34	-18	13	-25	7	23
LMN	0	0	0	0	0	1	29	28	8	5	13	16	59	23
IHR	0	0	0	0	0	-26	55	64	-65	17	133	18	54	22

WY1937 Average Generation Differences: NAA vs MO1

WY for comparison: 1937

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
SYS	28	-117	99	177	-129	-50	-36	35	-1390	-858	-864	-1172	-829	-489
GCL	19	-9	-7	48	-39	-2	-6	-12	-174	-97	-217	-238	-141	-153
CHJ	10	-0	-0	28	-20	0	0	-0	-95	-51	-114	-127	-78	-83
WEL	3	-0	-0	9	-7	0	0	-0	-29	-15	-36	-36	-25	-29
RRC	5	-0	-0	14	-11	0	0	-0	-49	-23	-53	-57	-39	-44
RKI	2	-0	-0	5	-5	0	0	-0	-16	-7	-18	-20	-14	-20
WAN	4	-0	-0	12	-9	0	0	-0	-42	-22	-51	-56	-35	-37
PRD	4	-0	-0	11	-8	0	0	-0	-38	-19	-45	-49	-31	-34
MCN	-4	-7	19	20	2	-41	-70	-79	-252	-275	-90	2	-33	-29
TDA	5	-0	-0	13	-9	0	-8	-0	-73	-8	-28	-59	-35	-25
JDA	-0	-7	-0	17	-12	0	-16	-3	-280	-170	-61	-45	-95	-36
BON	-2	-6	-8	0	-9	24	-9	0	-87	-57	-34	-48	2	-22
LIB	-1	-87	96	-1	-2	-2	-2	-2	-34	-51	-56	-56	-55	-77
HGH	-0	-0	-1	-1	-1	-1	-0	-0	-0	-0	-38	-38	-34	-12
DWR	0	0	0	0	0	0	0	0	0	82	-0	-243	-150	99
LWG	0	0	0	0	0	0	0	0	-81	-85	7	0	6	16
LGS	0	0	0	0	0	0	0	0	-65	-76	5	0	3	17
LMN	0	0	0	0	0	0	0	30	37	37	7	0	21	17
IHR	0	0	0	0	0	-29	75	102	-111	-23	58	0	6	17

80 Year Average Generation Differences: NAA vs MO2

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
SYS	6	222	450	572	468	-380	-294	602	1102	361	772	1574	1449	177
GCL	-13	30	97	63	34	-162	-143	-130	-16	-32	-43	-59	-22	40
CHJ	-2	20	53	44	77	-63	-71	-61	-11	-8	-7	-30	-11	25
WEL	-1	6	17	17	21	-22	-24	-22	6	11	-6	-9	-4	9
RRC	-1	10	27	28	31	-34	-38	-37	-3	-3	-10	-14	-6	13
RKI	-0	4	10	10	12	-14	-16	-13	-3	-1	-4	-4	-2	6
WAN	-1	8	22	15	28	-25	-33	-29	-7	1	-8	-13	-5	11
PRD	-1	7	20	14	24	-23	-30	-26	-5	-4	-7	-11	-4	10
MCN	-8	3	34	18	20	-17	43	139	165	92	243	326	277	1
TDA	11	13	25	44	42	-8	-50	208	313	280	273	336	319	3
JDA	17	10	33	61	50	-38	-157	87	144	59	14	241	166	39
BON	3	2	7	11	14	4	49	136	144	122	160	406	405	8
LIB	1	95	104	-84	-9	4	-4	14	-42	-50	-36	-17	-17	-27
HGH	0	0	2	38	15	3	0	-7	22	-59	-14	-10	-9	1
DWR	0	0	0	134	42	-2	-76	-56	14	-81	-4	-5	-12	0
LWG	7	8	0	25	9	-1	22	36	34	8	50	114	100	8
LGS	-0	5	0	25	10	0	-10	38	86	17	26	83	69	12
LMN	-0	5	0	25	10	0	56	92	91	19	39	114	100	11
IHR	-0	5	0	24	9	-1	184	236	156	4	118	141	120	12

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WY1937 Average Generation Differences: NAA vs MO2

WY for comparison: **1937**

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
SYS	90	-105	246	-586	1210	17	-106	618	1027	994	332	1122	866	-224
GCL	7	-44	-2	-135	353	0	-0	-0	-39	-9	-108	-154	-85	-36
CHJ	13	-9	-0	-96	182	0	0	-0	-23	-4	-55	-81	-47	-17
WEL	5	-3	-0	-32	62	0	0	-0	-7	-1	-17	-23	-15	-6
RRC	7	-5	-0	-49	94	0	0	-0	-12	-2	-25	-36	-24	-9
RKI	3	-2	-0	-18	41	0	0	-0	-4	-1	-9	-13	-9	-4
WAN	6	-4	-0	-42	80	0	0	-0	-10	-2	-24	-36	-21	-7
PRD	5	-3	-0	-37	73	0	0	-0	-9	-1	-21	-32	-19	-7
MCN	-11	-7	19	-29	82	1	-39	62	162	261	211	361	240	-25
TDA	19	-0	-0	-45	85	0	-44	132	303	359	216	319	290	1
JDA	26	-7	-0	-58	110	0	-113	-38	17	36	-34	234	118	14
BON	8	-6	-8	-39	55	24	54	209	206	196	182	414	397	-3
LIB	-2	-38	237	-8	-8	-8	-8	-8	-81	-61	-64	-63	-62	-83
HGH	0	0	0	0	0	0	0	0	0	0	-42	-41	-41	-27
DWR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LWG	5	7	0	0	0	0	23	43	54	-103	85	89	61	6
LGS	0	5	0	0	0	0	-52	-8	110	7	7	92	51	10
LMN	0	5	0	0	0	0	33	108	150	123	56	81	52	10
IHR	0	5	0	0	0	0	40	117	210	194	52	91	63	12

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80 Year Average Generation Differences: NAA vs MO3

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
SYS	-646	-234	-380	-1243	-1481	-1451	-1889	-2490	-2786	-2032	-1151	678	716	-804
GCL	-18	84	99	-66	-97	-10	-29	-103	-69	-112	-137	-127	-77	-59
CHJ	-9	43	52	-30	-48	2	-16	-53	-31	14	-56	-66	-40	-31
WEL	-3	15	18	-7	-11	0	-5	-20	10	-2	-18	-19	-13	-11
RRC	-5	23	29	-11	-20	2	-8	-30	-4	-11	-29	-30	-20	-17
RKI	-2	9	11	-4	-7	0	-3	-10	-5	-7	-11	-10	-7	-7
WAN	-4	19	24	-3	-7	0	-7	-44	-33	-13	-24	-28	-17	-14
PRD	-3	17	21	-3	-6	1	-6	-20	-11	-8	-20	-24	-16	-13
MCN	-10	13	36	3	5	-3	-177	-240	-259	-89	-90	320	299	-22
TDA	9	25	29	-9	-1	42	-206	-282	-316	-141	-86	321	307	-5
JDA	13	25	35	-12	-19	10	-346	-444	-370	-124	37	364	295	6
BON	2	10	8	-7	-1	-0	-29	-62	-36	6	-5	398	398	-8
LIB	1	95	104	-84	-9	4	-4	14	-42	-50	-36	-17	-17	-27
HGH	-1	-4	-8	-0	3	-3	-13	-8	-1	-3	4	13	13	16
DWR	0	0	0	0	-0	-1	0	1	3	9	0	0	0	0
LWG	-145	-145	-201	-250	-311	-373	-295	-359	-475	-425	-196	-98	-90	-158
LGS	-154	-149	-203	-254	-315	-375	-331	-362	-458	-432	-203	-137	-129	-154
LMN	-156	-153	-210	-263	-336	-392	-291	-333	-471	-445	-210	-105	-96	-154
IHR	-148	-146	-200	-244	-309	-358	-118	-125	-224	-193	-66	-66	-66	-145

WY1937 Average Generation Differences: NAA vs MO3

WY for comparison: 1937

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
SYS	-366	-520	-184	217	-247	-658	-1388	-986	-2784	-1831	-1378	246	263	-1112
GCL	19	-18	22	216	66	-1	-5	-11	-208	-70	-215	-238	-141	-153
CHJ	10	-9	-0	103	34	0	0	-0	-116	-38	-113	-127	-78	-83
WEL	3	-3	-0	34	12	0	0	-0	-36	-11	-35	-36	-25	-29
RRC	5	-5	-0	53	18	0	0	-0	-60	-17	-53	-57	-39	-44
RKI	2	-2	-0	20	8	0	0	-0	-20	-5	-18	-20	-14	-20
WAN	4	-4	-0	45	15	0	0	-0	-52	-17	-50	-56	-35	-37
PRD	4	-3	-0	40	14	0	0	-0	-47	-14	-45	-49	-31	-34
MCN	-13	-7	19	50	23	1	-179	-85	-259	-282	-84	384	269	-52
TDA	17	-0	-0	48	16	0	-274	-130	-311	-196	-32	298	275	-30
JDA	24	-7	-0	62	21	0	-373	-242	-461	-270	4	350	244	-26
BON	7	-6	-8	24	8	1	-85	0	-122	-63	-38	400	387	-24
LIB	-2	-38	237	-8	-8	-8	-8	-8	-81	-61	-64	-63	-62	-83
HGH	-0	-0	-1	-1	-1	-1	-0	-0	-0	-0	-38	-38	-34	-12
DWR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LWG	-102	-102	-112	-117	-110	-169	-86	-138	-357	-239	-91	-80	-80	-115
LGS	-108	-106	-113	-119	-111	-171	-161	-191	-342	-258	-149	-80	-93	-110
LMN	-112	-107	-117	-120	-130	-184	-85	-84	-296	-205	-99	-85	-85	-104
IHR	-107	-103	-113	-115	-123	-175	-67	-66	-176	-88	-66	-67	-67	-97

80 Year Average Generation Differences: NAA vs MO4

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
SYS	-457	-83	-402	244	-49	-3549	-2938	-2552	-2793	-2462	-1834	-1693	-1336	-308
GCL	-105	3	-97	54	-50	-31	-30	-86	73	-59	-41	-266	-262	-52
CHJ	-53	2	-49	37	-3	-10	-16	-43	69	20	14	-128	-138	-25
WEL	-19	1	-16	15	-3	-4	-7	-18	38	23	0	-39	-44	-9
RRC	-28	1	-25	25	-7	-6	-9	-27	37	2	-1	-60	-69	-13
RKI	-12	0	-10	9	-2	-3	-4	-10	8	-3	-1	-20	-26	-6
WAN	-23	2	-21	12	0	-5	-19	-20	23	8	2	-58	-61	-11
PRD	-22	1	-18	11	0	-4	-7	-18	18	2	2	-51	-55	-10
MCN	-30	-13	3	11	6	-437	-328	-272	-360	-243	-217	-118	-67	-9
TDA	-24	1	-22	22	-9	-639	-610	-478	-653	-569	-453	-308	-183	-11
JDA	-41	-9	-30	33	-6	-831	-828	-628	-719	-645	-583	-432	-326	-7
BON	-21	-3	-19	3	-1	-500	-387	-241	-315	-237	-248	-129	-45	-12
LIB	1	2	-80	42	29	16	1	34	1	-23	-0	-8	-10	-49
HGH	-1	-3	-6	-10	-1	2	-11	-16	7	3	24	9	10	-15
DWR	0	0	0	0	-0	-3	0	1	3	15	1	0	0	0
LWG	-14	-14	0	0	1	-274	-193	-215	-283	-193	-115	-17	-9	0
LGS	-15	-15	0	0	-0	-280	-235	-228	-283	-214	-122	-56	-48	0
LMN	-15	-15	0	0	0	-257	-202	-221	-326	-262	-126	-20	-12	0
IHR	-14	-14	0	0	-0	-290	-52	-55	-147	-92	-1	1	0	0

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WY1937 Average Generation Differences: NAA vs MO4

WY for comparison: 1937

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
SYS	-873	-197	-48	-369	-131	-1627	-1147	-653	-601	-2442	-1747	-2768	-1976	-388
GCL	-209	-9	-23	-114	-39	-2	-6	-12	462	-221	-324	-870	-540	-36
CHJ	-107	-0	-0	-54	-20	0	0	-0	320	-51	-123	-440	-289	-11
WEL	-38	-0	-0	-18	-7	0	0	-0	94	-15	-38	-133	-92	-4
RRC	-57	-0	-0	-28	-11	0	0	-0	159	-23	-58	-203	-144	-6
RKI	-25	-0	-0	-10	-5	0	0	-0	56	-7	-19	-68	-54	-3
WAN	-47	-0	-0	-24	-9	0	0	-0	141	-22	-55	-195	-128	-5
PRD	-43	-0	-0	-21	-8	0	0	-0	124	-19	-49	-175	-115	-5
MCN	-62	-17	19	-12	2	-213	-166	-72	-252	-273	-87	6	-31	-12
TDA	-50	-0	-0	-25	-9	-315	-283	-140	-324	-400	-212	-199	-125	-5
JDA	-73	-10	-0	-33	-12	-389	-386	-254	-475	-578	-346	-278	-263	0
BON	-41	-6	-8	-25	-9	-324	-216	-4	-199	-291	-75	-49	2	-7
LIB	-4	-93	-50	-1	-2	-2	-2	-2	84	-58	-63	-61	-60	-82
HGH	-2	-2	-2	-2	-2	-2	-2	-2	-1	-1	-61	-56	-35	-28
DWR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LWG	-14	-14	0	0	0	-87	-5	-57	-276	-159	-10	1	0	0
LGS	-15	-15	0	0	0	-88	-81	-110	-261	-178	-68	1	-12	0
LMN	-15	-15	0	0	0	-98	-0	0	-211	-121	-14	0	0	0
IHR	-14	-14	0	0	0	-107	-0	0	-111	-23	1	1	0	0

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80 Year Average System Generation Differences: NAA vs PA

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
SYS	189	-78	1	281	244	-130	-855	-1221	-1370	-496	4	-53	678	137
GCL	30	-38	-22	-23	42	-50	-2	15	10	-19	-33	-29	-46	44
CHJ	21	-15	-7	-3	37	-17	0	5	18	17	-2	-14	-24	27
WEL	7	-5	-2	-1	10	-7	-3	-29	-6	-1	-4	-4	-8	10
RRC	11	-8	-4	-1	16	-12	-2	-17	3	-2	-8	-6	-12	14
RKI	5	-3	-1	-0	6	-5	-1	-3	1	-1	-3	-2	-4	6
WAN	9	-6	-3	-1	11	-6	-7	-34	-3	-3	-6	-6	-10	12
PRD	8	-6	-3	-1	9	-6	-1	-3	1	-0	-5	-5	-10	11
MCN	1	-11	14	8	11	-7	-167	-256	-307	-82	-69	-31	233	3
TDA	22	-7	-2	15	20	-6	-49	-59	-105	-62	-71	-40	63	0
JDA	64	26	44	75	79	38	-179	-330	-243	-88	6	8	177	36
BON	11	-9	-10	-1	4	11	30	-13	17	42	6	10	168	-3
LIB	4	7	-2	24	7	5	-1	36	-28	-28	-21	-6	-6	-14
HGH	0	0	2	6	2	-1	-3	-1	4	2	-4	-4	-4	-3
DWR	0	0	0	103	-9	-38	-32	-12	-3	-1	0	-1	-0	-0
LWG	0	0	0	19	-0	-9	-106	-141	-167	-37	10	4	53	-0
LGS	0	0	0	19	-0	-8	-163	-176	-205	-88	27	8	12	-0
LMN	0	0	0	19	-1	-8	-148	-177	-265	-120	19	3	47	-0
IHR	0	0	0	18	-1	-7	-25	-31	-99	-24	163	72	59	-0
Other projects	(5)	(3)	(2)	6	1	2	5	4	8	(1)	(1)	(9)	(9)	(5)
DS from HGH														
KER	(1)	(0)	1	1	1	(0)	(0)	(0)	0	0	(1)	(1)	(1)	(1)
TFL	(0)	(0)	0	0	0	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
NOX	(1)	(0)	1	2	1	(0)	(1)	(1)	1	0	(1)	(1)	(1)	(1)
CBG	(1)	(0)	0	1	0	(0)	(0)	(0)	0	0	(1)	(1)	(1)	(0)
ALF	(0)	(0)	(0)	(0)	0	0	0	0	(0)	(0)	(0)	(0)	(0)	0
BXC	(0)	(0)	0	0	0	0	(0)	0	(0)	(0)	(0)	(0)	(0)	(0)
BND	(2)	(0)	1	3	2	(0)	(1)	(1)	1	1	(2)	(2)	(2)	(1)
Westsiders														
ROS	(0)	(1)	(2)	(1)	(1)	1	2	2	1	(0)	1	(1)	(1)	(1)
DBL	(0)	(1)	(1)	(0)	(1)	1	2	2	1	0	1	(1)	(1)	(1)
GOR	(0)	(1)	(1)	(0)	(1)	1	2	2	1	0	1	(1)	(1)	(1)
UBK	(0)	-	-	(0)	0	-	1	(0)	1	(1)	0	(0)	(0)	0
LBK	1	0	-	(0)	0	-	1	0	0	(1)	(0)	(1)	(1)	0

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WY1937 Average Generation Differences: NAA vs PA

WY for comparison: **1937**

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP
SYS	254	-102	8	-622	93	46	-510	-479	-1596	-1017	-477	-338	55	-171
GCL	45	-35	-43	-204	16	-0	-1	-2	-23	-22	-113	-124	-115	-10
CHJ	34	-0	-0	-104	8	0	0	-0	-12	-10	-58	-65	-63	-3
WEL	12	-0	-0	-34	3	0	0	-0	-4	-3	-18	-19	-20	-1
RRC	18	-0	-0	-53	4	0	0	-0	-6	-4	-27	-29	-32	-1
RKI	8	-0	-0	-20	2	0	0	-0	-2	-1	-9	-10	-11	-1
WAN	15	-0	-0	-46	4	0	0	-0	-5	-4	-26	-29	-28	-1
PRD	14	-0	-0	-40	3	0	0	-0	-5	-4	-22	-25	-25	-1
MCN	-3	-7	19	-32	13	1	-177	-79	-253	-275	-72	36	189	-18
TDA	28	-0	-0	-49	4	-12	-8	-0	-3	-2	-16	-10	57	-14
JDA	69	33	40	-28	37	35	-240	-230	-449	-179	-14	51	123	16
BON	15	-6	-8	-41	-0	24	-1	2	14	9	-20	-6	149	-13
LIB	-1	-87	0	30	-0	-1	-1	-1	-21	-41	-45	-44	-43	-42
HGH	0	0	0	0	0	0	0	0	0	0	-42	-41	-41	-27
DWR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LWG	0	0	0	0	0	0	-3	-58	-242	-159	0	0	6	0
LGS	0	0	0	0	0	0	-79	-111	-262	-179	0	31	-7	0
LMN	0	0	0	0	0	0	0	0	-212	-121	0	0	0	0
IHR	0	0	0	0	0	0	0	0	-111	-23	81	28	0	0
Other projects	-	-	-	-	-	-	-	-	-	-	(74)	(75)	(78)	(50)
DS from HGH														
KER	-	-	-	-	-	-	-	-	-	-	(19)	(19)	(19)	(12)
TFL														
NOX	-	-	-	-	-	-	-	-	-	-	(15)	(15)	(15)	(10)
CBG	-	-	-	-	-	-	-	-	-	-	(9)	(10)	(10)	(7)
ALF	-	-	-	-	-	-	-	-	-	-	-	(1)	(3)	(0)
BXC	-	-	-	-	-	-	-	-	-	-	(4)	(4)	(4)	(3)
BND	-	-	-	-	-	-	-	-	-	-	(28)	(27)	(28)	(18)
Westsiders														
ROS	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DBL	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GOR	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UBK	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LBK	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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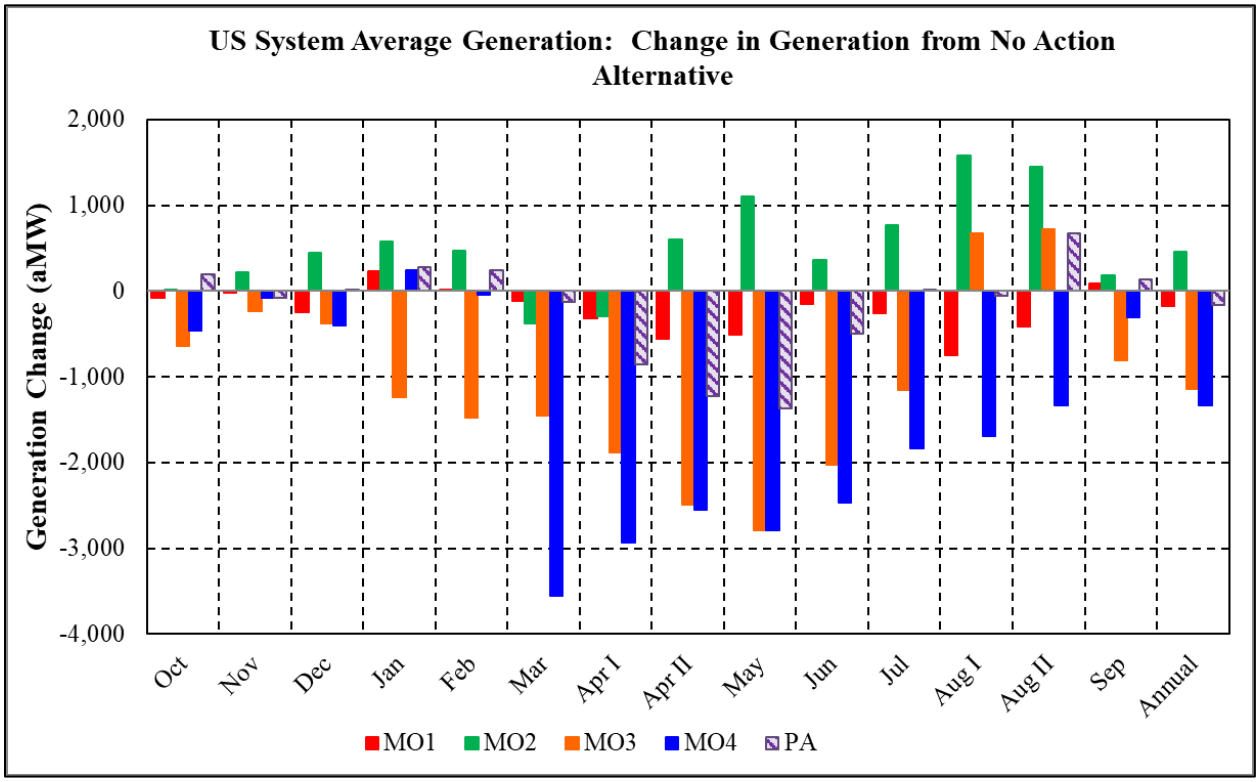
Exhibit 4. Annual Average Generation for NW-US, CRS (Federal), Mid-Columbia, and Canadian Systems – All Alternatives

NW-US System Average Generation: Change from NAA



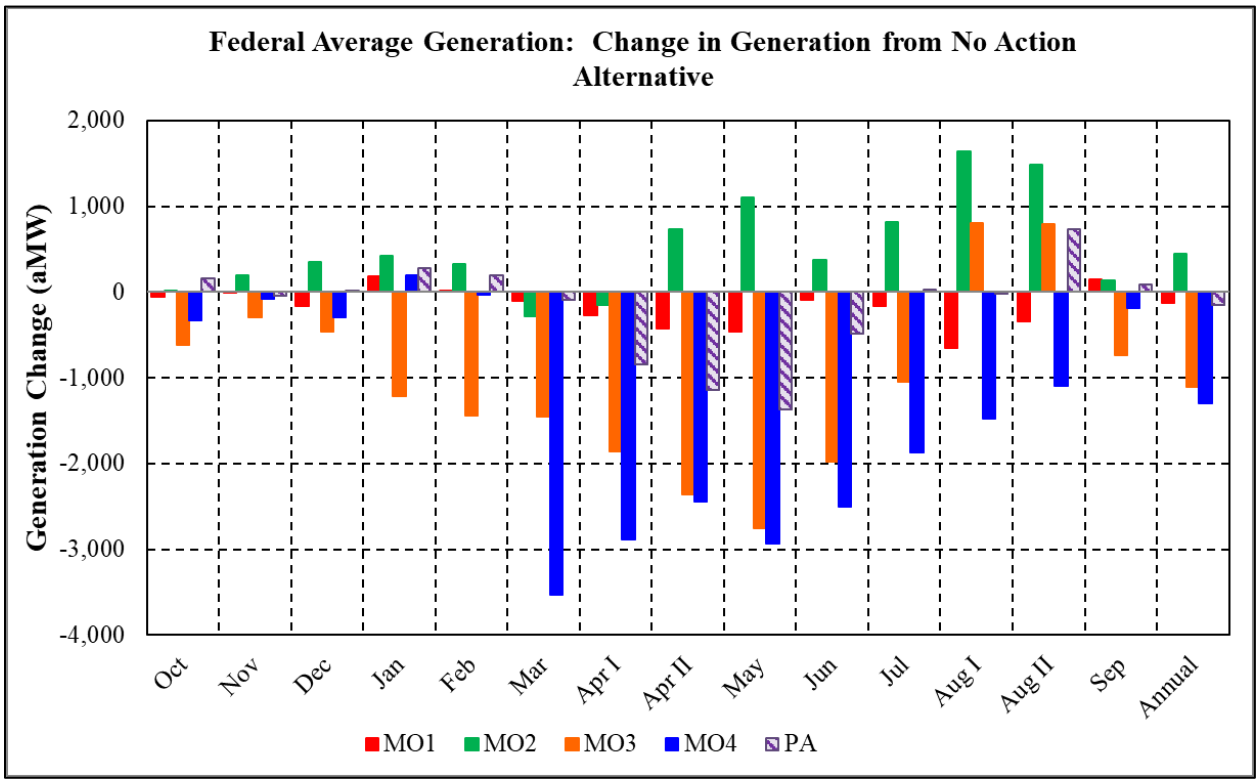
US System Average Generation: Change in Generation from No Action Alternative

	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
NAA	9,364	12,205	13,519	15,115	15,299	13,724	12,643	13,469	16,462	17,504	14,173	11,770	10,229	9,215	13,373
MO1	9,280	12,188	13,277	15,343	15,315	13,607	12,326	12,911	15,956	17,358	13,915	11,025	9,813	9,306	13,200
MO2	9,370	12,428	13,970	15,686	15,768	13,344	12,349	14,071	17,564	17,865	14,945	13,344	11,678	9,392	13,826
MO3	8,718	11,971	13,139	13,872	13,819	12,273	10,754	10,980	13,676	15,473	13,022	12,448	10,945	8,410	12,236
MO4	8,906	12,122	13,117	15,358	15,250	10,175	9,705	10,918	13,669	15,042	12,339	10,077	8,893	8,906	12,034
PA	9,552	12,128	13,521	15,395	15,544	13,594	11,788	12,249	15,093	17,008	14,177	11,718	10,907	9,352	13,211

US System Average Generation: Change in Generation from No Action Alternative

	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
NAA	9,364	12,205	13,519	15,115	15,299	13,724	12,643	13,469	16,462	17,504	14,173	11,770	10,229	9,215	13,373
MO1	-83	-17	-242	228	16	-117	-317	-558	-506	-147	-258	-745	-416	92	-173
MO2	6	222	450	572	468	-380	-294	602	1,102	361	772	1,574	1,449	177	453
MO3	-646	-234	-380	-1,243	-1,481	-1,451	-1,889	-2,490	-2,786	-2,032	-1,151	678	716	-804	-1,137
MO4	-457	-83	-402	244	-49	-3,549	-2,938	-2,552	-2,793	-2,462	-1,834	-1,693	-1,336	-308	-1,339
PA	189	-78	1	281	244	-130	-855	-1,221	-1,370	-496	4	-53	678	137	-162

3683 # CRS (Federal) Average Generation: Change from NAA



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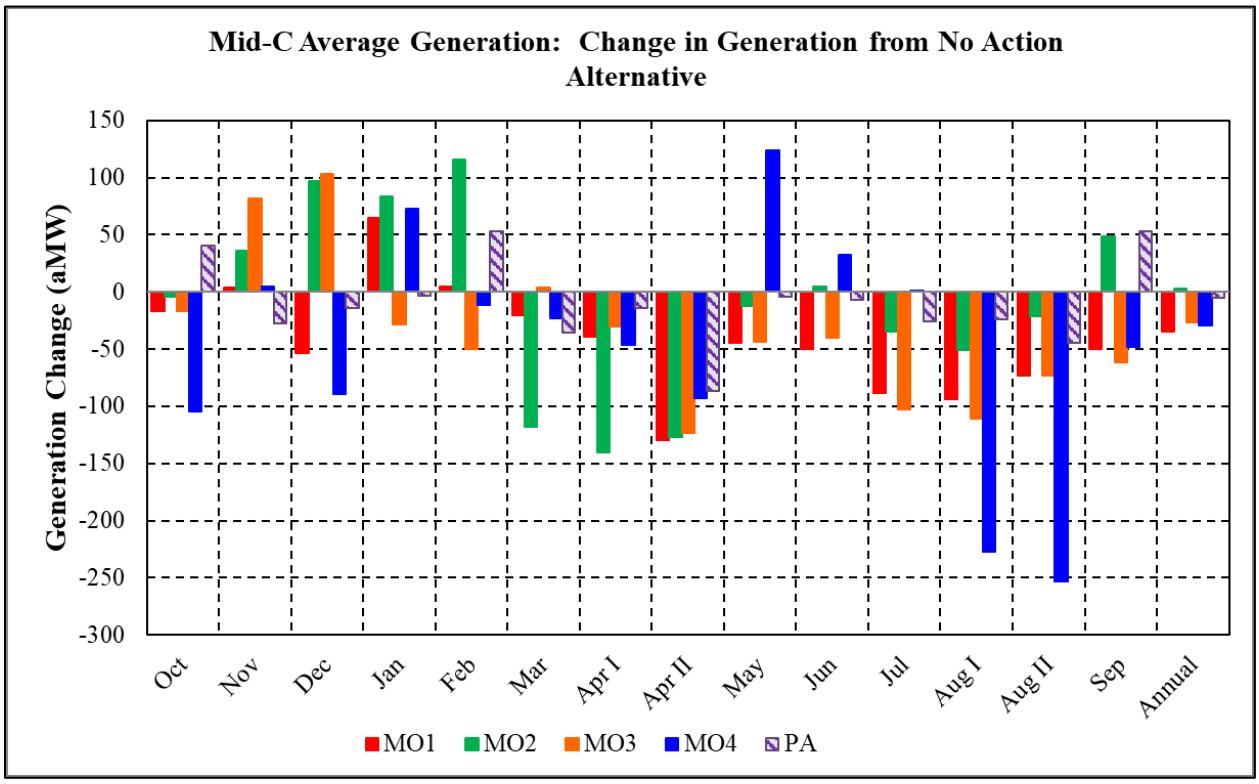
Federal Average Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
NAA	5,548	7,420	8,302	9,453	9,730	8,819	7,842	8,220	10,324	10,895	8,796	7,592	6,455	5,843	8,339
MO1	5,491	7,410	8,133	9,636	9,744	8,717	7,567	7,794	9,858	10,800	8,631	6,936	6,113	5,990	8,207
MO2	5,565	7,617	8,656	9,880	10,053	8,537	7,685	8,953	11,424	11,266	9,614	9,232	7,940	5,976	8,784
MO3	4,931	7,120	7,841	8,239	8,292	7,362	5,987	5,864	7,575	8,910	7,752	8,392	7,252	5,100	7,234
MO4	5,215	7,341	8,002	9,646	9,695	5,284	4,951	5,773	7,391	8,394	6,929	6,118	5,365	5,661	7,036
PA	5,701	7,373	8,318	9,731	9,920	8,723	6,997	7,081	8,951	10,406	8,826	7,573	7,187	5,933	8,183

Federal Average Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
NAA	5,548	7,420	8,302	9,453	9,730	8,819	7,842	8,220	10,324	10,895	8,796	7,592	6,455	5,843	8,339
MO1	-57	-10	-168	183	14	-102	-275	-426	-466	-94	-165	-656	-343	147	-132
MO2	18	197	354	426	324	-282	-157	733	1,100	371	818	1,641	1,484	132	445
MO3	-617	-300	-461	-1,215	-1,437	-1,457	-1,855	-2,356	-2,749	-1,984	-1,044	801	797	-743	-1,105
MO4	-333	-79	-300	192	-35	-3,535	-2,891	-2,447	-2,932	-2,501	-1,866	-1,474	-1,091	-182	-1,303
PA	153	-47	16	278	190	-96	-845	-1,139	-1,373	-488	31	-19	731	90	-156

3686

3687

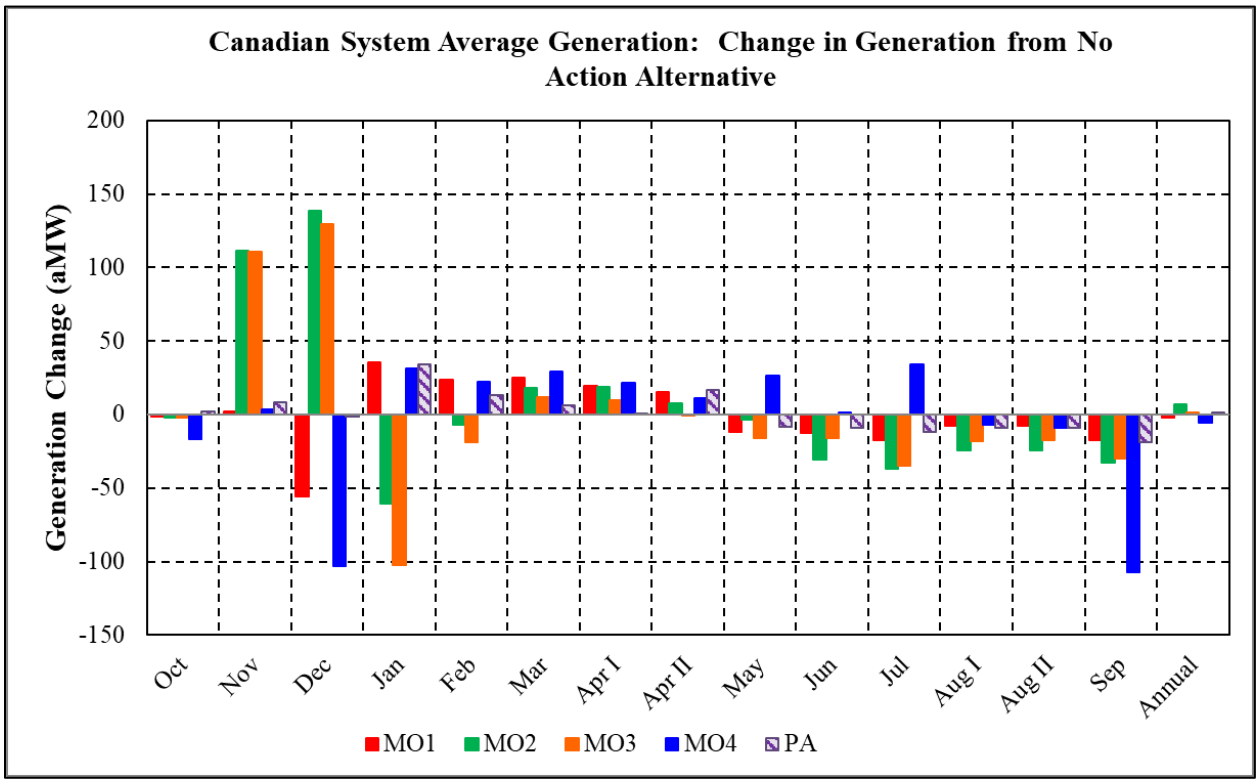
Mid-Columbia Average Generation: Change from NAA



Mid-C Average Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
NAA	1,834	2,499	2,666	2,982	2,892	2,482	2,399	2,610	3,217	3,337	2,904	2,691	2,467	1,845	2,644
MO1	1,818	2,503	2,613	3,047	2,897	2,461	2,360	2,481	3,173	3,287	2,815	2,597	2,394	1,796	2,609
MO2	1,830	2,535	2,763	3,065	3,008	2,364	2,258	2,483	3,205	3,341	2,869	2,640	2,446	1,894	2,647
MO3	1,818	2,580	2,769	2,953	2,842	2,485	2,369	2,486	3,174	3,297	2,801	2,580	2,394	1,784	2,617
MO4	1,730	2,503	2,577	3,055	2,881	2,459	2,353	2,517	3,341	3,369	2,905	2,464	2,214	1,797	2,614
PA	1,875	2,471	2,653	2,978	2,946	2,446	2,385	2,524	3,213	3,330	2,878	2,667	2,423	1,899	2,639

Mid-C Average Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
NAA	1,834	2,499	2,666	2,982	2,892	2,482	2,399	2,610	3,217	3,337	2,904	2,691	2,467	1,845	2,644
MO1	-16	4	-54	65	5	-21	-39	-129	-44	-50	-88	-94	-73	-50	-35
MO2	-4	36	97	83	116	-118	-141	-127	-12	4	-35	-50	-21	48	3
MO3	-17	82	103	-29	-50	3	-30	-124	-43	-40	-103	-111	-73	-62	-27
MO4	-104	5	-89	73	-11	-23	-46	-93	124	32	1	-227	-253	-48	-30
PA	41	-28	-14	-4	53	-36	-14	-86	-4	-7	-26	-24	-44	53	-5

3693 # Canadian Average Generation: Change from NAA



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Canadian System Average Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
NAA	2,522	3,219	3,709	2,379	3,276	2,360	2,429	2,698	3,917	4,281	4,836	4,761	4,136	3,285	3,401
MO1	2,520	3,221	3,653	2,415	3,300	2,385	2,448	2,713	3,905	4,268	4,818	4,754	4,129	3,268	3,399
MO2	2,520	3,330	3,848	2,319	3,270	2,378	2,448	2,705	3,913	4,250	4,799	4,736	4,112	3,252	3,408
MO3	2,520	3,329	3,839	2,277	3,257	2,372	2,439	2,697	3,901	4,265	4,801	4,743	4,119	3,255	3,402
MO4	2,505	3,222	3,606	2,411	3,299	2,390	2,451	2,708	3,943	4,283	4,870	4,754	4,127	3,177	3,395
PA	2,524	3,227	3,708	2,414	3,289	2,367	2,429	2,714	3,908	4,272	4,824	4,752	4,127	3,267	3,402

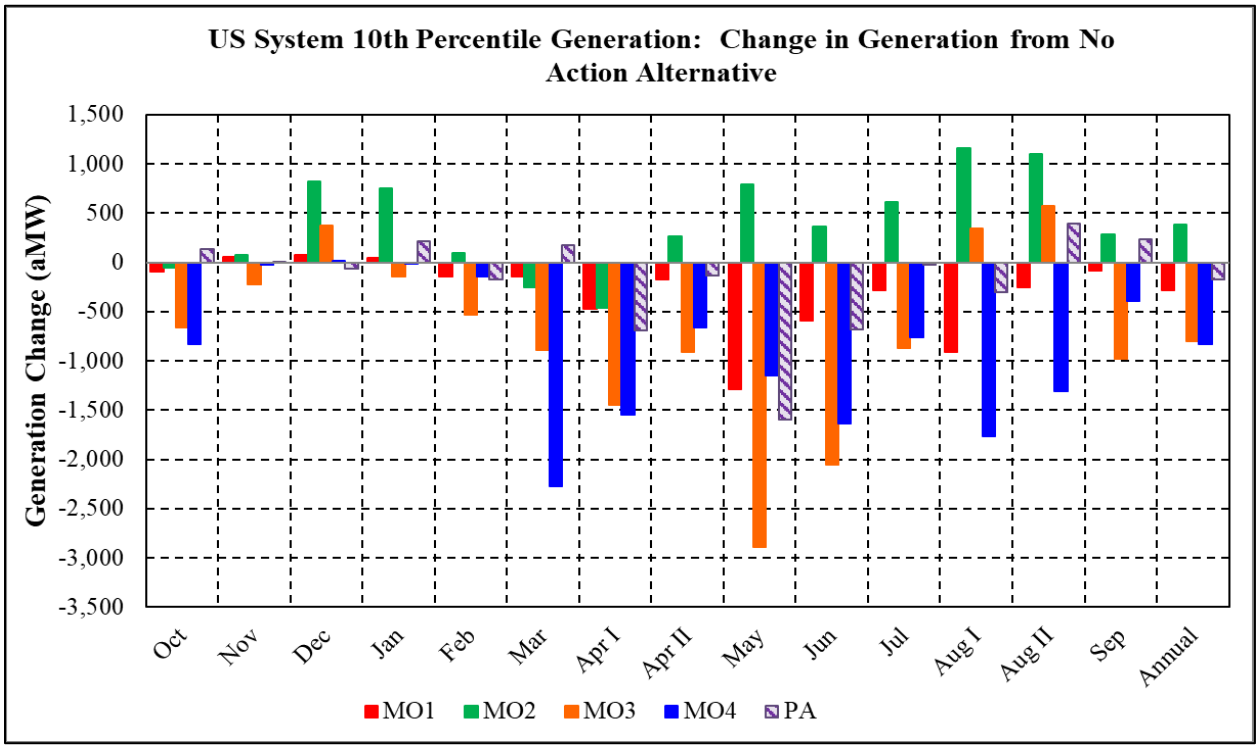
Canadian System Average Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
All Water Years															
NAA	2,522	3,219	3,709	2,379	3,276	2,360	2,429	2,698	3,917	4,281	4,836	4,761	4,136	3,285	3,401
MO1	-2	2	-56	36	23	25	19	15	-12	-13	-18	-7	-7	-17	-2
MO2	-2	111	139	-61	-7	18	19	8	-3	-31	-37	-25	-24	-33	7
MO3	-2	111	129	-102	-19	12	10	-1	-16	-16	-35	-18	-18	-30	2
MO4	-17	3	-103	32	22	29	22	11	27	2	34	-7	-9	-108	-6
PA	2	8	-2	34	13	7	0	16	-9	-9	-12	-9	-9	-19	1

3696

3697

Exhibit 5. P(10) Generation for NW-US, CRS (Federal), Mid-Columbia, and Canadian Systems – All Alternatives

NW-US System P10 Generation: Change from NAA



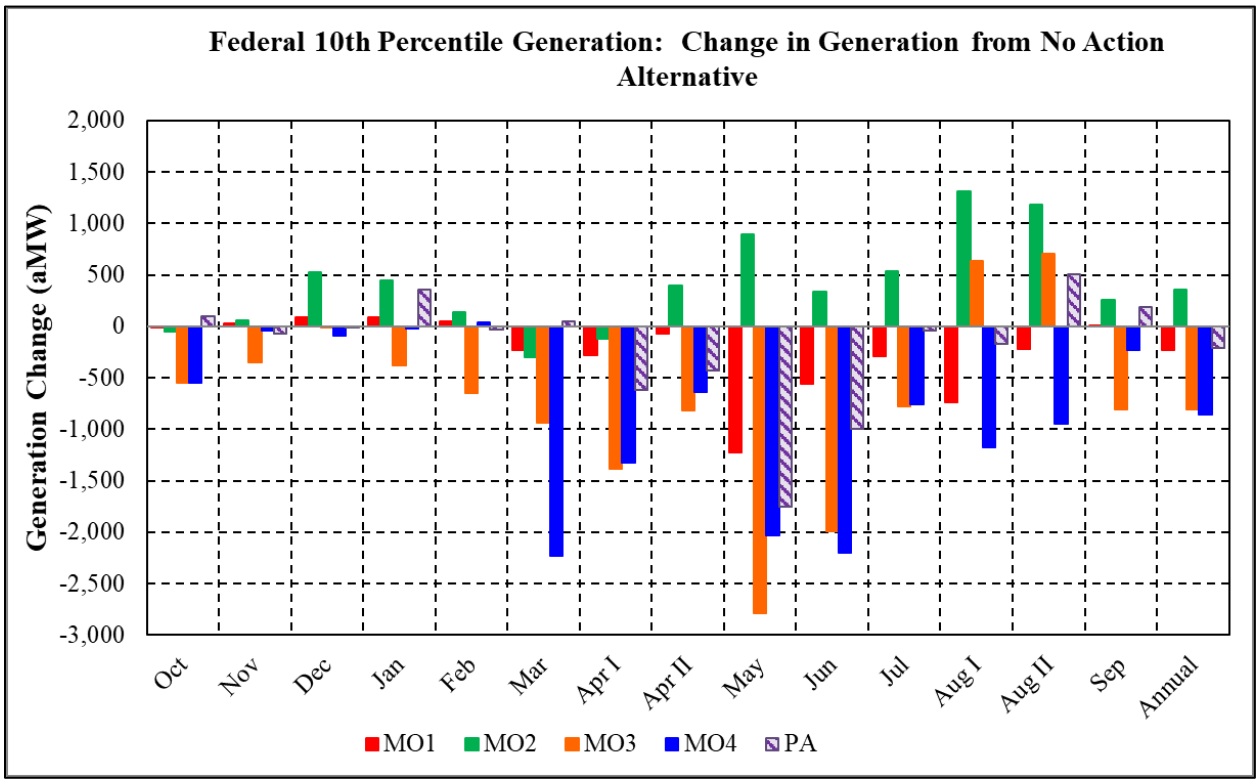
US System 10th Percentile Generation: Change in Generation from No Action Alternative

	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
NAA	8,530	10,662	10,904	10,866	10,228	9,713	8,736	7,814	12,570	13,017	9,557	9,599	8,635	8,307	10,144
MO1	8,438	10,715	10,983	10,915	10,085	9,573	8,260	7,637	11,286	12,426	9,274	8,687	8,385	8,222	9,865
MO2	8,480	10,736	11,722	11,613	10,319	9,458	8,278	8,077	13,364	13,377	10,166	10,757	9,729	8,592	10,524
MO3	7,865	10,441	11,279	10,725	9,692	8,825	7,287	6,908	9,678	10,960	8,691	9,938	9,208	7,329	9,347
MO4	7,700	10,643	10,921	10,864	10,085	7,435	7,185	7,151	11,420	11,385	8,792	7,829	7,322	7,912	9,319
PA	8,668	10,670	10,844	11,081	10,057	9,887	8,042	7,682	10,977	12,335	9,536	9,295	9,025	8,546	9,969

US System 10th Percentile Generation: Change in Generation from No Action Alternative

	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
NAA	8,530	10,662	10,904	10,866	10,228	9,713	8,736	7,814	12,570	13,017	9,557	9,599	8,635	8,307	10,144
MO1	-92	53	79	49	-143	-140	-476	-177	-1,284	-591	-284	-912	-250	-85	-280
MO2	-50	73	818	747	91	-255	-458	263	794	360	609	1,158	1,095	285	380
MO3	-665	-221	374	-140	-536	-888	-1,449	-907	-2,892	-2,056	-867	339	573	-978	-798
MO4	-830	-20	17	-2	-143	-2,278	-1,551	-663	-1,150	-1,632	-766	-1,770	-1,313	-395	-826
PA	138	8	-60	215	-171	174	-694	-132	-1,593	-682	-21	-305	390	239	-176

3705 # CRS (Federal) P10 Generation: Change from NAA



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3707

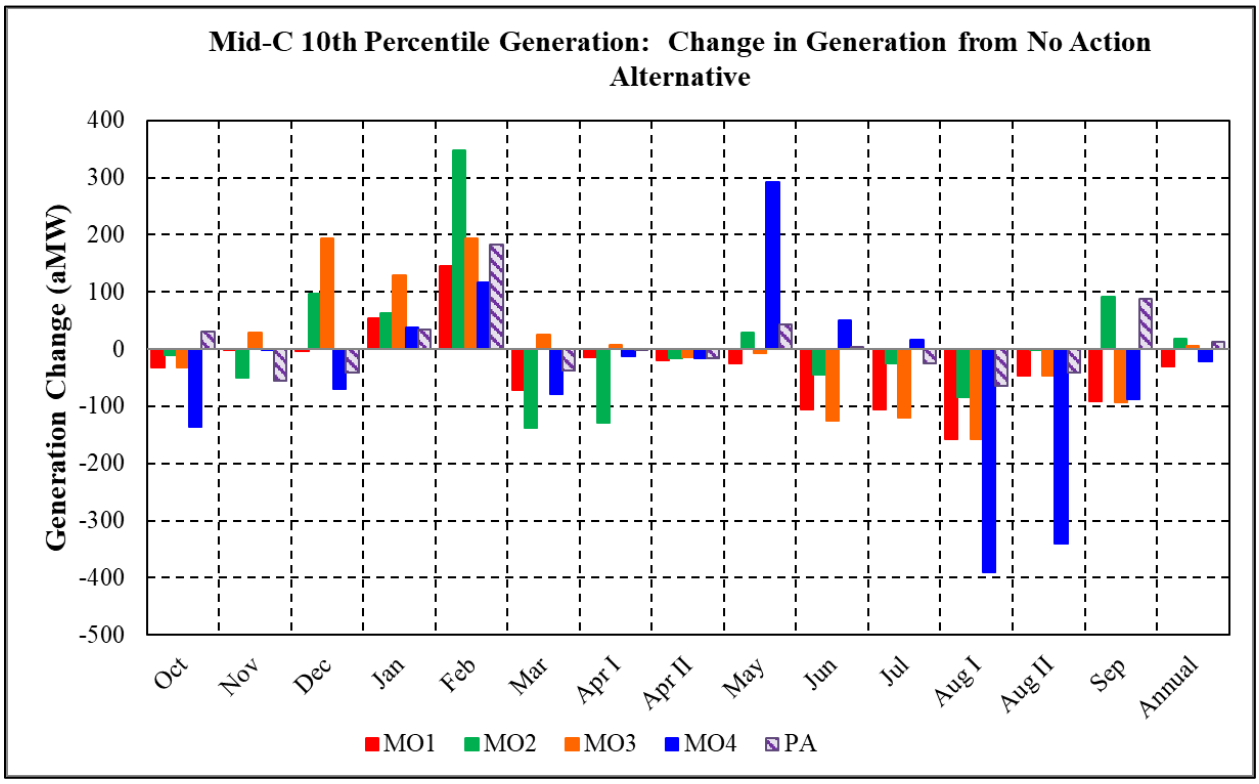
Federal 10th Percentile Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
NAA	5,029	6,575	6,741	6,452	6,202	6,156	5,043	4,472	8,031	7,851	5,954	6,202	5,495	5,239	6,237
MO1	5,026	6,603	6,824	6,535	6,245	5,923	4,765	4,402	6,808	7,296	5,666	5,464	5,271	5,245	6,009
MO2	4,975	6,631	7,266	6,896	6,337	5,853	4,921	4,873	8,928	8,183	6,493	7,512	6,676	5,495	6,591
MO3	4,476	6,225	6,732	6,075	5,556	5,220	3,659	3,658	5,246	5,859	5,173	6,834	6,200	4,434	5,433
MO4	4,476	6,531	6,649	6,430	6,244	3,924	3,715	3,832	5,996	5,653	5,196	5,026	4,545	5,004	5,382
PA	5,122	6,501	6,740	6,807	6,167	6,203	4,420	4,046	6,280	6,852	5,910	6,034	6,001	5,427	6,023

Federal 10th Percentile Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
NAA	5,029	6,575	6,741	6,452	6,202	6,156	5,043	4,472	8,031	7,851	5,954	6,202	5,495	5,239	6,237
MO1	-3	28	83	83	43	-233	-278	-71	-1,223	-555	-287	-738	-224	6	-228
MO2	-54	56	526	444	135	-303	-122	401	897	332	540	1,310	1,181	255	354
MO3	-553	-349	-9	-377	-646	-935	-1,383	-814	-2,785	-1,992	-780	632	705	-805	-804
MO4	-553	-43	-92	-22	42	-2,232	-1,328	-640	-2,035	-2,198	-757	-1,175	-950	-236	-855
PA	93	-74	-1	355	-35	48	-623	-426	-1,751	-999	-44	-168	506	188	-214

3708

3709

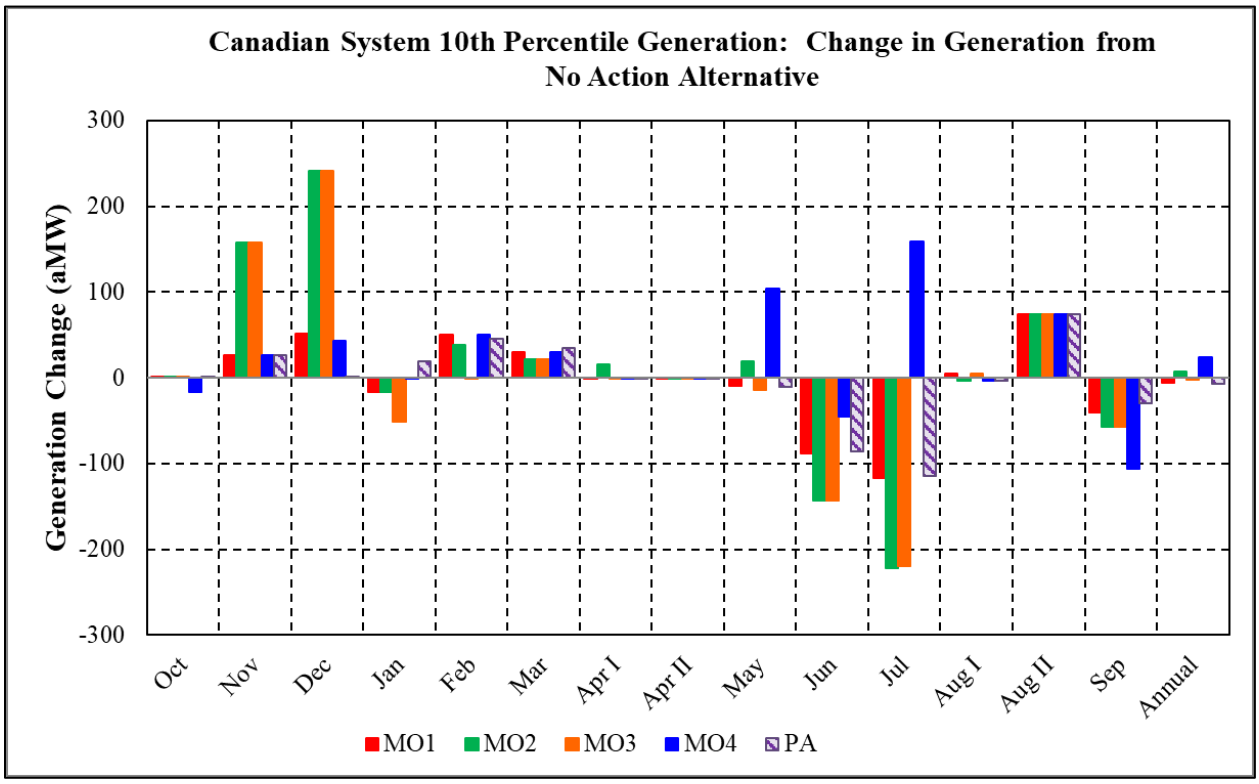
Mid-Columbia P10 Generation: Change from NAA



Mid-C 10th Percentile Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
NAA	1,623	2,224	2,234	2,188	1,747	1,784	1,692	1,444	2,437	2,659	1,979	2,167	2,091	1,612	2,018
MO1	1,592	2,223	2,231	2,242	1,893	1,712	1,678	1,426	2,412	2,554	1,873	2,009	2,044	1,521	1,987
MO2	1,612	2,174	2,330	2,251	2,095	1,646	1,563	1,428	2,465	2,615	1,953	2,083	2,090	1,703	2,036
MO3	1,592	2,253	2,427	2,318	1,941	1,809	1,700	1,430	2,429	2,535	1,858	2,009	2,044	1,518	2,024
MO4	1,487	2,223	2,164	2,226	1,863	1,706	1,680	1,428	2,728	2,710	1,995	1,778	1,752	1,525	1,996
PA	1,654	2,170	2,193	2,222	1,929	1,746	1,691	1,428	2,479	2,663	1,954	2,103	2,050	1,700	2,030

Mid-C 10th Percentile Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
NAA	1,623	2,224	2,234	2,188	1,747	1,784	1,692	1,444	2,437	2,659	1,979	2,167	2,091	1,612	2,018
MO1	-31	-1	-3	53	146	-72	-14	-19	-24	-105	-106	-158	-47	-91	-31
MO2	-11	-50	96	62	347	-138	-129	-17	28	-44	-26	-84	-1	91	18
MO3	-31	29	193	129	194	24	8	-15	-7	-124	-121	-158	-47	-94	6
MO4	-136	-1	-70	38	116	-79	-12	-17	291	50	16	-389	-339	-87	-21
PA	31	-55	-41	34	182	-38	-1	-16	43	4	-25	-64	-41	88	12

Canadian P10 Generation: Change from NAA

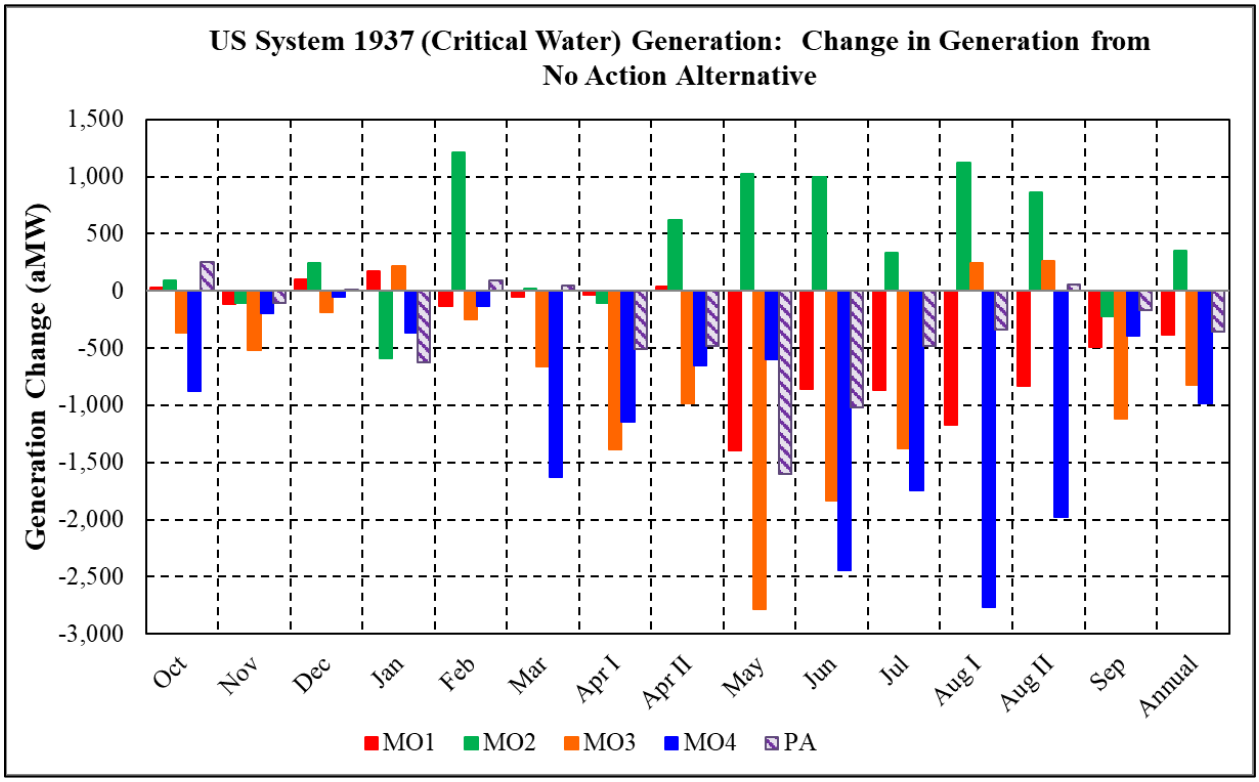


Canadian System 10th Percentile Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
NAA	2,114	2,653	3,338	1,799	1,979	1,800	1,528	1,655	3,268	3,598	3,101	3,079	3,170	2,957	2,615
MO1	2,114	2,679	3,390	1,783	2,029	1,830	1,528	1,654	3,258	3,509	2,985	3,085	3,243	2,917	2,608
MO2	2,114	2,810	3,580	1,782	2,017	1,822	1,543	1,654	3,288	3,454	2,879	3,076	3,243	2,900	2,621
MO3	2,114	2,810	3,580	1,748	1,978	1,822	1,528	1,654	3,254	3,454	2,882	3,085	3,243	2,900	2,613
MO4	2,097	2,679	3,382	1,799	2,029	1,830	1,528	1,654	3,372	3,552	3,260	3,077	3,243	2,851	2,638
PA	2,114	2,679	3,338	1,819	2,024	1,834	1,528	1,655	3,258	3,512	2,987	3,076	3,243	2,927	2,608

Canadian System 10th Percentile Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
10th Percentile															
NAA	2,114	2,653	3,338	1,799	1,979	1,800	1,528	1,655	3,268	3,598	3,101	3,079	3,170	2,957	2,615
MO1	0	26	52	-16	50	30	0	0	-10	-88	-117	5	74	-41	-6
MO2	0	157	242	-17	38	22	15	0	19	-144	-223	-3	74	-57	7
MO3	0	157	242	-52	-1	22	0	0	-15	-144	-220	5	74	-57	-2
MO4	-17	26	43	0	50	30	0	0	104	-46	158	-3	74	-106	24
PA	0	26	0	19	45	35	0	0	-10	-85	-115	-3	74	-30	-7

Exhibit 6. Critical water (1937) Generation for NW-US, CRS (Federal), Mid-Columbia, and Canadian Systems – All Alternatives

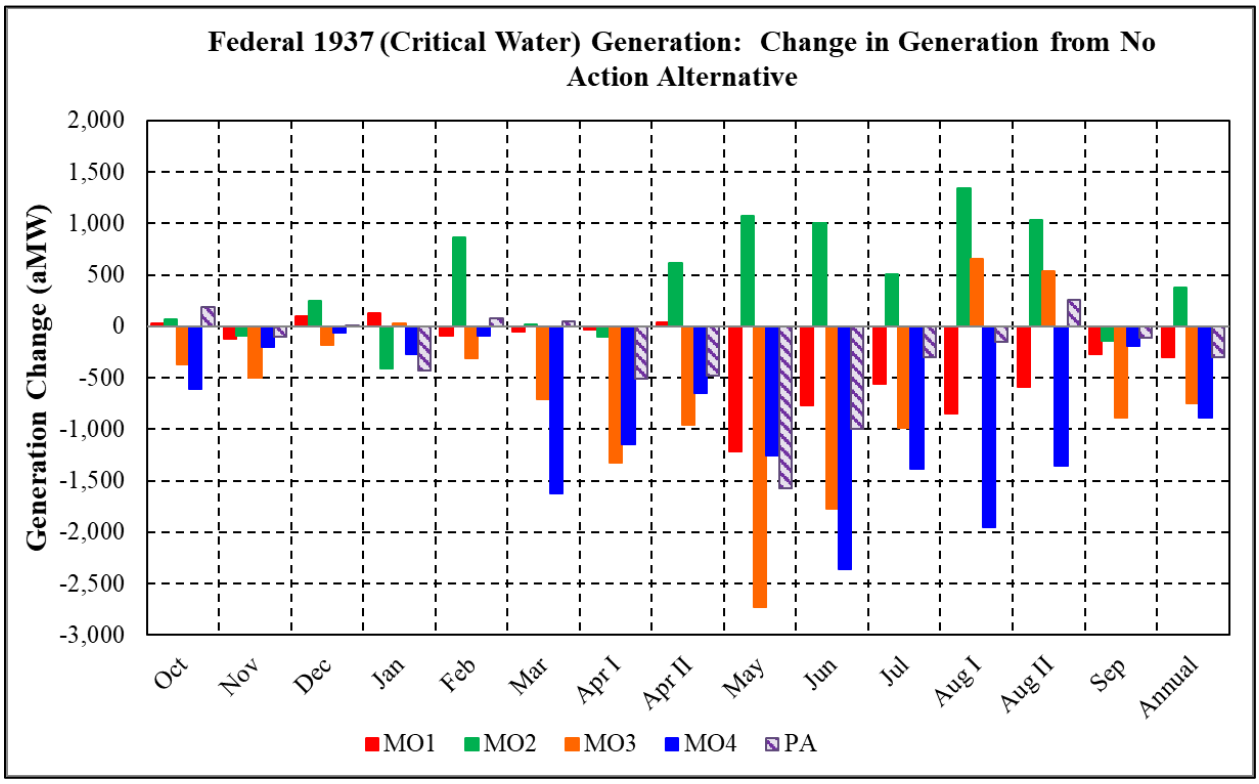
NW-US System Critical Water (1937) Generation: Change from NAA



US System 1937 (Critical Water) Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
Water Year 1937 (Critical Water)															
NAA	8,766	11,079	11,224	10,754	8,690	9,034	8,707	7,841	11,424	13,914	11,117	10,539	9,405	9,221	10,297
MO1	8,794	10,962	11,323	10,931	8,560	8,984	8,671	7,876	10,034	13,056	10,252	9,366	8,576	8,732	9,912
MO2	8,856	10,973	11,470	10,168	9,900	9,051	8,601	8,459	12,451	14,908	11,449	11,661	10,270	8,997	10,645
MO3	8,400	10,558	11,040	10,971	8,443	8,376	7,318	6,855	8,640	12,083	9,738	10,785	9,668	8,109	9,480
MO4	7,894	10,882	11,176	10,385	8,558	7,407	7,560	7,188	10,823	11,472	9,370	7,770	7,429	8,833	9,317
PA	9,021	10,977	11,232	10,132	8,782	9,080	8,196	7,362	9,828	12,897	10,639	10,201	9,459	9,051	9,943

US System 1937 (Critical Water) Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
Water Year 1937 (Critical Water)															
NAA	8,766	11,079	11,224	10,754	8,690	9,034	8,707	7,841	11,424	13,914	11,117	10,539	9,405	9,221	10,297
MO1	28	-117	99	177	-129	-50	-36	35	-1,390	-858	-864	-1,172	-829	-489	-385
MO2	90	-105	245	-586	1,210	17	-106	618	1,027	994	332	1,122	866	-224	348
MO3	-366	-520	-184	217	-247	-658	-1,388	-986	-2,784	-1,831	-1,378	246	263	-1,112	-817
MO4	-873	-197	-48	-369	-131	-1,627	-1,147	-653	-601	-2,442	-1,747	-2,768	-1,976	-388	-980
PA	254	-102	8	-622	93	46	-510	-479	-1,596	-1,017	-477	-338	55	-171	-354

3728 # CRS (Federal) Critical Water (1937) Generation: Change from NAA



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Federal 1937 (Critical Water) Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
Water Year 1937 (Critical Water)															
NAA	5,221	7,137	6,853	6,421	5,213	5,553	5,013	4,441	7,187	7,857	6,585	6,740	5,927	5,688	6,237
MO1	5,247	7,020	6,952	6,546	5,123	5,502	4,977	4,476	5,972	7,084	6,024	5,888	5,341	5,416	5,940
MO2	5,285	7,048	7,098	6,013	6,073	5,569	4,907	5,059	8,257	8,857	7,092	8,081	6,961	5,550	6,615
MO3	4,853	6,633	6,669	6,446	4,899	4,845	3,688	3,485	4,460	6,084	5,600	7,395	6,460	4,799	5,489
MO4	4,614	6,940	6,788	6,154	5,121	3,925	3,866	3,788	5,935	5,500	5,198	4,791	4,570	5,500	5,349
PA	5,409	7,035	6,860	5,993	5,290	5,599	4,502	3,962	5,613	6,856	6,288	6,593	6,180	5,576	5,933

Federal 1937 (Critical Water) Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
Water Year 1937 (Critical Water)															
NAA	5,221	7,137	6,853	6,421	5,213	5,553	5,013	4,441	7,187	7,857	6,585	6,740	5,927	5,688	6,237
MO1	26	-117	99	125	-90	-50	-36	35	-1,215	-773	-561	-852	-586	-272	-297
MO2	64	-89	246	-408	860	17	-106	618	1,070	1,001	507	1,341	1,034	-138	378
MO3	-368	-504	-184	25	-314	-707	-1,324	-956	-2,727	-1,772	-985	655	533	-889	-748
MO4	-607	-197	-65	-267	-92	-1,628	-1,147	-653	-1,252	-2,357	-1,386	-1,949	-1,357	-188	-888
PA	188	-102	8	-428	77	46	-510	-479	-1,574	-1,001	-297	-146	253	-112	-304

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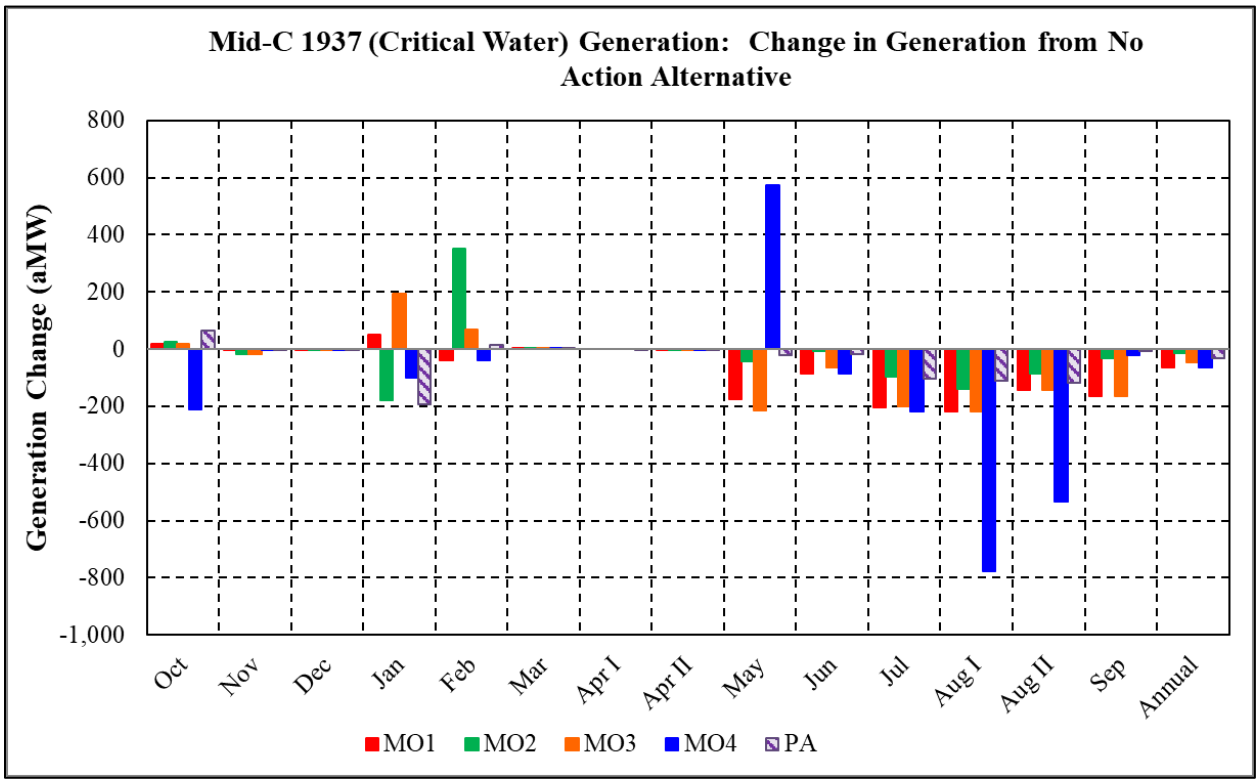
3733 # Mid-Columbia Critical Water (1937) Generation: Change from NAA



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Mid-C 1937 (Critical Water) Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
Water Year 1937 (Critical Water)															
NAA	1,796	2,521	2,446	2,328	1,750	1,713	1,707	1,430	2,123	2,848	2,241	2,439	2,272	1,877	2,133
MO1	1,815	2,521	2,446	2,381	1,710	1,713	1,707	1,430	1,948	2,763	2,038	2,221	2,128	1,713	2,068
MO2	1,822	2,504	2,446	2,150	2,100	1,713	1,707	1,430	2,080	2,842	2,144	2,299	2,185	1,844	2,120
MO3	1,815	2,504	2,446	2,521	1,817	1,713	1,707	1,430	1,908	2,785	2,040	2,221	2,128	1,713	2,085
MO4	1,586	2,521	2,446	2,227	1,710	1,713	1,707	1,430	2,696	2,763	2,022	1,664	1,738	1,854	2,069
PA	1,863	2,521	2,446	2,134	1,766	1,713	1,707	1,430	2,101	2,833	2,139	2,327	2,156	1,871	2,101

Mid-C 1937 (Critical Water) Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
Water Year 1937 (Critical Water)															
NAA	1,796	2,521	2,446	2,328	1,750	1,713	1,707	1,430	2,123	2,848	2,241	2,439	2,272	1,877	2,133
MO1	19	0	0	52	-39	0	0	0	-175	-85	-203	-218	-144	-164	-65
MO2	26	-17	0	-178	350	0	0	0	-43	-7	-96	-140	-86	-33	-12
MO3	19	-17	0	192	67	0	0	0	-214	-64	-201	-218	-144	-164	-47
MO4	-210	0	0	-101	-39	0	0	0	574	-85	-218	-775	-534	-22	-63
PA	67	0	0	-194	16	0	0	0	-22	-16	-102	-112	-116	-5	-32

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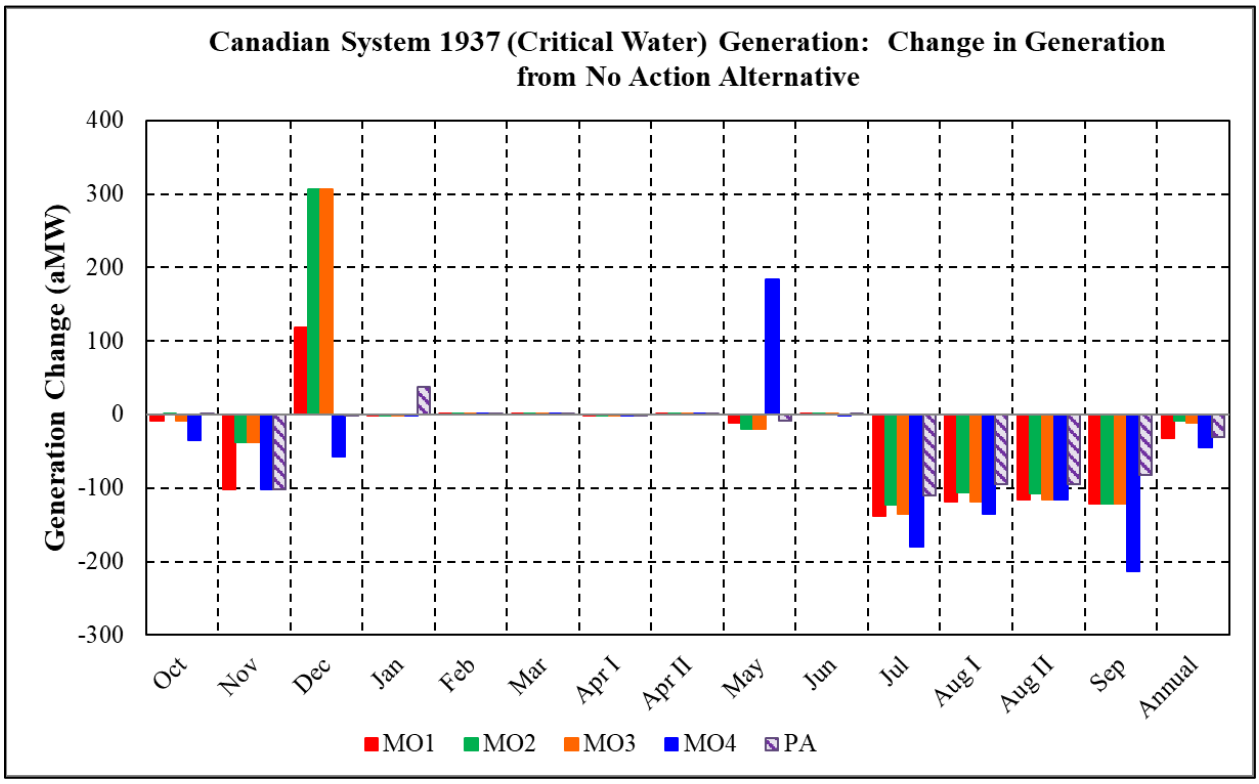
3738 # Canadian Critical Water (1937) Generation: Change from NAA



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Canadian System 1937 (Critical Water) Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
Water Year 1937 (Critical Water)															
NAA	2,076	3,528	3,644	2,813	2,479	2,212	1,597	1,633	3,334	3,932	2,939	3,432	4,537	3,254	2,989
MO1	2,067	3,425	3,761	2,813	2,479	2,212	1,597	1,633	3,323	3,933	2,802	3,314	4,422	3,132	2,957
MO2	2,076	3,489	3,951	2,813	2,479	2,212	1,597	1,633	3,314	3,933	2,816	3,326	4,430	3,132	2,981
MO3	2,067	3,489	3,951	2,813	2,479	2,212	1,597	1,633	3,314	3,933	2,804	3,314	4,422	3,132	2,978
MO4	2,041	3,425	3,586	2,813	2,479	2,212	1,597	1,633	3,517	3,930	2,760	3,296	4,422	3,041	2,945
PA	2,076	3,425	3,644	2,851	2,479	2,212	1,597	1,633	3,325	3,933	2,829	3,337	4,442	3,171	2,959

Canadian System 1937 (Critical Water) Generation: Change in Generation from No Action Alternative															
	October	November	December	January	February	March	April I	April II	May	June	July	August I	August II	September	Annual
Water Year 1937 (Critical Water)															
NAA	2,076	3,528	3,644	2,813	2,479	2,212	1,597	1,633	3,334	3,932	2,939	3,432	4,537	3,254	2,989
MO1	-9	-102	118	0	0	0	0	0	-11	1	-137	-118	-115	-122	-32
MO2	0	-38	307	0	0	0	0	0	-20	2	-123	-106	-107	-122	-8
MO3	-9	-38	307	0	0	0	0	0	-20	2	-135	-118	-115	-122	-11
MO4	-35	-102	-57	0	0	0	0	0	183	-1	-179	-136	-115	-213	-44
PA	0	-102	0	38	0	0	0	0	-9	1	-110	-95	-95	-82	-30

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Exhibit 7. Hydropower Generation Impacts of Snake River Dam Breaching

This exhibit examines the hydropower effects of breaching Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams as a single measure alternative.

Overview

Bonneville prepared the hydropower analyses because of the high-profile nature of this measure. Snake River dam breaching is included as one of several measures in MO3. The generation effects of dam breaching were difficult to distinguish from the total effects of the measures in MO3. This analysis assesses the loss of lower Snake River generation due to breaching as a single measure.

Methodology

Bonneville used the HYDSIM model to estimate the generation averages for the 14 periods in each of the 80 years study record for the NAA. Detailed inputs for the NAA study are in the *Hydroregulation Appendix* of the CRSO DEIS. Bonneville modified the NAA by simply treating the four lower Snake River dams as gauge points with no powerhouses. All other NAA input was unchanged.

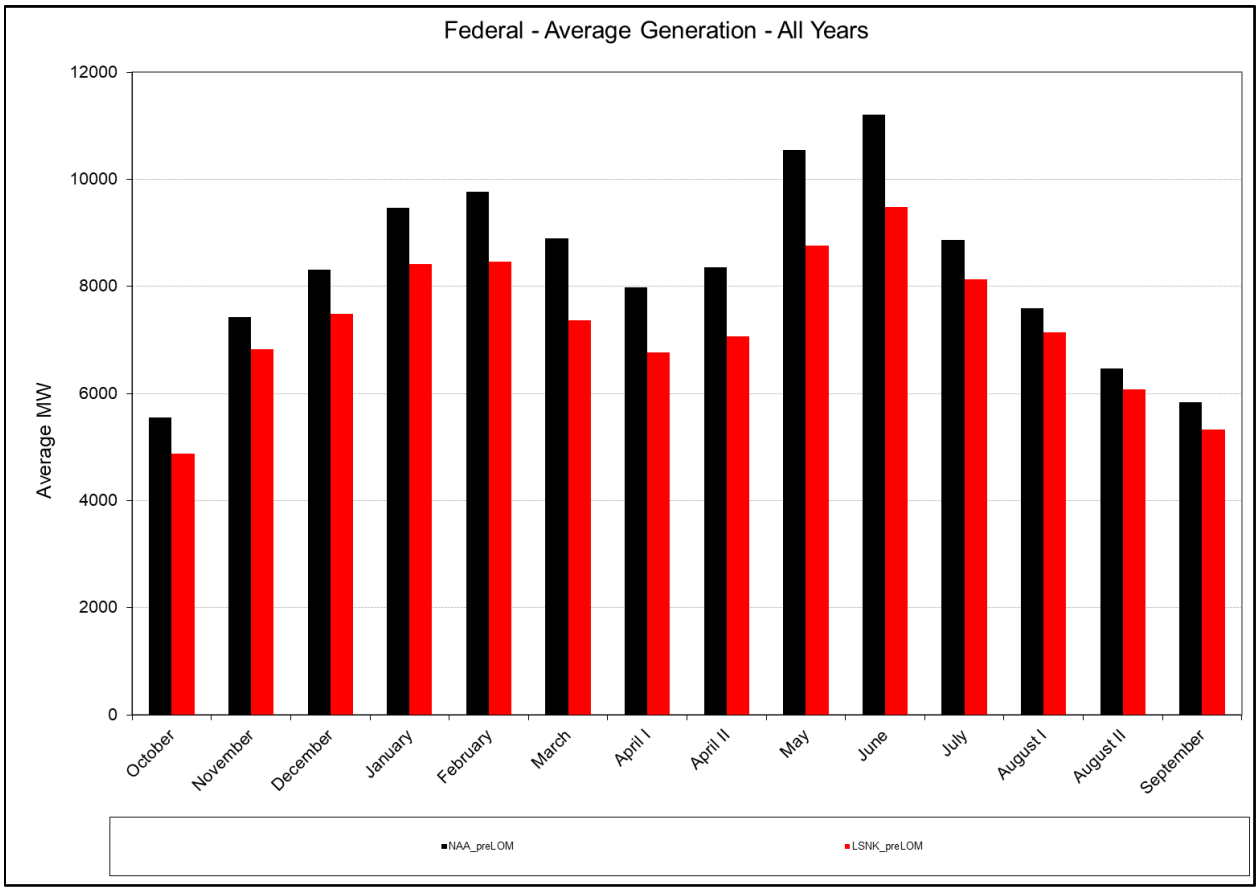
Results

Because the four Snake River dams are Federal dams operated by the Corps, results are provided only for the CRS (Federal) system average and critical water generation.

3762 # Average Generation

3763 Average CRS (Federal) system results and changes from the NAA are provided below.

3764 ## CRS (Federal) Average Generation: NAA without Lower Snake River Dam Generation



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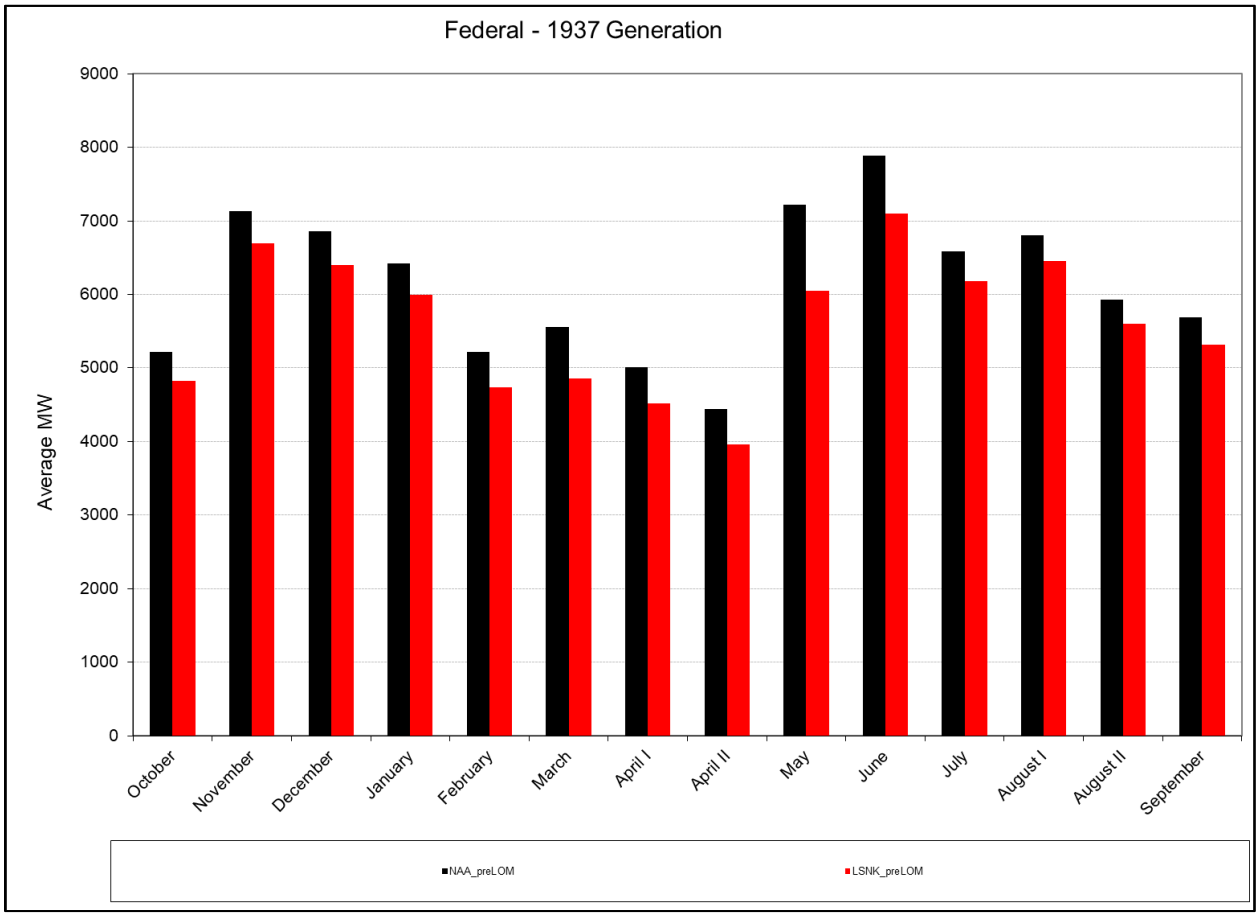
	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	5,549	7,422	8,306	9,465	9,763	8,889	7,978	8,356	10,542	11,207	8,871	7,585	6,459	5,844	8,411
Dam Br.	4,877	6,834	7,489	8,417	8,458	7,367	6,762	7,061	8,759	9,481	8,129	7,148	6,074	5,332	7,381
Change	-672	-588	-817	-1,048	-1,306	-1,522	-1,216	-1,294	-1,783	-1,726	-741	-436	-385	-512	-1,030
% Change	-12.1	-7.9	-9.8	-11.1	-13.4	-17.1	-15.2	-15.5	-16.9	-15.4	-8.4	-5.8	-6.0	-8.8	-12.2

3767

Critical Water (1937) Generation

Critical Water (1937) CRS (Federal) system results and changes from the NAA are provided below.

CRS (Federal) Critical Water (1937) Generation: NAA without Lower Snake River Dams



	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NAA	5,221	7,137	6,853	6,421	5,213	5,553	5,014	4,441	7,215	7,889	6,583	6,800	5,927	5,689	6,245
No Dams	4,826	6,695	6,402	5,994	4,735	4,854	4,523	3,962	6,044	7,097	6,178	6,458	5,603	5,316	5,706
Change	-396	-441	-450	-427	-478	-699	-491	-479	-1,170	-791	-405	-342	-324	-373	-538
% Change	-7.6%	-6.2%	-6.6%	-6.7%	-9.2%	-12.6%	-9.8%	-10.8%	-16.2%	-10.0%	-6.2%	-5.0%	-5.5%	-6.6%	-8.6%

Breaching of the four Snake River dams results in year-round generation losses that reflect Snake River seasonal flows. Generation losses are low in September through November because of generally lower natural streamflows. Losses are higher in January through March from higher natural flows and storage releases from upstream reservoirs. Losses remain relatively high April through June from spring runoff flows; losses would be higher, but generation is already reduced during these months for fish passage spills. Losses are relatively low in August due to low flows and already lower generation in the NAA for fish passage spills.

Exhibit 8. Generation Summaries for MO Alternatives

This exhibit provides summaries of the energy and peak generation metrics.

3784 **MO1 Generation Results Summary**

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NW-US System Average Generation: NAA vs. MO1															
NAA	9,364	12,205	13,519	15,115	15,299	13,724	12,643	13,469	16,462	17,504	14,173	11,770	10,229	9,215	13,373
MO1	9,280	12,188	13,277	15,343	15,315	13,607	12,326	12,911	15,956	17,358	13,915	11,025	9,813	9,306	13,200
Change	-83	-17	-242	228	16	-117	-317	-558	-506	-147	-258	-745	-416	92	-173
NW-US System P10 Generation: NAA vs. MO1															
NAA	8,530	10,662	10,904	10,866	10,228	9,713	8,736	7,814	12,570	13,017	9,557	9,599	8,635	8,307	10,144
MO1	8,438	10,715	10,983	10,915	10,085	9,573	8,260	7,637	11,286	12,426	9,274	8,687	8,385	8,222	9,865
Change	-92	53	79	49	-143	-140	-476	-177	-1,284	-591	-284	-912	-250	-85	-280
NW-US System Critical Water Generation: NAA vs. MO1															
NAA	8,766	11,079	11,224	10,754	8,690	9,034	8,707	7,841	11,424	13,914	11,117	10,539	9,405	9,221	10,297
MO1	8,794	10,962	11,323	10,931	8,560	8,984	8,671	7,876	10,034	13,056	10,252	9,366	8,576	8,732	9,912
Change	28	-117	99	177	-129	-50	-36	35	-1,390	-858	-864	-1,172	-829	-489	-385
CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA vs. MO1															
NAA	7,719	9,822	11,038	11,888	12,181	11,540	9,798	10,218	12,438	13,145	11,599	10,890	9,241	8,058	10,784
MO1	7,668	9,828	10,832	11,960	12,192	11,384	9,821	9,896	12,304	13,324	11,708	10,162	8,616	8,212	10,712
Change	-51	6	-206	73	11	-156	23	-322	-134	179	109	-728	-625	155	-72
CRS (Federal) HLH P10 Generation: NAA vs. MO1															
NAA	6,159	7,872	7,956	7,681	7,265	7,376	6,005	5,437	10,113	10,097	7,885	8,318	7,099	6,383	7,688
MO1	6,193	7,899	8,037	7,815	7,326	7,093	6,082	5,371	8,980	9,747	7,430	7,170	6,498	6,384	7,456
Change	34	27	81	135	61	-283	77	-66	-1,132	-350	-455	-1,148	-601	2	-232
CRS (Federal) HLH Critical Water Generation: NAA vs. MO1															
NAA	6,457	8,625	8,106	7,681	6,110	6,673	5,981	5,399	8,797	10,251	8,847	9,309	7,633	7,036	7,738
MO1	6,516	8,524	8,212	7,833	6,016	6,672	6,085	5,525	7,641	9,370	8,069	7,887	6,751	6,673	7,395
Change	59	-101	106	152	-94	-1	104	126	-1,156	-881	-778	-1,422	-882	-363	-343

3785

MO2 Generation Results Summary

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NW-US System Average Generation: NAA vs. MO2															
NAA	9,364	12,205	13,519	15,115	15,299	13,724	12,643	13,469	16,462	17,504	14,173	11,770	10,229	9,215	13,373
MO2	9,370	12,428	13,970	15,686	15,768	13,344	12,349	14,071	17,564	17,865	14,945	13,344	11,678	9,392	13,826
Change	6	222	450	572	468	-380	-294	602	1,102	361	772	1,574	1,449	177	453
NW-US System P10 Generation: NAA vs. MO2															
NAA	8,530	10,662	10,904	10,866	10,228	9,713	8,736	7,814	12,570	13,017	9,557	9,599	8,635	8,307	10,144
MO2	8,480	10,736	11,722	11,613	10,319	9,458	8,278	8,077	13,364	13,377	10,166	10,757	9,729	8,592	10,524
Change	-50	73	818	747	91	-255	-458	263	794	360	609	1,158	1,095	285	380
NW-US System Critical Water Generation: NAA vs. MO2															
NAA	8,766	11,079	11,224	10,754	8,690	9,034	8,707	7,841	11,424	13,914	11,117	10,539	9,405	9,221	10,297
MO2	8,856	10,973	11,470	10,168	9,900	9,051	8,601	8,459	12,451	14,908	11,449	11,661	10,270	8,997	10,645
Change	90	-105	245	-586	1,210	17	-106	618	1,027	994	332	1,122	866	-224	348
CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA vs. MO2															
NAA	7,719	9,822	11,038	11,888	12,181	11,540	9,798	10,218	12,438	13,145	11,599	10,890	9,241	8,058	10,784
MO2	7,794	10,246	11,330	12,192	12,394	11,214	10,085	11,053	13,673	14,025	12,605	12,051	10,456	8,281	11,293
Change	75	424	292	304	213	-327	287	835	1,235	880	1,006	1,162	1,215	224	509
CRS (Federal) HLH P10 Generation: NAA vs. MO2															
NAA	6,159	7,872	7,956	7,681	7,265	7,376	6,005	5,437	10,113	10,097	7,885	8,318	7,099	6,383	7,688
MO2	6,143	8,349	8,563	8,191	7,388	6,955	6,193	6,038	10,744	10,470	8,447	9,249	8,126	6,755	8,073
Change	-16	477	607	511	123	-421	188	601	631	374	562	931	1,027	372	385
CRS (Federal) HLH Critical Water Generation: NAA vs. MO2															
NAA	6,457	8,625	8,106	7,681	6,110	6,673	5,981	5,399	8,797	10,251	8,847	9,309	7,633	7,036	7,738
MO2	6,573	8,968	8,417	7,183	7,189	6,728	6,195	6,191	9,687	10,975	9,247	10,056	8,412	6,932	8,114
Change	116	343	311	-498	1,079	55	214	792	890	724	400	747	779	-104	376

MO3 Generation Results Summary

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NW-US System Average Generation: NAA vs. MO3															
NAA	9,364	12,205	13,519	15,115	15,299	13,724	12,643	13,469	16,462	17,504	14,173	11,770	10,229	9,215	13,373
MO3	8,718	11,971	13,139	13,872	13,819	12,273	10,754	10,980	13,676	15,473	13,022	12,448	10,945	8,410	12,236
Change	-646	-234	-380	-1,243	-1,481	-1,451	-1,889	-2,490	-2,786	-2,032	-1,151	678	716	-804	-1,137
NW-US System P10 Generation: NAA vs. MO3															
NAA	8,530	10,662	10,904	10,866	10,228	9,713	8,736	7,814	12,570	13,017	9,557	9,599	8,635	8,307	10,144
MO3	7,865	10,441	11,279	10,725	9,692	8,825	7,287	6,908	9,678	10,960	8,691	9,938	9,208	7,329	9,347
Change	-665	-221	374	-140	-536	-888	-1,449	-907	-2,892	-2,056	-867	339	573	-978	-798
NW-US System Critical Water Generation: NAA vs. MO3															
NAA	8,766	11,079	11,224	10,754	8,690	9,034	8,707	7,841	11,424	13,914	11,117	10,539	9,405	9,221	10,297
MO3	8,400	10,558	11,040	10,971	8,443	8,376	7,318	6,855	8,640	12,083	9,738	10,785	9,668	8,109	9,480
Change	-366	-520	-184	217	-247	-658	-1,388	-986	-2,784	-1,831	-1,378	246	263	-1,112	-817
CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA vs. MO3															
NAA	7,719	9,822	11,038	11,888	12,181	11,540	9,798	10,218	12,438	13,145	11,599	10,890	9,241	8,058	10,784
MO3	7,062	9,447	10,251	10,433	10,446	9,697	8,519	7,894	9,778	11,075	10,470	11,501	10,037	7,282	9,573
Change	-657	-375	-787	-1,455	-1,735	-1,843	-1,279	-2,324	-2,660	-2,071	-1,129	612	796	-776	-1,210
CRS (Federal) HLH P10 Generation: NAA vs. MO3															
NAA	6,159	7,872	7,956	7,681	7,265	7,376	6,005	5,437	10,113	10,097	7,885	8,318	7,099	6,383	7,688
MO3	5,506	7,525	7,871	7,265	6,486	6,285	5,338	4,419	7,600	8,183	6,805	8,831	7,790	5,393	6,847
Change	-654	-347	-85	-416	-779	-1,091	-667	-1,018	-2,513	-1,914	-1,080	513	690	-990	-841
CRS (Federal) HLH Critical Water Generation: NAA vs. MO3															
NAA	6,457	8,625	8,106	7,681	6,110	6,673	5,981	5,399	8,797	10,251	8,847	9,309	7,633	7,036	7,738
MO3	6,026	8,067	7,841	7,696	5,852	5,890	5,382	4,239	6,024	8,592	7,476	9,628	8,097	5,963	6,932
Change	-431	-558	-265	15	-258	-783	-599	-1,160	-2,773	-1,659	-1,371	319	464	-1,073	-805

MO4 Generation Results Summary

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NW-US System Average Generation: NAA vs. MO4															
NAA	9,364	12,205	13,519	15,115	15,299	13,724	12,643	13,469	16,462	17,504	14,173	11,770	10,229	9,215	13,373
MO4	8,906	12,122	13,117	15,358	15,250	10,175	9,705	10,918	13,669	15,042	12,339	10,077	8,893	8,906	12,034
Change	-457	-83	-402	244	-49	-3,549	-2,938	-2,552	-2,793	-2,462	-1,834	-1,693	-1,336	-308	-1,339
NW-US System P10 Generation: NAA vs. MO4															
NAA	8,530	10,662	10,904	10,866	10,228	9,713	8,736	7,814	12,570	13,017	9,557	9,599	8,635	8,307	10,144
MO4	7,700	10,643	10,921	10,864	10,085	7,435	7,185	7,151	11,420	11,385	8,792	7,829	7,322	7,912	9,319
Change	-830	-20	17	-2	-143	-2,278	-1,551	-663	-1,150	-1,632	-766	-1,770	-1,313	-395	-826
NW-US System Critical Water Generation: NAA vs. MO4															
NAA	8,766	11,079	11,224	10,754	8,690	9,034	8,707	7,841	11,424	13,914	11,117	10,539	9,405	9,221	10,297
MO4	7,894	10,882	11,176	10,385	8,558	7,407	7,560	7,188	10,823	11,472	9,370	7,770	7,429	8,833	9,317
Change	-873	-197	-48	-369	-131	-1,627	-1,147	-653	-601	-2,442	-1,747	-2,768	-1,976	-388	-980
CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA vs. MO4															
NAA	7,719	9,822	11,038	11,888	12,181	11,540	9,798	10,218	12,438	13,145	11,599	10,890	9,241	8,058	10,784
MO4	7,449	9,831	10,704	11,966	12,156	7,395	6,777	7,718	9,620	10,594	9,870	8,772	7,408	7,911	9,384
Change	-270	9	-334	78	-25	-4,146	-3,021	-2,500	-2,818	-2,551	-1,729	-2,118	-1,833	-147	-1,400
CRS (Federal) HLH P10 Generation: NAA vs. MO4															
NAA	6,159	7,872	7,956	7,681	7,265	7,376	6,005	5,437	10,113	10,097	7,885	8,318	7,099	6,383	7,688
MO4	5,582	7,899	7,787	7,646	7,324	4,421	4,309	4,640	7,998	7,691	6,376	6,166	5,731	6,120	6,600
Change	-577	27	-169	-35	59	-2,955	-1,696	-797	-2,115	-2,405	-1,509	-2,152	-1,368	-263	-1,088
CRS (Federal) HLH Critical Water Generation: NAA vs. MO4															
NAA	6,457	8,625	8,106	7,681	6,110	6,673	5,981	5,399	8,797	10,251	8,847	9,309	7,633	7,036	7,738
MO4	5,773	8,520	8,012	7,342	6,015	4,383	4,456	4,606	7,920	7,692	6,522	6,290	5,840	6,919	6,643
Change	-684	-105	-94	-339	-95	-2,290	-1,525	-793	-877	-2,559	-2,325	-3,019	-1,793	-117	-1,095

PA Generation Results Summary

	OCT	NOV	DEC	JAN	FEB	MAR	AP1	AP2	MAY	JUN	JUL	AG1	AG2	SEP	Annual
NW-US System Average Generation: NAA vs. PA															
NAA	9,364	12,205	13,519	15,115	15,299	13,724	12,643	13,469	16,462	17,504	14,173	11,770	10,229	9,215	13,373
PA	9,552	12,128	13,521	15,395	15,544	13,594	11,788	12,249	15,093	17,008	14,177	11,718	10,907	9,352	13,211
Change	189	-78	1	281	244	-130	-855	-1,221	-1,370	-496	4	-53	678	137	-162
NW-US System P10 Generation: NAA vs. PA															
NAA	8,530	10,662	10,904	10,866	10,228	9,713	8,736	7,814	12,570	13,017	9,557	9,599	8,635	8,307	10,144
PA	8,668	10,670	10,844	11,081	10,057	9,887	8,042	7,682	10,977	12,335	9,536	9,295	9,025	8,546	9,969
Change	138	8	-60	215	-171	174	-694	-132	-1,593	-682	-21	-305	390	239	-176
NW-US System Critical Water Generation: NAA vs. PA															
NAA	8,766	11,079	11,224	10,754	8,690	9,034	8,707	7,841	11,424	13,914	11,117	10,539	9,405	9,221	10,297
PA	9,021	10,977	11,232	10,132	8,782	9,080	8,196	7,362	9,828	12,897	10,639	10,201	9,459	9,051	9,943
Change	254	-102	8	-622	93	46	-510	-479	-1,596	-1,017	-477	-338	55	-171	-354
CRS (Federal) Peak-Load-Period (120 Hour) Generation: NAA vs. PA															
NAA	7,719	9,822	11,038	11,888	12,181	11,540	9,798	10,218	12,438	13,145	11,599	10,890	9,241	8,058	10,784
PA	7,907	9,940	10,947	12,074	12,230	11,333	9,630	9,241	11,226	12,647	11,662	10,659	9,779	8,292	10,651
Change	188	118	-92	186	49	-208	-168	-977	-1,213	-498	63	-230	538	234	-132
CRS (Federal) HLH P10 Generation: NAA vs. PA															
NAA	6,159	7,872	7,956	7,681	7,265	7,376	6,005	5,437	10,113	10,097	7,885	8,318	7,099	6,383	7,688
PA	6,244	8,100	7,907	8,050	7,120	7,371	5,980	5,098	8,576	9,386	7,684	7,909	7,496	6,753	7,540
Change	85	229	-49	369	-145	-5	-25	-339	-1,537	-711	-201	-409	397	370	-148
CRS (Federal) HLH Critical Water Generation: NAA vs.PA															
NAA	6,457	8,625	8,106	7,681	6,110	6,673	5,981	5,399	8,797	10,251	8,847	9,309	7,633	7,036	7,738
PA	6,652	8,960	8,047	7,099	6,146	6,673	5,969	5,019	7,700	9,399	8,336	8,721	7,714	6,981	7,482
Change	195	335	-59	-582	36	0	-12	-380	-1,097	-852	-511	-588	81	-55	-255

Exhibit 9. Average Annual Generation for Revenue Determination

This exhibit provides 80 years of monthly generation used for estimating Bonneville's hydropower sales revenue and supplements the information in Section 3.5. A summary of 1937 generation that was used to determine Bonneville's FELCC is also provided in the attached tables.

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3801 **Summary of 1937 Generation Used to Determine Bonneville's FELCC**

CRSO Alternative	WY	OCT	NOV	DEC	JAN	FEB	MAR	15-Apr	30-Apr	MAY	JUNE	JULY	15-Aug	31-Aug	SEP	AVG.
NAA	1937	5,221	7,137	6,853	6,421	5,213	5,553	5,013	4,441	7,187	7,857	6,585	6,740	5,927	5,688	6,237
MO1	1937	5,247	7,020	6,952	6,546	5,123	5,502	4,977	4,476	5,972	7,084	6,024	5,888	5,341	5,416	5,940
MO2	1937	5,285	7,048	7,098	6,013	6,073	5,569	4,907	5,059	8,257	8,857	7,092	8,081	6,961	5,550	6,615
MO3	1937	4,853	6,633	6,669	6,446	4,899	4,845	3,688	3,485	4,460	6,084	5,600	7,395	6,460	4,799	5,489
MO4	1937	4,614	6,940	6,788	6,154	5,121	3,925	3,866	3,788	5,935	5,500	5,198	4,791	4,570	5,500	5,349
PA	1937	5,409	7,035	6860	5993	5290	5599	4502	3962	5613	6856	6288	6593	6180	5576	5933

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3803 **NAA: Average Annual Generation for Bonneville Revenue Determination**

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	15-Apr	30-Apr	MAY	JUNE	JULY	15-Aug	31-Aug	SEP	AVG.
1929	5,053	6,729	6,790	6,911	6,903	6,258	5,018	4,476	6,441	9,073	5,534	6,477	5,844	5,606	6,343
1930	5,280	6,966	6,363	6,013	6,463	5,939	5,481	5,580	6,394	7,802	6,971	7,239	6,356	6,071	6,378
1931	5,334	6,831	6,872	5,846	5,724	6,158	5,716	4,334	6,568	7,071	6,649	7,135	6,086	5,517	6,187
1932	4,970	6,495	6,640	6,276	4,840	8,647	9,361	10,862	11,873	12,199	7,960	6,869	6,592	5,969	7,731
1933	5,371	6,425	8,611	10,249	11,120	9,420	7,131	6,764	10,102	13,008	11,509	9,338	7,983	5,926	8,936
1934	6,055	9,980	12,467	13,098	13,146	10,889	11,627	11,033	10,744	10,106	5,750	6,280	5,860	5,301	9,552
1935	5,303	5,900	7,650	9,538	10,640	8,058	6,206	7,435	9,710	9,244	8,642	8,893	6,020	5,334	7,843
1936	5,163	6,745	6,785	6,087	6,130	6,464	6,121	9,056	12,742	11,105	7,476	6,359	5,724	5,200	7,295
1937	5,221	7,137	6,853	6,421	5,213	5,553	5,013	4,441	7,187	7,857	6,585	6,740	5,927	5,688	6,237
1938	5,271	6,575	7,816	9,651	9,633	9,063	9,195	11,259	11,101	10,626	8,787	5,811	5,363	5,739	8,329
1939	5,424	6,495	6,479	7,893	8,412	6,795	6,538	8,425	10,216	7,215	6,961	6,212	5,791	5,373	7,055
1940	5,412	7,292	7,206	8,188	6,210	8,601	8,495	9,493	9,932	8,027	5,976	6,333	5,596	5,537	7,281
1941	5,426	7,656	7,821	7,221	6,943	7,228	5,463	4,252	7,015	8,301	6,368	6,864	5,872	5,716	6,741
1942	5,352	7,474	9,132	9,756	8,745	6,321	6,061	7,145	8,622	11,692	9,463	7,538	6,924	6,157	8,040
1943	5,452	6,239	7,198	10,286	10,958	9,561	11,826	11,780	11,032	12,687	11,686	7,635	6,457	5,565	9,110
1944	5,020	6,706	6,546	6,711	7,368	5,850	4,816	3,972	5,672	7,354	5,607	6,784	5,632	5,443	6,066
1945	5,225	6,826	6,882	6,084	5,704	5,854	4,964	4,042	9,110	11,152	6,205	6,502	5,759	5,462	6,597
1946	5,065	6,871	7,876	9,275	8,843	9,802	10,216	11,345	11,493	10,819	9,496	7,575	6,478	5,874	8,598
1947	5,058	7,255	10,882	11,599	11,853	10,322	7,998	8,239	11,629	11,025	9,347	7,233	5,927	5,866	9,115
1948	7,821	8,867	9,377	11,448	11,726	8,285	7,239	10,767	12,988	12,884	9,176	9,139	7,838	6,279	9,687
1949	5,641	7,034	7,093	9,127	8,482	10,134	8,075	11,257	12,531	10,044	6,384	6,027	5,156	5,213	8,075
1950	5,007	6,571	7,989	11,100	11,250	10,859	10,652	9,863	10,564	12,764	12,387	8,595	7,727	6,057	9,403
1951	6,266	9,186	10,993	12,736	13,597	12,142	11,416	10,578	11,287	10,555	9,784	8,611	6,530	5,868	10,060
1952	7,283	8,048	9,382	10,910	11,032	8,768	10,061	11,901	12,916	10,907	9,325	7,817	5,823	5,183	9,290
1953	5,030	7,025	6,718	7,558	11,849	7,627	5,119	5,469	10,253	13,288	10,870	7,023	6,760	5,956	8,170
1954	5,410	7,337	8,617	10,778	11,738	9,560	7,973	8,767	11,213	12,282	12,211	10,320	10,059	7,898	9,623
1955	5,741	8,253	8,693	7,621	8,017	5,625	6,356	5,394	9,291	13,077	12,223	9,097	7,433	5,779	8,204
1956	5,682	8,712	10,926	13,142	12,992	11,309	11,039	11,755	12,325	13,193	10,346	7,906	6,655	5,913	10,257

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	15-Apr	30-Apr	MAY	JUNE	JULY	15-Aug	31-Aug	SEP	AVG.
1957	5,735	6,966	8,712	9,525	8,256	9,118	8,791	8,374	13,051	13,692	7,332	6,298	5,500	5,547	8,534
1958	5,183	6,841	7,191	9,693	9,959	8,185	7,182	9,537	13,224	12,452	7,517	6,398	5,883	5,626	8,351
1959	5,297	8,051	10,349	12,629	13,013	9,527	9,263	8,661	10,421	12,778	11,833	8,717	7,061	8,682	9,929
1960	9,048	10,070	10,319	10,591	10,178	8,578	10,509	10,315	9,866	11,333	9,040	8,195	5,856	5,644	9,334
1961	5,425	7,366	7,953	10,085	10,525	10,651	8,328	7,890	11,066	12,616	7,483	6,731	6,136	5,537	8,590
1962	4,931	6,830	7,778	8,889	11,062	6,736	8,666	10,604	10,511	11,264	7,596	7,843	6,622	5,614	8,146
1963	5,841	8,237	9,959	9,910	10,813	7,244	6,247	5,578	9,910	10,982	8,795	8,054	6,291	6,188	8,398
1964	5,235	6,762	7,906	7,835	9,407	6,227	8,030	6,685	10,676	13,334	12,062	9,300	6,995	6,790	8,469
1965	6,393	7,892	11,120	13,589	14,460	11,897	7,560	10,550	11,640	12,725	9,348	9,340	7,945	5,797	10,191
1966	5,784	6,864	8,224	9,004	10,478	7,263	8,007	7,905	8,825	9,927	8,645	7,728	5,994	5,640	7,937
1967	5,126	6,616	8,700	11,050	12,475	9,684	7,818	6,721	10,359	12,682	10,923	8,287	6,420	6,125	9,009
1968	5,559	7,581	8,303	9,904	10,722	10,218	5,383	4,835	9,375	11,444	9,335	8,606	7,223	7,359	8,562
1969	6,584	8,873	9,405	12,456	13,097	11,110	10,183	10,803	12,497	11,586	8,809	6,783	5,600	5,743	9,714
1970	5,410	7,152	7,302	9,255	11,039	7,411	5,713	5,480	10,624	12,730	6,799	6,810	5,839	5,377	7,894
1971	5,190	6,796	7,898	12,990	14,156	12,193	10,747	10,547	12,550	13,361	11,480	9,310	6,895	6,137	10,098
1972	5,734	7,159	8,535	11,997	13,011	13,337	11,124	9,552	12,050	12,819	11,540	9,717	8,704	6,373	10,169
1973	5,781	7,303	8,061	8,545	8,808	6,606	5,043	3,964	8,125	8,379	6,198	6,911	5,591	5,539	6,998
1974	5,176	6,620	9,133	13,879	13,794	13,205	11,449	11,669	11,590	12,735	12,389	9,301	8,269	6,063	10,394
1975	5,062	6,688	7,295	9,222	9,944	9,790	6,638	7,607	10,376	12,864	12,480	8,225	7,410	6,486	8,757
1976	6,576	9,164	12,055	12,281	12,849	10,598	10,774	10,715	12,448	11,474	11,617	11,044	11,099	8,297	10,763
1977	5,990	6,768	6,914	7,183	7,688	5,762	4,221	3,641	6,351	6,707	5,625	6,787	5,860	4,932	6,174
1978	4,650	6,611	8,541	9,320	7,902	9,356	9,952	8,695	10,580	10,530	10,482	6,847	5,936	6,985	8,392
1979	6,049	7,228	6,961	8,575	7,105	7,791	7,048	7,482	10,679	8,363	5,958	6,320	5,447	5,575	7,288
1980	5,312	6,775	6,423	8,584	8,046	6,609	5,154	7,699	12,781	12,099	7,395	5,983	5,582	5,800	7,666
1981	5,333	7,112	10,032	11,375	12,156	7,492	5,041	5,282	10,527	13,386	10,570	9,594	8,122	6,133	8,995
1982	5,301	7,642	8,313	10,595	13,372	13,503	10,095	9,061	11,741	12,867	12,619	9,344	7,707	7,161	10,081
1983	6,496	7,647	8,972	11,119	10,845	12,257	8,743	8,373	10,652	11,542	11,802	9,268	7,378	6,326	9,543
1984	5,622	9,464	9,200	11,001	10,744	10,458	9,040	10,717	10,584	12,491	11,315	8,600	6,669	6,338	9,552
1985	5,632	7,498	8,144	9,424	9,113	7,456	8,441	9,202	10,364	7,958	5,781	5,835	5,156	5,510	7,588

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	15-Apr	30-Apr	MAY	JUNE	JULY	15-Aug	31-Aug	SEP	AVG.
1986	5,826	8,230	8,459	9,987	11,683	12,681	10,025	9,664	10,454	11,303	7,649	7,108	5,770	5,479	8,982
1987	5,036	7,211	8,305	8,228	6,903	7,787	6,145	7,302	10,204	8,486	5,499	6,300	5,446	5,339	7,136
1988	5,128	6,739	6,417	6,025	5,453	5,614	5,199	6,123	8,531	7,994	7,086	6,804	5,997	5,583	6,389
1989	5,070	6,891	7,679	6,763	5,832	8,017	8,432	10,179	10,411	8,341	6,692	6,638	5,740	5,407	7,224
1990	5,282	7,671	8,846	9,471	11,794	9,213	7,362	10,391	9,034	11,679	9,783	8,620	6,760	5,453	8,708
1991	5,022	9,422	9,691	10,798	12,509	9,245	8,672	8,011	10,346	11,018	11,413	9,496	7,722	5,405	9,298
1992	5,259	6,908	6,269	7,591	7,057	7,280	5,762	5,570	9,110	7,520	5,651	6,455	5,784	5,372	6,650
1993	5,254	7,010	6,984	6,437	5,291	6,955	6,689	5,633	10,646	9,672	7,428	6,716	5,968	5,500	6,985
1994	5,259	7,182	7,088	6,454	7,177	6,209	4,999	7,328	8,438	7,743	6,708	6,549	5,705	5,604	6,674
1995	5,202	6,454	7,241	7,600	8,065	9,512	7,048	6,779	9,960	12,098	8,591	7,151	6,161	6,101	7,863
1996	6,369	10,243	13,435	13,523	14,111	13,197	10,545	11,537	11,396	12,927	11,616	9,108	6,522	5,966	10,959
1997	5,352	7,373	9,326	14,166	14,346	13,458	11,257	11,749	12,333	13,127	11,784	9,183	7,521	7,076	10,661
1998	8,259	8,554	8,124	8,804	10,643	7,954	5,973	6,676	12,664	13,120	9,296	8,046	5,540	5,464	8,820
1999	5,116	6,405	9,066	12,252	11,463	13,474	9,711	10,767	9,842	11,824	11,604	10,533	9,531	5,748	9,753
2000	5,084	9,389	9,936	10,158	9,841	9,332	9,780	10,989	10,173	8,793	8,345	8,020	5,558	5,464	8,632
2001	5,252	6,741	6,830	7,066	7,464	6,133	4,766	3,974	6,521	6,421	5,914	6,827	5,668	4,957	6,153
2002	4,491	6,630	7,148	6,654	6,339	7,391	7,921	10,066	10,072	12,511	10,395	6,251	5,584	5,379	7,662
2003	5,347	7,056	6,743	6,839	6,255	8,589	7,750	8,877	9,652	11,264	6,556	5,973	5,423	5,037	7,280
2004	5,272	7,732	8,188	7,843	7,326	7,062	6,815	7,123	8,680	9,482	6,431	5,857	6,065	5,861	7,231
2005	5,936	7,248	8,838	8,823	9,065	7,407	6,432	5,526	9,788	8,820	7,251	6,636	5,752	5,242	7,544
2006	5,031	7,486	8,122	10,111	12,333	8,591	10,938	11,120	12,445	12,452	7,678	5,982	5,229	4,916	8,785
2007	4,814	7,429	8,179	10,272	8,851	10,900	8,863	8,632	9,862	9,268	8,078	6,465	5,356	4,711	8,083
2008	5,373	7,395	6,852	8,361	8,030	8,142	5,922	5,753	10,940	13,225	9,767	6,104	6,270	5,578	7,974
Average	5,548	7,420	8,302	9,453	9,726	8,819	7,842	8,220	10,324	10,895	8,796	7,592	6,455	5,843	8,340

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3805 **MO1: Average Annual Generation for Bonneville Revenue Determination**

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1929	5,065	6,708	6,697	6,886	7,115	5,876	4,999	4,550	5,016	8,608	5,446	5,885	5,595	5,555	6,112
1930	5,363	6,946	6,477	6,390	6,460	5,881	4,631	4,764	5,679	7,477	6,442	6,305	5,850	5,716	6,130
1931	5,399	7,055	7,201	6,374	5,617	6,073	5,825	4,341	5,217	5,997	6,593	6,693	5,920	5,816	6,064
1932	5,014	6,474	6,519	6,328	4,966	8,514	9,058	10,078	11,936	12,174	7,698	6,233	6,188	6,086	7,628
1933	5,241	6,609	8,048	10,306	11,085	9,666	7,336	6,773	9,342	13,213	11,672	8,800	7,339	6,280	8,868
1934	5,774	9,321	12,303	13,067	12,877	10,722	11,609	11,108	11,036	10,123	5,550	5,457	5,549	5,308	9,388
1935	5,344	5,877	7,085	9,617	10,823	7,799	6,053	7,127	9,121	8,732	8,651	7,728	5,710	5,443	7,632
1936	5,134	6,709	6,799	6,299	6,119	6,401	5,284	7,102	12,420	11,098	7,240	5,886	5,592	5,400	7,132
1937	5,247	7,020	6,952	6,546	5,123	5,502	4,977	4,476	5,972	7,084	6,024	5,888	5,341	5,416	5,940
1938	5,268	7,136	7,384	10,119	9,397	9,188	8,503	10,555	11,264	10,830	8,613	5,271	5,186	5,967	8,318
1939	5,279	6,472	6,468	7,918	8,499	6,708	6,116	7,791	9,080	6,934	6,830	5,912	5,669	5,589	6,867
1940	5,437	6,980	7,478	8,156	6,640	8,068	7,748	8,184	9,123	8,175	5,635	5,594	5,412	5,700	7,072
1941	5,242	7,625	8,178	6,998	6,259	6,249	6,304	4,441	6,787	6,893	6,420	6,526	5,972	6,333	6,552
1942	5,133	7,271	8,847	10,334	8,225	5,927	4,993	6,605	8,023	11,805	9,360	6,251	6,330	6,028	7,750
1943	5,389	6,527	7,064	10,595	11,283	9,430	11,643	11,925	10,614	12,667	11,580	6,903	6,083	5,576	9,064
1944	5,058	6,697	6,719	7,254	7,550	5,260	4,044	3,540	4,621	6,677	5,641	6,424	5,703	5,824	5,922
1945	5,176	6,795	7,088	6,089	5,713	5,809	4,992	3,905	7,926	10,853	5,968	5,921	5,564	5,515	6,427
1946	5,107	6,637	7,408	9,433	9,577	9,305	9,422	11,146	11,985	10,922	9,225	6,799	6,126	5,941	8,515
1947	4,950	7,489	10,439	11,792	12,090	10,328	7,937	8,139	11,441	10,564	9,242	6,445	5,532	6,012	9,016
1948	7,799	8,844	8,837	11,764	11,526	8,482	6,805	9,467	13,389	13,363	8,833	8,272	7,257	6,486	9,594
1949	5,438	7,323	7,221	9,068	8,505	10,350	8,277	11,646	12,472	9,191	5,903	5,150	4,868	5,249	7,970
1950	5,064	6,551	7,523	11,115	11,211	11,144	10,067	9,120	10,081	13,124	13,017	8,143	7,012	6,422	9,357
1951	6,056	9,141	10,672	12,647	13,584	12,115	11,828	11,196	11,569	10,074	9,513	7,744	6,117	5,831	9,948
1952	7,444	8,018	8,840	11,270	11,373	8,877	9,344	11,422	13,158	11,037	9,175	6,883	5,567	5,214	9,244
1953	5,106	6,973	6,827	7,838	11,554	7,692	5,212	5,242	9,348	13,531	10,743	6,287	6,362	6,082	8,077
1954	5,365	7,306	8,187	10,927	11,323	10,080	6,885	7,632	11,503	12,809	12,747	9,431	9,485	8,276	9,597
1955	5,641	8,370	8,143	8,335	8,049	5,384	6,155	5,670	8,216	13,385	12,646	8,936	6,384	6,177	8,154
1956	5,624	8,690	10,469	13,109	12,724	11,304	10,922	12,147	12,764	13,667	10,066	7,143	6,248	6,012	10,209

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1957	5,588	7,134	8,339	9,240	8,107	8,784	10,661	8,930	13,372	13,941	7,080	5,725	5,276	5,631	8,539
1958	5,213	6,810	6,985	9,903	10,241	8,291	6,291	7,910	12,991	12,695	7,147	5,827	5,702	5,704	8,222
1959	5,317	7,992	9,896	12,754	12,800	9,879	8,972	8,909	10,016	13,102	11,740	7,867	6,557	8,923	9,857
1960	8,870	10,057	10,030	10,925	10,204	8,493	10,346	9,093	9,517	11,518	9,009	7,075	5,581	5,847	9,201
1961	5,366	7,232	7,519	10,344	9,671	10,834	9,930	7,604	10,706	13,030	7,212	6,058	5,784	5,447	8,493
1962	5,027	6,958	7,344	9,141	11,185	6,652	7,986	9,463	10,199	11,493	7,410	7,117	6,255	5,617	8,008
1963	5,903	8,208	9,432	10,118	11,019	7,159	6,397	5,660	8,679	10,890	8,846	7,209	5,912	6,448	8,254
1964	5,075	6,732	7,472	8,655	9,112	6,180	7,015	5,216	10,268	13,794	12,078	8,524	6,604	7,229	8,348
1965	6,203	7,862	10,662	13,612	14,392	11,856	7,842	10,495	11,416	12,745	9,233	8,671	7,602	6,182	10,098
1966	5,650	6,546	7,851	9,591	10,096	7,179	7,089	6,248	8,418	10,093	8,358	7,091	5,700	5,607	7,688
1967	5,151	6,688	8,327	11,125	12,333	10,212	7,779	6,629	9,437	12,987	10,800	7,570	6,210	6,014	8,908
1968	5,460	7,710	7,870	10,149	10,924	10,354	4,529	4,225	8,495	11,578	8,924	7,841	7,044	7,680	8,405
1969	6,364	8,770	8,949	12,658	12,923	11,372	10,521	11,437	12,785	11,580	8,344	6,131	5,388	5,543	9,646
1970	5,480	7,395	7,660	9,629	10,610	7,325	4,790	4,408	9,762	12,791	6,788	6,359	5,730	5,639	7,789
1971	5,236	6,657	7,180	12,942	14,228	11,862	10,936	11,180	12,888	13,569	11,266	8,463	6,437	6,231	10,017
1972	5,634	7,448	8,103	11,826	13,330	13,130	11,342	8,847	12,376	13,158	11,299	8,989	8,035	6,774	10,130
1973	5,907	7,272	8,418	9,002	8,700	6,333	4,443	3,932	6,887	7,489	5,669	6,052	5,167	5,167	6,710
1974	5,251	7,201	8,711	13,795	13,691	12,944	11,439	11,827	11,983	13,222	12,934	8,969	7,149	6,730	10,493
1975	4,946	6,783	7,780	9,241	10,105	9,643	6,558	7,640	9,594	12,931	12,336	7,421	6,956	7,006	8,712
1976	6,380	9,015	11,768	12,715	12,702	10,784	10,195	10,013	12,623	11,539	11,601	10,496	11,038	8,865	10,738
1977	5,676	6,615	7,001	7,634	7,840	5,076	4,173	3,696	4,854	5,216	5,547	6,636	5,962	5,311	5,907
1978	4,724	6,546	8,837	9,112	7,888	9,226	8,531	7,591	10,851	10,468	10,312	6,231	5,695	7,330	8,281
1979	5,819	7,197	7,320	8,368	7,856	7,001	6,572	6,505	10,713	7,718	5,761	5,708	5,290	5,660	7,118
1980	5,333	6,681	6,606	8,632	7,730	6,627	4,354	6,659	12,965	12,279	7,097	5,401	5,279	5,741	7,544
1981	5,295	7,082	10,095	11,357	11,631	7,406	5,125	5,506	9,535	13,666	10,336	9,106	7,388	6,331	8,841
1982	5,251	7,612	8,471	10,711	13,161	13,407	9,229	8,095	11,915	12,967	12,751	9,050	6,833	7,632	10,021
1983	6,276	7,616	8,891	11,345	10,957	12,604	8,676	8,384	9,816	11,197	11,720	8,775	6,523	6,593	9,428
1984	5,434	9,448	8,771	11,062	10,833	10,421	8,406	9,863	9,842	12,849	11,340	7,968	6,395	6,734	9,410
1985	5,417	7,468	7,711	10,022	8,613	6,879	8,930	8,858	9,873	7,671	5,630	5,056	4,978	5,677	7,396

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1986	5,731	8,071	8,027	9,756	11,486	13,195	9,988	9,143	9,900	11,792	7,052	6,446	5,602	5,515	8,821
1987	5,040	7,180	7,872	8,424	7,539	7,345	6,273	7,504	9,608	7,570	5,101	5,464	4,995	5,001	6,897
1988	5,052	7,020	7,016	6,026	5,956	5,980	4,327	5,145	6,811	7,808	6,671	6,167	5,609	5,406	6,198
1989	5,101	7,116	7,353	6,962	6,052	7,990	9,007	10,503	9,795	7,519	6,363	5,704	5,489	5,337	7,083
1990	5,207	7,534	8,460	10,174	11,482	9,191	6,500	9,126	8,634	11,987	9,423	7,926	6,381	5,621	8,534
1991	4,977	9,264	9,334	10,898	12,486	9,458	8,929	7,927	9,785	10,739	11,374	8,984	7,068	5,761	9,188
1992	5,046	6,779	6,367	7,705	7,794	6,829	4,992	4,487	7,775	7,157	5,502	5,873	5,451	5,357	6,388
1993	5,130	6,980	7,344	6,438	5,297	6,822	6,559	5,307	10,105	9,092	7,255	6,480	5,980	5,973	6,895
1994	5,252	6,969	7,169	6,371	7,064	6,149	4,081	6,342	7,726	7,312	6,130	5,964	5,374	5,440	6,367
1995	5,283	6,925	6,826	7,990	8,521	9,565	7,166	5,953	9,157	12,148	8,479	6,010	5,980	6,266	7,802
1996	5,905	10,142	13,331	13,485	14,250	12,893	9,431	11,810	11,425	12,986	11,637	8,467	6,254	5,915	10,817
1997	5,260	7,064	8,909	14,130	14,205	13,060	11,910	12,120	12,761	13,512	11,850	8,803	6,851	7,576	10,656
1998	8,057	8,177	8,481	9,038	10,495	7,867	4,980	5,338	11,960	13,334	9,282	7,599	5,633	5,809	8,678
1999	5,091	6,264	8,354	12,224	11,671	13,235	9,954	11,303	9,362	11,692	11,625	9,895	9,391	6,202	9,659
2000	4,902	8,965	9,521	10,420	10,085	9,401	9,062	10,889	10,318	8,253	7,874	7,377	5,302	5,290	8,437
2001	5,270	6,686	7,190	7,518	7,427	5,627	4,780	4,050	4,834	5,293	5,851	6,323	5,552	5,167	5,927
2002	4,575	6,645	6,877	6,855	6,679	7,332	7,257	9,110	9,346	12,979	10,154	5,671	5,299	5,457	7,546
2003	5,398	7,069	7,051	7,065	6,650	8,151	7,978	8,650	8,649	10,787	6,041	5,399	5,229	5,059	7,125
2004	5,351	7,701	7,755	7,979	7,613	6,978	5,712	5,801	7,924	9,490	6,216	5,251	5,655	6,058	7,018
2005	5,729	7,577	8,965	9,618	9,017	6,940	6,193	5,415	8,454	8,200	7,032	6,104	5,450	5,130	7,346
2006	5,122	7,604	7,690	10,827	12,037	8,568	10,621	10,315	12,481	12,769	7,418	5,411	5,024	4,913	8,730
2007	4,905	7,399	7,673	10,453	9,281	10,753	8,759	8,173	9,187	8,888	7,736	5,729	5,136	4,608	7,892
2008	5,463	7,408	7,211	8,329	8,248	7,972	4,868	4,218	10,757	13,527	9,366	5,505	5,891	5,794	7,858
Average	5,491	7,410	8,133	9,636	9,741	8,717	7,567	7,794	9,858	10,800	8,631	6,936	6,113	5,990	8,208

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3807 **MO2: Average Annual Generation for Bonneville Revenue Determination**

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1929	5,315	6,803	6,854	7,413	7,310	5,990	4,923	4,986	7,140	9,776	6,014	8,084	7,167	5,987	6,758
1930	5,224	7,042	6,634	6,311	6,339	5,983	6,073	6,687	8,400	8,300	7,123	8,343	7,287	5,831	6,783
1931	5,298	7,253	7,758	6,016	6,021	6,176	5,852	4,799	7,819	7,094	7,134	8,526	7,156	5,707	6,626
1932	5,056	6,568	6,672	6,187	5,948	8,747	9,677	11,267	13,263	12,376	9,048	8,615	8,229	5,924	8,229
1933	5,474	6,818	8,733	11,174	10,971	8,118	6,489	8,066	11,104	13,454	12,305	11,190	9,804	6,014	9,323
1934	6,017	9,760	12,515	12,920	12,820	11,286	12,120	12,551	11,930	10,653	6,266	7,370	7,094	5,542	9,920
1935	5,253	5,865	7,552	10,814	11,157	7,195	4,110	7,540	11,176	9,885	10,011	10,292	7,500	5,530	8,252
1936	5,363	6,734	7,042	6,794	6,668	7,108	5,740	8,999	13,821	10,778	8,224	7,943	7,111	5,508	7,751
1937	5,285	7,048	7,098	6,013	6,073	5,569	4,907	5,059	8,257	8,857	7,092	8,081	6,961	5,550	6,615
1938	5,402	6,342	7,940	10,316	10,125	9,053	7,526	12,854	12,556	11,423	9,993	7,405	6,679	5,918	8,851
1939	5,490	6,459	7,285	8,995	8,822	6,585	5,935	7,487	11,224	7,079	7,902	8,095	7,329	5,834	7,507
1940	5,327	7,203	8,120	7,772	7,366	9,365	8,151	9,233	11,469	8,805	6,291	7,309	6,707	5,576	7,753
1941	5,384	7,258	8,731	7,569	5,847	6,643	6,161	4,519	8,960	8,650	7,248	8,627	7,432	5,860	7,139
1942	5,411	7,644	9,367	10,188	9,253	5,853	6,050	7,711	9,873	12,148	10,663	8,930	8,342	6,042	8,493
1943	5,480	6,840	7,621	11,417	11,711	7,648	11,339	13,357	12,433	12,683	12,345	9,614	8,238	5,595	9,570
1944	5,063	6,795	7,332	7,601	7,532	5,202	4,863	4,391	6,133	7,945	6,343	8,439	6,993	5,672	6,492
1945	5,288	6,805	7,652	6,296	5,004	6,045	5,011	4,819	10,732	11,960	6,871	8,075	7,090	5,536	7,070
1946	5,106	6,606	7,998	9,750	9,544	9,026	9,411	13,220	12,744	11,455	10,478	9,288	7,897	5,909	9,040
1947	5,137	7,734	10,991	11,543	12,501	9,373	8,032	10,022	13,032	11,422	10,294	8,463	7,274	5,893	9,554
1948	7,887	9,232	9,482	11,696	11,437	8,401	7,316	11,712	13,568	13,118	10,260	10,965	9,600	6,128	10,081
1949	5,699	7,659	7,779	9,341	9,868	9,223	8,683	11,980	13,163	9,774	6,981	7,252	6,290	5,369	8,486
1950	5,035	6,648	8,138	11,325	12,216	9,906	10,632	11,201	11,658	13,317	13,318	10,565	9,600	5,989	9,866
1951	6,180	9,521	11,191	12,342	13,815	12,398	12,211	12,024	12,525	11,384	10,620	10,297	7,844	5,554	10,540
1952	7,623	8,429	9,488	11,542	11,892	7,663	9,679	12,645	13,545	11,588	10,438	9,589	7,201	5,520	9,765
1953	5,046	7,068	6,984	8,966	11,182	7,408	4,739	6,141	11,619	13,592	11,958	8,776	8,489	6,081	8,650
1954	5,416	7,624	8,738	11,210	11,778	9,086	7,995	10,295	12,393	12,888	13,176	11,977	11,681	7,923	10,094
1955	5,999	8,711	8,814	8,921	8,135	5,432	6,097	5,977	10,219	13,717	13,119	10,983	9,054	5,927	8,758
1956	5,647	9,021	11,031	12,814	12,776	11,530	11,772	12,375	13,042	13,615	11,302	9,792	8,409	5,783	10,637

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1957	5,714	7,498	8,891	9,474	9,558	8,532	10,381	8,492	13,556	13,964	8,314	8,045	7,028	5,843	9,019
1958	5,168	7,038	7,545	10,476	11,365	7,336	5,554	10,147	13,745	12,653	8,196	8,149	7,439	5,898	8,737
1959	5,207	8,355	10,457	12,515	12,488	9,555	9,172	10,495	11,963	13,349	12,460	10,499	8,677	8,761	10,361
1960	9,509	10,432	10,509	10,698	10,816	8,774	10,817	10,513	10,973	11,658	10,290	9,786	7,417	5,825	9,890
1961	5,506	7,477	8,075	10,134	10,981	11,032	8,608	7,513	12,245	13,049	8,369	8,259	7,500	5,811	9,040
1962	4,851	7,165	7,900	10,643	10,760	5,767	7,967	11,659	11,780	11,757	8,687	9,710	8,306	5,907	8,651
1963	5,643	8,578	10,065	10,520	11,034	6,925	5,812	6,216	10,923	11,721	10,197	9,400	7,840	6,366	8,872
1964	5,418	6,881	8,028	9,037	9,770	5,093	6,902	7,981	12,065	13,678	12,970	11,224	8,817	6,883	8,935
1965	6,440	8,256	11,234	13,309	14,266	11,932	8,103	11,927	13,189	12,594	10,614	11,251	9,837	5,908	10,677
1966	5,756	6,851	8,453	10,109	10,080	6,897	7,002	8,552	10,337	10,541	9,650	9,556	7,322	5,822	8,383
1967	5,213	6,820	8,878	11,657	12,126	9,269	7,913	7,315	11,437	13,107	11,772	9,994	7,834	6,059	9,391
1968	5,560	8,037	8,425	10,720	11,178	10,369	5,083	4,393	9,759	12,182	10,170	10,388	8,943	7,484	9,020
1969	6,677	9,221	9,511	12,622	12,419	10,961	10,930	12,321	13,230	12,251	9,553	8,392	6,913	5,643	10,098
1970	5,246	7,726	8,217	9,918	11,549	7,684	5,569	4,879	11,097	12,704	7,889	8,810	7,586	5,899	8,425
1971	5,186	6,758	7,818	12,895	14,017	11,977	11,126	12,125	13,280	13,801	12,141	11,169	8,562	5,932	10,418
1972	5,729	7,787	8,657	12,176	13,038	13,300	12,127	11,024	12,802	13,262	12,156	11,407	10,455	6,201	10,630
1973	6,093	7,622	8,970	9,057	8,253	6,348	4,639	4,440	8,924	9,182	6,549	8,231	6,549	5,535	7,370
1974	5,128	7,411	9,335	13,638	13,674	13,088	12,284	12,460	12,541	13,170	13,306	11,094	10,042	6,407	10,874
1975	5,318	6,860	8,306	10,447	9,979	7,903	6,524	8,930	11,553	12,885	13,235	10,185	9,298	6,537	9,208
1976	6,608	9,381	12,254	12,538	12,530	10,377	11,123	12,078	13,226	11,941	12,379	12,842	12,864	8,540	11,187
1977	6,119	6,726	7,787	8,180	7,897	4,833	4,026	3,776	6,452	6,764	5,996	8,153	7,017	5,338	6,460
1978	4,742	6,634	9,354	8,828	9,364	8,562	9,569	8,799	12,368	10,800	11,475	8,654	7,588	7,100	8,877
1979	6,133	7,542	7,877	8,549	8,718	8,423	5,639	5,784	12,550	8,128	6,681	7,793	6,792	5,724	7,779
1980	5,426	6,551	6,644	8,334	7,159	6,735	5,281	9,630	13,789	12,737	8,358	7,513	6,955	5,791	8,020
1981	5,335	7,401	10,660	11,381	11,847	7,565	5,093	5,857	11,861	14,225	11,578	11,488	9,921	6,316	9,521
1982	5,355	7,882	9,022	11,131	13,112	12,989	10,429	10,751	12,718	13,235	13,456	11,325	9,568	7,267	10,587
1983	6,584	8,014	9,408	10,999	11,788	12,513	8,523	9,639	11,746	11,081	12,608	11,195	8,995	6,379	10,022
1984	5,691	9,707	9,306	11,629	11,692	10,443	8,142	11,895	11,288	12,625	12,188	10,587	8,423	6,365	10,030
1985	5,711	7,812	8,266	10,310	9,988	6,400	7,380	9,849	11,842	8,866	6,510	7,018	6,366	5,588	8,037

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1986	5,787	8,564	8,581	9,796	11,960	13,362	10,453	11,470	11,349	11,817	8,252	8,808	7,134	5,696	9,488
1987	5,057	7,425	8,427	8,132	8,205	7,446	6,221	7,128	11,942	7,963	5,775	7,408	6,340	5,394	7,441
1988	4,977	7,047	7,497	6,010	5,964	6,082	5,208	7,790	8,928	8,860	7,496	8,065	6,947	5,516	6,867
1989	4,817	7,208	7,909	7,376	6,316	7,667	8,467	11,714	11,686	9,090	7,308	7,641	6,922	5,498	7,694
1990	5,137	7,959	9,043	10,277	11,908	9,403	7,260	10,602	10,021	12,276	10,615	10,482	8,495	5,625	9,205
1991	4,961	9,635	9,866	11,654	11,954	9,430	8,038	8,677	11,643	11,853	12,077	11,370	9,456	5,513	9,770
1992	5,411	6,884	6,984	7,910	8,140	6,930	5,180	5,784	9,877	7,450	6,207	7,885	7,013	5,702	7,036
1993	4,895	7,133	7,901	6,602	3,989	7,546	7,670	5,918	12,373	9,162	8,599	9,030	8,063	6,030	7,493
1994	5,218	7,080	7,342	7,180	6,867	6,226	5,048	8,611	9,577	8,189	6,958	7,784	6,612	5,753	7,035
1995	5,191	7,029	7,386	8,238	9,312	9,242	6,303	5,988	11,641	12,030	10,005	8,508	7,855	6,204	8,381
1996	6,022	10,552	13,449	13,253	14,363	13,241	10,435	13,097	12,750	13,245	12,416	11,019	8,203	5,815	11,365
1997	5,364	7,383	9,431	13,999	14,109	13,067	11,976	12,366	12,805	13,475	12,715	11,165	9,464	7,205	10,986
1998	8,472	8,614	9,032	9,361	10,876	7,989	5,842	6,314	12,818	13,008	10,733	10,254	7,372	5,922	9,303
1999	5,266	6,364	8,957	12,231	12,568	12,555	9,923	12,371	11,234	12,378	12,244	12,246	11,180	5,794	10,197
2000	5,252	9,128	10,139	10,504	10,939	9,028	8,882	12,443	11,983	8,439	9,131	9,869	6,818	5,418	9,074
2001	5,192	6,990	7,748	8,501	7,618	5,562	4,710	4,307	6,727	6,905	6,211	8,001	6,643	5,466	6,559
2002	4,506	6,232	7,491	7,557	7,581	5,853	7,147	11,992	11,088	13,138	11,358	7,939	7,104	5,561	8,119
2003	5,252	7,273	7,678	6,907	7,269	8,621	8,441	8,939	10,884	11,621	6,854	7,503	6,809	5,338	7,794
2004	5,045	7,893	8,309	8,481	8,879	6,833	5,644	7,096	9,866	10,132	6,873	7,203	7,323	5,661	7,628
2005	5,968	7,950	9,598	10,091	9,175	7,039	5,577	5,552	10,654	9,238	8,176	8,285	7,038	5,661	8,064
2006	4,683	7,948	8,243	11,813	11,556	8,600	10,285	11,655	13,351	12,556	8,702	7,548	6,499	5,434	9,220
2007	4,739	7,446	8,301	10,434	10,238	10,737	8,159	8,900	11,219	9,150	8,995	7,814	6,601	5,178	8,509
2008	5,041	7,738	7,768	8,886	8,917	6,894	4,710	6,180	12,456	13,644	10,834	7,767	7,956	5,826	8,443
Average	5,565	7,617	8,656	9,880	10,051	8,537	7,685	8,953	11,424	11,266	9,614	9,232	7,940	5,976	8,785

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3809 **MO3: Average Annual Generation for Bonneville Revenue Determination**

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1929	4,562	6,318	6,619	6,250	6,576	5,363	3,712	3,622	3,787	6,400	4,545	7,288	6,574	4,888	5,484
1930	4,964	6,614	6,389	6,083	5,565	5,081	3,802	3,861	4,318	5,618	5,684	7,676	6,766	4,922	5,526
1931	4,925	7,018	7,314	5,264	5,791	5,360	4,302	3,662	3,997	5,311	6,005	8,009	6,795	4,997	5,614
1932	4,622	6,338	6,233	5,583	4,122	6,723	7,280	8,323	9,290	9,978	6,969	7,825	7,582	5,243	6,724
1933	4,810	6,449	8,056	9,225	9,747	8,460	5,789	4,790	7,740	11,225	10,732	10,486	8,958	5,523	8,076
1934	5,328	9,050	10,914	11,254	11,508	9,326	10,319	9,241	9,115	9,007	5,225	6,835	6,723	4,765	8,483
1935	4,984	5,326	7,203	8,655	9,699	7,375	4,486	4,531	7,481	7,437	8,082	9,491	6,960	4,793	6,971
1936	4,750	6,294	6,701	6,004	6,111	5,272	4,265	4,234	9,646	9,085	6,468	7,238	6,558	4,524	6,337
1937	4,853	6,633	6,669	6,446	4,899	4,845	3,688	3,485	4,460	6,084	5,600	7,395	6,460	4,799	5,489
1938	4,870	6,172	7,170	8,595	8,154	7,494	6,925	8,160	8,711	8,221	7,755	6,596	6,102	5,210	7,183
1939	4,768	5,948	6,813	7,167	7,653	5,289	4,077	5,026	7,042	5,519	6,386	7,423	6,828	4,948	6,096
1940	5,020	6,866	7,485	7,342	5,721	6,204	6,304	6,321	6,658	6,591	5,249	6,850	6,351	4,896	6,249
1941	4,707	6,919	7,991	5,814	5,648	5,460	4,795	3,782	5,276	5,443	5,596	7,877	6,823	5,210	5,812
1942	4,522	6,961	8,141	8,135	7,698	5,318	4,078	3,967	5,671	9,533	8,401	7,831	7,674	5,263	6,781
1943	4,945	6,385	6,735	8,771	9,115	7,284	9,230	9,120	8,309	10,148	9,898	8,458	7,345	4,487	7,753
1944	4,484	6,335	6,818	6,164	6,907	4,995	3,420	3,228	3,508	4,825	4,780	7,660	6,391	4,855	5,330
1945	4,720	6,481	7,099	5,330	4,814	4,848	3,546	3,020	5,474	8,725	4,933	7,246	6,438	4,462	5,588
1946	4,610	6,271	7,055	7,827	7,133	7,755	7,808	8,477	9,497	9,236	8,424	8,390	7,356	5,049	7,409
1947	4,270	7,146	9,262	10,086	9,977	8,558	5,720	5,419	8,705	9,024	8,442	7,752	6,768	5,163	7,781
1948	7,284	8,516	8,419	9,155	10,591	7,219	5,724	7,325	10,874	11,138	7,823	9,870	8,729	5,475	8,520
1949	4,896	7,169	7,170	8,324	7,190	7,793	5,983	7,879	9,579	7,718	5,285	6,478	5,790	4,351	6,878
1950	4,531	6,115	7,656	9,634	9,588	9,156	8,168	6,871	7,591	10,963	11,359	9,684	8,465	5,223	8,196
1951	5,331	8,642	9,886	10,843	11,131	10,570	9,738	8,442	9,060	8,513	8,540	9,380	7,372	4,994	8,736
1952	6,718	7,724	8,380	9,581	9,415	7,519	6,883	8,518	10,009	8,306	8,287	8,318	6,692	4,389	7,961
1953	4,609	6,602	6,606	7,223	9,130	6,363	3,568	3,492	7,481	11,427	9,379	7,814	7,682	5,248	7,100
1954	4,850	7,209	8,032	9,576	9,553	8,661	5,772	5,920	8,738	10,687	11,386	10,992	10,743	7,406	8,568
1955	5,126	8,262	8,118	6,938	7,448	4,906	4,550	3,888	6,195	11,143	11,279	10,139	8,133	5,170	7,326
1956	5,139	8,453	9,537	10,744	11,035	9,757	9,464	9,965	10,142	11,565	9,148	8,779	7,538	4,972	9,022

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1957	4,983	6,982	8,041	8,047	6,037	6,999	8,422	6,300	10,907	11,677	6,299	7,145	6,284	4,776	7,409
1958	4,639	6,721	6,776	8,781	8,398	6,831	5,180	5,962	10,158	10,656	6,320	7,258	6,741	4,892	7,221
1959	4,707	7,593	9,056	10,296	11,262	8,590	6,846	6,659	8,189	10,876	10,828	9,533	7,898	8,058	8,725
1960	8,065	9,516	9,614	9,365	9,011	7,045	8,923	7,563	7,336	9,310	8,431	8,783	6,699	5,033	8,221
1961	4,858	7,075	7,433	8,985	7,854	10,034	8,270	5,496	8,753	11,708	6,781	7,576	6,947	4,692	7,692
1962	4,498	6,835	7,285	7,800	9,480	5,478	6,373	7,401	7,898	9,078	6,656	8,784	7,563	4,834	7,056
1963	5,116	7,871	8,880	8,855	9,004	6,200	4,419	4,006	6,328	8,905	8,005	8,577	7,231	5,588	7,229
1964	4,556	6,584	7,390	6,783	8,675	5,255	5,410	4,299	7,625	11,665	10,860	10,127	7,956	6,124	7,443
1965	5,639	7,715	9,458	10,870	11,665	9,974	5,531	6,835	8,782	10,377	7,932	10,096	8,820	4,937	8,569
1966	4,944	6,330	7,694	7,787	9,287	6,264	5,840	5,262	6,441	8,462	7,923	8,841	6,780	4,878	6,933
1967	4,671	6,586	8,130	9,647	10,605	8,902	6,087	5,112	7,257	10,999	9,734	9,232	7,330	5,218	7,954
1968	4,825	7,468	7,644	9,080	8,527	9,005	3,783	3,914	6,411	9,600	8,375	9,609	7,940	6,774	7,526
1969	5,678	8,364	8,620	10,270	11,142	9,714	8,168	8,554	9,942	10,023	7,658	7,613	6,305	4,747	8,439
1970	4,918	7,325	7,536	7,755	9,609	6,119	4,248	4,183	6,466	9,652	5,500	7,870	6,808	4,621	6,733
1971	4,596	6,007	7,083	10,399	11,546	9,971	8,683	7,838	9,971	11,671	9,834	10,050	7,707	5,104	8,592
1972	4,802	7,201	7,737	9,864	10,859	10,719	10,013	7,106	9,883	11,118	10,205	10,407	9,550	5,567	8,871
1973	5,081	7,010	7,976	7,427	7,076	5,721	3,661	3,453	5,322	6,360	5,125	7,504	5,990	4,439	5,983
1974	4,731	6,646	7,947	11,289	11,587	10,720	10,056	9,220	9,386	10,994	11,183	10,023	8,971	5,568	9,087
1975	4,351	6,670	7,542	7,972	8,495	7,849	4,380	5,154	7,105	11,122	10,567	8,944	8,170	5,741	7,558
1976	5,377	8,603	10,378	10,055	11,070	9,202	7,908	7,836	9,692	9,081	10,535	11,814	11,884	7,781	9,292
1977	4,932	6,231	7,134	6,486	7,129	5,058	3,244	3,135	4,435	4,787	5,058	7,649	6,615	4,325	5,486
1978	4,210	6,372	7,990	7,346	6,340	7,037	6,810	5,779	7,870	8,227	9,133	7,689	6,709	6,383	7,040
1979	5,258	7,124	7,267	7,525	6,425	6,029	4,839	4,650	8,217	6,346	5,176	7,055	6,148	4,809	6,297
1980	4,870	6,069	6,406	6,970	6,690	5,614	3,522	5,250	10,305	10,107	6,295	6,693	6,276	4,835	6,587
1981	4,792	6,906	9,560	9,684	10,489	6,495	3,510	3,906	7,474	11,596	9,575	10,764	9,036	5,555	7,966
1982	4,752	7,488	8,169	9,363	10,016	11,083	7,424	6,212	9,245	10,368	11,026	10,266	8,484	6,593	8,688
1983	5,406	7,364	8,317	9,657	8,504	10,183	6,667	5,691	7,231	8,547	10,387	10,223	7,900	5,609	8,042
1984	4,577	8,884	8,200	9,378	8,990	7,916	6,500	7,106	6,473	10,352	9,619	9,302	7,442	5,457	7,911
1985	4,581	7,063	7,397	8,054	8,062	5,692	6,216	5,522	7,764	6,301	5,153	6,232	5,789	4,484	6,359

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1986	4,953	7,672	7,761	8,868	7,495	10,733	7,956	6,924	7,068	9,503	6,425	8,028	6,528	4,573	7,481
1987	4,376	6,902	7,585	7,506	6,153	6,606	4,741	4,860	8,053	6,943	4,716	6,816	5,891	4,375	6,201
1988	4,644	6,978	7,009	5,320	5,360	5,205	3,840	3,931	4,969	6,202	6,116	7,486	6,508	4,533	5,604
1989	4,711	6,923	7,358	6,216	5,056	6,321	5,319	6,842	7,832	6,265	5,819	7,063	6,429	4,566	6,168
1990	4,678	7,390	8,404	9,090	10,307	7,969	5,527	7,390	6,840	10,246	8,807	9,691	7,812	4,878	7,802
1991	4,483	9,061	9,288	9,768	11,010	8,575	7,367	5,750	8,090	9,380	10,528	10,670	8,692	5,041	8,442
1992	4,624	6,341	6,570	7,039	6,342	6,376	4,276	4,170	6,085	5,598	5,069	7,338	6,623	4,744	5,836
1993	4,774	6,907	7,408	5,191	5,031	5,654	4,556	3,744	7,026	6,090	6,389	8,031	7,173	5,059	5,951
1994	4,728	6,598	6,892	6,164	6,814	5,222	3,447	4,921	5,646	5,886	5,564	7,250	6,206	4,704	5,755
1995	4,871	6,863	6,821	6,769	6,382	7,987	4,864	3,908	6,672	9,796	7,298	7,524	7,080	5,461	6,720
1996	5,252	9,519	11,184	11,211	11,373	10,894	7,848	9,124	8,721	10,583	10,499	10,016	7,439	5,029	9,285
1997	4,693	6,852	8,309	11,182	11,593	10,859	10,044	9,503	10,646	11,395	10,505	9,897	8,440	6,487	9,275
1998	7,419	7,884	8,145	8,095	8,900	6,473	4,017	4,169	8,511	10,875	8,267	9,232	6,662	4,884	7,618
1999	4,410	5,756	8,226	10,152	9,538	10,961	8,208	8,057	6,901	9,524	10,514	11,271	10,474	5,176	8,349
2000	4,357	8,766	9,182	9,123	8,293	7,693	7,703	8,698	7,835	6,512	7,379	9,110	6,267	4,484	7,456
2001	4,668	6,578	7,107	6,426	6,925	5,034	3,642	3,469	3,668	4,662	5,284	7,714	6,443	4,337	5,437
2002	4,118	6,075	6,879	5,823	5,319	5,846	5,791	7,640	7,197	10,987	9,425	7,130	6,393	4,532	6,645
2003	4,962	6,952	7,176	6,457	5,475	6,692	5,961	5,486	6,306	9,155	5,310	6,789	6,250	4,235	6,250
2004	4,920	7,496	7,779	7,269	6,472	5,727	4,689	4,869	5,616	7,257	5,347	6,440	6,627	4,940	6,177
2005	5,184	7,406	8,824	8,144	8,439	6,675	4,725	4,219	5,999	6,843	6,493	7,572	6,483	4,442	6,656
2006	4,674	7,498	7,589	8,831	10,704	7,123	8,692	7,544	9,694	10,913	6,891	6,829	5,938	4,152	7,689
2007	4,403	7,091	7,519	9,233	7,607	9,400	7,295	6,219	7,368	8,114	7,367	7,181	6,104	3,968	7,124
2008	4,935	7,238	7,119	7,408	7,060	6,280	4,101	3,683	8,021	11,274	8,292	6,880	7,165	4,790	6,946
Average	**4,931**	**7,120**	**7,841**	**8,239**	**8,291**	**7,362**	**5,987**	**5,864**	**7,575**	**8,910**	**7,752**	**8,392**	**7,252**	**5,100**	**7,235**

3810

3811 **MO4: Average Annual Generation for Bonneville Revenue Determination**

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1929	4,993	6,636	6,697	6,986	6,994	3,944	3,918	3,916	5,386	6,191	4,695	5,126	4,735	5,086	5,526
1930	4,690	6,871	6,393	6,186	6,459	4,021	3,919	4,227	5,796	5,612	5,654	5,395	4,862	5,471	5,521
1931	4,726	6,975	6,900	6,286	5,616	4,231	3,827	3,811	5,739	5,516	6,007	5,535	5,185	5,439	5,551
1932	4,340	6,399	6,408	6,062	4,965	4,321	5,301	7,089	8,202	8,505	6,146	5,953	5,882	5,686	6,095
1933	5,168	6,537	8,091	10,434	10,916	6,030	5,008	5,048	6,970	11,382	8,773	7,810	6,442	5,962	7,678
1934	5,702	9,301	12,301	13,067	12,880	6,479	7,684	8,045	7,982	8,071	5,178	5,398	5,389	5,081	8,245
1935	5,273	5,805	7,085	9,586	10,418	5,512	4,452	4,727	6,902	6,513	6,984	7,118	5,244	5,184	6,648
1936	5,063	6,637	6,829	6,371	6,119	3,914	4,161	4,807	8,942	7,948	7,539	5,077	4,654	5,369	6,174
1937	4,614	6,940	6,788	6,154	5,121	3,925	3,866	3,788	5,935	5,500	5,198	4,791	4,570	5,500	5,349
1938	4,593	7,048	6,669	10,117	9,376	4,918	5,230	7,347	7,444	6,815	6,674	5,161	4,941	5,703	6,706
1939	5,207	6,400	6,468	8,048	8,343	3,795	3,786	5,443	6,689	7,517	5,935	5,200	4,786	5,346	6,096
1940	4,783	6,899	7,055	8,222	6,558	4,309	5,146	6,015	6,331	7,236	5,542	4,470	4,530	5,728	6,056
1941	4,608	7,539	7,588	6,997	6,258	4,097	4,549	3,956	6,665	5,228	5,420	5,277	4,894	5,986	5,807
1942	4,462	7,193	8,558	10,277	8,223	3,823	3,574	4,684	6,443	7,871	7,137	5,674	5,001	5,338	6,556
1943	4,873	6,455	7,063	10,632	11,103	4,898	7,459	9,180	7,383	9,234	7,826	6,212	5,377	5,070	7,357
1944	4,987	6,624	6,719	7,254	7,549	3,756	3,644	3,529	5,154	4,695	4,808	5,102	4,694	5,630	5,464
1945	4,502	6,718	6,851	6,077	5,703	3,774	3,722	3,124	6,268	7,386	5,459	5,013	4,589	5,247	5,513
1946	4,434	6,556	6,933	9,420	9,411	4,765	5,778	7,826	8,336	7,707	7,143	6,405	5,508	5,650	6,907
1947	4,878	7,419	10,452	11,821	11,976	5,873	4,763	5,481	7,889	7,454	7,216	6,042	5,187	5,726	7,596
1948	7,878	8,784	8,880	11,754	11,525	5,199	4,885	6,710	11,186	12,892	6,503	7,117	6,423	6,028	8,585
1949	5,366	7,251	7,221	9,087	8,483	5,514	4,719	7,580	9,345	6,282	5,031	5,059	4,727	4,853	6,612
1950	4,992	6,478	7,523	11,115	11,203	6,182	5,931	6,295	6,666	10,870	9,740	6,900	6,197	5,819	7,746
1951	5,986	9,089	10,686	12,670	13,513	7,450	7,219	7,411	8,035	6,840	7,232	6,986	5,462	5,524	8,349
1952	7,492	7,947	8,883	11,330	11,247	5,084	5,155	8,521	10,038	7,097	7,001	6,377	5,058	4,933	7,792
1953	5,034	6,901	6,827	7,837	11,543	4,605	3,701	3,820	6,728	11,620	7,657	5,840	5,859	5,762	6,973
1954	5,293	7,234	8,187	10,967	11,198	6,021	4,883	5,739	7,661	9,167	9,596	7,962	7,856	7,946	8,022
1955	5,570	8,298	8,173	8,348	8,050	3,983	4,234	4,304	6,606	10,217	9,353	7,048	5,929	5,368	7,051
1956	5,284	8,635	10,451	13,108	12,725	6,207	6,688	10,776	9,967	11,485	7,459	6,420	5,722	5,575	8,788

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1957	5,515	7,062	8,339	9,374	7,960	4,567	6,011	6,000	11,453	11,440	5,743	5,494	5,018	5,344	7,331
1958	5,141	6,738	6,985	10,007	10,096	4,895	4,496	5,433	10,004	9,148	5,957	5,603	5,338	5,435	7,050
1959	5,245	7,922	9,917	12,751	12,800	5,915	5,389	6,443	7,115	10,033	8,757	7,134	5,870	8,834	8,441
1960	9,098	10,005	10,013	10,925	10,205	4,954	6,422	6,866	6,695	7,749	7,233	6,686	5,143	5,528	7,904
1961	5,294	7,161	7,519	10,343	9,651	6,823	6,571	5,544	7,828	11,223	6,247	5,919	5,571	5,188	7,405
1962	4,955	6,886	7,344	9,183	11,166	4,151	4,787	6,700	7,003	7,567	5,941	6,667	5,658	5,333	6,753
1963	5,831	8,136	9,473	10,217	10,881	4,552	4,198	4,304	6,164	7,433	7,416	6,246	5,368	5,930	7,151
1964	4,736	6,660	7,472	8,653	9,111	4,021	4,624	4,686	6,803	12,651	8,817	7,518	5,838	6,811	7,238
1965	6,136	7,790	10,683	13,612	14,440	6,862	4,802	6,546	7,914	10,397	6,591	7,489	6,271	5,750	8,523
1966	5,578	6,474	7,851	9,588	10,094	4,663	4,877	5,464	6,931	7,408	7,678	5,725	5,130	5,373	6,834
1967	4,477	6,603	7,818	11,095	12,160	6,313	5,395	5,443	6,464	11,116	7,927	6,992	5,523	5,725	7,580
1968	5,388	7,639	7,870	10,186	10,907	6,275	3,900	4,214	6,840	7,850	7,170	6,783	5,991	7,216	7,302
1969	6,120	8,713	8,991	12,649	12,923	6,764	5,826	7,640	9,399	8,209	6,715	5,908	5,156	5,265	8,138
1970	5,407	7,324	7,661	9,628	10,589	4,391	4,099	4,308	6,389	9,796	6,614	5,322	4,887	5,260	6,835
1971	4,563	6,579	6,791	12,812	14,202	6,897	6,402	7,192	9,981	12,424	7,861	7,426	5,724	5,742	8,392
1972	5,562	7,376	8,103	11,847	13,322	10,672	7,290	6,457	9,190	12,867	8,163	7,557	7,048	6,220	8,940
1973	5,836	7,200	8,418	9,001	8,700	4,226	3,832	3,575	6,840	5,984	4,992	5,028	4,546	5,141	6,223
1974	4,578	7,115	8,133	13,789	13,679	7,807	7,413	8,793	8,495	12,714	9,442	7,383	6,457	6,135	8,873
1975	4,873	6,711	7,780	9,352	9,974	5,651	4,057	5,368	6,596	11,456	8,520	6,500	6,079	6,426	7,340
1976	6,343	8,960	11,784	12,717	12,704	6,404	6,061	6,937	9,301	7,609	8,563	8,604	8,622	8,587	8,999
1977	5,605	6,543	7,001	7,634	7,839	3,840	3,541	3,438	6,068	4,940	5,275	5,513	4,873	4,889	5,683
1978	4,052	6,470	8,550	9,246	7,874	4,929	4,886	5,777	7,349	6,468	7,407	5,863	5,314	7,062	6,687
1979	5,749	7,125	7,320	8,368	7,856	4,017	4,557	4,951	7,422	6,845	5,706	4,883	4,589	5,577	6,279
1980	4,670	6,599	6,090	8,543	7,728	4,094	3,573	5,405	9,330	8,421	7,082	4,477	4,450	5,610	6,421
1981	4,622	6,993	9,415	11,333	11,617	4,538	3,657	4,274	7,051	10,542	8,073	8,092	6,593	6,011	7,599
1982	5,179	7,540	8,471	10,710	13,174	8,292	5,527	5,648	8,217	10,717	9,031	7,546	6,059	7,254	8,380
1983	6,218	7,544	8,892	11,344	10,963	7,578	4,881	5,584	6,462	7,576	8,424	7,529	5,649	6,234	7,738
1984	5,363	9,394	8,771	11,181	10,721	5,195	4,670	6,726	6,256	11,050	7,795	6,953	5,571	6,425	7,822
1985	5,345	7,397	7,711	10,061	8,592	4,117	4,647	5,175	6,800	5,745	5,078	5,041	4,826	5,428	6,330

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1986	5,660	8,043	8,027	9,756	11,486	8,554	5,828	6,368	6,624	7,987	7,296	5,331	4,813	5,232	7,460
1987	4,368	7,095	7,422	8,549	7,383	4,392	4,478	5,554	7,431	7,788	4,880	4,417	4,235	4,988	6,125
1988	4,528	7,005	6,444	6,025	5,955	4,058	3,716	4,361	6,420	5,805	5,812	5,123	4,756	5,287	5,523
1989	4,435	7,035	6,893	6,905	5,990	4,086	4,919	6,460	6,882	5,601	5,512	5,544	5,125	5,075	5,783
1990	5,134	7,499	8,468	10,172	11,465	5,759	4,827	6,631	6,776	8,584	7,452	7,168	5,633	5,143	7,353
1991	4,794	9,228	9,357	10,959	12,384	6,124	6,160	5,915	7,061	7,677	8,512	7,879	6,304	5,437	7,858
1992	4,973	6,707	6,367	7,832	7,646	4,485	4,280	4,446	7,086	6,333	4,974	5,169	4,580	4,977	5,878
1993	4,479	6,904	7,060	6,436	5,296	3,762	3,724	3,874	6,676	6,099	7,002	5,484	4,352	5,026	5,624
1994	4,582	6,896	7,169	6,371	7,063	4,085	3,672	5,427	6,822	6,347	5,286	5,050	4,665	5,210	5,759
1995	4,615	6,844	6,359	7,988	8,499	5,465	4,040	4,157	5,997	8,610	6,385	5,492	4,826	5,861	6,304
1996	5,712	10,118	13,325	13,483	14,241	7,999	5,747	8,347	7,803	10,170	8,495	7,459	5,574	5,652	9,194
1997	5,187	6,992	8,909	14,129	14,190	8,034	7,373	9,668	11,526	12,838	8,467	7,240	6,113	7,204	9,354
1998	8,174	8,107	8,481	9,035	10,497	4,515	3,834	4,782	8,710	9,727	6,801	6,835	4,981	5,561	7,464
1999	5,020	6,191	8,355	12,222	11,780	7,991	6,011	7,229	6,139	8,915	8,494	8,126	7,647	5,751	7,927
2000	4,829	8,912	9,558	10,484	9,956	5,295	5,870	7,655	7,050	5,657	6,507	6,905	4,897	5,021	7,149
2001	5,198	6,613	7,190	7,518	7,427	3,776	3,653	3,603	5,389	4,870	5,242	5,253	4,690	5,052	5,563
2002	3,900	6,570	6,404	6,975	6,516	4,594	4,775	6,820	6,662	9,470	7,846	5,504	5,124	5,005	6,247
2003	5,326	6,997	7,051	7,065	6,650	4,727	4,856	5,968	6,307	7,449	6,717	4,744	4,360	5,027	6,100
2004	4,678	7,613	7,129	8,100	7,450	4,072	4,271	4,911	5,956	6,392	6,080	4,583	4,517	5,525	6,003
2005	5,059	7,496	8,464	9,599	9,016	4,859	4,487	4,498	5,987	7,369	6,798	5,672	4,302	4,519	6,538
2006	4,460	7,525	7,468	10,710	12,038	4,957	6,169	7,050	9,344	9,307	6,202	5,356	4,891	4,651	7,331
2007	4,833	7,329	7,673	10,533	9,154	6,302	5,723	6,222	6,712	7,245	7,560	5,389	4,377	4,640	6,890
2008	4,977	7,324	6,719	8,450	8,105	4,783	4,106	3,834	6,893	11,021	6,902	5,350	5,537	5,313	6,648
Average	**5,215**	**7,341**	**8,002**	**9,646**	**9,693**	**5,284**	**4,951**	**5,773**	**7,391**	**8,394**	**6,929**	**6,118**	**5,365**	**5,661**	**7,038**

3812

3813 **PA: Average Annual Generation for Bonneville Revenue Determination**

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1929	5,476	6,724	6,816	6,824	6,722	6,297	4,479	4,051	4,833	8,062	5,530	6,510	6,340	5,886	6,149
1930	5,346	6,786	6,401	6,894	6,186	5,681	4,416	4,284	5,494	6,637	6,634	7,002	6,653	5,961	6,100
1931	5,421	7,025	6,938	6,053	5,801	6,206	4,891	3,944	5,184	6,481	6,792	7,334	6,737	6,020	6,118
1932	5,204	6,487	6,661	5,970	5,585	8,471	8,659	9,094	10,546	11,632	7,943	6,942	7,376	5,824	7,534
1933	5,598	6,419	8,674	10,570	11,573	8,844	6,546	5,884	8,240	13,340	11,736	9,257	8,986	5,924	8,841
1934	6,144	9,729	12,452	13,096	13,088	10,821	11,360	10,005	9,809	9,615	5,729	6,003	6,361	5,512	9,381
1935	5,376	5,902	7,058	9,972	10,834	8,118	5,434	6,143	8,005	8,277	8,858	8,429	6,687	5,429	7,583
1936	5,486	6,681	6,740	6,057	5,997	6,841	4,756	6,624	11,775	10,094	7,470	6,520	6,395	5,605	7,081
1937	5,409	7,035	6,860	5,993	5,290	5,599	4,502	3,962	5,613	6,856	6,288	6,593	6,180	5,576	5,933
1938	5,529	6,894	7,875	10,289	9,559	9,127	7,811	9,741	10,022	9,834	8,829	5,874	5,940	5,817	8,198
1939	5,614	6,498	6,409	7,970	8,440	6,844	5,073	6,355	8,190	7,137	7,043	6,556	6,496	5,733	6,836
1940	5,451	7,011	7,048	8,440	7,168	8,011	7,321	7,716	7,826	7,685	5,814	6,034	6,041	5,590	6,966
1941	5,549	7,571	7,880	6,843	6,559	6,542	5,640	4,461	6,290	6,622	6,657	7,241	6,911	6,032	6,558
1942	5,535	7,425	9,187	10,217	8,802	6,366	4,922	5,458	6,671	10,656	9,462	6,956	7,484	5,941	7,719
1943	5,604	6,440	7,555	10,726	11,553	9,068	11,860	11,548	9,585	12,299	11,846	7,698	7,372	5,489	9,098
1944	5,184	6,716	6,578	6,655	7,227	5,911	4,171	3,628	4,270	5,817	5,914	7,151	6,535	5,842	5,900
1945	5,412	6,756	6,926	6,133	5,743	5,899	4,375	3,744	6,987	10,533	6,315	6,627	6,450	5,713	6,419
1946	5,228	6,541	7,762	9,508	9,884	8,940	9,137	10,163	10,566	10,013	9,378	7,551	7,199	5,804	8,379
1947	5,257	7,342	10,963	11,718	11,982	10,462	6,717	7,016	10,101	10,126	9,391	7,027	6,622	5,934	8,903
1948	8,041	8,890	9,437	11,518	11,805	8,345	6,542	9,307	12,985	13,650	9,040	9,013	8,715	6,028	9,705
1949	5,824	7,265	7,146	10,032	8,462	10,030	7,068	9,951	11,685	8,713	6,121	5,742	5,636	5,315	7,899
1950	5,155	6,569	7,744	11,703	11,606	10,306	9,831	8,476	8,825	12,874	13,110	8,652	8,777	5,885	9,293
1951	6,441	9,184	11,076	12,709	13,741	12,363	11,097	9,566	10,310	9,698	9,729	8,451	7,291	5,623	9,903
1952	7,772	8,050	9,441	11,406	11,445	8,903	8,814	10,971	12,315	9,973	9,302	7,886	6,622	5,454	9,264
1953	5,167	6,972	6,739	8,199	11,349	7,634	4,420	4,197	8,690	13,539	10,925	7,038	7,633	5,979	8,047
1954	5,539	7,231	8,678	11,395	11,882	9,373	6,450	7,331	9,915	11,807	12,691	10,129	10,935	7,842	9,474
1955	6,139	8,332	8,754	7,669	8,069	5,651	5,500	4,582	7,696	12,824	12,607	9,051	8,380	5,859	8,114
1956	5,772	8,686	11,007	13,129	12,733	12,045	10,615	12,271	11,896	13,304	10,239	7,922	7,544	5,678	10,297

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1957	5,838	7,104	8,775	9,406	9,023	8,111	9,457	7,380	13,195	13,560	7,284	6,407	6,191	5,738	8,557
1958	5,289	6,776	7,102	10,250	10,301	8,343	5,711	7,259	12,399	11,991	7,370	6,511	6,598	5,794	8,209
1959	5,327	7,971	10,422	12,768	12,998	9,901	7,693	7,656	8,928	12,546	11,887	8,581	7,832	8,707	9,757
1960	9,727	10,117	10,394	10,698	10,557	8,404	9,916	8,497	8,374	10,613	9,182	7,872	6,579	5,722	9,179
1961	5,628	7,084	8,010	10,787	9,898	10,455	8,982	6,841	9,623	12,638	7,428	6,717	6,667	5,708	8,479
1962	4,983	6,848	7,755	9,251	11,564	6,371	7,269	8,900	8,928	10,488	7,612	7,867	7,448	5,803	7,917
1963	5,763	8,197	10,025	10,167	10,876	7,297	5,107	4,589	7,936	10,420	9,059	7,701	7,085	6,268	8,173
1964	5,541	6,650	7,789	7,881	9,705	6,271	6,607	5,813	8,661	13,921	12,287	9,268	7,952	6,784	8,350
1965	6,568	7,869	11,210	13,580	14,481	12,103	6,551	9,011	10,985	11,558	9,443	9,385	9,058	5,886	10,040
1966	5,878	6,501	8,234	9,056	10,542	7,316	6,888	6,242	7,510	9,045	8,632	7,834	6,525	5,719	7,664
1967	5,335	6,663	8,569	11,379	12,656	9,818	6,762	5,865	8,502	13,025	10,991	8,266	7,133	5,885	8,881
1968	5,682	7,649	8,363	10,911	10,213	10,397	4,453	4,275	7,643	10,850	9,092	8,588	8,164	7,388	8,410
1969	6,804	8,872	9,463	12,541	13,084	11,220	9,706	9,896	11,698	10,941	8,586	6,815	6,157	5,744	9,582
1970	5,367	7,334	7,355	9,439	11,285	7,509	4,938	4,493	8,517	13,110	6,985	7,095	6,742	5,789	7,833
1971	5,305	6,679	7,420	13,067	14,276	12,123	10,243	9,335	12,163	13,896	11,526	9,213	7,726	5,902	10,025
1972	5,849	7,394	8,595	12,536	13,346	13,313	11,125	8,154	11,233	13,527	11,554	9,571	9,647	6,264	10,233
1973	6,229	7,231	8,120	9,034	8,728	6,651	4,476	3,701	6,543	7,302	5,831	6,686	5,759	5,461	6,778
1974	5,249	7,015	9,289	13,875	13,785	13,128	11,727	10,919	10,737	13,460	12,936	9,194	9,209	6,284	10,508
1975	5,438	6,778	7,189	9,713	10,592	9,296	5,302	6,264	8,560	13,380	12,685	8,249	8,411	6,433	8,672
1976	6,754	9,164	12,175	12,439	12,902	10,974	9,867	9,239	11,742	10,754	11,816	11,053	12,359	8,470	10,707
1977	6,242	6,646	6,797	7,187	7,764	5,811	3,815	3,474	5,251	5,533	5,873	7,114	6,668	5,513	6,090
1978	4,860	6,231	8,603	9,457	9,100	8,635	7,930	7,409	9,125	9,334	10,537	6,959	6,747	7,004	8,115
1979	6,259	7,146	7,012	8,765	7,676	7,539	5,650	5,478	9,695	7,389	5,932	6,323	6,023	5,772	7,078
1980	5,550	6,695	6,183	8,483	8,158	6,762	4,380	6,487	11,790	11,495	7,307	5,992	6,127	5,684	7,465
1981	5,457	7,005	10,102	11,361	12,188	7,550	4,127	4,590	8,834	13,138	10,489	9,522	9,090	6,217	8,818
1982	5,478	7,492	8,376	11,121	13,787	13,097	8,937	7,753	10,608	13,336	12,974	9,317	8,735	7,174	10,047
1983	6,711	7,624	9,032	11,444	11,877	12,223	7,552	7,162	8,730	10,673	11,956	9,211	8,181	6,279	9,377
1984	5,811	9,378	9,258	11,267	11,022	10,407	8,134	8,832	8,681	13,324	11,410	8,666	7,638	6,343	9,452
1985	5,833	7,422	8,203	10,150	9,045	6,966	7,178	7,257	8,491	7,273	5,778	5,618	5,563	5,574	7,285

Water Year	OCT 1-31	NOV 1-30	DEC 1-31	JAN 1-31	FEB 1-28	MAR 1-31	APR 1-15	APR 16-30	MAY 1-31	JUN 1-30	JUL 1-31	AUG 1-15	AUG 16-31	SEP 1-30	Avg.
1986	5,909	8,189	8,518	10,238	10,944	13,182	9,774	8,478	8,437	11,115	7,288	7,163	6,359	5,587	8,759
1987	5,177	7,029	8,364	8,285	7,701	7,136	5,435	6,647	9,101	7,713	5,276	6,029	5,595	5,303	6,909
1988	5,098	6,925	6,540	6,259	5,781	6,112	4,450	5,327	6,192	7,113	6,947	6,789	6,366	5,717	6,181
1989	5,066	6,988	7,736	7,353	5,960	7,706	7,460	9,294	8,913	7,257	6,542	6,244	6,175	5,392	6,966
1990	5,351	7,572	8,909	10,185	11,608	9,215	6,362	8,417	7,826	11,110	9,602	8,607	7,648	5,584	8,520
1991	5,125	9,336	9,758	11,158	12,461	9,226	7,858	7,015	8,534	10,178	11,516	9,400	8,712	5,415	9,082
1992	5,537	6,808	6,293	7,744	7,277	7,337	5,135	5,017	7,277	6,823	5,683	6,475	6,263	5,612	6,486
1993	5,045	6,834	7,038	6,869	5,336	6,933	5,175	4,002	9,251	8,864	7,514	7,230	7,192	5,926	6,798
1994	5,341	7,001	7,097	6,644	6,754	6,333	4,323	6,352	7,009	6,805	6,338	6,538	5,992	5,748	6,387
1995	5,313	6,630	7,316	7,902	8,929	9,188	5,775	4,696	8,162	11,743	8,705	6,754	7,003	6,104	7,668
1996	6,474	10,233	13,414	13,491	14,322	13,385	8,995	10,548	10,242	12,995	11,799	9,085	7,466	5,817	10,843
1997	5,485	6,988	9,385	14,246	14,350	13,343	11,305	11,380	12,842	13,821	12,061	9,217	8,603	7,115	10,805
1998	8,584	8,232	8,185	9,458	10,524	8,018	4,979	5,312	11,298	12,732	9,459	8,312	6,524	5,816	8,730
1999	5,386	6,283	8,571	12,367	12,381	13,059	9,103	9,426	8,239	11,951	11,888	10,510	10,642	5,804	9,640
2000	5,374	8,891	10,007	10,611	10,133	9,381	8,650	9,718	8,861	7,275	8,108	8,096	6,042	5,376	8,351
2001	5,313	6,680	6,790	7,374	7,511	6,181	4,198	3,678	4,672	5,466	6,073	7,048	6,338	5,572	6,015
2002	4,627	6,278	7,351	7,040	7,196	6,718	6,547	8,542	8,469	12,209	10,366	6,336	6,272	5,457	7,461
2003	5,375	7,098	6,787	7,666	6,329	7,899	6,664	7,710	7,837	10,446	6,240	6,042	6,002	5,327	7,018
2004	5,168	7,653	8,247	8,147	7,659	6,869	5,513	5,859	6,810	8,294	6,402	5,869	6,618	5,681	6,903
2005	6,094	7,560	9,175	9,335	9,118	7,460	5,695	4,763	7,595	7,917	7,269	6,736	6,216	5,554	7,393
2006	4,803	7,559	8,181	10,931	12,357	8,465	10,240	9,244	11,746	12,039	7,656	6,031	5,686	5,327	8,692
2007	4,857	7,056	8,240	10,626	9,637	10,401	8,187	7,007	8,354	8,747	7,981	6,341	5,811	5,072	7,880
2008	5,162	7,346	6,905	8,885	8,806	7,583	5,052	4,835	8,983	13,273	9,557	6,166	7,103	5,721	7,812
Average	5,701	7,373	8,318	9,731	9,917	8,723	6,997	7,081	8,951	10,406	8,826	7,573	7,187	5,933	8,183

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Draft Columbia River System Operations Environmental Impact Statement

Appendix K
Flood Risk Management

CHAPTER 1 - FLOOD RISK

The purpose of the flood risk analysis is to assess the risk of an area to flooding and determine if there is a difference in flood risk under the Action Alternatives when compared to the No Action Alternative. Flood risk is a function of the hydrologic and hydraulic flood hazards that exist in a particular area (river flows and stages), the expected performance of levees and other infrastructure to protect against these hazards, and finally, the consequences of these hazards reaching communities or property (i.e., the harm that may be caused).

Flood hazards measure the potential for inundation that involves risks to life, health, property, and natural floodplain resources and functions (FEMA 2019). The National Weather Service (NWS) ranks flood hazards by river stage (gage height), and includes the following categories:

- **Action stage**: the stage which, when reached by a rising stream, represents the level where the NWS or a partner/user needs to take some type of mitigation action in preparation for possible significant hydrologic activity.
- **Flood stage**: the stage above which a rise in water surface level begins to create a hazard to lives, property, or commerce. The issuance of flood advisories or warnings is linked to flood stage.
- **Moderate Flood Stage**: the stage above which a rise in water surface level begins to have some inundation of structures and roads near the stream. Some evacuations of people and/or transfer of property to higher elevations may be necessary. A **Flood Warning** should be issued if moderate flooding is expected during the event.
- **Major Flood Stage**: the stage above which a rise in water surface level begins to have extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations are necessary. A **Flood Warning** should be issued if major flooding is expected during the event.

This appendix provides an overview of the methodology used to estimate changes in flood risk resulting from the Action Alternatives. It also contains tabulated results of the analysis, referenced in the main report of the EIS, chapter 3.9. Discussion of the results and conclusions are in the main report of the EIS as well.

1.1 EFFECTS ASSESSMENT METHODOLOGY

The flood risk analysis began by establishing the anticipated flood risk conditions under the No Action Alternative. Hydrologic modeling of anticipated river flows and stages were estimated at each gage for each alternative using 5,000 simulated water years (refer to H&H Appendix A for more information on hydrologic modeling). Flood risk conditions were then evaluated using a sample of annual peak flows and stages for each of the simulated water years at gage locations throughout the CRSO study area. These peaks figures were then compared to thresholds for flood hazards established by the National Weather Service (NWS) to evaluate whether flood risk would change under the CRSO EIS alternatives. Flood risks are measured in terms of the likelihood that established flood thresholds would be exceeded, which is called the annual exceedance probability (AEP).

The No Action Alternative flood risk conditions were determined using the H & H modeling described in Section 3.2 of the EIS, as well as in the H&H Appendix A, which includes rule-based reservoir operations and assumed future conditions. The No Action Alternative provides a basis from which the other alternatives can be evaluated in a comparative-type analysis.

1.2 GAGE LOCATIONS USED IN THIS ANALYSIS

The analysis used flow and stage estimates at 14 river gages. These gage locations were selected because they provide a good representative sample of potential flood hazard locations throughout the study area, as they are either located near populated areas or are commonly used to communicate estimated flood levels for a given area. Given this, the gage locations characterize the flood hazards and consequences in the river reaches where they are located.

The NWS, the U.S. Geological Survey, the Corps, and Reclamation work jointly to gather and disseminate data to inform the public about river conditions at significant locations. The gage location data includes historical stage or flow conditions, which are communicated to the public through the NWS's Advanced Hydrologic Prediction Service (https://water.weather.gov/ahps). These gages are useful in assessing the thresholds at which river and possible flood conditions become hazardous (Figure 1-1).

NWS specifies flows or elevations (stages) that are associated with four different flood categories: action stage, flood stage, moderate flood stage, and major flood stage. The thresholds for each flood hazard category for each gage location are presented in Table 1-1 and Table 1-2, as measured in elevation (feet).

Table 1-1. Thresholds for Flood Hazard Categories at Gage Locations

Region	H & H Reach	Gage or other Consequence Source	Stages in NAVD88 datum feet (unless otherwise noted)			
			Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
A	R22 & R23	Pend Oreille River Outflow from Albeni Falls 1/	85 1/	95 1/	115 1/	130 1/
A	R24	Lake Pend Oreille near Hope, ID	2066.6	2067.5	2070	2073
A	R25 to R27	Clark Fork Near Plains, Mt	2467.9	2468.9	2470.9	2472.4
A	R28	Columbia Falls, MT Gage	2993.8	2994.3	2999.3	3003.3
A	R29	Bonners Ferry, ID Gage	1760.8	1767.8	1773.8	1781.8
B	R21	Grand Coulee Pool	Simulations do not exceed normal full pool level of 1,290 ft (NGVD29) under any alternative			
B	R20	Chief Joseph Pool	Simulations do not exceed normal full pool level of 956 ft (NGVD29) under any alternative			
B	R19	Wells Pool	Simulations do not exceed normal full pool level of 781 ft (NGVD29) under any alternative			
B	R18	Rocky Reach Pool	Simulations do not exceed normal full pool level of 707 ft (NGVD29) under any alternative			
B	R17	Rock Island Pool	Simulations do not exceed normal full pool level of 613 ft (NGVD29) under any alternative			

Region	H & H Reach	Gage or other Consequence Source	Stages in NAVD88 datum feet (unless otherwise noted)			
			Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
B	R16	Wanapum Pool	Simulations do not exceed normal full pool level of 570 ft (NGVD29) under any alternative			
B	R15	Priest Rapids Pool	Simulations do not exceed normal full pool level of 488 ft (NGVD29) under any alternative			
B	R14	Below Priest Rapids, WA Gage	424.3	425.3	426.3	427.3
C	R06	Ice Harbor Pool	Simulations do not exceed normal full pool level of 440 ft (NGVD29) under any alternative			
C	R07	Lower Monumental Pool	Simulations do not exceed normal full pool level of 540 ft (NGVD29) under any alternative			
C	R08	Little Goose Pool	Simulations do not exceed normal full pool level of 638 ft (NGVD29) under any alternative			
C	R09	Anatone, WA Gage	829.2	830.2	833.2	834.2
C	R09	Orofino, ID Gage	1010.2	1011.2	1012.7	1014.2
C	R09	Spalding, ID Gage	790.9	791.9	792.9	793.3
D	R02	Bonneville Pool	Simulations do not exceed normal full pool level of 77 ft (NGVD29) under any alternative			
D	R03	The Dalles Pool	Simulations do not exceed normal full pool level of 160 ft (NGVD29) under any alternative			
D	R04	John Day Pool	Simulations do not exceed normal full pool level of 268 ft (NGVD29) under any alternative			
D	R05	McNary Pool	Simulations do not exceed normal full pool level of 340 ft (NGVD29) under any alternative			
D	R01	Vancouver, WA	20.1	21.1	25.1	30.1
D	R01	St. Helens, OR	18.7	19.7	22.2	25.2
D	R01	Woodland, WA	22	24	– [2/]	28
D	R01	Kelso, WA	19.5	21.5	24.5	26.5
D	R01	Longview, WA	15	16.5	18	21
D	R01	Wauna, OR	13	13.5	– [2/]	14.5

[1/] Flow thresholds are in thousands of cfs (kcfs).

Note: Vertical datum for stages was adjusted to NAVD88 from NWS datum (typically NGVD29) where applicable using National Geodetic Survey conversion factors.

Source:

3 (A) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=alfw1
4 (A) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=plnm8
2 (A) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=cfmm8
1 (A) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=bfei1
5 (B) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=prdw1
8 (C) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=anaw1
7 (C) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=orfi1
6 (C) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=spdi1
9 (D) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=vapw1
10 (D) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=shno3
11 (D) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=lrww1

13 (D) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=kelw1
12 (D) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=lopw1
14 (D) https://water.weather.gov/ahps2/hydrograph.php?wfo=otx&gage=wauo3

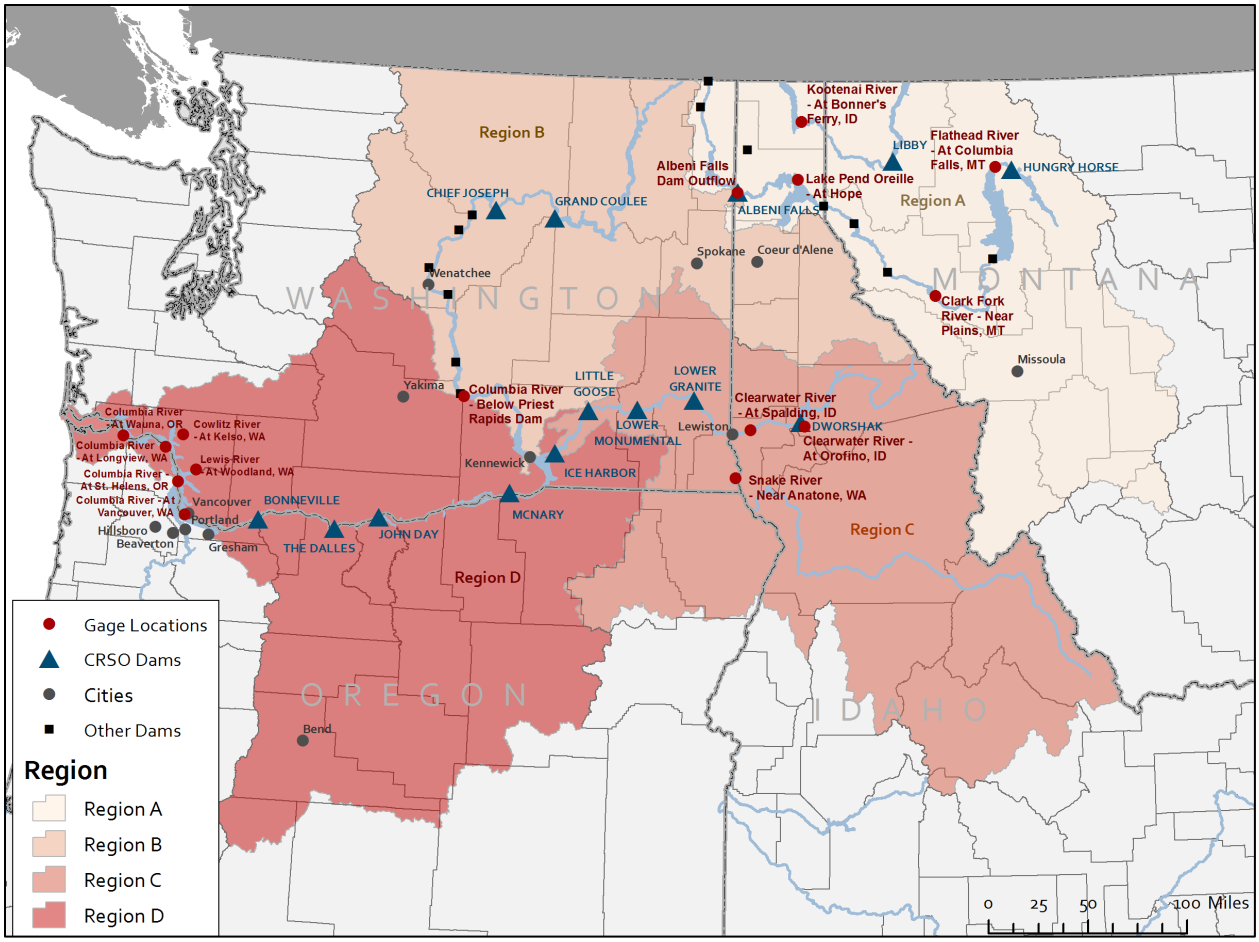

Figure 1-1. Gage Locations Used in this Analysis

Note: The gage locations on the above map as well as historical stage/flow and flood hazard category threshold data used in this assessment are taken from the National Weather Service Advanced Hydrologic Prediction Service at https://water.weather.gov/ahps/.

1.3 EVALUATING ANNUAL EXCEEDANCE PROBABILITY FOR FLOOD HAZARDS

For each gage location used in this analysis, flood risk is defined by determining the AEP from the H&H analysis that corresponds to the various NWS stage or flow thresholds for that location. The H&H analysis includes a rule-based reservoir operations model of the Columbia River basin and a flow-stage transformation tool, and a product of the analysis is annual and seasonal peak stage and flow frequency statistics throughout the basin. These modeling tools are described in detail in the Appendix A. AEPs were identified at each gage location for four flood hazard categories (action stage, flood stage, moderate stage, and major stage) for the No Action Alternative and each CRSO alternative. The differences between AEP in each of the CRSO alternatives and the No Action Alternative were the metric used to evaluate changes in flood risk.

The results of this flood risk analysis are shown in tables in the following section. The sections are divided by alternative first, then by region. The tables for the No Action Alternative contain the AEP results for each flood hazard stage category at each of the gage locations. The tables for the Action Alternatives present the changes in AEP, which are calculated as the difference in AEP from the No Action Alternative to a given alternative.

The accuracy of AEP results from the H & H model is uncertain for very rare flooding conditions, defined in this analysis as less than 1 percent AEP. Similarly, changes in AEP at a given location and stage are assumed to be accurate at approximately 1 percent (due to modeling challenges), thus change values are reported to the whole percent Additional notes on AEP results, such as limitations of use and model anomalies, are included in the footnotes associated with the results tables presented in the following section and discussed in greater detail in Appendix A, Part 1 - H&H Data Analysis.

1.4 NO ACTION ALTERNATIVE

The detailed AEP results for each flood hazard category under the No Action Alternative are identified by region and by gage location in the following sections.

1.4.1 Region A

Region A includes four gage locations: Pend Oreille River Outflow from Below Albeni Falls, Clark Fork Near Plains, MT, Columbia Falls, MT, and Bonner's Ferry, ID. The AEP's for each consequence threshold for each gage under the No Action Alternative are summarized in Table 1-2. As shown, the Pend Oreille River outflow from below Albeni Falls gage is anticipated to have the highest probability of exceeding the moderate and major flooding thresholds, relative to the other locations shown in the table. Communities near this gage on reach R24 include Clark Fork, Dover, Hope, East Hope, Kootenai, Ponderay, Priest River, and Sandpoint, Idaho. The areas around the Columbia Falls, Montana, gage have a high probability of exceeding flood stage, relative to the other locations in the table. Communities around the Columbia Falls, Montana, gage include Kalispell, Montana, and surrounding towns. These comparisons are not intended to quantify the differences in risk across regions, but rather to orient the reader to the table and the probabilities contained therein.

Table 1-2. Flood Risk Annual Exceedance Probabilities under the No Action Alternative in Region A, by Hazard Category

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
3 (A)	Pend Oreille River Outflow from Albeni Falls*	50%	34%	9%	6%
4 (A)	Clark Fork Near Plains, MT	12%	5%	<1%	<1%
2 (A)	Columbia Falls, MT Gage	83%	73%	<1%	<1%
1 (A)	Bonner's Ferry, ID Gage	85%	<1%	<1%	<1%

Note: Modeled estimates are rounded to the nearest whole percentage. *Measured in flow.

1.4.2 Region B

Region B includes one gage locations: the gage called "Below Priest's Rapids." The AEP's for each consequence threshold for this gage under the No Action Alternative are summarized in Table 1-3. As shown, AEP is less than 1 percent for all thresholds at this gage under the No Action Alternative. As noted in Table 1-1, there are no changes in AEP above Priest Rapids Dam. This does not mean those elevations cannot be exceeded, however these areas were not affected in any CRSO alternative (either No Action or the action alternatives

Table 1-3. Flood Risk Annual Exceedance Probabilities under the No Action Alternative in Region B, by Hazard Category

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
5 (B)	Below Priest Rapids, WA Gage	<1%	<1%	<1%	<1%

Note: Modeled estimates are rounded to the nearest whole percentage.

1.4.3 Region C

Region C includes three gage locations: Anatone, WA; Orofino, ID, and Spalding, ID. The AEP's for each consequence threshold for each gage under the No Action Alternative are summarized in Table 1-4. As shown, the Spalding gage on the Clearwater River exhibits the highest AEP at moderate and major flood stages under the No Action Alternative. As noted in Table 1-1, there are no changes in AEP in reaches R06, R07, and R08. This does not mean those elevations cannot be exceeded, however there are no changes related to CRSO EIS that have the potential to affect AEP in these reaches.

Table 1-4. Flood Risk Annual Exceedance Probabilities under the No Action Alternative in Region C, by Hazard Category

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
8 (C)	Anatone, WA Gage	28%	14%	2%	2%
7 (C)	Orofino, ID Gage	20%	13%	3%	<1%
6 (C)	Spalding, ID Gage	57%	41%	28%	23%

Note: Modeled estimates are rounded to the nearest whole percentage.

1.4.4 Region D

Region D includes six gage locations: Vancouver, WA; St. Helens, OR; Woodland, WA; Kelso, WA; Longview, WA; and Wauna, OR. The flood risk AEP's for each flood stage for this gage under the No Action Alternative are summarized in Table 1-5.

The AEP for winter and spring events are shown separately for consequence locations in Region D. Winter events are those modeled to occur from November 1 and March 31, while spring events are those occurring from April 1 to July 31. Winter high-water events are commonly the result of extended periods of precipitation producing historically higher stages but for a lesser

duration than spring events. Spring high-water events typically have a longer duration as late-season lower elevation snow is followed by heavy rain. As shown, the gages at Vancouver, Washington, and St. Helens, Oregon, exhibit the highest AEP at moderate and major flood stages under the No Action Alternative.

Table 1-5. Flood Risk Annual Exceedance Probabilities under the No Action Alternative in Region D, by Hazard Category

Region	Gage Location	Season	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
9 (D)	Vancouver, WA	Annual	43%	32%	11%	3%
9 (D)	Vancouver, WA	Winter	38%	28%	10%	3%
9 (D)	Vancouver, WA	Spring	22%	14%	2%	<1%
10 (D)	St. Helens, OR	Annual	26%	16%	11%	6%
10 (D)	St. Helens, OR	Winter	23%	14%	10%	5%
10 (D)	St. Helens, OR	Spring	9%	6%	1%	<1%
11 (D)	Woodland, WA	Annual	45%	32%	-	12%
11 (D)	Woodland, WA	Winter	45%	32%	-	12%
11 (D)	Woodland, WA	Spring	3%	<1%	-	<1%
13 (D)	Kelso, WA	Annual	53%	19%	7%	6%
13 (D)	Kelso, WA	Winter	49%	17%	6%	5%
13 (D)	Kelso, WA	Spring	11%	2%	1%	<1%
12 (D)	Longview, WA	Annual	24%	12%	8%	3%
12 (D)	Longview, WA	Winter	22%	12%	8%	3%
12 (D)	Longview, WA	Spring	9%	2%	<1%	<1%
14 (D)	Wauna, OR	Annual	4%	3%	-	3%
14 (D)	Wauna, OR	Winter	3%	%	-	3%
14 (D)	Wauna, OR	Spring	<1%	0%	-	0%

Note: Modeled estimates are rounded to the nearest whole percentage.
Sources: National Weather Service Hydrograph Data and H&H analysis.

1.5 MULTIPLE OBJECTIVE ALTERNATIVE 1

This section describes changes in flood risk that would be anticipated under MO1, as measured in terms of changes in AEP.

1.5.1 Region A

Table 1-6 presents the anticipated changes in AEP that would occur under MO1 at gage locations in Region A. Under typical to lower annual peak flow conditions, AEP would be anticipated to decrease under this alternative. In particular, the AEP at Bonners Ferry, Idaho, would decrease by 6 percent under MO1 at the action stage. This would be caused by a variety of operational measures at Libby Dam that would result in deeper drafts earlier in the spring, including the *Modified Draft at Libby* measure. Because this decrease occurs at the Action Stage, which does not result in flood consequences, but is rather an indication that flood

monitoring would occur, it has a negligible effect on flood risk. The Canadian Border is downstream of Bonners Ferry. No effect to Canada is anticipated under MO1.

On the Flathead River below Hungry Horse Dam, operational changes related to *Hungry Horse Additional Water Supply* measure result in slightly decreased AEP at Columbia Falls, Montana, at the action and flood stage levels (of 1 to 2 percent) but negligible changes in probability at the larger flood stages leading to no effect on flood risk conditions. Because the 7% AEP decrease occurs at the action stage, which does not result in flood consequences, it has a negligible effect on flood risk.

Related to the change at Hungry Horse, some minor decreases in AEP (1 to 2 percent) would be evident in the action and moderate flood stages on the Pend Oreille River outflow from below Albeni Falls. There would not be changes in flood risk at the Clark Fork gage near Plains, Montana.

Table 1-6. Changes in Flood Risk Annual Exceedance Probabilities under MO1 in Region A

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
3 (A)	Pend Oreille River Outflow from Albeni Falls	-1%	-1%	No change	No change
4 (A)	Clark Fork Near Plains, MT	No change	No change	No change	No change
2 (A)	Columbia Falls, MT Gage	-1%	-2%	No change	No change
1 (A)	Bonner's Ferry, ID Gage	-6%	No change	No change	No change

1.5.2 Region B

Table 1-7 presents the anticipated changes in AEP that would occur under MO1 at gage locations in Region B. As noted in Table 1-1, there are no changes in AEP above Priest Rapids Dam. This does not mean those elevations cannot be exceeded, however these areas were not affected in any CRSO alternative (either No Action or the action alternatives). No changes to flood risk are anticipated in Region B under MO1.

Table 1-7. Changes in Flood Risk Annual Exceedance Probabilities under MO1 in Region B

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
5 (B)	Below Priest Rapids, WA Gage	No change	No change	No change	No change

Note: Modeled estimates are rounded to the nearest whole percentage.

1.5.3 Region C

Table 1-8 presents the anticipated changes in AEP that would occur under MO1 at gage locations in Region C. As noted in Table 1-1, there are no changes in AEP in reaches R06, R07, and R08. This does not mean those elevations cannot be exceeded, however there are no changes related to CRSO EIS that have the potential to affect AEP in these reaches. No changes to flood risk are anticipated in Region C under MO1.

Table 1-8. Changes in Flood Risk Annual Exceedance Probabilities under MO1 in Region C[1/]

Region	Consequence Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
8 (C)	Anatone, WA Gage	No change	No change	No change	No change
7 (C)	Orofino, ID Gage	No change	No change	No change	No change
6 (C)	Spalding, ID Gage[1/]	No change	No change	No change	No change

Note: [1/] Estimated using comparable flow metrics.

1.5.4 Region D

Table 1-9 presents the anticipated changes in in AEP that would occur under MO1 at gage locations in Region D.

Under MO1, it is anticipated that there are minor decreases in AEP in Region D. In particular, there are negligible changes at the action stages and minor decreases at higher flood stages. Where changes occur, the modeling results suggest minor increases at the action stage, and minor decreases at flood stage. There are small increases at the action stage. Because this increase occurs at the Action Stage, which does not result in flood consequences, it has a negligible effect on flood risk.[1] Due to the *Winter System FRM Space* measure at Grand Coulee Dam, which would result in more storage in December and January in order to reduce Columbia River flows coincident with peak flood conditions in the Portland/Vancouver area in reach R01, winter and annual AEPs would be 1 to 4 percent lower for larger flood conditions near the mainstem Columbia River. The Vancouver, Washington, gage shows a decrease in AEP at the action and flood stages of 1 to 2 percent. Similar decreases are seen downstream at the St. Helens, Oregon, and Longview, Washington, gages. Changes in flood risk at the Woodland and Kelso, Washington, gages would be similar to but likely smaller than those on the mainstem Columbia River downstream.[2]

Table 1-9. Changes in Flood Risk Annual Exceedance Probabilities under MO1 in Region D

Region	Consequence Location	Season	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
9 (D)	Vancouver, WA	Annual	1%	-1%	No change	No change
9 (D)	Vancouver, WA	Winter	-2%	-1%	No change	No change
9 (D)	Vancouver, WA	Spring	-1%	-1%	No change	No change
10 (D)	St. Helens, OR	Annual	-1%	-1%	No change	-1%
10 (D)	St. Helens, OR	Winter	-1%	-2%	No change	No change
10 (D)	St. Helens, OR	Spring	No change	No change	No change	No change
11 (D)	Woodland, WA	Annual	1%	-1%	No change	No change
11 (D)	Woodland, WA	Winter	1%	-1%	No change	No change

[1] Personal communication with A. Marshall, Reservoir Regulation Team Lead Operations Manager for Northwest Division Columbia Basin Water Management, February 2020.

[2] AEP calculated at the Woodland and Kelso gages includes some model anomalies and should not be used directly. Stage on these relatively steep reaches is sensitive to changes in the downstream water level, and changes in AEP water levels can be more reflective of the random variable of event timing and peak coincidence than actual expected changes in mainstem Columbia River flows.

Region	Consequence Location	Season	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
11 (D)	Woodland, WA	Spring	No change	No change	No change	No change
13 (D)	Kelso, WA	Annual	No change	-3%	-1%	-2%
13 (D)	Kelso, WA	Winter	-2%	-4%	-1%	-1%
13 (D)	Kelso, WA	Spring	No change	No change	No change	No change
12 (D)	Longview, WA	Annual	-2%	-1%	No change	No change
12 (D)	Longview, WA	Winter	-3%	-2%	-1%	No change
12 (D)	Longview, WA	Spring	No change	No change	No change	No change
14 (D)	Wauna, OR	Annual	1%	No change	No change	No change
14 (D)	Wauna, OR	Winter	1%	No change	No change	No change
14 (D)	Wauna, OR	Spring	No change	No change	No change	No change

Note: A decrease in AEP means that a decrease in flood risk is expected, while an increase in AEP means that an increase in flood risk is expected when compared to the No Action Alternative. Modeled estimates are rounded to the nearest whole percentage. AEP calculated at the Woodland and Kelso gages includes reflect some model anomalies and should not be used directly. Stage on these relatively steep reaches are sensitive to changes in the downstream water level, and changes in AEP water levels can be more reflective of the random variable of event timing and peak coincidence than actual expected changes in mainstem Columbia flows

1.6 MULTIPLE OBJECTIVE ALTERNATIVE 2

This section describes changes in flood risk, as measured in terms of changes in AEP, for MO2.

1.6.1 Region A

Table 1-10 presents the anticipated changes in AEP that would occur under MO2 at gage locations in Region A. Overall, there would be little change to flood risk anticipated under MO2 in Region A. Changes in flood risk in the Kootenai River Basin under MO2 would be similar to those under MO1. Note, H&H model output shows minor increases in peak flows at Columbia Falls, MT; however, these changes are a modeling artifact related to modeled refill logic in the ResSim model made during the simulations of the *Deeper Drafts for Hydropower* measure under MO2. As such, flood risk is not anticipated to change at this gage. In fact, any changes, should any occur, would be expected to decrease at Columbia Falls, MT as a result of Hungry Horse reservoir being drafted deeper during the spring months.

At the Bonners Ferry, Idaho, gage, negligible changes would be expected at flood stages, and there would be a 7 percent decrease in AEP at the action stage primarily due to the *Modified Draft at Libby* measure. Because this decrease occurs at the Action Stage, which does not result in flood consequences, it has a negligible effect on flood risk, however it could reduce the number of instances where flood risk monitoring is required. There would not be anticipated changes in flood risk in the Flathead and Pend Oreille River Basins under MO2.[3] No effect to Canada is anticipated downstream of Bonners Ferry under MO2.

[3] H&H model output shows increased peak flows; however, these changes are a modeling artifact related to modeled refill logic in the ResSim model made during the simulations of the *Slightly Deeper Draft for Hydropower*

Table 1-10. Changes in Flood Risk Annual Exceedance Probabilities under MO2 in Region A

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
3 (A)	Pend Oreille River Outflow from Albeni Falls[1/]	-1%	No change	No change	No change
4 (A)	Clark Fork Near Plains, MT	No change	No change	No change	No change
2 (A)	Columbia Falls, MT Gage[2]	3%	7%	No change	No change
1 (A)	Bonner's Ferry, ID Gage	-7%	No change	No change	No change

Note: A decrease in AEP means that a decrease in flood risk is expected, while an increase in AEP means that an increase in flood risk is expected when compared to the No Action Alternative. Modeled estimates are rounded to the nearest whole percentage.

[1/] Measured in flow.

[2/] H&H model output shows increased peak flows; however, these changes are a modeling artifact related to modeled refill logic in the ResSim model made during the simulations of the Deeper Drafts for Hydropower measure. If any change, flood risk would be expected to be lower due to typically being drafted deeper in the Hungry Horse reservoir during the spring months.

1.6.2 Region B

Table 1-11 presents the anticipated changes in AEP that would occur under MO2 at gage locations in Region B. As noted in Table 1-1, there are no changes in AEP above Priest Rapids Dam. This does not mean those elevations cannot be exceeded, however there are no changes related to CRSO EIS that have the potential to affect AEP in these reaches. No changes to flood risk are anticipated in Region B under MO2.

Table 1-11. Changes in Flood Risk Annual Exceedance Probabilities under MO2 in Region B

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
5 (B)	Below Priest Rapids, WA Gage	No change	No change	No change	No change

Note: A decrease in AEP means that a decrease in flood risk is expected, while an increase in AEP means that an increase in flood risk is expected when compared to the No Action Alternative. Modeled estimates are rounded to the nearest whole percentage.

1.6.3 Region C

Table 1-12 presents the anticipated changes in AEP that would occur under MO2 at gage locations in Region C. Some minor changes in AEP would be anticipated under MO2 in Region C at the Orofino, ID gage, with minor decreases at major and minor flood stages and minor increases at the action (lowest) stage. Because the increase occurs at the Action Stage, which does not result in flood consequences, it has a negligible effect on flood risk. *The storage projects may be drafted slightly deeper for hydropower* measure would result in increased outflow from Dworshak and higher peak flows during typical, non-flood years. As noted in Table 1-1, there are no changes in AEP in reaches R06, R07, and R08. This does not mean those

measure. If any change, flood risk would be expected to be lower due to typically being drafted deeper in the Hungry Horse Reservoir during the spring months.

elevations cannot be exceeded, however there are no changes related to CRSO EIS that have the potential to affect AEP in these reaches.

Table 1-12. Changes in Flood Risk Annual Exceedance Probabilities under MO2 in Region C[1/]

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
8 (C)	Anatone, WA Gage	No change	No change	No change	No change
7 (C)	Orofino, ID Gage	1%	0	-1%	-1%
6 (C)	Spalding, ID Gage[2/]	No change	No change	No change	No change

[1/] A decrease in AEP means that a decrease in flood risk is expected. Modeled estimates are rounded to the nearest whole percentage.

[2/] Estimated using comparable flow metrics.

1.6.4 Region D

There would be little change to flood risk in Region D under MO2. Changes in flood risk in Region D under MO2 are anticipated to be similar to those under MO1, largely due to the *Winter System FRM Space* measure at Grand Coulee Dam. This measure would result in more storage in December and January in order to reduce Columbia River flows coincident with peak flood conditions in the Portland/Vancouver area in reach R01. As a result, winter and annual AEPs would be 1 to 4 percent lower for larger flood conditions near the mainstem Columbia River. The Vancouver, Washington, gage shows a decrease in AEP at the action and flood stages of 1 to 2 percent, and negligible changes at the moderate and major flood stages. Similar changes would occur downstream at the St. Helens, Oregon, and Longview, Washington, gages. Changes in flood risk at the Woodland and Kelso, Washington, gages would be similar to but likely smaller than those on the mainstem Columbia River.[4] There are small increases at the action stage. Because this increase occurs at the Action Stage, which does not result in flood consequences, it has a negligible effect on flood risk. The model is showing some small increase at the flood stage on the order of 1% point. Based on professional judgment, this small increase can be attributed to an artifact of the modeling process, which relies on a daily timestep computation of flows. In real time operations, which occur on an hourly basis, it is unlikely any increase in AEP would occur at these locations as a result of the action alternative.[5]

Table 1-13 presents the anticipated changes in AEP that would occur under MO1 at gage locations in Region D.

[4] AEP calculated at the Woodland and Kelso gages reflects some model anomalies. Stage on these relatively steep reaches is sensitive to changes in the downstream water level. Given this, changes in water levels and associated AEP changes may be more reflective of the random variable of event timing and peak coincidence than actual expected changes in mainstem Columbia River flows.

[5] Personal communication with A. Marshall, Reservoir Regulation Team Lead Operations Manager for Northwest Division Columbia Basin Water Management, February 2020.

Table 1-13. Changes in Flood Risk Annual Exceedance Probabilities under MO2 in Region D

Region	Gage Location	Season	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
9 (D)	Vancouver, WA	Annual	-1%	-1%	No change	No change
9 (D)	Vancouver, WA	Winter	-1%	No change	No change	No change
9 (D)	Vancouver, WA	Spring	No change	-1%	No change	No change
10 (D)	St. Helens, OR	Annual	-1%	No change	-1%	-1%
10 (D)	St. Helens, OR	Winter	-1%	No change	No change	No change
10 (D)	St. Helens, OR	Spring	No change	1%	No change	No change
11 (D)	Woodland, WA	Annual	2%	-1%	No change	No change
11 (D)	Woodland, WA	Winter	-1%	-1%	No change	No change
11 (D)	Woodland, WA	Spring	No change	No change	No change	No change
13 (D)	Kelso, WA	Annual	-2%	-3%	-3%	-3%
13 (D)	Kelso, WA	Winter	-1%	-4%	-3%	-2%
13 (D)	Kelso, WA	Spring	No change	No change	No change	No change
12 (D)	Longview, WA	Annual	-3%	-1%	-1%	No change
12 (D)	Longview, WA	Winter	-1%	-2%	-1%	No change
12 (D)	Longview, WA	Spring	No change	No change	No change	No change
14 (D)	Wauna, OR	Annual	1%	No change	No change	No change
14 (D)	Wauna, OR	Winter	No change	No change	No change	No change
14 (D)	Wauna, OR	Spring	No change	No change	No change	No change

Note: A decrease in AEP means that a decrease in flood risk is expected, while an increase in AEP means that an increase in flood risk is expected when compared to the No Action Alternative. Modeled estimates are rounded to the nearest whole percentage. AEP calculated at the Woodland and Kelso gages includes reflect some model anomalies and should not be used directly. Stage on these relatively steep reaches are sensitive to changes in the downstream water level, and changes in AEP water levels can be more reflective of the random variable of event timing and peak coincidence than actual expected changes in mainstem Columbia flows.

1.7 MULTIPLE OBJECTIVE ALTERNATIVE 3

1.7.1 Region A

Table 1-14 presents the anticipated changes in AEP that would occur under MO3 at gage locations in Region A. There is little change to flood risk anticipated under MO3. Additionally, under some flow conditions, flood risk would be anticipated to decrease in probability at some locations. In particular, the AEP at Bonners Ferry, Idaho, would decrease by 7 percent under MO3 at the action stage. Because this decrease occurs at the Action Stage, which does not result in flood consequences, it has a negligible effect on flood risk. AEP would be reduced by 1 percent at the action stage and 2 percent at the flood stage at Columbia Falls, Montana. No effect to Canada would be anticipated downstream of Bonners Ferry under MO3.

Table 1-14. Changes in Flood Risk Annual Exceedance Probabilities under MO3 in Region A

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
3 (A)	Pend Oreille River Outflow from Albeni Falls	No change	-1%	No change	No change
4 (A)	Clark Fork Near Plains, MT	No change	No change	No change	No change
2 (A)	Columbia Falls, MT Gage	-1%	-2%	No change	No change
1 (A)	Bonner's Ferry, ID Gage	-7%	No change	No change	No change

Note: A decrease in AEP means that a decrease in flood risk is expected, while an increase in AEP means that an increase in flood risk is expected when compared to the No Action Alternative. Modeled estimates are rounded to the nearest whole percentage.

[1/] Measured in flow.

1.7.2 Region B

Table 1-15 presents the anticipated changes in AEP that would occur under MO3 at gage locations in Region B. As noted in Table 1-1, there are no changes in AEP above Priest Rapids Dam. This does not mean those elevations cannot be exceeded, however these areas were not affected in any CRSO alternative (either No Action or the action alternatives). No changes to flood risk are anticipated in Region B under MO3.

Table 1-15. Changes in Flood Risk Annual Exceedance Probabilities under MO3 in Region B

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
5 (B)	Below Priest Rapids, WA Gage	No change	No change	No change	No change

Note: Modeled estimates are rounded to the nearest whole percentage.

1.7.3 Region C

Table 1-16 presents the anticipated changes in AEP that would occur under MO3 at gage locations in Region C. MO3 would generally reduce river stages from the draining of Lower Granite Reservoir and the breaching of the other lower Snake River dams. Overall, in Region C under MO3, no effect to flood risk is expected.[6]

Table 1-16. Changes in Flood Risk Annual Exceedance Probabilities under MO3 in Region C[1/]

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
8 (C)	Anatone, WA Gage	No change	No change	No change	No change
7 (C)	Orofino, ID Gage	No change	No change	No change	No change
6 (C)	Spalding, ID Gage[2/]	No change	No change	No change	No change

[1/] A decrease in AEP means that a decrease in flood risk is expected, while an increase in AEP means that an increase in flood risk is expected when compared to the No Action Alternative. Modeled estimates are rounded to the nearest whole percentage.

[2/] Estimated using comparable flow metrics.

[6] Dworshak has the same operational ruleset in the No Action Alternative as MO3, therefore, any changes in the modeling results are a modeling artifact likely related to system refill timing changes.

1.7.4 Region D

Table 1-17 presents the anticipated changes in AEP that would occur under MO3 at gage locations in Region D. There would be little change anticipated to flood risk in Region D under MO3. Due to the *Winter System FRM Space* measure at Grand Coulee Dam, which would result in more storage in December and January to reduce Columbia River flows coincident with peak flood conditions in the Portland/Vancouver area in reach R01, winter and annual AEPs would be lower for larger flood conditions near the mainstem Columbia River. Under flow conditions at some locations, AEP would decrease in probability by 1 to 2 percent. There are small increases at the action stage. Because this increase occurs at the Action Stage, which does not result in flood consequences, it has a negligible effect on flood risk. The model is showing some small increase at the flood stage on the order of 1% point. Based on professional judgment, this small increase can be attributed to an artifact of the modeling process, which relies on a daily timestep computation of flows. In real time operations, which occur on an hourly basis, it is unlikely any increase in AEP would occur at these locations as a result of the action alternative.[7]

Table 1-17. Changes in Flood Risk Annual Exceedance Probabilities under MO3 in Region D

Region	Gage Location	Season	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
9 (D)	Vancouver, WA	Annual	-1%	No change	No change	No change
9 (D)	Vancouver, WA	Winter	-3%	No change	No change	No change
9 (D)	Vancouver, WA	Spring	-1%	-1%	No change	No change
10 (D)	St. Helens, OR	Annual	-1%	1%	No change	-1%
10 (D)	St. Helens, OR	Winter	-1%	1%	No change	No change
10 (D)	St. Helens, OR	Spring	No change	No change	No change	No change
11 (D)	Woodland, WA	Annual	-1%	No change	No change	No change
11 (D)	Woodland, WA	Winter	-1%	No change	No change	No change
11 (D)	Woodland, WA	Spring	No change	No change	No change	No change
13 (D)	Kelso, WA	Annual	No change	-2%	-2%	-2%
13 (D)	Kelso, WA	Winter	-1%	-2%	-1%	-1%
13 (D)	Kelso, WA	Spring	1%	No change	No change	No change
12 (D)	Longview, WA	Annual	No change	No change	No change	No change
12 (D)	Longview, WA	Winter	-2%	No change	No change	No change
12 (D)	Longview, WA	Spring	No change	No change	No change	No change
14 (D)	Wauna, OR	Annual	No change	No change	No change	No change
14 (D)	Wauna, OR	Winter	1%	No change	No change	No change
14 (D)	Wauna, OR	Spring	No change	No change	No change	No change

Note: A decrease in AEP means that a decrease in flood risk is expected, while an increase in AEP means that an increase in flood risk is expected when compared to the No Action Alternative. Modeled estimates are rounded to the nearest whole percentage. AEP calculated at the Woodland and Kelso gages includes reflect some model anomalies and should not be used directly. Stage on these relatively steep reaches are sensitive to changes in the downstream water level, and changes in AEP water levels can be more reflective of the random variable of event timing and peak coincidence than actual expected changes in mainstem Columbia flows.

[7] Personal communication with A. Marshall, Reservoir Regulation Team Lead Operations Manager for Northwest Division Columbia Basin Water Management, February 2020.

1.8 MULTIPLE OBJECTIVE ALTERNATIVE 4

1.8.1 Region A

Table 1-18 presents the anticipated changes in AEP that would occur under MO4 at gage locations in Region A. There is little change anticipated to AEP in Region A under MO4. Additionally, under flow conditions at some locations, flood risk would decrease in probability. The AEP at Bonners Ferry, Idaho, is anticipated to decrease by 5 percent under MO4 at the action stage primarily due to the *Modified Draft at Libby* measure. Because this decrease occurs at the Action Stage, which does not result in flood consequences, it has a negligible effect on flood risk. The AEP at the flood stage is anticipated to decrease by 2 percent at the Columbia Falls, Montana, gage. No effect to Canada is anticipated downstream of Bonners Ferry under MO4. No change would be anticipated at the Pend Oreille River outflow from below Albeni Falls gage.

Table 1-18. Changes in Flood Risk Annual Exceedance Probabilities under MO4 in Region A

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
3 (A)	Pend Oreille River Outflow from Albeni Falls	No change	No change	No change	No change
4 (A)	Clark Fork Near Plains, MT	No change	No change	No change	No change
2 (A)	Columbia Falls, MT Gage	No change	-2%	No change	No change
1 (A)	Bonner's Ferry, ID Gage	-5%	No change	No change	No change

Note: A decrease in AEP means that a decrease in flood risk is expected, while an increase in AEP means that an increase in flood risk is expected when compared to the No Action Alternative. Modeled estimates are rounded to the nearest whole percentage.

1.8.2 Region B

Table 1-19 presents the anticipated changes in AEP that would occur under MO4 at gage locations in Region B. As noted in Table 1-1, there are no changes in AEP above Priest Rapids Dam. This does not mean those elevations cannot be exceeded, however these areas were not affected in any CRSO alternative (either No Action or the action alternatives). No changes to flood risk are anticipated in Region B under MO4.

Table 1-19. Changes in Flood Risk Annual Exceedance Probabilities under MO4 in Region B

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
5 (B)	Below Priest Rapids, WA Gage	No change	No change	No change	No change

Note: Modeled estimates are rounded to the nearest whole percentage.

1.8.3 Region C

Table 1-20 presents the anticipated changes in AEP that would occur under MO4 at gage locations in Region C. As noted in Table 1-1, there are no changes in AEP in reaches R06, R07, and R08. This does not mean those elevations cannot be exceeded, however these areas were

not affected in any CRSO alternative (either No Action or the action alternatives). No effect to flood risk is expected in Region C under MO4.

Table 1-20. Changes in Flood Risk Annual Exceedance Probabilities under MO4 in Region C[1/]

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
8 (C)	Anatone, WA Gage	No change	No change	No change	No change
7 (C)	Orofino, ID Gage	No change	No change	No change	No change
6 (C)	Spalding, ID Gage[2/]	No change	No change	No change	No change

[1/] A decrease in AEP means that a decrease in flood risk is expected, while an increase in AEP means that an increase in flood risk is expected when compared to the No Action Alternative. Modeled estimates are rounded to the nearest whole percentage.

[2/] Estimated using comparable flow metrics.

1.8.4 Region D

Table 1-21 presents the anticipated changes in AEP that would occur under MO4 at gage locations in Region D. There is little change anticipated to flood risk in Region D under MO4. Changes in flood risk in Region D under MO4 are anticipated to be similar to those under MO1, largely due to both alternatives including the *Winter System FRM Space* measure at Grand Coulee Dam. This measure results in more storage in December and January in order to reduce Columbia River flows coincident with peak flood conditions in the Portland/Vancouver area in reach R01. As a result, winter and annual AEPs are 1 to 4 percent lower for larger flood conditions near the mainstem Columbia River. The Vancouver, Washington, gage shows a decrease in AEP at the action and flood stages of 1 to 2 percent, and negligible changes at the moderate and major flood stages. Similar changes are seen downstream at the St. Helens, Oregon, and Longview, Washington, gages. Changes in AEP at the Woodland and Kelso, Washington, gages would be similar to but likely smaller than those on the mainstem Columbia River downstream.[8] The model is showing some small increase at the flood stage on the order of 1% point. Based on professional judgment, this small increase can be attributed to an artifact of the modeling process, which relies on a daily timestep computation of flows. In real time operations, which occur on an hourly basis, it is unlikely any increase in AEP would occur at these locations as a result of the action alternative

Table 1-21. Changes in Flood Risk Annual Exceedance Probabilities under MO4 in Region D

Region	Gage Location	Season	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
9 (D)	Vancouver, WA	Annual	-2%	-2%	No change	No change
9 (D)	Vancouver, WA	Winter	-1%	-1%	No change	No change
9 (D)	Vancouver, WA	Spring	-2%	-2%	No change	No change

[8] AEP calculated at the Woodland and Kelso gages reflects some model anomalies. Stage on these relatively steep reaches is sensitive to changes in the downstream water level. Given this, changes in water levels and associated AEP changes may be more reflective of the random variable of event timing and peak coincidence than actual expected changes in mainstem Columbia River flows.

Region	Gage Location	Season	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
10 (D)	St. Helens, OR	Annual	-1%	-1%	No change	-1%
10 (D)	St. Helens, OR	Winter	-9%	-2%	No change	No change
10 (D)	St. Helens, OR	Spring	No change	No change	No change	No change
11 (D)	Woodland, WA	Annual	-1%	-1%	No change	No change
11 (D)	Woodland, WA	Winter	-13%	-1%	No change	No change
11 (D)	Woodland, WA	Spring	No change	No change	No change	No change
13 (D)	Kelso, WA	Annual	No change	-2%	-1%	-1%
13 (D)	Kelso, WA	Winter	-3%	-2%	-1%	-1%
13 (D)	Kelso, WA	Spring	No change	1%	No change	No change
12 (D)	Longview, WA	Annual	-2%	-1%	-1%	No change
12 (D)	Longview, WA	Winter	-1%	-2%	No change	No change
12 (D)	Longview, WA	Spring	-1%	No change	No change	No change
14 (D)	Wauna, OR	Annual	No change	No change	No change	No change
14 (D)	Wauna, OR	Winter	No change	No change	No change	No change
14 (D)	Wauna, OR	Spring	No change	No change	No change	No change

Note: A decrease in AEP means that a decrease in flood risk is expected, while an increase in AEP means that an increase in flood risk is expected when compared to the No Action Alternative. Modeled estimates are rounded to the nearest whole percentage. AEP calculated at the Woodland and Kelso gages includes reflect some model anomalies and should not be used directly. Stage on these relatively steep reaches are sensitive to changes in the downstream water level, and changes in AEP water levels can be more reflective of the random variable of event timing and peak coincidence than actual expected changes in mainstem Columbia flows.

1.9 PREFERRED ALTERNATIVE

1.9.1 Region A

Table 1-22 presents the anticipated changes in AEP that would occur under the Preferred Alternative at gage locations in Region A. Under typical to lower annual peak flow conditions, flood risk would be anticipated to decrease in probability under this alternative. In particular, the AEP at Bonners Ferry, Idaho, would decrease by 6 percent under MO1 at the action stage. This would be caused by a variety of operational measures at Libby Dam that would result in deeper drafts earlier in the spring, including the *Modified Draft at Libby* measure. Because this decrease occurs at the Action Stage, which does not result in flood consequences, it has a negligible effect on flood risk. There would be negligible changes to the probability of higher flood stage at the Bonners Ferry gage, thus no effect to flood risk conditions are expected. The Canadian Border is downstream of Bonners Ferry. No effect to Canada is anticipated under MO1.

Table 1-22. Changes in Flood Risk Annual Exceedance Probabilities under the Preferred Alternative in Region A

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
3 (A)	Pend Oreille River Outflow from Albeni Falls	No change	No change	No change	No change
4 (A)	Clark Fork Near Plains, MT	No change	No change	No change	No change
2 (A)	Columbia Falls, MT Gage	No change	No Change	No change	No change
1 (A)	Bonner's Ferry, ID Gage	-6%	No change	No change	No change

Note: A decrease in AEP means that a decrease in flood risk is expected, while an increase in AEP means that an increase in flood risk is expected when compared to the No Action Alternative. Modeled estimates are rounded to the nearest whole percentage.

1.9.2 Region B

Table 1-23 presents the anticipated changes in AEP that would occur under the Preferred Alternative at gage locations in Region B. As noted in Table 1-1, there are no changes in AEP above Priest Rapids Dam. This does not mean those elevations cannot be exceeded, however these areas were not affected in any CRSO alternative (either No Action or the action alternatives). No changes to flood risk are anticipated in Region B under the Preferred Alternative.

Table 1-23. Changes in Flood Risk Annual Exceedance Probabilities under the Preferred Alternative in Region B

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
5 (B)	Below Priest Rapids, WA Gage	No change	No change	No change	No change

Note: Modeled estimates are rounded to the nearest whole percentage.

1.9.3 Region C

Table 1-24 presents the anticipated changes in AEP that would occur under the Preferred Alternative at gage locations in Region C. Some changes in AEP would be anticipated under MO2 in Region C at the Spalding, ID gage, with minor decreases at the major flood stage and minor increases at the action (lowest) stage. Because the increase occurs at the Action Stage, which does not result in flood consequences, it has a negligible effect on flood risk. As noted in Table 1-1, there are no changes in AEP in reaches R06, R07, and R08. This does not mean those elevations cannot be exceeded, however these areas were not affected in any CRSO alternative (either No Action or the action alternatives).

Table 1-24. Changes in Flood Risk Annual Exceedance Probabilities under the Preferred Alternative in Region C[1/]

Region	Gage Location	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
8 (C)	Anatone, WA Gage	No change	No change	No change	No change
7 (C)	Orofino, ID Gage	No change	No change	No change	No change
6 (C)	Spalding, ID Gage[2/]	1%	No change	No change	-3%

[1/] A decrease in AEP means that a decrease in flood risk is expected, while an increase in AEP means that an increase in flood risk is expected when compared to the No Action Alternative. Modeled estimates are rounded to the nearest whole percentage.

[2/] Estimated using comparable flow metrics.

1.9.4 Region D

Table 1-25 presents the anticipated changes in AEP that would occur under the Preferred Alternative at gage locations in Region D. There is little change anticipated to flood risk in Region D under MO4. Changes in flood risk in Region D under MO4 are anticipated to be similar to those under MO1, largely due to both alternatives including the *Updated System FRM Space Calculation* measure at Grand Coulee Dam. This measure results in more storage in December and January in order to reduce Columbia River flows coincident with peak flood conditions in the Portland/Vancouver area in reach R01. As a result, winter and annual AEPs flows are 1 to 3 percent lower for larger flood conditions near the mainstem Columbia River. Downstream at the St. Helens, Oregon, and Longview, Washington, gages would experience decreases in AEP at those stages. Changes in AEP at the Woodland and Kelso, Washington, gages would be similar to but likely smaller than those on the mainstem Columbia River downstream.[9] There are small increases at the action stage. Because these increases occur at the Action Stage, which does not result in flood consequences, they have a negligible effect on flood risk. The model is showing some small increase at the flood stage on the order of 1% point. Based on professional judgment, this small increase can be attributed to an artifact of the modeling process, which relies on a daily timestep computation of flows. In real time operations, which occur on an hourly basis, it is unlikely any increase in AEP would occur at these locations as a result of the action alternative.

[9] AEP calculated at the Woodland and Kelso gages reflects some model anomalies. Stage on these relatively steep reaches is sensitive to changes in the downstream water level. Given this, changes in water levels and associated AEP changes may be more reflective of the random variable of event timing and peak coincidence than actual expected changes in mainstem Columbia River flows.

Table 1-25. Changes in Flood Risk Annual Exceedance Probabilities under the Preferred Alternative in Region D

Region	Gage Location	Season	Action Stage	Flood Stage	Moderate Flood Stage	Major Flood Stage
9 (D)	Vancouver, WA	Annual	1%	1%	No change	No change
9 (D)	Vancouver, WA	Winter	No Change	1%	No change	No change
9 (D)	Vancouver, WA	Spring	No Change	No Change	No change	No change
10 (D)	St. Helens, OR	Annual	No change	No change	No change	No change
10 (D)	St. Helens, OR	Winter	No Change	1%	No change	No change
10 (D)	St. Helens, OR	Spring	No change	No change	No change	No change
11 (D)	Woodland, WA	Annual	2%	No Change	No change	No change
11 (D)	Woodland, WA	Winter	2%	No Change	No change	No change
11 (D)	Woodland, WA	Spring	No change	No change	No change	No change
13 (D)	Kelso, WA	Annual	-3%	-1%	-2%	-1%
13 (D)	Kelso, WA	Winter	-3%	-1%	-1%	-1%
13 (D)	Kelso, WA	Spring	No change	No Change	No change	No change
12 (D)	Longview, WA	Annual	-1%	-1%	No Change	No change
12 (D)	Longview, WA	Winter	-1%	-2%	No change	No change
12 (D)	Longview, WA	Spring	-1%	No change	No change	No change
14 (D)	Wauna, OR	Annual	No change	No change	No change	No change
14 (D)	Wauna, OR	Winter	No change	No change	No change	No change
14 (D)	Wauna, OR	Spring	No change	No change	No change	No change

Note: A decrease in AEP means that a decrease in flood risk is expected, while an increase in AEP means that an increase in flood risk is expected when compared to the No Action Alternative. Modeled estimates are rounded to the nearest whole percentage. AEP calculated at the Woodland and Kelso gages includes reflect some model anomalies and should not be used directly. Stage on these relatively steep reaches are sensitive to changes in the downstream water level, and changes in AEP water levels can be more reflective of the random variable of event timing and peak coincidence than actual expected changes in mainstem Columbia flows.

CHAPTER 2 - REFERENCES

National Weather Service Hydrograph Data and H&H analysis.

Personal communication with A. Marshall, Reservoir Regulation Team Lead Operations Manager for Northwest Division Columbia Basin Water Management, February 2020.

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Draft Columbia River System Operations Environmental Impact Statement

Appendix L
Navigation and Transportation

CHAPTER 1 - INTRODUCTION

The purpose of this Navigation and Transportation Appendix is to provide supplemental information on the navigation and transportation analysis.

1.1 APPROACH FOR EVALUATING CONSEQUENCES TO NAVIGATION FROM THE CRSO

The conceptual flow chart shown in Figure 1-1 demonstrates, in a generalized manner, how the Columbia River System Operations (CRSO) Environmental Impact (EIS) alternatives may result in socioeconomic impacts to navigation and transportation industries. As shown, structural and operational changes resulting from CRSO EIS alternatives, including multi-objective alternatives (MOs) or preferred action alternative (PAA) may affect hydrology and hydraulics and river mechanics of the Columbia River and its tributaries. These changes in flow or channel depths may affect behavior of the navigation and transportation industries, which leads to changes in

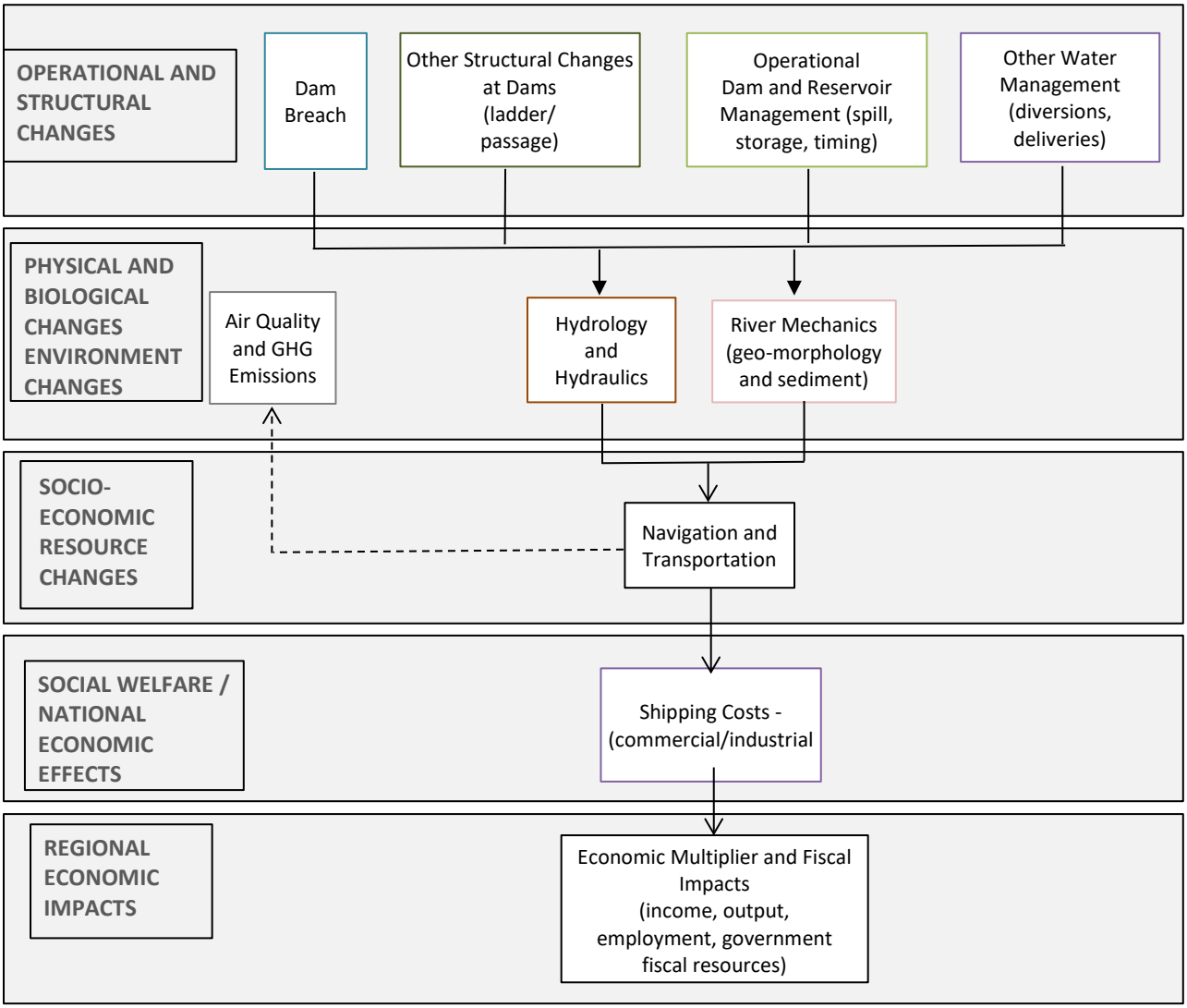


Figure 1-1. Flow Chart of Navigation Analysis

operational costs. These changes in Figure 1-1: Flow Chart of Navigation Analysis industry behaviors and associated operational costs may lead to regional economic changes, including changes in industry and consumer spending patterns, including impacts on employment. Other social effects (not shown in Figure 1-1) can result from all of these effects, including changes in air emissions, accident rates, as well as changes in community well-being, community cohesion, or other social effects.

The analysis assesses impacts of action alternatives associated with changes to commercial navigation, commercial cruise line operations, ferry operations, and related transportation systems (e.g. road and/or railway). Impacts to dredging activities are also described. The analysis begins by establishing the baseline conditions that would be anticipated under the No Action Alternative. For each activity, the analysis then assesses potential effects of CRSO EIS alternatives on social welfare (i.e. national economic development), regional economic spending patterns, as well as other social effects.

> Social welfare effects are changes to the economic value of the national output of goods and services. It includes producer surplus gained from commercial navigation activities, as well as the value, or the improved well-being, gleaned by tourists and recreationists associated with cruise line visits (referred to by economists as consumer surplus or net economic value). For this analysis, changes in the benefits of commercial navigation activities are measured in terms of the transportation rate savings, which are equivalent to the change in transportation costs in this case.
>
> Regional economic effects are changes in the distribution of regional economic activity (e.g., income and jobs), which is affected by changes in expenditures. Because the pattern of freight transportation may change in the Columbia River Basin under different management alternatives, so too might the distribution of regional economic activity. Other regional effects may be associated with changes in cruise line or ferry operations.
>
> Other social effects are community and social effects that are relevant to various CRSO alternatives, but are not addressed under social welfare or regional economic effects. If commercial navigation freight is moved to other transportation modes, impacts to air emissions as well as accident rates can result. Other impacts may include impacts to community well-being, identity and cohesion. The Tribal Perspectives and Cultural Resources sections provide additional information about ongoing effects as well unique effects of Action alternatives on tribal ceremonial activities, subsistence activities, and other cultural practices.

This appendix focuses on describing approaches used to develop the social welfare effects analysis for commercial navigation activities. Additional analysis of related industries, as well as the regional economic analysis and other social effects analysis is described in section 3.10 of the CRSO EIS. This appendix also briefly summarizes all of the effects of the No Action Alternative and the MOs in a summary section at for each MO and for the Preferred Alternative.

1.2 MODELING TECHNIQUES

In this report, commercial navigation and transportation systems refers to movements of cargo by waterway, road, or rail within the CRSO region. Impacts to these cargo movements were assessed using two models, the Snake Columbia Economic Navigation Tool (SCENT) and the Transportation Optimization Model (TOM). While the SCENT calculates changes in transportation costs attributable to operational measures, or changes in flows and/or navigation channel depths on the commercially navigable portions of the Columbia and Snake Rivers, the TOM assesses the impact to transportation system under a dam breach scenario where navigation on the LSR is eliminated. The SCENT was used to evaluate operations-based impacts for all alternatives (MO1, MO2, MO3, and MO4). The TOM was only used to analyze the impacts from MO3. Both models are discussed in this appendix.

CHAPTER 2 - SCENT - MODELING IMPACTS THAT MAKE CHANGES TO RIVER FLOW AND TIMING

2.1 OVERVIEW

Social welfare, or national economic development (NED) benefits are realized through the reduction in transportation costs associated with a waterway transportation system, therefore the difference in costs between water transportation and the next least costly transportation alternative are the benefits of inland waterway system. Therefore, to measure how the benefits of the Columbia Snake Navigation System (CSNS) change in response to the CRSO alternatives, the SCENT calculates the additional transportation costs attributable to changes in flows on the commercially navigable portions of the Columbia and Snake Rivers. As shown in Figure 2-1, the SCENT calculates the additional cost from changes in river conditions using data on hydrological conditions, vessel costs, river operator behavior, and other data. These calculations are performed by the following three major components: 1) Hydraulic &Hydrology (H&H) Module; 2) Consequences Module; and 3) SCENT Combination Module. This section discusses the each of general approach used by the SCENT as well as the raw data, modules, and outputs of the model is discussed in this section.

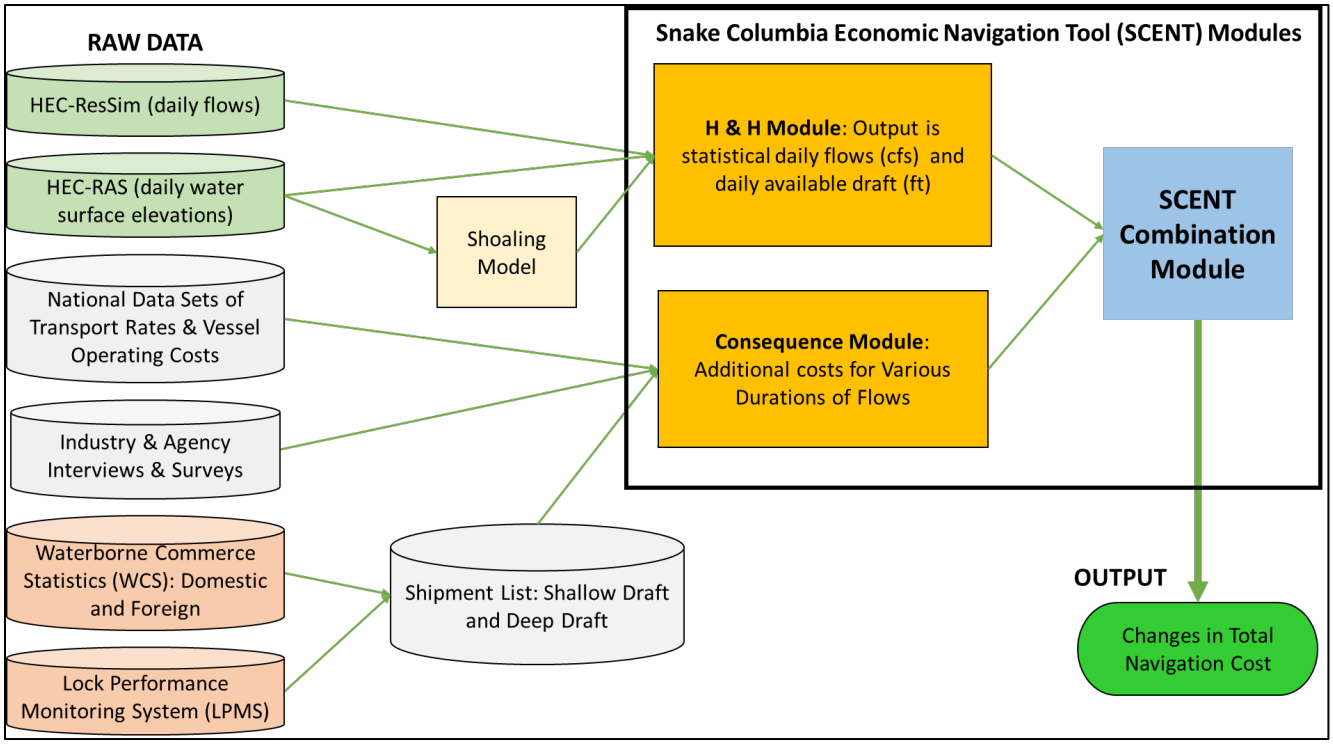


Figure 2-1. Flowchart of Snake Columbia Economic Navigation Tool Process

2.2 L.2.2 ASSUMPTIONS

The following assumptions were used in the SCENT model evaluation of impacts to navigation from CRSO-EIS alternatives (other than dam breaching under MO3):

The economic analysis uses data from the hydrologic and hydraulic (H&H) modeling of the river system. The analysis assumes that the H&H models reasonably estimate river flows and reservoir levels over the 50-year period of analysis under each of the CRSO-EIS alternatives as well as No Action Alternative).

The shipment list (i.e. commodity movements), modeled within SCENT are based on 2016 data, which was the most recent year of data availability at the time of modeling. Because there was a planned shutdown of the Snake River at the end of 2016 of a few weeks, the freight tonnage on the Snake River as well as on the overall on the CSNS was slightly lower in 2016 than other recent years (4 percent lower than the 10-year average, per Waterborne Statistics data, 2020).

The commodity movement assumptions remain the same for all simulations and years. This assumption was made due to the complexity and uncertainty in forecasting commercial river traffic over the period of analysis.

The SCENT assumes all shipments will move from their origin to their destination. If an alternative results in a flow or draft restriction that limits the normal movement, like a four-barge-tow being reduced down to a three-barge-tow, another movement will occur to get the remaining, single barge to its destination (which is captured as an increased transportation cost).

2.3 H&H MODULE

As shown in Figure 2, the H&H Module relies on two standard USACE H&H models to generate the inputs necessary for analyzing the shallow draft and deep draft impacts. To estimate the impacts from changes in flows, USACE HEC-Reservoir System Simulation (ResSim) model uses historical river data to generate 5,000 years of daily flows. Creating statistical distribution from the historical data allows for the SCENT to account for natural variation in hydrology and for the uncertainty in forecasts. An example output of the H&H Module, shown in Figure 2-2, is a table of flows by reach (Columbia River deep draft, Columbia River shallow draft, and Snake River Shallow Draft), by type (Low, Normal, High, Very High, or Too High), by duration in days, and by total number of occurrences for each quarter of every year.

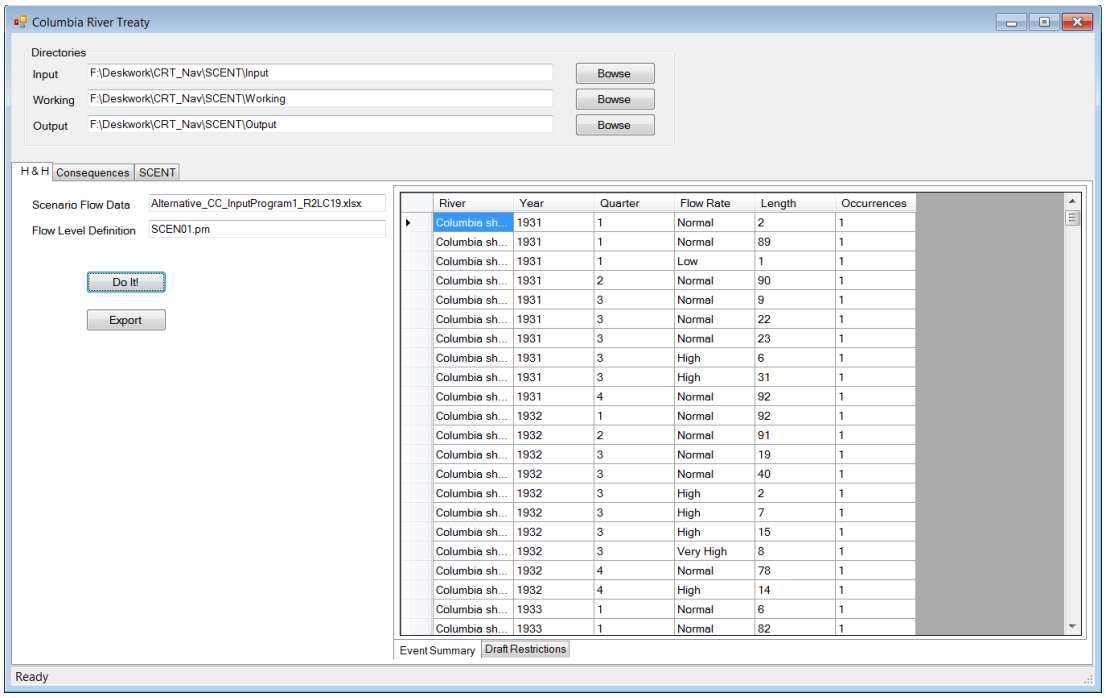


Figure 2-2. Output of H&H Module for Shallow Draft Traffic

As shown in Figure 2-3, the SCENT relies on the USACE HEC-RAS model and a shoaling model to analyze the impacts on changing draft depth on the Columbia River navigation channel. The HEC-RAS model estimates the daily water surface elevations in feet. The shoaling model combines the daily water surface elevations with depth curves to estimate the daily draft available draft for vessels traveling on the deep draft portion of the Columbia Snake. Figure 2-4 displays an example output of the H&H Module for the deep draft analysis.

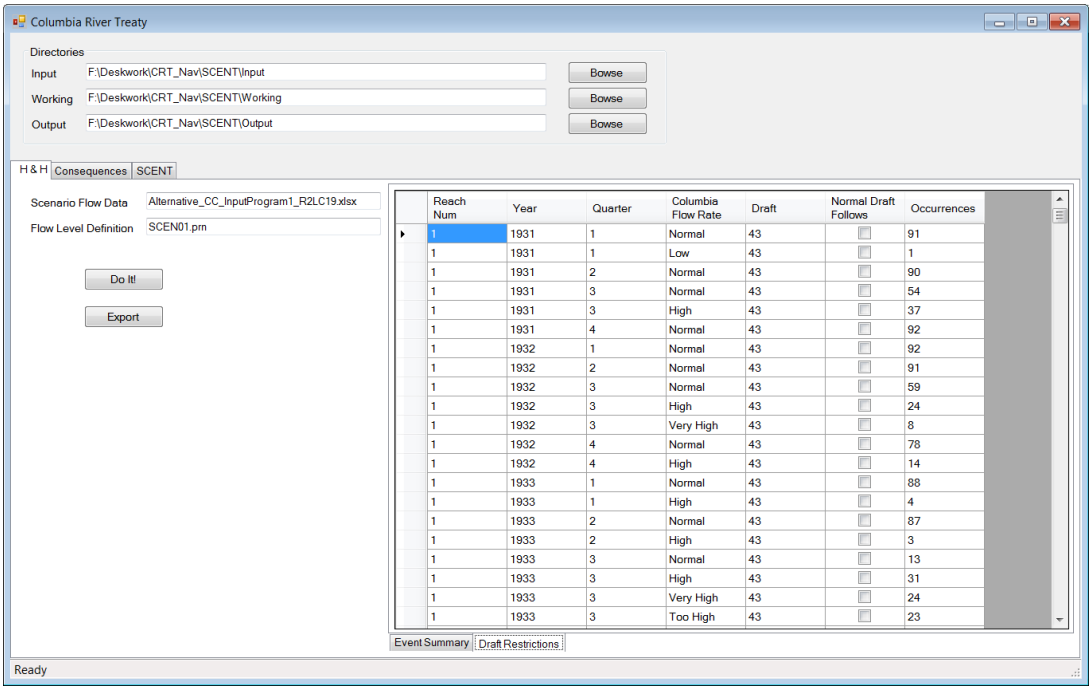


Figure 2-3. Output of H&H Module for Deep Draft Traffic

2.4 CONSEQUENCES MODULE

As shown in Figure 2-4, the Consequences Module combines the following data to estimate the change in costs for changing flow and draft conditions.

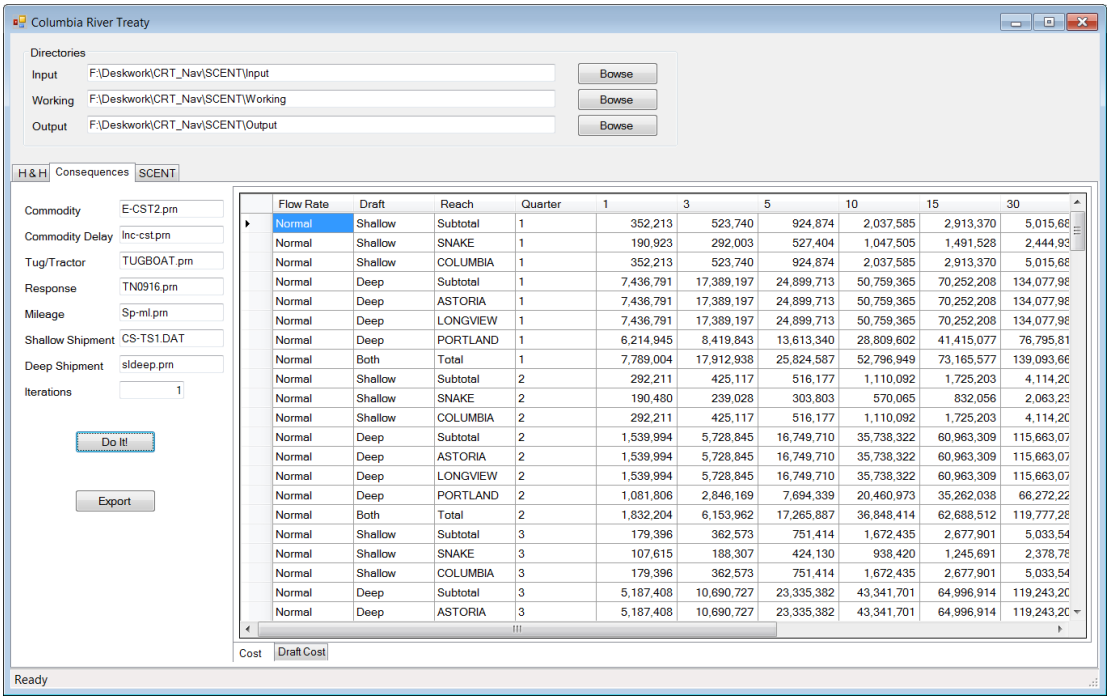


Figure 2-4. Consequence Module Output for Shallow Draft Analysis

National Data Set of Transportation Rates and Vessel Operating Costs – This is database maintained by the USACE Planning Center of Expertise for Inland Navigation and Risk-Informed Economics Division (PCXIN-RED). The PCXIN-RED built this database on vessel operating costs reports from USACE Institute for Water Resources entitled Shallow-Draft / Inland Vessel Operating Costs (2017) and Deep-Draft Vessel Operating Costs (2016). The costs within the database include the costs of loading, shipping, and unloading commodities, tugboat and tractor assistance costs, fuel costs, and other costs.

Industry & Agency Interviews & Surveys – Surveys of inland shippers, deep draft shippers, inland carriers, and ship assist companies (companies that provide tugs/towboats to assist large ships moving along the Lower Columbia) were conducted in the late summer of 2014 through the spring of 2015. The surveys gathered information on the characteristics that affect shippers operational decisions (i.e. flow, stage, depth and velocity), the thresholds associated with these characteristics, and the responses (i.e. change to barge and/or tow configuration, light loading, etc.). Table 2-1 summarizes flow thresholds that were identified based on the survey responses.

Table 2-1. Flow Range Categories for Commercial Navigation on the CSNS (kcfs)

Flow Category	Columbia Shallow/Deep	Snake Shallow
Normal	80-299	15-80
Low	0-79	0-14
High	300-399	80-120
Very High	400-499	120-180
Too High	>500	180-1000

Potential responses for shallow draft vessels include waiting for flows to return to normal, change the tow configuration, change the amount loaded into the barge or the number of barge trips required, or ship the cargo by rail or some other mode. For deep draft vessels, channel depth changes that cause draft restrictions affect operating costs by requiring light loading or other adjustments to account for limitations in channel depth. All of these responses and added costs were transformed into a disruption response matrix.

Shipment List: Shallow Draft and Deep Draft – The shipment list is a table of all shallow draft and deep draft commodity movements that occurred on the CSNS in 2016. This shipment list is assumed to remain constant for all simulations and years. This assumption was made due to the complexity and uncertainty in forecasting commercial river traffic over the period of analysis. As shown in Figure 2, the shipment list is derived from USACE Waterborne Commerce Statistics Center (WCSC) database and the USACE Lock Performance Monitoring System (LPMS). For domestic movements, the WCSC gathers data on the commodity shipped, the origin, the destination, and other information from operators moving on the CSNS. For international movements, the WCSC compiles a database from multiple sources including operators, the Port Import/Export Report Service (PIERS), Census Bureau, and US Customs and Border Protection. The USACE LPMS database records information such as the towboat identification number, the number and draft of barges in the tow, the direction of the movement, the arrival and lockage time, and other similar information, but it does not include origin and destination information. Combining the WCSC and LPMS data provides the SCENT with shipment lists showing the

number and type of vessels carrying each commodity, the miles traveled for each vessel, the number of locks transited for each vessel, and the origin and destination for each model.

The Consequence Module uses shipper reactions to changes in flows, miles traveled and locks transited for each movement, and other information to calculate the increased costs to commercial navigation activities when compared with normal flow conditions. Figure 2-5 and Figure 2-6 below shows a portion of the consequence model output file that is used in the SCENT Combination Module.

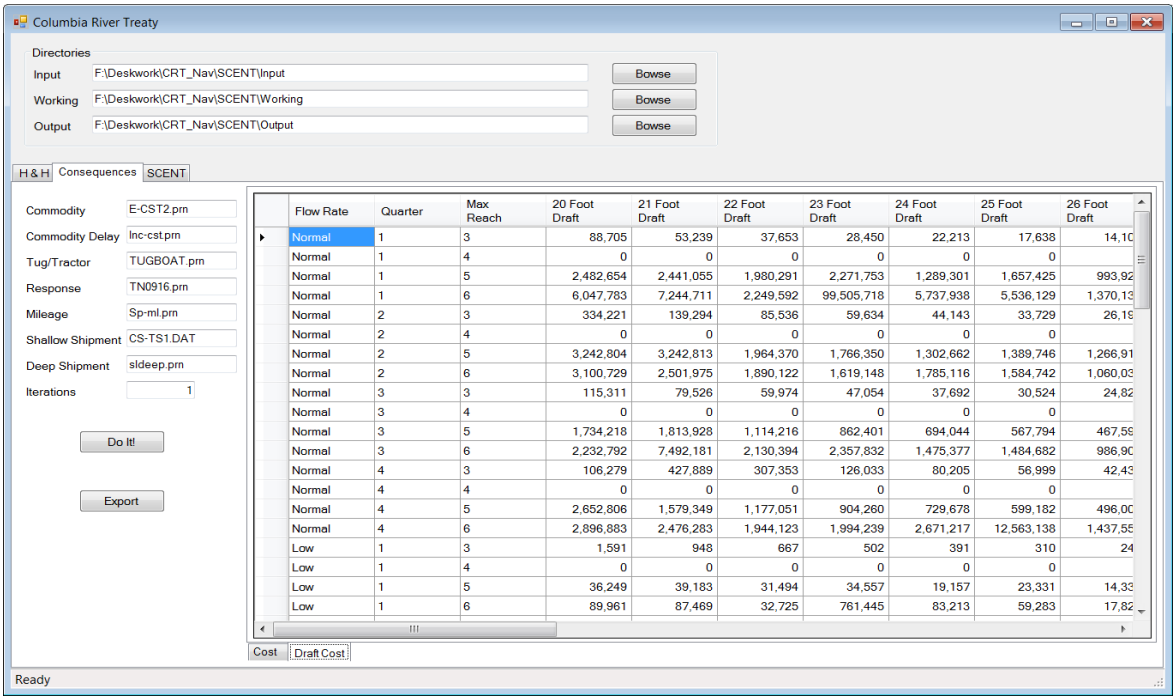


Figure 2-5. Consequences Module Output for Deep Draft Analysis

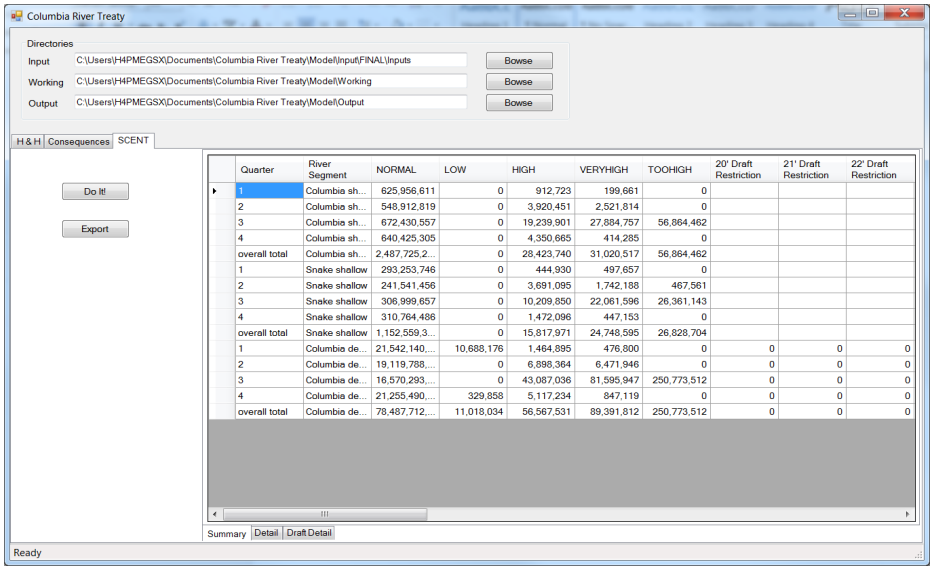


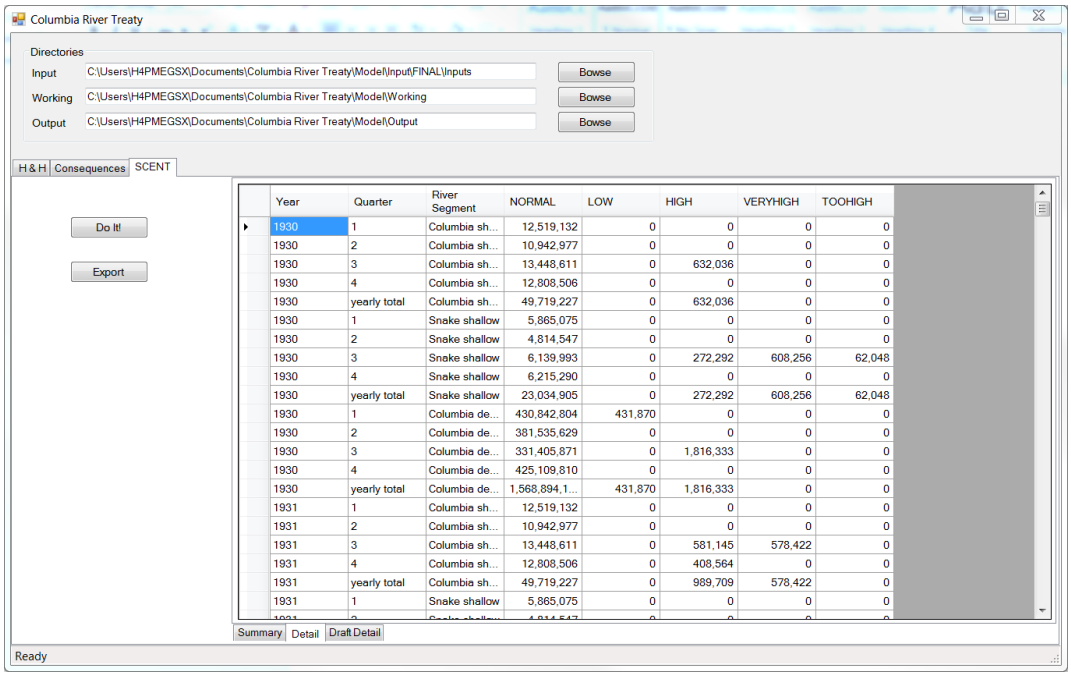
Figure 2-6. SCENT Summary Output – Costs From Flow Increases and Draft Restrictions

2.5 SCENT COMBINATION MODULE

The SCENT Combination Module combines the input from the H&H Module and the Consequence Module to generate the output, the navigation transportation costs under each alternative. A comparison in transportation costs between the No Action Alternatives and the action alternative determines the impact to waterway transportation costs under each action alternative. The SCENT results are broken into the following four subcategories:

Deep draft pertains to the Columbia River below Bonneville Dam;
Snake Shallow refers to movements that originate and terminate on the Snake River;[1]
Columbia Shallow refers to movements that originate and terminate on the Columbia River; and
Columbia-Snake Shallow refers to movements that originate on the Snake and terminate on the Columbia, or vice versa.

The output from the SCENT model displays the average cost consequences associated with flow rates and draft restrictions in each quarter of the year as well as the total for the year based on the outputs from the H&H and Consequences models. The model provides a summary view as well as the full 50-year detailed views of both flow rate and draft restriction consequences. Figure 2-7and Figure 2-8, present these three output displays.



Year	Quarter	River Segment	NORMAL	LOW	HIGH	VERYHIGH	TOOHIGH
1930	1	Columbia sh...	12,519,132	0	0	0	0
1930	2	Columbia sh...	10,942,977	0	0	0	0
1930	3	Columbia sh...	13,448,611	0	632,036	0	0
1930	4	Columbia sh...	12,808,506	0	0	0	0
1930	yearly total	Columbia sh...	49,719,227	0	632,036	0	0
1930	1	Snake shallow	5,865,075	0	0	0	0
1930	2	Snake shallow	4,814,547	0	0	0	0
1930	3	Snake shallow	6,139,993	0	272,292	608,256	62,048
1930	4	Snake shallow	6,215,290	0	0	0	0
1930	yearly total	Snake shallow	23,034,905	0	272,292	608,256	62,048
1930	1	Columbia de...	430,842,804	431,870	0	0	0
1930	2	Columbia de...	381,535,629	0	0	0	0
1930	3	Columbia de...	331,405,871	0	1,816,333	0	0
1930	4	Columbia de...	425,109,810	0	0	0	0
1930	yearly total	Columbia de...	1,568,894,1...	431,870	1,816,333	0	0
1931	1	Columbia sh...	12,519,132	0	0	0	0
1931	2	Columbia sh...	10,942,977	0	0	0	0
1931	3	Columbia sh...	13,448,611	0	581,145	578,422	0
1931	4	Columbia sh...	12,808,506	0	408,564	0	0
1931	yearly total	Columbia sh...	49,719,227	0	989,709	578,422	0
1931	1	Snake shallow	5,865,075	0	0	0	0

Figure 2-7. SCENT Detailed Output - Costs from Increase in Flows

[1] For this analysis, there were no movements in 2016 (the year the SCENT datasets are from) that originated and terminated solely on the Snake River. Therefore, the Snake Shallow category is not included within the alternative results tables.

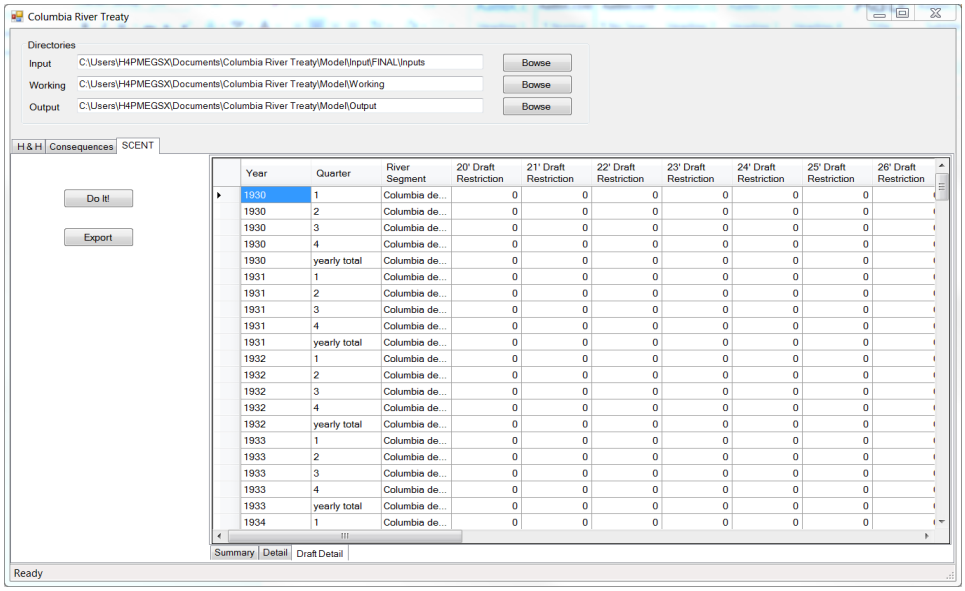


Figure 2-8. SCENT Detailed Output - Costs from Draft Restrictions

It should be noted that a standard deviation of the results was calculated to determine the range of costs that would be anticipated to fall within one standard deviation of the deep and shallow draft flow categories and the deep draft restrictions under the No Action Alternative. The standard deviation range was utilized to highlight those changes in additional costs that would be outside of one standard deviation of the baseline (No Action) condition.

2.6 SOCIAL WELFARE EFFECTS FOR MO1

As described in the CRSO EIS, Navigation and Transportation Section 3.10.3.3, there are a number of planned structural measures under MO1 but they are unlikely to have measurable impacts to commercial navigation or cruise lines in the CSNS because they do not affect flow or elevation of water. However, there are operational measures under MO1 that could affect these things. For example, *Summer Spill Stop Trigger, Modified Dworshak Summer Draft*, and *Planned Draft Rate at Grand Coulee* measures may alter reservoir levels and/or the quantity or the timing of the flows in the Snake River and lower Columbia River (or both). Additionally, commercial ferry operations on Lake Roosevelt potential could be affected by operational changes that result in lower reservoir levels in the early spring at Grand Coulee. Other operational measures within MO1 may have notable effects on water levels and flow in upstream regions, but these flow changes are increasingly diluted as they reach the mainstem Columbia River downstream.

2.6.1 SCENT Results

The H&H data used as input into the SCENT model, as presented in (Table 2-2) shows that MO1 would result in a negligible change in non-normal flow days when compared to the No Action Alternative.

The average annual change in transportation costs under MO1 in the Columbia-Snake Shallow category is estimated to be $9,000 more than the No Action Alternative. Less than $1,000 in increased average annual costs would occur under MO1 for Columbia Shallow operations. The average annual extra transportation costs for transportation in the Deep Draft segment are estimated to be $4,000 more than the No Action Alternative under MO1. The driver behind the minor increases in costs is additional days of low flow in late summer causing draft restrictions for some vessels. These increases in low flow conditions are primarily associated with the combination of the Lake Roosevelt Additional Water Supply and Modified Dworshak Summer Draft measures. As shown in Table 2-3, the total increase in average annual costs to commercial navigation operations would be approximately $14,000.

Table 2-2. Changes in Average Commercial Navigation Flow Days Under Multiple Objective Alternative 1 Relative to No Action Alternative, over 50 years

River Segment	Number of Days Under Various Flow Condition (Days Per Year)					Number of Days Experiencing Draft Restriction (Days Per Year)					
	Low	Normal	High	Very High	Too High	37 ft	38 ft	39 ft	40 ft	41 ft	42 ft
Shallow	< -0.1	0.4	<0.1	< -0.1	< -0.1	–	–	–	–	–	–
Deep Draft	–	–	–	–	–	–	–	–	–	< -0.1	< -0.1

Note: The "Shallow" categories include both the Columbia-Snake Shallow category, which refers to traffic that traveled on both the Columbia and Snake Rivers, and the Columbia Shallow, which presents the impact to traffic only traveling on the Columbia.

Source: SCENT modeling for MO1 presents anticipated changes in average annual operating costs that would occur under MO1 as a result of flow changes. Costs of operations under normal flow range categories would not be affected under MO1.[2]

[2] The Columbia-Snake Shallow category refers to traffic that traveled on both the Columbia and Snake Rivers while the Columbia Shallow presents the impact to traffic only traveling on the Columbia River.

Table 2-3. Changes in Average Annual Costs of Commercial Navigation Operations Under Multiple Objective Alternative 1 Relative to No Action Alternative (2019 Dollars), over 50 years

River Segment	Change in Costs Associated with Flow Range Categories				Changes in Costs Associated with Draft Restrictions						
	Low	High	Very High	Too High	37 ft	38 ft	39 ft	40 ft	41 ft	42 ft	Total
Columbia-Snake Shallow	–	$6,000	$4,000	–	–	–	–	–	–	–	$9,000
Columbia Shallow	–	$0	$0	$0	–	–	–	–	–	–	<$1,000
Deep Draft	–	–	–	–	–	<$1,000	–	$1,000	$1,000	<$1,000	$4,000
Total	$0	$6,000	$4,000	$0	$0	<$1,000	$0	$1,000	$1,000	<$1,000	$14,000

Note: The Columbia-Snake Shallow category refers to traffic that traveled on both the Columbia and Snake Rivers while the Columbia Shallow presents the impact to traffic only traveling on the Columbia. These effects are all within one standard deviation of the No Action Alternative conditions. Costs of operations under normal flow range categories are not anticipated to be affected under any alternatives and are therefore excluded from the table. Numbers may not sum due to rounding.

Source: SCENT modeling

2.6.2 Summary of Effects of MO1

MO1 would result in negligible increases in average annual costs for deep draft navigation and shallow draft navigation. The increase in costs for deep draft navigation would result from additional days of low flows, which would require an increase in the number of tug operations. Overall, this would represent a change in average annual costs of $14,000 to the industry, representing a negligible (less than 0.1 percent) increase in costs in comparison to the No Action Alternative. Effects to the cruise line industry would be negligible.

As described in the CRSO EIS, Navigation Section 3.10.3.3, adverse effects would occur to the Inchelium-Gifford Ferry under MO1 because it would be able to operate 9 days fewer under MO1 than under the No Action Alternative during high water years, or a total of 36 consecutive days, which could represent 3,700 ferry trips. Longer inoperable periods would be expected in high water years that require more flood risk management (FRM) space in the reservoir. During those years minor social welfare effects could be experienced due to the longer inoperable period. Minor regional economic effects due to loss or redistribution of expenditures associated with the ferry trips could also occur. Changes in access to healthcare and educational facilities, in addition to food and shopping resources, could result in moderate adverse effects. Table 2-4 provides a summary of the navigation and transportation system effects of MO1.

Table 2-4. Changes in Economic Effects of Navigation and Transportation Under Multiple Objective Alternative 1 Relative to the No Action Alternative, over 50 years

Region	Social Welfare Effects	Regional Economic Effects	Other Social Effects
Region B	Minor effects due to decrease in Inchelium-Gifford Ferry operations of an additional 9 days in wet years (for a total of 36 consecutive days).[1/] Longer inoperable periods would be expected in wetter years that require more FRM space.	Minor effects due to loss or redistribution of expenditures associated with approximately 3,700 Inchelium-Gifford Ferry trips in wet years. Longer inoperable periods would be expected in wetter years that require more FRM space.	Moderate effects due to reduced access to healthcare and other services of the Inchelium-Gifford for 9 days in wet years. Longer inoperable periods would be expected in wetter years that require more FRM space.
Region C (Snake Shallow)	Negligible effects anticipated to commercial navigation or commercial cruise lines. Average annual cost increases represent less than 0.1 percent of total costs of navigation operations.	Negligible effects from increased costs to cruise lines or shipping operations. Negligible effects to port operations.	No effects.
Region D (Columbia Shallow)	Negligible effects anticipated to commercial navigation or commercial cruise lines. Average annual cost increases represent less than 0.1 percent of total costs of navigation operations.	Negligible effects from increased costs to cruise lines or shipping operations. Negligible effects to port operations.	No effects.
Region D (Deep Draft)	Negligible effects anticipated. Average annual cost increases represent less than 0.1 percent of total costs of navigation operations. No effects to ferries.	Negligible effects from increased costs to cruise lines or shipping operations. No effects to ferry operations.	No effects.

[1/] "Wet" water years are defined as conditions under the highest 20th percentile forecasted volume at The Dalles Dam.

2.7 SOCIAL WELFARE EFFECTS FOR MO2

Similar to MO1, a number of planned structural measures under MO2, such as installing 'fish-friendly' high efficiency turbines at John Day or adding additional surface passage routes at specific projects, are unlikely to have measurable impacts to commercial navigation or cruise lines in the CSNS because they do not affect flow or elevation of water. However, operational measures have the potential to affect operations on the CSNS by altering reservoir levels and/or the quantity or the timing of the flows in the lower Snake and lower Columbia River (or both). For example, *Spill to 110% TDG*, *Ramping Rates for Safety*, and *Full Range Reservoir Operations* measures could alter reservoir levels and/or the quantity or the timing of the flows in the lower Snake and lower Columbia Rivers (or both), and have the potential to affect operations on the CSNS. Commercial ferry operations on Lake Roosevelt have potential to be affected by operational changes at Grand Coulee that result in lower reservoir levels earlier in the year.

2.7.1 SCENT Results

The H&H data used as input into the SCENT model, as presented in Table 2-5, shows that MO2 would have slightly fewer days in normal and high flow conditions and a greater number of days in the low category than the No Action Alternative.

Table 2-5. Changes in Average Commercial Navigation Flow Days Under Multiple Objective Alternative 2 Relative to No Action Alternative, over 50 years

Number of Days Under Various Flow Condition (Days Per Year)					Number of Days Experiencing Draft Restriction (Days Per Year)					
River Segment	**Low**	**High**	**Very High**	**Too High**	**37 ft**	**38 ft**	**39 ft**	**40 ft**	**41 ft**	**42 ft**
Shallow	3.0	(0.5)	(0.3)	–	–	–	–	–	–	–
Deep Draft	3.0	(0.5)	(0.3)	–	<0.1	–	<0.1	<0.1	0.1	(0.2)

Note: The "Shallow" categories include both the Columbia-Snake Shallow category, which refers to traffic that traveled on both the Columbia and Snake Rivers, and the Columbia Shallow, which presents the impact to traffic only traveling on the Columbia.

SCENT modeling Table 2-6 for Alternative MO2 presents anticipated changes in average annual operating costs that would occur under MO2. Costs of operations under normal flow range categories would not be affected under MO2. The impact to shallow draft traffic equates to a decrease in average annual costs of approximately $18,000. However, low flow conditions affect the costs for deep draft traffic, which would see an increase of $178,000. The combination of shallow and deep draft effects would result in an increase in average annual costs to commercial navigation operations of $160,000.

2.7.2 Summary Results

MO2 would result in negligible increases in average annual costs for deep draft navigation and a minor decrease in costs for shallow draft navigation. The increase in costs for deep draft navigation would result from additional days of low flows, which would require an increase in the number of tug operations. Overall, this would represent a change in average annual costs of $160,000 to the industry, representing a negligible (less than 0.1 percent) increase in costs in comparison to the No Action Alternative. Effects to the cruise line industry would be negligible.

Moderate effects would occur to the Inchelium-Gifford Ferry, as while no effects on ferry operations would occur in normal or dry water years, in wet years, the ferry could operate 9 days fewer under MO2 than under the No Action Alternative in wet years (for a total of 36 consecutive days when the ferry would not operate annually), which could represent 3,700 \fewer ferry trips. During those years minor social welfare effects could be experienced due to the longer inoperable period. Minor effects due to loss or redistribution of expenditures associated with the ferry trips could also occur. Changes in access to healthcare and educational facilities, in addition to food and shopping resources could result in moderate adverse effects. Other ferries would not be affected under MO2.

Table 2-7 provides a summary of the navigation and transportation system effects of MO2.

Table 2-6. Changes in Average Annual Costs of Commercial Navigation Operations Under Multiple Objective Alternative 2 Relative to No Action Alternative (2019 Dollars), over 50 years

	Change in Costs Associated with Flow Range Categories				Changes in Costs Associated with Draft Restrictions						
River Segment	**Low**	**High**	**Very High**	**Too High**	**37 ft**	**38 ft**	**39 ft**	**40 ft**	**41 ft**	**42 ft**	**Total**
Columbia-Snake Shallow	–	-$8,000	-$20,000	$12,000	–	–	–	–	–	–	-$16,000
Columbia Shallow	–	-$1,000	-$4,000	$2,000	–	–	–	–	–	–	-$2,000
Deep Draft	$237,000	-$17,000	-$45,000	-$10,000	$1,000	–	$4,000	$4,000	$9,000	$5,000	$178,000
Total	$237,000	-$26,000	-$69,000	$4,000	$1,000	$0	$4,000	$4,000	$9,000	$5,000	$160,000

Note: The Columbia-Snake Shallow category refers to traffic that traveled on both the Columbia and Snake Rivers while the Columbia Shallow presents the impact to traffic only traveling on the Columbia. These effects are all within one standard deviation of the No Action Alternative conditions. Costs of operations under normal flow range categories are not anticipated to be affected under any alternatives and are therefore excluded from the table. Numbers may not sum due to rounding.

Source: SCENT modeling

Table 2-7. Changes in Economic Effects of Navigation and Transportation Under Multiple Objective Alternative 2 Relative to the No Action Alternative, over 50 years

Region	Social Welfare Effects	Regional Economic Effects	OSE
Region B	Minor effect due to decrease in Inchelium-Gifford Ferry operations of an additional 9 days in wet years (for a total of 36 consecutive days).[1/] Longer inoperable periods would be expected in wetter years that require more FRM space.	Minor impact due to loss or redistribution of expenditures associated with approximately 3,700 Inchelium-Gifford Ferry trips in wet years. Longer inoperable periods would be expected in wetter years that require more FRM space.	Moderate impact due to reduced access to healthcare and other services of the Inchelium-Gifford for 9 fewer days in wet years for a total inoperable period of 36 consecutive days annually. Longer inoperable periods would be expected in wetter years that require more FRM space.
Region C (Snake Shallow)	Negligible effects anticipated to commercial navigation or commercial cruise lines. Average annual cost increases represent less than 0.1 percent of total costs of navigation operations.	Negligible effects from increased costs to cruise lines or shipping operations. Negligible effects to port operations.	No effects.
Region D (Columbia Shallow)	Negligible effects anticipated to commercial navigation or commercial cruise lines. Average annual cost increases represent less than 0.1 percent of total costs of navigation operations.	Negligible effects from increased costs to cruise lines or shipping operations. Negligible effects to port operations.	No effects.
Region D (Deep Draft)	Negligible effects anticipated. Average annual cost increases represent less than 0.1 percent of total costs of navigation operations. No effects to ferries.	Negligible effects from increased costs to cruise lines or shipping operations. No effects to ferry operations.	No effects.

[1/] "Wet" water years are defined as conditions under the highest 20th percentile forecasted volume at The Dalles Dam.

2.8 SOCIAL WELFARE EFFECTS FOR M04

As described in the CRSO EIS, Navigation and Transportation Section 3.10.3.3 there are a number of planned structural measures under MO4, like the addition of spillway notch weirs or modifying turbine intake bypass screens that cause juvenile lamprey impingement, that are unlikely to have measurable impacts to navigation in the CSNS. The *Drawdown to MOP*, *Winter System FRM Space*, *Spring & Fall Transport* measures may channel flow and depths, affecting the costs for vessel movements on the CSNS, while the *Spill to 125% TDG* measure operations may affect sediment accumulate and increase shoaling in the navigation channel. In addition to these measures, commercial ferry operations on Lake Roosevelt have the potential to be affected by operational measures at Grand Coulee that result in lower reservoir levels in the early spring (*Winter System FRM Space*, 0.8 foot SRD, etc.)

2.8.1 SCENT Results

Table 2-8 shows the difference between MO4 and the No Action Alternative in terms of flow days. The H&H data used as input into the SCENT model shows that MO4 would have slightly fewer days in normal and high flow conditions and a greater number of days in the low category than the No Action Alternative. In both the shallow and deep draft segments of the river, there would be approximately 9 more days of average annual low flows under MO4 than under the No Action Alternative.

Table 2-8. Changes in Average Commercial Navigation Flow Days Under Multiple Objective Alternative 4 Relative to No Action Alternative, over 50 years

River Segment	Number of Days Under Various Flow Condition (Days Per Year)					Number of Days Experiencing Draft Restriction (Days Per Year)					
	Low	Normal	High	Very High	Too High	37 ft	38 ft	39 ft	40 ft	41 ft	42 ft
Shallow	8.5	(7.4)	(1.0)	(0.5)	(<.1)	–	–	–	–	–	–
Deep Draft	8.6	(7.7)	(1.0)	(0.5)	(<.1)	–	–	–	(<0.1)	(<0.1)	(0.2)

Note: The "Shallow" category includes both the Columbia-Snake Shallow category, which refers to traffic that traveled on both the Columbia and Snake Rivers, and the Columbia Shallow, which presents the impact to traffic only traveling on the Columbia River.

Source: SCENT modeling. Table 9 for MO4 shows the average annual costs associated with each river segment and the additional transportation costs for the various flow conditions and draft restrictions compared to the No Action Alternative. As shown, the difference between these two alternatives is small, which is consistent with the H&H data used as input into the SCENT.

As shown in Table 2-9, average annual extra transportation costs in the Columbia Shallow are estimated to be $15,000 less than the No Action Alternative under MO4. These effects are within one standard deviation of the No Action Alternative conditions. The average annual extra transportation costs for transportation in the Deep Draft segment are estimated to be $300,000 more than the No Action Alternative under MO4 across the industry. These effects are slightly higher than one standard deviation above the No Action Alternative conditions.

The $300,000 increase represents less than 0.1 percent of average annual industry operational costs. 2.8.2 Summary Results for MO4

Table 2-9. Changes in Average Annual Costs of Operations Under Multiple Objective Alternative 4 Relative to No Action Alternative (2019 Dollars), 50 years

River Segment	Change in Costs Associated with Flow Range Categories				Changes in Costs Associated with Draft Restrictions						
	Low	High	Very High	Too High	37 ft	38 ft	39 ft	40 ft	41 ft	42 ft	Total
Columbia-Snake Shallow	–	-$7,000	-$1,000	-$7,000	–	–	–	–	–	–	-$15,000
Columbia Shallow	–	-$5,000	-$4,000	-$5,000	–	–	–	–	–	–	-$14,000
Deep Draft	$576,000	-$49,000	-$82,000	-$123,000	–	–	–	-$2,000	-$1,000	-$5,000	$315,000
Total	$576,000	-$61,000	-$88,000	-$135,000	$0	$0	$0	-$2,000	-$1,000	-$5,000	$286,000

Note: These effects are all within one standard deviation of the current conditions. Costs of operations under normal flow range categories are not anticipated to be affected under any alternatives and are therefore excluded from the table.

Source: SCENT modeling

MO4 would result in minor increases in average annual costs for deep draft navigation and minor decreases in average annual costs for shallow draft navigation. The increase in costs for deep draft navigation would result from additional days of low flows requiring an increase in the number of tug operations. Overall, this would represent an increase in average annual costs of $300,000 to the industry, representing a less than 0.1 percent increase in costs in comparison to the No Action Alternative. Effects to the cruise line industry would be negligible.

The Inchelium-Gifford Ferry would be able to operate 9 days fewer under MO4 than under the No Action Alternative in wet years, which could represent 3,700 fewer ferry trips. Longer inoperable periods would be expected in wetter years that require more FRM space. During those years minor social welfare effects could be experienced due to the longer inoperable period. Minor effects due to loss or redistribution of expenditures associated with the ferry trips could also occur. Changes in access to healthcare and educational facilities, in addition to food and shopping resources could result in moderate adverse effects. Other ferries would not be affected under MO4.

Other than the ferry effects in wet years, effects to commercial navigation and transportation systems under MO4 are anticipated to be negligible over the short and long term when compared to the No Action Alternative. Table 2-10 provides a summary of the navigation and transportation system effects of MO4.

Table 2-10. Changes in Costs of Commercial Navigation Operations Under Multiple Objective Alternative 4 Relative to No Action Alternative, over 50 years (2019 Dollars)

Region	Social Welfare Effects	Regional Economic Effects	OSE
Region B	Minor effects due to decrease in Inchelium-Gifford Ferry operations of an additional 9 days in wet years (for a total of 36 consecutive days), which could represent 3,700 ferry trips.[1/] Longer inoperable periods would be expected in wetter years that require more FRM space.	Minor effects due to loss or redistribution of expenditures associated with approximately 3,700 Inchelium-Gifford Ferry trips in wet years. Longer inoperable periods would be expected in wetter years that require more FRM space.	Moderate adverse effects due to reduced access to healthcare and other services of the Inchelium-Gifford for an additional 9 days in wet years. Longer inoperable periods would be expected in wetter years that require more FRM space.
Region C (Snake Shallow)	Negligible effects anticipated to commercial navigation or commercial cruise lines. Average annual costs would slightly decrease.	No effects from commercial navigation, cruise lines, or port operations.	No effects.
Region D (Columbia Shallow)	Negligible effects anticipated to commercial navigation or commercial cruise lines. Average annual costs would slightly decrease.	No effects to cruise lines or port operations.	No effects.
Region D (Deep Draft)	Negligible effects anticipated due to average annual cost increases representing less than 0.1 percent of total costs of navigation operations. No effects to ferries.	Negligible effects to cruise line and port operations. No effects to ferries.	No effects.

[1/] "Wet" water years are defined as conditions under the highest 20th percentile forecasted volume at The Dalles Dam.

2.9 SOCIAL WELFARE EFFECTS FOR THE PREFERRED ALTERNATIVE

In Region B, the effects to the operation of the Inchelium-Gifford Ferry resulted in minor effects due to the *Planned Draft Rate at Grand Coulee* measure, and would be addressed by extending the boat ramp for the Inchelium-Gifford Ferry in Lake Roosevelt. Ferry operations on Lake Roosevelt could be affected under the Preferred Alternative due to anticipated drawdowns in wet years, the wettest 20 percent of years as measured at The Dalles. In the median wet years, when Lake Roosevelt's draw down for flood risk management begins sooner than for No Action Alternative, the Inchelium-Gifford Ferry on Lake Roosevelt would not be able to operate for approximately 31 days in the year, which is four additional days than would have been anticipated under the No Action Alternative in the median wet years at this location. Effects would primarily occur on the Confederated Tribes of the Colville Reservation. Other operational measures within the Preferred Alternative may have notable effects on water levels and flow in upstream regions, but these flow changes are increasingly diluted as they reach the mainstem Columbia River.

The planned structural measures under the Preferred Alternative are unlikely to have measurable impacts to commercial navigation or cruise lines in the Columbia-Snake Navigation System (CSNS) because they do not affect flow or elevation of water. Some of the operational

measures have the potential to affect operations on the CSNS. In particular, the *John Day Full Pool measure* as well as a combination of upstream measures, primarily at Grand Coulee and Libby Dams have the potential to impact how vessels move on the CSNS. It is expected that higher spill and variable timing of the spill over the course of a day due to the *Juvenile Fish Passage Spill* measure could result in changes to the tailraces at Lower Monumental and Lower Granite projects. The Corps would monitor the tailrace at each project to track changes that could affect safe navigation. If changes to the tailrace warrant action, coffer cells to dissipate energy may be constructed in the tailrace at either of the projects.

2.9.1 SCENT Results

The H&H data used as input into the SCENT model, as presented in Table 2-11, shows that the Preferred Alternative could result in approximately a one day per year decrease in navigable days under low flow conditions when compared to the No Action Alternative, and approximately a one day increase in navigable days during normal flow conditions. In all other flow conditions there would be basically negligible or no effect from the No Action Alternative.

Table 2-11. Changes in Average Commercial Navigation Flow Days Under Preferred Alternative Relative to No Action Alternative, over 50 years

River Segment	Number of Days Under Various Flow Condition (Days Per Year)					Number of Days Experiencing Draft Restriction (Days Per Year)					
	Low	Normal	High	Very High	Too High	37 ft	38 ft	39 ft	40 ft	41 ft	42 ft
Shallow	-1.2	1.2	<-0.1	<0.1	<0.1	–	–	–	–	–	–
Deep Draft	-1.2	1.2	<-0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-

Note: The "Shallow" categories include both the Columbia-Snake Shallow category, which refers to traffic that traveled on both the Columbia and Snake Rivers, and the Columbia Shallow, which presents the impact to traffic only traveling on the Columbia.
Source: SCENT modeling

Table 2-12 for the Preferred Alternative presents anticipated changes in average annual operating costs that would occur under the Preferred Alternative as a result of flow changes. Costs of operations under normal flow range categories would not be affected under the Preferred Alternative. [3]

The average annual extra transportation costs for transportation in the Deep Draft segment are estimated to be $93,000 less under the Preferred Alternative than under the No Action Alternative. The reason for the minor decrease in costs is that there would be slightly fewer days of low flow under this alternative related to the John Day Full Pool measure. The average annual change in transportation costs under the Preferred Alternative in the Columbia-Snake Shallow segment is estimated to be $4,000 higher than the No Action Alternative. The slight

[3] The Columbia-Snake Shallow category refers to traffic that traveled on both the Columbia and Snake Rivers while the Columbia Shallow presents the impact to traffic only traveling on the Columbia River.

increase in cost would occur in the spring resulting from a combination of upstream measures, primarily at Grand Coulee and Libby Dams.

As shown in Table 2-12 , the total decrease in average annual costs to commercial navigation operations would be approximately $93,000.

Table 2-12. Changes in Average Annual Costs of Commercial Navigation Operations Under Preferred Alternative Relative to No Action Alternative (2019 Dollars), over 50 years

	Change in Costs Associated with Flow Range Categories				Changes in Costs Associated with Draft Restrictions						
River Segment	Low	High	Very High	Too High	37 ft	38 ft	39 ft	40 ft	41 ft	42 ft	Total
Columbia-Snake Shallow	-	$1,000	$1,000	$1,000	-	-	-	-	-	-	$4,000
Columbia Shallow	-	-$1,000	$1,000	$1,000	-	-	-	-	-	-	-
Deep Draft	-$118,000	-$1,000	$4,000	$14,000	$1,000	-$2,000	$1,000	$1,000	$3,000	-	-$97,000
Total	-$118,000	-$1,000	$6,000	$16,000	$1,000	-$2,000	$1,000	$1,000	$3,000	-	-$93,000

Note: The Columbia-Snake Shallow category refers to traffic that traveled on both the Columbia and Snake Rivers while the Columbia Shallow presents the impact to traffic only traveling on the Columbia. These effects are all within one standard deviation of the No Action Alternative conditions. Costs of operations under normal flow range categories are not anticipated to be affected under any alternatives and are therefore excluded from the table. Numbers may not sum due to rounding.
Source: SCENT modeling.

2.9.2 Summary Results for the Preferred Alternative

Overall effects of the Preferred Alternative on recreational visitation are anticipated to range from negligible, or basically no effect to moderate adverse to major beneficial, depending on the Region. Table 2-13 presents a summary of the Preferred Alternative effects, including the anticipated changes in average annual recreational visitation, social welfare, and regional economic effects by region and in total relative to the No Action Alternative. Across the basin, total recreational visitation and associated social welfare effects are anticipated to decrease by less than 0.1 percent annually (approximately 250 visits and $2,000) in a typical year associated due to changes in boat ramp access. Expenditures associated with non-local visitation would decrease by $12,000 annually across the region, a change of less than 0.1 percent compared to the No Action Alternative. Regional economic effects of this change in expenditures would be negligible. Effects to the quality of hunting, wildlife viewing, swimming, and water sports at river recreation sites in the region under the Preferred Alternative would be generally negligible.

Table 2-13. Changes in Economic Effects of Recreation Under Preferred Alternative Relative to the No Action Alternative

Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
Region A	A decrease of approximately 400 water-based recreational visits would occur at Lake Koocanusa (less than 1.0 percent of water-based visitation at the site) in a typical year associated with changes in boat ramp access. In high-water-level years, water-based visitation would not change at Lake Koocanusa and would decrease by about 1.0 percent in low-water-level years. Annual social welfare benefits would decrease by $4,300 in a typical year. Negligible effects to the quality of recreation experiences would occur.	Expenditures associated with non-local recreational visits would decrease by $18,000 across the region (less than 0.1 percent) associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be negligible.	Negligible change resulting in no noticeable effect to recreationist well-being when compared No Action.
Region B	An increase of approximately 200 water-based visits at Lake Roosevelt (less than 0.1 percent of water-based visitation at the site) would occur in a typical year. In years with high or low water, visitation would decrease by less than 1.0 percent. Annual social welfare benefits would increase by approximately $2,600 in a typical year. Negligible effects to the quality of recreation experiences would occur.	Expenditures associated with non-local recreational visits would increase by $7,000 across the region (less than 0.1 percent) associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be negligible.	Negligible change resulting in no noticeable effect to recreationist well-being when compared No Action
Region C	No changes in reservoir visitation associated with changes in boat ramp access in a typical year or high-water-level year. A reduction of approximately 1,300 water-based visits at Dworshak Reservoir (less than one percent of water-based visitation at the site) would occur in a low-water-level year. Annual social welfare benefits would not change in typical or high-water-level years, but would decrease by about $14,000 in a low-water-level year. Moderate adverse to major beneficial effects to quality of fishing may occur. Impacts to hunting, wildlife viewing, swimming, and water sports associated with changing river and reservoir conditions are likely to be negligible.	No changes in visitor expenditures or regional effects associated with changes in boat ramp access in most years. Regional effects of potential changes in expenditures during low-water-levels years would be negligible.	No change to visitor well-being associated with access to reservoir-based recreation. Moderate adverse to major beneficial change in recreationist well-being when compared No Action.

Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
Region D	No changes in reservoir visitation associated with changes in boat ramp access. Moderate adverse to major beneficial effects to quality of fishing may occur Impacts to hunting, wildlife viewing, swimming, and water sports associated with changing river and reservoir conditions are likely to be negligible.	No changes in visitor expenditures or regional effects associated with changes in boat ramp access.	No change to visitor well-being associated with access to reservoir-based recreation. Moderate adverse to major beneficial change in recreationist well-being when compared No Action.
Total	Negligible effects to reservoir visitation (reduction of 250 visits, representing less than 0.1 percent of total visitation compared to the No Action Alternative) in a typical year, with decreases in social welfare of approximately $2,000 annually associated with changes in boat ramp access. Potential for negligible to minor effects in most areas to quality of fishing, hunting, wildlife viewing, swimming, and water sports associated with changing river and reservoir conditions may occur. There is the potential for minor adverse effects to moderate improvements in recreational fishing conditions along in Regions C and D.	Expenditures associated with non-local recreational visits would decrease by $12,000 across the region (a change of less than 0.1 percent from No Action) in a typical year associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be negligible.	Recreation would continue to provide other social effects associated with considerable recreational opportunities in the region. Continued operation of the system would provide benefits to community well-being, cohesion, and identity. Negligible change from No Action in most locations, with the exception of potential moderate beneficial social effects to anglers in Regions C and Region D.

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CHAPTER 3 - L.3. TOM - MODELING IMPACTS OF CHANGES IN CHANNEL ACCESSIBILITY

This section discusses the methodology of the Transportation Optimization Model (TOM), the data sources and key modeling assumptions, the scenarios used to account for uncertainty with rail rates, and the outputs generated by the model. Additional discussion of the results are presented in Section 3.10 of the CRSO EIS.

3.1 MODEL OVERVIEW

The TOM is used to assess the movements of shipments under M03 dam breaching, where it is assumed that navigation on the lower Snake River would no longer be possible. Without lower Snake River shallow draft barge, shippers would be required to use a different transportation mode or combination of modes (e.g., shuttle rail, connector rail, roadway, Columbia River shallow and/or deep draft channel). Therefore, the TOM is used to evaluate the flow of goods from origin points, through intermediate destinations, and ultimately to final destinations.

The TOM is a constrained optimization model designed to simulate the transportation choices facing shippers that use the CSNS. The lower Snake River portion of the CSNS is predominately used to move grain (wheat) downriver, while fuel, fertilizer and some paper mill inputs (wood chips and/or shavings) are moved upriver, wheat comprises more than 87 percent of the tonnage moved on the lower Snake River. Therefore, the TOM is designed to capture the choices faced by shippers moving grain (wheat) to market. A survey of shippers was completed for this EIS and informed the structure of the TOM, establishing how goods would move through the system if the lower Snake River navigation channel is no longer available.

The objective function of the TOM is to move wheat from where it is produced, its origin in the Pacific Northwest, through the various intermediate, and then final destinations via the various mode combinations in a least cost fashion. The diagram below (Figure 10) depicts these alternatives for the TOM. Wheat is produced and harvested in the field and primarily moved to export terminals in Portland, OR throughout the year, after passing through different elevators and terminal facilities. The different route and mode combinations, as shown in Table 3-1, reflect choices that shippers face in moving grain from origination (production) to final market. Model parameters that were informed by the survey of shippers include the capacities of each facility, shipping alternatives, cost of each shipping alternative, choices made under the No Action Alternative, and choices that would be made if the navigation channel was unavailable. For the social welfare analysis, the relevant output of the TOM is the change in transportation costs as grain (wheat) reaches its final destination of Portland, OR (export terminal).

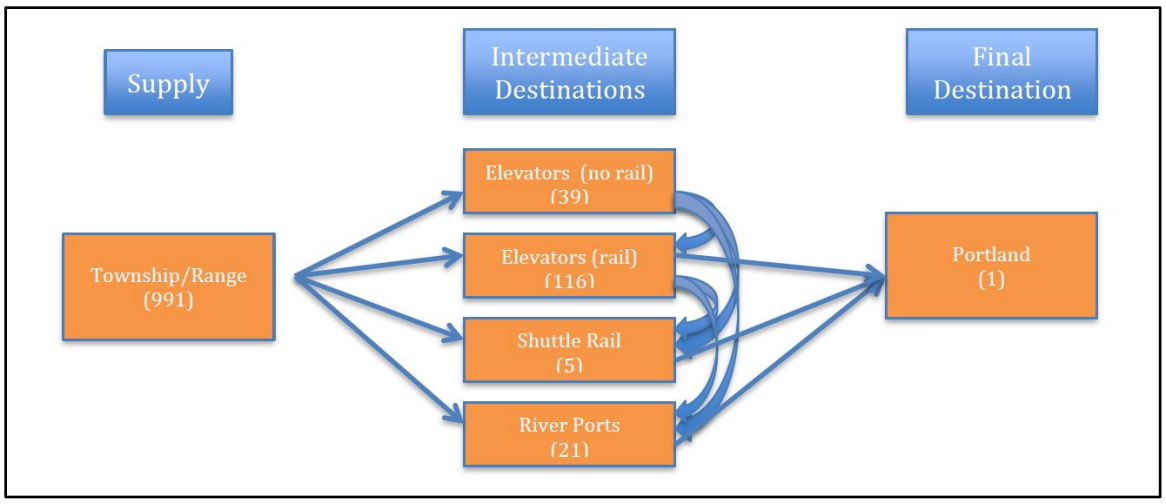


Figure 3-1. Transportation Optimization Model Schematic

Table 3-1. Origin/Destination Mode Combinations included in Transportation Optimization Model

Origination Node	Destination Node	Mode	Total Route Options
Farms (991)	Elevators no Rail (5 closest)	Truck	4,955
	Elevators with Rail (5 closest)		4,955
	Shuttle Elevators (all 5)		4,955
	River Ports (all 21)		20,811
Elevators no Rail (65)	Elevators with Rail (5 closest)		325
	Shuttle Elevators (all 5)		325
	River Ports (all 21)		1,365
Elevators with Rail (90)	Shuttle Elevators (all 5)	Truck	450
		Rail	450
	River Ports (all 21)	Truck	1,890
Shuttle Elevators (5)	Portland, OR	Rail	5
River Ports (21)		Barge	21
Total Route Combinations			40,507

3.2 DATA SOURCES

The TOM data inputs include shipment lists or commodity movements, grain production data and locations (GIS based data), transportation systems in GIS, and input from shippers gathered via survey. The complete list of sources include:

1. USACE Waterborne Commerce Statistics Center (WCSC) database, and the USACE Lock Performance Monitoring System (LPMS) – USACE maintains two databases containing information on the waterway. The WCSC contains data on the type of commodity moved, the amount of the commodity moved, the origin, the destination, and other information. This data is gather by USACE National Data Center from operators using the inland waterways. The USACE LPMS data is collected by USACE employees at locks on the inland waterways and contains information such as the towboat identification

number, the number and draft of barges in the tow, the direction of the movement, the arrival and lockage time. This data is collected from USACE lock operators. The WCSC and LPMS data provided the following model inputs:

- Amount and type of commodities moving on the Columbia and Lower Snake
- The name of businesses utilizing the CSNS
- The number of vessel uses the CSNS
- The mileage traveled by vessels moving on the CSNS

2. Other Governmental Databases – Databases such as the State of Washington Department of Agriculture License database and listed in its Public Grain Warehouses and Grain Dealers publication provided more contacts for the stakeholder survey.

3. USDA Cropscape Wheat Production – This is a GIS layer file showing average production (2014-2018) for spring and fall wheat for all counties potentially affected by changes to CSNS.

4. Columbia River Basin Transportation Database – This is a GIS layer showing the location of roads and railways potentially affected by changes to CSNS. The transportation data provided all possible transportation pathways for grain to travel from origin to market

5. Stakeholder Survey - Between January 2019 and continued through August 2019, the Social and Economic Sciences Research Center (SESRC) at Washington State University conducted a survey of 257 businesses utilizing the CSNS specifically the Lower Snake River. The purpose of the survey was to obtain information from shippers of agricultural products, forest products, fertilizer, or fuel on the capacities of each facility, shipping alternatives, cost of each shipping alternative, choices made under the No Action Alternative, and choices that would be made if the navigation channel was unavailable.

Table 3-2. CRSO Survey Disposition Summary

Category	Number
Completed Questionnaires	152
Refusals	70
Ineligible (No Shipping)	17
Ineligible (Out of Business)	1
Other Codes	6
Non-Response	69
Total Sample	315
Response Rate (Completes/Sample Size)	48.3%
Completion Rate (Completes/Completes + Refusals + No Response)	52.2%

The shipper survey conducted by the SESRC ultimately produced a collective response rate of 48.3 percent, as illustrated in Table 3-2. The majority of survey respondents were moving wheat (74%) or other agricultural Products, including peas, wood chips, and alfalfa produced in the region. The information collected from the survey informed the

transportation cost functions for truck, rail and barge. The shipper survey also provided the following information for the TOM:

- Preferred alternate shipping mode if lower Snake River barge were unavailable
- Location of grain elevators
- Amount of grain moving by transportation routes
- Costs for various transportation modes

The costs for moving grain by rail, other than shuttle were gathered from the survey. The shipping rates for shuttle and barge are also developed from a combination of data from the shipper survey and port to port shipper tariffs.

3.3 ASSUMPTIONS

Several assumptions were critical for the TOM evaluation including grain supply, cost function (least cost behavior), characteristics of intermediate locations and volume. These assumptions were developed based upon existing information as described in the following sections.

3.3.1 Grain Supply

The grain supply used to estimate origination in the TOM was developed based upon a combination of USDA county level spring and fall wheat production averages (2014-2018), and GIS data. The specific location of grain production is derived from the 2017 Cropscape wheat production layer. This field-specific data was developed by the USDA based upon satellite imagery data and with information gathered from producers participating in USDA-sponsored programs. For the purpose of this study, this comprised more than 17,000 field parcels including regions in Washington, Idaho and Oregon, as illustrated in Figure 3-2. PNW Wheat Production and Facilities below. This far exceeded the granular scale of origination supply points that could be modeled so grain supply was aggregated to Township/Range level and the centroid of each Township/Range was utilized as the origination point (see Figure 11 below). This produced 991 origination supply points in TOM from which wheat is shipped. All grain shipments leaving these origination supply points (farms) utilize truck transport (assumes 1,000 bu. capacity). The cost to transport via truck is a distance based function, estimated from data collected from the survey of grain shippers. The total volume of grain production being modeled throughout the study region is 202,583,270 bushels or 6.1 million tons.

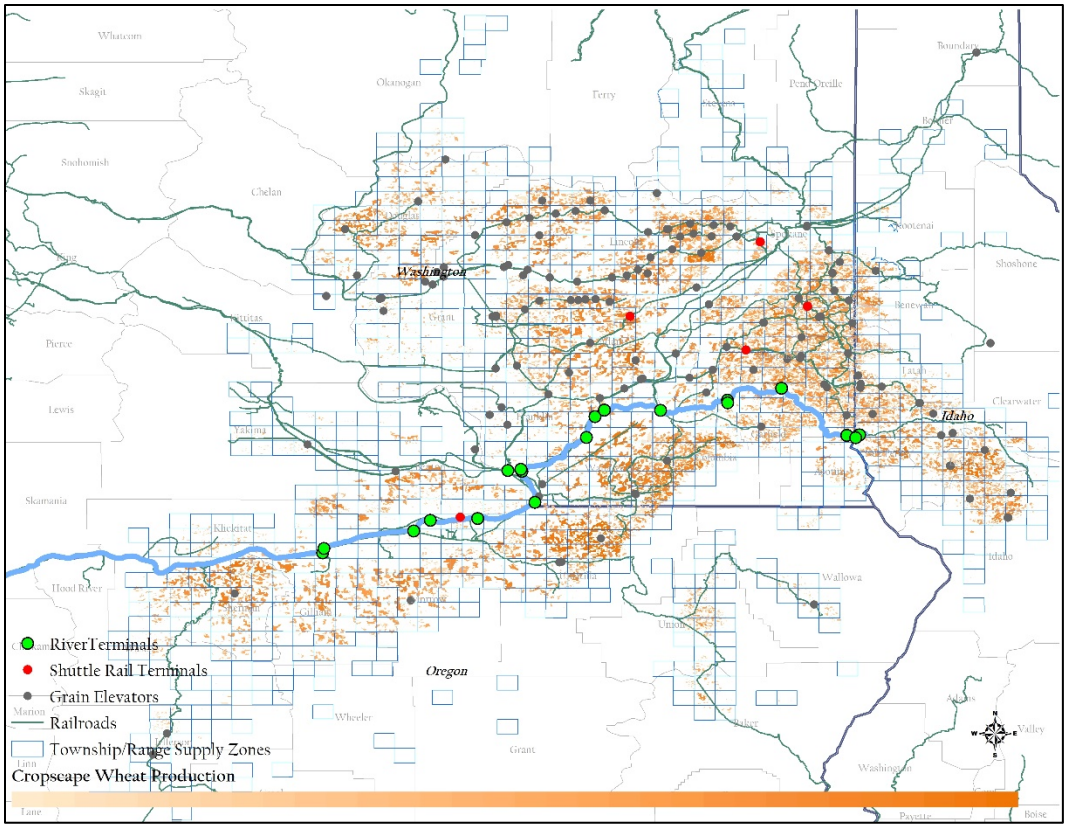


Figure 3-2. PNW Wheat Production and Facilities

3.3.2 Cost Functions

The costs for moving grain by truck utilizes the function in Figure 3-3, which was developed from based upon the SESRC shipper survey results. The costs for moving grain by rail, other than shuttle, utilizes the function in Figure 3-4, which was also developed based upon the SESRC shipper survey results. Every effort was made to obtain accurate rate data for each shipping mode. However, in most cases shuttle rail rates are negotiated between the shipper and the rail carrier and are not made public. The shipping rates for shuttle and barge were developed from a combination of data from the shipper survey and port to port shipper tariffs. There is also a handling charge of five cents per bushel included for any shipment delivered to grain elevators, shuttle facilities or river ports. The model, in terms of volume of shipments traversing particularly routes, is sensitive to fluctuations in rates which is an accurate characteristic to the way grain merchandising exists. The barge rates used in the TOM are presented in Figure 3-5. The average shuttle rail rate across the four rail shuttle facilities range between 0.50 and 0.75 cents per bushel. The grain barge freight rate assumptions are presented in Figure 3-5.

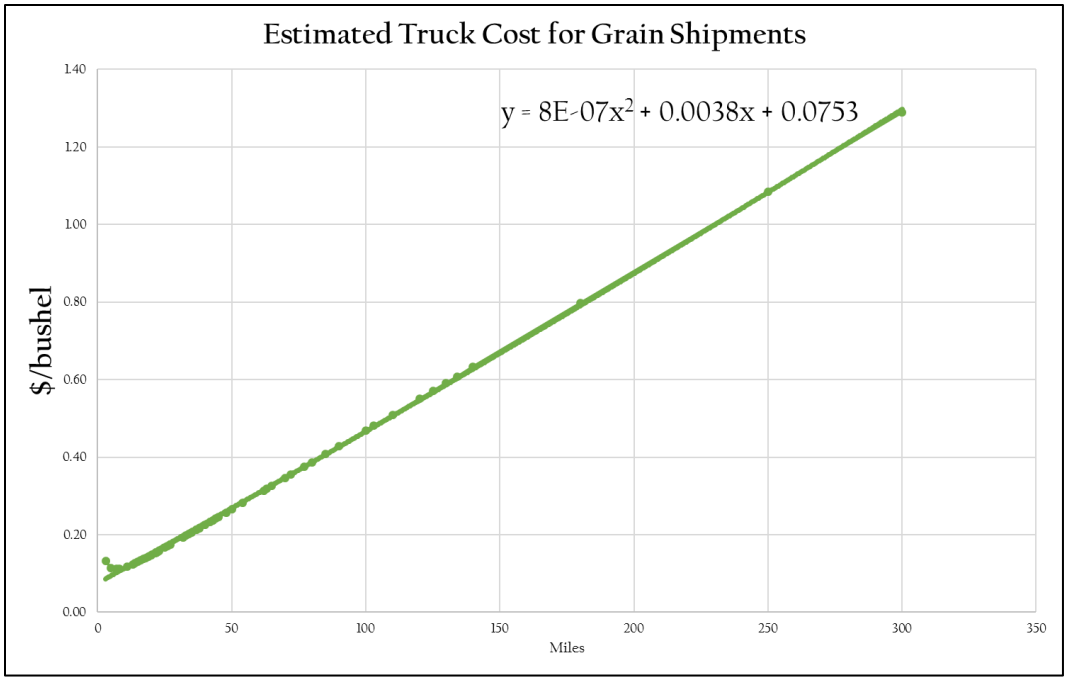


Figure 3-3 Estimated Grain Truck Cost Function

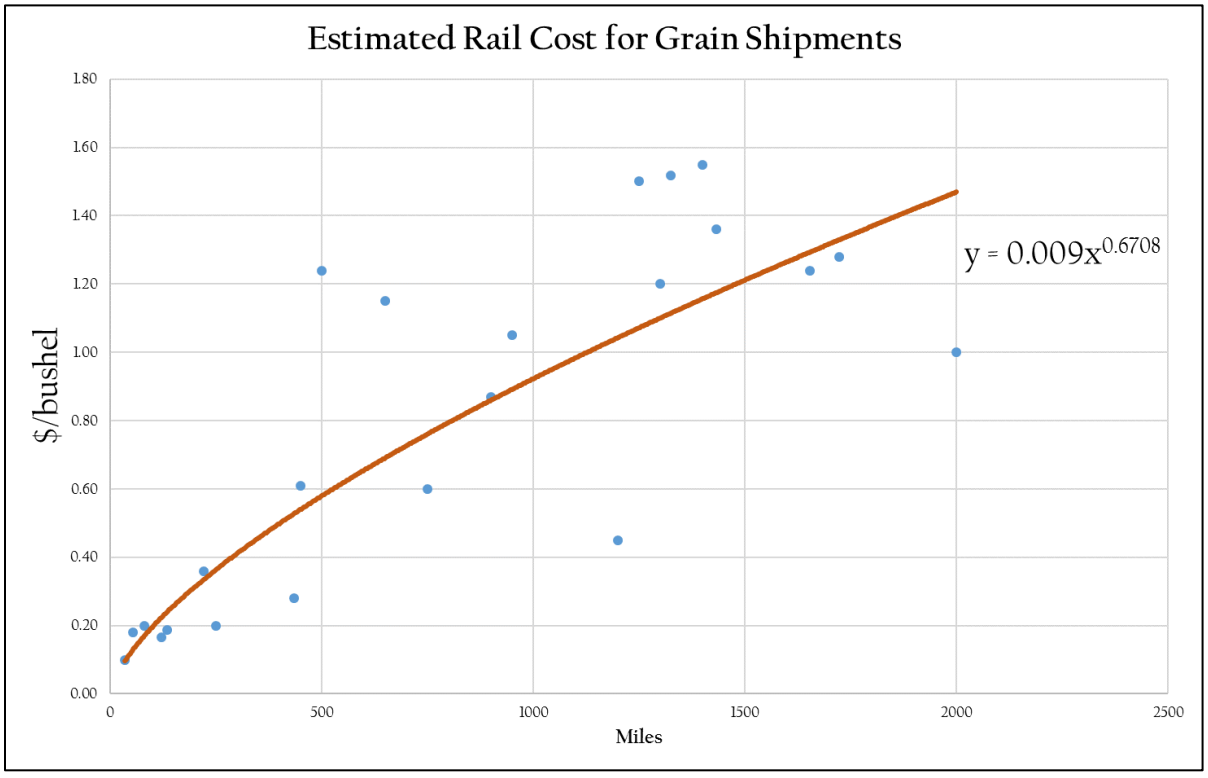


Figure 3-4. Estimated Non-Shuttle Rail Cost Function

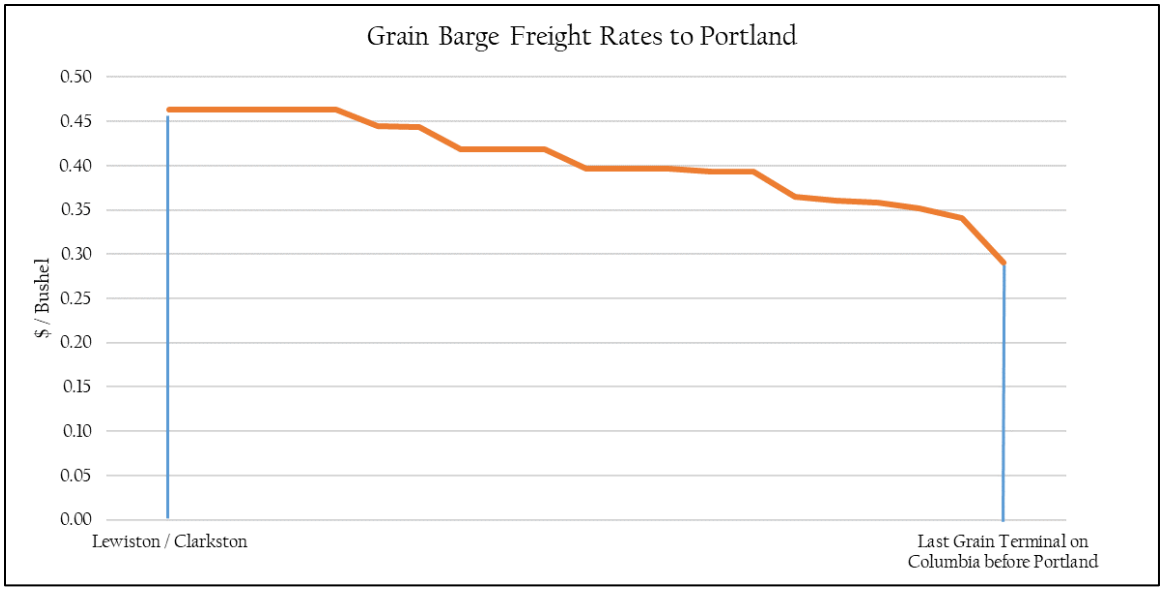


Figure 3-5. Barge Freight Rates utilized in Transportation Optimization Model

3.3.3 Intermediate Locations

Between the point of production and arriving at the final destination of the export market (Portland, OR), all grain is moved through one or more intermediate locations (Portland, OR). These include 1) elevators without rail, 2) elevator with rail access but not shuttle rail, 3) shuttle rail facilities and 4) river port elevators. The information on grain elevators and river ports was compiled from a combination of USDA grain facilities and the states warehousing licensing division.

These sources provide licensed storage capacity for elevators, but not volume processed or shipped through the facilities. Information on volumes moved and turn ratios is developed from the shipper survey. The shipment combinations for the intermediate locations include truck, rail and barge, depending on the facility type. Shipments may move from elevators without rail to those with rail or port facilities (via truck) and shipments may also move from rail facilities to the river ports (via truck).[4] These shipment combinations are designed to replicate actual choices as they currently exist for grain shippers.

Including route flexibility in the model is important, particularly for constrained optimization models where individual constraints (facility volume or others) are met and alternative routes must be available. This is especially true in the instance where one scenario involves removing one set of shipping locations (i.e. lower Snake River shallow draft barge ports) and then re-

[4] Note, in TOM, shipments cannot move from rail elevators to river ports via shuttle rail. Information gathered through personal communication with Port of Lewiston and shippers (December 2019) indicate that this modal movement for grain shipments no longer exists. Discussions with WDOT (January 2020) further corroborated these findings.

optimizing the flows. The set of route combinations (40,507) included in the constrained optimization model are provided in the table below and visually in the flow diagram. Generally, these options currently exist for any shipper moving grain to the export market. The two options not included in this model are truck shipments directly to Portland, OR and shipments from shuttle rail facilities to river ports via shuttle rail. These movements could occur, but would be relatively rare given the distance and the lower cost to move via alternative mode combinations.

3.3.4 Volume

The volume of grain that moves down the lower Snake River is assumed to be 2.4 million tons under the No Action Alternative. Figure 15 displays the volume of grain moving down the lower Snake River from 2000 to 2018 from the Waterborne Commerce data. The amount of grain moving by barge is a result of a combination of factors, including total production, which has been relatively stable over time, as well as market driven forces, including competition between and within transportation modes, which change from year to year. One of the market forces obviously are the market prices for grain, which are primarily determined internationally. The price point for grain at any one point in time may cause the growers and elevator managers to empty or fill their storage, leading to volume movements that vary from year to year. Further, some occasions have arisen in the market when it is more profitable for an elevator to sell railroad future car contracts for the secondary premium, moving grain to the river during that time. Additionally, over time the advent of new shuttle facilities has shaped the competitive geographical map in the region.

As shown in Figure 3-6, the total grain volumes using the river have varied but generally declined since the early 2000s, with more precipitous declines since the opening of two additional shuttle rail facilities (McCoy and High Line Shuttle Terminals), followed by a decade of relative stable volumes of grain movements.. In light of these historic trends the volume of grain shipped down the lower Snake River has is assumed to remain constant over time, even as modest increases in grain production and technological improvements in yield are anticipated over time. As such, an estimate of 2.4 million tons was chosen to model future downbound grain shipments. The estimate of 2.4 million tons represents the 10-year average of downbound grain and barley shipments on the lower Snake River as well as the most recent data volume (2018) shipped in 2018, the latest year of reported data.

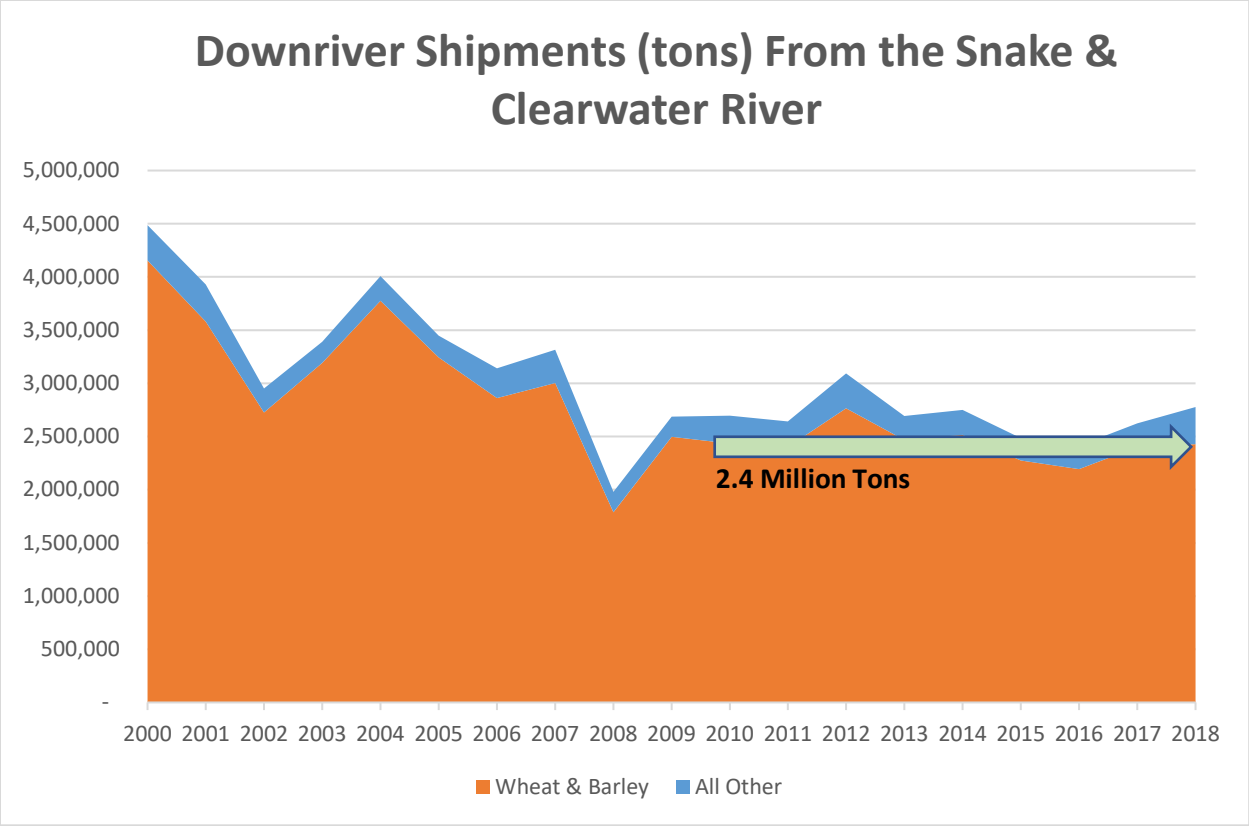


Figure 3-6. Recent Grain Shipments on the Snake River, with No Action Alternative Forecast[5]
Source: Corps Waterborne Commerce data, 2020.

3.4 SCENARIOS AND OUTPUTS

The TOM presents the following outputs to characterize the effects of scenarios evaluated:

1. Change in barge ton miles - To demonstrate how waterway traffic will change due to the alternative and scenario assumptions.

2. Change in highway ton-miles - To demonstrate how roadway traffic will change due to the alternative and scenario assumptions.[6]

3. Change in railroad ton-miles – To demonstrate how railway traffic will change due to the alternative and scenario assumptions.

[5] Note, large decreases in grain tons during 2002 and 2008 are more reflective of exogenous factors and do not suggest an isolated effect from new unit train facilities. In 2002, there was a drought in Eastern Washington that reduced grain supply. In 2008, the global recession influenced demand for grain.
[6] Highway ton-miles include backhaul to more accurately calculate increased demands on road infrastructure.

4. Total transportation costs for grain – To demonstrate the impact to costs for grain production in areas potentially influenced by changes to the CSNS.

5. Change in $ per bushel – To demonstrate how the change in the transportation system will impact the cost of grain production in areas potentially influenced by changes to the CSNS.

The output from the TOM (changes in grain flows, transportation costs and ton-miles) can be displayed in geographic as well as tabular formats.

3.4.1 No Action Alternative

Table 3-3 summarizes specific assumptions about grain movements under the No Action Alternative, which were developed for the transportation optimization model, and then parameterized for the No Action Alternative. Figure 16 depicts shipping patterns by mode for grain shippers under the No Action Alternative. Specifically, the figure illustrates the highway flows of grain shipments, the location of origination points used in the transportation optimization model, river port terminals along the Columbia/Snake navigation channel (green circles) and shuttle rail terminals (orange dots). The intensity of highway flows is represented by thicker lines that change colors (moving toward dark red) as the volumes increase. The No Action Alternative illustrates the intensity of highways being used to move grain in the existing, base-case scenario and it shows thicker lines for highways connecting river port terminals and shuttle rail facilities. The size of the circles also reflects the increasing volume moving through each facility type (river port, shuttle rail, and elevator with rail) as grain is consolidated from farm to country elevators and on toward the tidewater terminals for export.

Table 3-3. Modal Transit of Wheat and Barley in Eastern Washington and Idaho Under the No Action Alternative

Origin-Destination Type	Mode	Volume (bushels)	Total Cost	Cents/ Bushel	Ton-Miles	Average Distance (miles one direction)
Farm to Elevator (no rail)	Truck	1,413,000	$330,740	$0.23	2,629,978	28.2
Farm to Elevator (with rail)	Truck	17,916,392	$4,022,993	$0.22	30,355,061	25.7
Farm to Elevator (shuttle rail)	Truck	58,178,017	$12,605,471	$0.22	91,038,006	23.7
Farm to River Port	Truck	125,075,861	$34,581,616	$0.28	322,393,030	39.1
Elevator to Elevator with Rail	Truck	0	$0	N/A	0	N/A
Elevator to Elevator Shuttle Rail	Truck	0	$0	N/A	0	N/A

Origin-Destination Type	Mode	Volume (bushels)	Total Cost	Cents/ Bushel	Ton-Miles	Average Distance (miles one direction)
Elevator to River Port	Truck	1,413,000	$396,910	$0.28	3,757,039	40.3
Elevator with Rail to Shuttle Rail	Truck	0	$0	N/A	0	N/A
Elevator with Rail to Shuttle Rail	Rail	13,289,664	$3,193,277	$0.24	29,669,201	74.4
Elevator with Rail to River Port	Truck	4,626,728	$1,389,845	$0.30	13,783,455	45.1
Elevator with Rail to River Port	Rail	0	0	N/A	0	0
Shuttle Rail Elevator to Portland	Rail	71,467,681	$36,258,211	$0.51	789,185,132	368.1
River Port to Portland[1/]	Barge	131,115,589	$52,126,818	$0.40	1,086,083,464	276.1
Total	–	202,583,270	$144,905,881	$0.72 (avg)	2,368,894,365	–

Note: avg = average.

[1/] Assumes 2.1 million tons of grain moving down the Snake River via barge.

Source: Transportation optimization model, parameterized to reflect current conditions

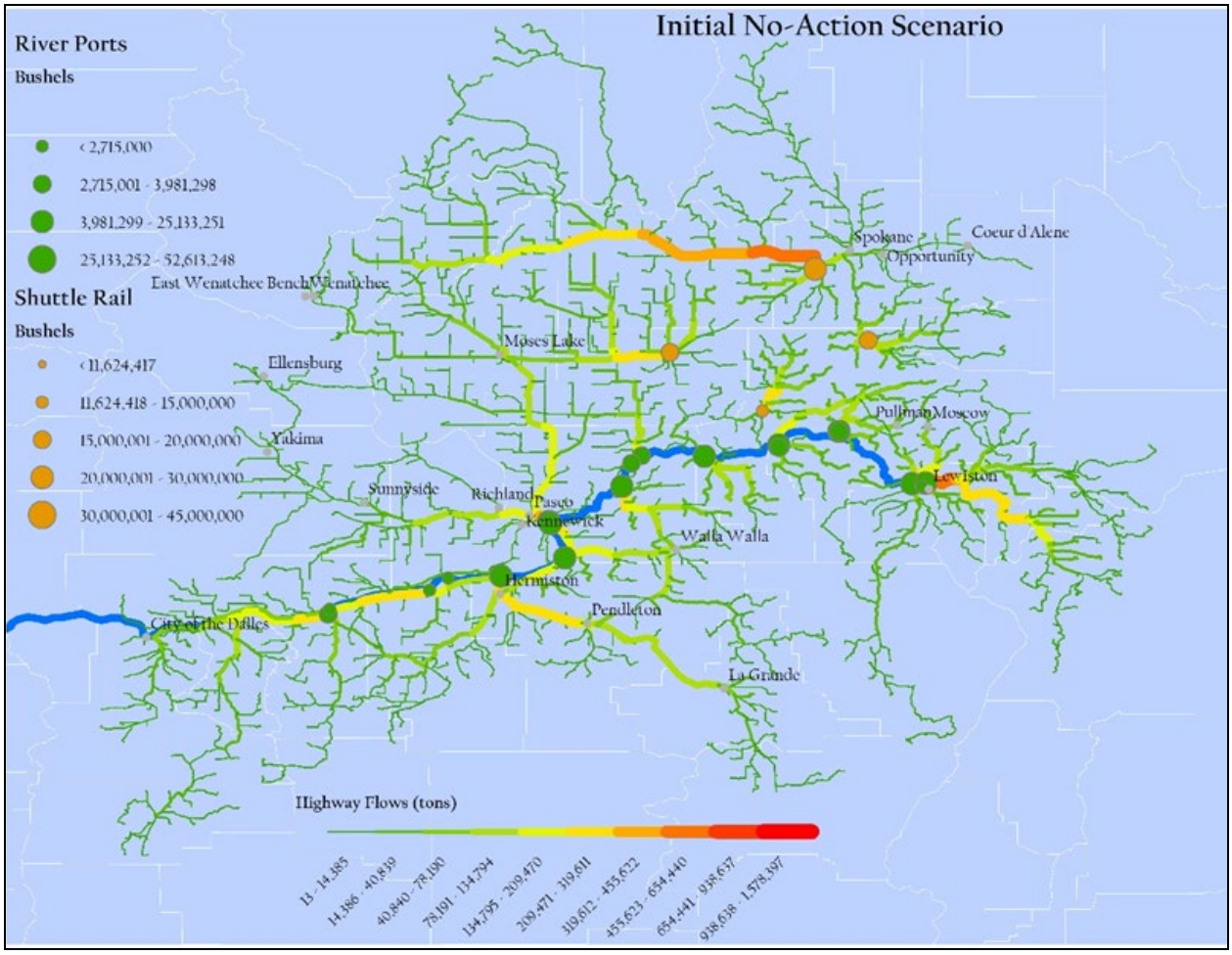


Figure 3-7. No Action Alternative Shipping Routes.

Source: Transportation optimization model, parameterized to reflect current conditions.

3.4.2 Multiple Objective 3

3.4.2.1 Social Welfare Effects to Commercial Navigation and Transportation

The transportation model developed to measure the impact of alternative river navigation scenarios under MO3 is a constrained optimization model designed to capture the choices currently facing shippers that use the Columbia-Snake River System, particularly the navigable portions of the lower Snake River. According to the lock reports maintained by the Corps, the commodities shipped on the system are predominately grain (wheat and barley) for downriver barge movements and fuel for upriver shipments. There are a variety of other commodities moved in smaller volumes, but grain (wheat and barley) comprises the majority (more than 87 percent in 2018) of the downbound tonnage moved on the lower Snake River and 62 percent of overall tonnage on the lower Snake River. The model captures the choices faced by shippers moving these products to market. Generally, data compiled from a variety of sources provides the necessary information to parameterize the model and establish the constraints and choice alternatives, representing current conditions, as they exist. Fuel comprises the majority of

upbound tonnage on the lower Snake River (91 percent in 2018), most of which terminates river passage above Pasco, WA. Fuel comprises 27 percent of overall tonnage on the lower Snake River. Fuel movements are not modeled due to data limitations and uncertainty of how movements may be affected under MO3. The Columbia River shallow draft channel would still be operable, however access to the shallow draft channel from certain port facilities at the confluence of the Snake with the Columbia and within the McNary Pool would require additional dredging. However, given the safety concerns associated with fuel movements it's unclear if fuel companies would continue movements in the McNary Pool to Pasco, WA.

Additional details on the data and model parameterization are available in Appendix L, *Navigation*.

Evaluating the impact of removing the lower Snake River locks and barge navigation above Pasco, Washington, is completed by modifying the transportation optimization model by not allowing shipments on river terminals along the lower Snake River.[7] It is likely that the facilities with rail access would continue to be used to some extent for storage and transport via rail or truck; however, these facilities are assumed to be closed for purposes of this analysis. To the extent that some terminals on the lower Snake River could continue to be used, the effects to shippers would be lower than model results suggest. Economic impacts on shippers would be most acute in the short term, as shippers, ports, port services and related companies have invested in equipment and labor that is suited to current conditions. As the industry adapts over time, more rail capacity and associated storage would likely be added in the region to accommodate freight affected by loss of river navigation on the lower Snake River. In addition, highways would be utilized more heavily. Ports have commented that the availability of land at port sites may constrain their ability to add rail capacity, as well as the time-intensive and uncertain permitting process to augment rail capacity (Port of Lewiston 2019).

Rail price increases are constrained by the market. By removing the option of shipment via barge, prices on the rail lines are likely to increase. As described in the following sections, three scenarios are considered for understanding potential effects of MO3: Scenario 1 assumes rail rates would not increase; Scenario 2 assumes rail rates would increase by 25 percent regionwide; and Scenario 3 assumes the rail rates would increase by 50 percent regionwide. Some stakeholders have stated their opinion that a 50 percent rail rate increase seems too low because railroads would take advantage of monopolistic pricing opportunities absent an operational Snake River channel as an alternative (e.g., comments of Idaho Cooperating Agencies, December 2019). However, others agree with the assessment that 50 percent is likely to be a reasonable upper bound estimate. As shown in the modeling results below, an increase

[7] Currently, modeling assumes that ports on the Columbia River above McNary Dam as well as the two facilities at the mouth of the Snake River would remain operational (in particular, Pasco and Kennewick). However, modeling indicates that some facilities on the Columbia River above McNary Dam may also experience interruptions in service if dredging to access these ports is not conducted under MO3. This is discussed in the Dredging Operations portion of section 3.10.3.5.

of 50 percent in rail rates would be high enough to entice shipping volume back to barge movements at the Tri-Cities, and would therefore be likely to constrain increases higher than 50 percent. At the highest end, rail prices would be constrained by costs to ship via truck, which is generally the most expensive option. Some commenters have expressed concern that because rail is privately owned, it is less reliably available than the river system (e.g., comments of Idaho Cooperating Agencies, December 2019). Shippers have expressed some concern that private decisions related to making train cars available based on prices of other commodities would also affect the reliability of the rail lines for supplying adequate capacity to serve the shipping needs (Personal communication with Port of Lewiston and shippers, December 2019). Commenters have further stated it is difficult to secure a unit train on short notice to take advantages of seasonal demand (comments of Idaho Cooperating Agencies, December 2019).

The modeling scenarios presented below are used to capture a reasonable range of effects on commodity movements and transportation costs, given the range of uncertainties surrounding how rates may change if the lower Snake River navigation channel is no longer available. Along with how movements and transportation costs would change, potential effects on infrastructure and the improvements that would be needed are described.

SCENARIO 1: EFFECTS OF DAM BREACH ON GRAIN TRANSPORTATION ASSUMING CONSTANT RAIL RATE

Under Scenario 1, commodities that would have been transported on the lower Snake River are assumed to be transported using the next least cost alternative. Costs of alternative shipping modes, including rail, are assumed not to change under this scenario. This scenario is likely to be a low estimate, as rail rates are likely to increase following dam breach. However, this scenario would also lead to the highest increase in rail usage because of the relative cost of rail compared to truck and/or truck and barge. As such, it captures the largest increase in demand for rail that could be expected under any scenario. In this way, it identifies the upper bound of potential demands on rail and rail infrastructure.

Scenario 1 is heavily dependent on two assumptions. First, the scenario assumes that existing shuttle rail facilities would be able to accommodate with some limited expansion for most of the grain that otherwise would have used the lower Snake River ports (slightly more than double existing shuttle rail facility volumes). This assumption appears as a reasonable starting point because shippers have reported that shuttle rail facilities can accommodate up to 25 million bushels per year with some storage adjustments, which is equivalent to 0.75 million tons per facility (Comments of Idaho Cooperating Agencies, December 2019). As such, total capacity of these facilities would be approximately 3 million tons, which is more than the total grain volume on the river in recent years. Second, the model assumes that the shortline railroads would be able to accommodate increased volumes going to shuttle rail facilities. It appears likely that improvements to the shortline rail lines would be required to accommodate this increased volume. Potential costs associated with required shortline rail improvements are discussed in the Regional Economic Effects section below. In addition, ports have commented that because grain does not move at the same export volume throughout the year, but rather is

dependent on world demand, issues could exist in providing adequate rail capacity at critical times (Port of Lewiston 2019).

Under Scenario 1, the total costs to transport grain to market would increase by 10 percent from $145 million to $159 million, representing an increase of $14 million, or approximately 7 cents per bushel. The cost increases to specific shippers would depend upon location and vary throughout the region, depending on transportation options at each location. Generally, those grain shippers that are the furthest from alternate shipping locations (shuttle rail facilities or river ports on the Columbia River) would be the most negatively impacted. Note, cost scenarios for specific farmers are presented below in the Regional Economic Effects section.

The primary reason that the transportation costs would not increase more dramatically under Scenario 1 is the assumed availability of the four shuttle rail facilities to absorb these shipments (in Ritzfield, Washington [Templin Facility], and Four Lakes, Washington [High Line Facility], 2 hours from Pasco, Washington, via highway; in Rosalia, Washington [McCoy Facility], south of Spokane and 2.5 hours from Pasco, Washington; and a new facility in Lacrosse, Washington [Endicott Facility], which is located closest to the Snake River and 1.5 hours from Pasco, Washington). As discussed above, each facility currently has approximately 25 million bushels of capacity, or the ability to handle 0.75 million tons per year, or 3 million tons across all of the facilities. Under MO3 Scenario 1, the total shuttle rail freight volume would almost double from current volumes, increasing from 71 million bushels under the No Action Alternative to 138 million bushels under Scenario 1. This would represent a substantial increase in shuttle rail volume that would exceed current shuttle rail capacities of 100 million bushels. As such, increased capacity would be needed at the four currently operating shuttle rail facilities under Scenario 1. Due to this required increased in capacity, it would seem that this increase would be unlikely to occur without an associated increase in rail rates. The majority of the increase in grain shipments by shuttle rail would arrive from other grain elevators with rail via rail, as opposed to truck shipments on highways. The analysis assumes that shortline railroads would be primarily responsible for this in rail volume increase; however, uncertainty exists about whether shortline railroads would be able to adjust operations and/or facilities to accommodate the increase in volume.

Given that the Snake River ports would be no longer accessible, the aggregate amount of grain coming directly from farms to river ports would decrease under Scenario 1. The total grain volume accessing any river port along the CSNS, moving directly from farm to river ports via truck at or below Pasco, Washington, would decrease from 125 to 45 million bushels (a decrease of 64 percent), while the average distance of truck trips for those shipments would increase from 39 to 48 miles (an increase of 22 percent relative to the No Action Alternative).

Columbia River barge transportation would continue to be important in the region downstream of Pasco under MO3, representing 32 percent of all grain moving to export (compared to 65 percent under the No Action Alternative). Grain transported on the river is assumed to arrive via truck.

The total impacts to transportation infrastructure (measured in ton-miles) would increase from 2.37 to 2.47 billion ton-miles, an increase of 96 million ton-miles, under MO3 Scenario 1 (representing an increase of 4.1 percent compared with the No Action Alternative). Highway (truck) ton-miles would increase from 464 million to 551 million, while barge ton-miles would decrease from 1.09 billion to 391 million on the CSNS.

Under Scenario 1, the decreasing barge volume could adversely affect companies that particularly depend on this transit mode, such as tow boat companies. The increase in highway ton-miles is primarily due to grain shippers moving commodities to rail shuttle facilities and also to commodities being trucked farther to river ports on the middle Columbia, below the closure, than would be anticipated under the No Action Alternative.

Assuming constant rail rates, railroad ton-miles would increase the most under Scenario 1 (No Rail Rate Increase), increasing from 819 million ton-miles under the No Action Alternative to 1.5 billion ton-miles under MO3. This would include a substantial increase in volume at each of the four shuttle rail facilities, particularly for the Lacrosse facility given its close proximity to the river and the fact that it would be the most likely alternative for production impacted by river closure. This increase would represent an increase in the number of unit trains (with approximately 110 cars per train) from approximately 4 trains to approximately 8 trains per month at each shuttle rail facility. Overall, the annual number of shuttle rail unit train trips in the region would increase by 185, and the number of shuttle rail cars loaded would increase by over 20,000. This would represent an increase of 94 percent over current shuttle rail activity.

A summary of the changes in grain flows, transportation costs, and ton-miles under the MO3 Scenario 1 are provided in the Table 3-4.Figure 3-8 depicts shipping patterns by mode for grain shippers under MO3 Scenario 1. Specifically, the figure illustrates the highway flows of grain shipments, the location of origination points used in the transportation optimization model, river port terminals along the Columbia-Snake navigation channel (green circles) and shuttle rail terminals (orange circles). Once the lower Snake River ports are eliminated in this scenario, the shuttle rail facilities accommodate the majority of grain displaced from the lower Snake River terminals. Given this, the intensity of highway flows changes and the thickness of lines (highways) accessing the shuttle rail terminals increases substantially under this scenario.

494 **Table 3-4. Multiple Objective Alternative 3 Scenario 1 (No Rail Rate Increase): Changes from No Action Alternative**

Origin-Destination Type	Mode	Volume (bushels)	Total Cost	Cents/Bushel	Ton-Miles	Average Distance (miles one direction)
Farm to Elevator (no rail)	Truck	892,106	$153,501	(0.02)	716,451.02	-6.2
Farm to Elevator (with rail)	Truck	32,495,497	$6,697,210	(0.01)	44,975,116.60	-3.0
Farm to Elevator (shuttle rail)	Truck	46,638,258	$17,585,877	0.07	198,778,387.35	18.2
Farm to River Port	Truck	(80,025,861)	($20,611,512)	0.03	180,552,934.00)	8.7
Elevator to Elevator with Rail	Truck	498,298	$111,709	0.22	845,211.88	25.7
Elevator to Elevator Shuttle Rail	Truck	–	$0	-	-	0.0
Elevator to River Port	Truck	393,808	$98,164	(0.01)	834,742.44	-1.8
Elevator with Rail to Shuttle Rail	Truck	–	$0	-	-	0.0
Elevator with Rail to Shuttle Rail	Rail	20,370,770	$3,616,605	(0.04)	26,371,415.15	-18.9
Elevator with Rail to River Port	Truck	12,623,025	$2,830,615	(0.06)	21,368,106.49	-14.3
Elevator with Rail to River Port	Rail	–	$0	-	-	0.0
Shuttle Rail Elevator to Portland	Rail	67,009,028	$33,288,202	(0.01)	678,577,651.95	-14.8
River Port to Portland	Barge	(67,009,028)	($29,907,142)	(0.05)	695,534,049.16)	-73.0
Total Change from NAA		–	$13,863,228	$0.07	(96,380,100)	–

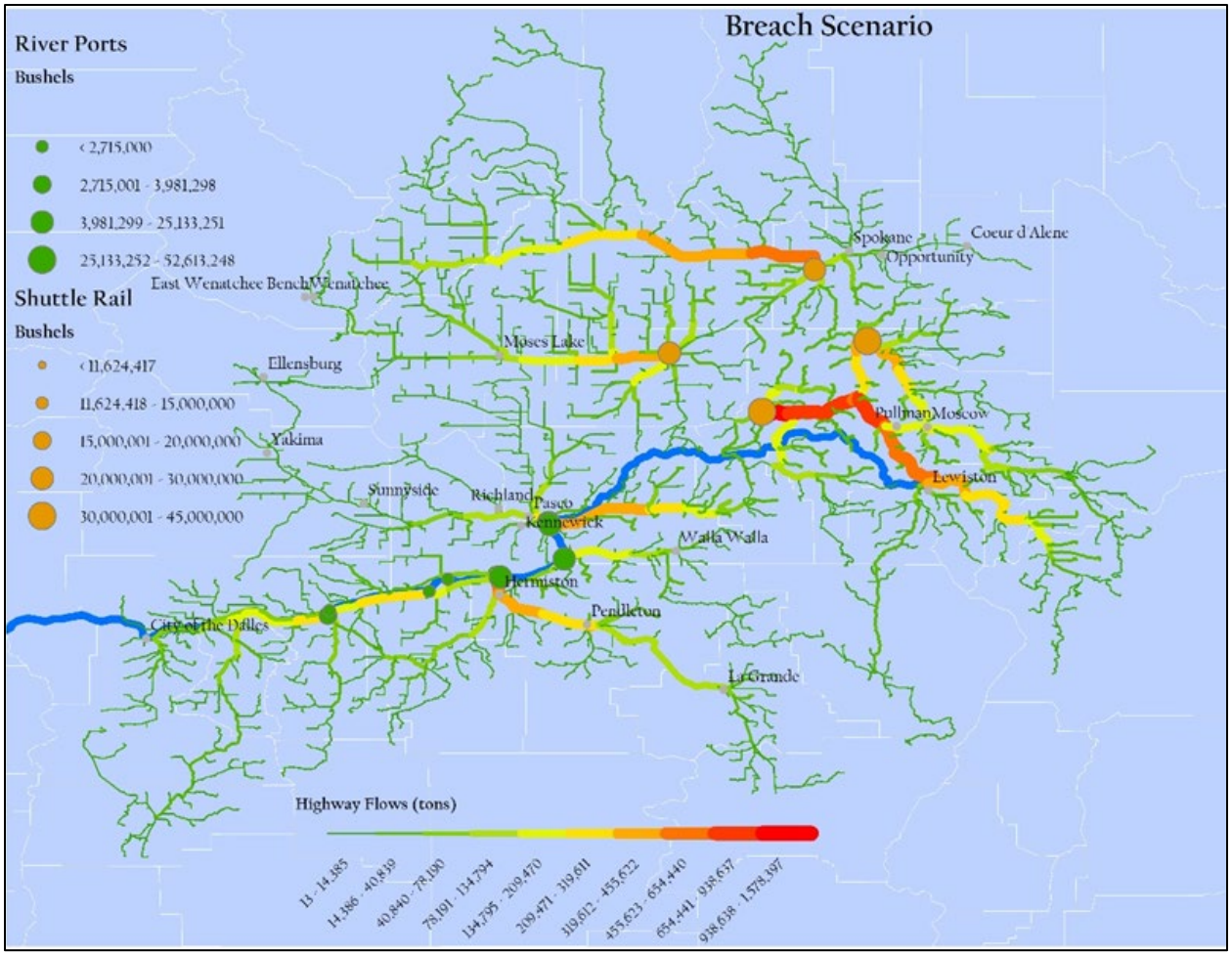


Figure 3-8. Multiple Objective Alternative 3 Scenario 1: Shipping Routes by Mode.

Source: Transportation optimization model, parameterized to reflect current conditions.

SCENARIO 2: EFFECTS OF DAM BREACH ON GRAIN TRANSPORTATION ASSUMING RAIL RATE INCREASE OF 25 PERCENT

Unlike Scenario 1, Scenario 2 assumes that rail rates would increase by 25 percent above the No Action Alternative rates. Increasing rail rates by 25 and then 50 percent (Scenario 3) allow for improved understanding of modal shift and pricing sensitivity between rail and river transport. As under MO3 Scenario 1, the cost increase to specific shippers would depend upon location and would vary throughout the region, depending on transportation options at each location. Generally, those grain shippers that are the farthest from alternative shipping locations (shuttle rail facilities or river ports on the Columbia River) would be the most negatively impacted.

Increasing rail rates by 25% in Scenario 2 would result in a total cost of $176 million, a $31 million (22 percent) increase in costs (in comparison to the $13 million increase under Scenario 1), and is equivalent to an average transportation cost of 87 cents per bushel. A transportation cost of 87 cents per bushel equates to an increase of 15 cents from the No Action Alternative (a percentage increase of 22). Some individual shippers may experience increases that are more than double this amount, depending on their location.

The distribution of volume moving via different transportation modes would change substantially under this scenario, as the increase in rail rates would shift grain shipments away from shuttle rail lines to a combination of truck and barge. In Scenario 2, the total volume moving by shuttle rail to export ports would be 120 million bushels, a 67 percent increase from the No Action Alternative and a decrease of 14 percent from Scenario 1. The total volume moving by barge, 83 million bushels, decreases from the No Action Alternative estimate of 131 million (a decrease of 37 percent) and increases from the Scenario 1 estimate of 64 million (an increase of 29 percent). Note, river ports still operating on the Columbia River at Pasco, Washington, would experience a large volume increase, mostly from shipments arriving via truck traveling longer distances to access the river ports.

Total ton-miles under Scenario 2 would increase from the No Action Alternative to 2.46 billion (an increase of 93 million compared to the No Action Alternative). In this scenario, barge ton-miles would substantially decrease from the No Action Alternative to 517 million while both truck and rail would increase from the No Action Alternative to 613 million and 1.33 billion ton-miles, respectfully. As in Scenario 1, this modal change would create a substantial increase in volume at each of the four shuttle rail facilities. Under Scenario 2, this increase would represent an increase in the number of unit trains (with approximately 110 cars per train) from approximately 4 trains to approximately 7 trains per month at each shuttle rail facility. Overall, the annual number of shuttle rail unit train trips in the region would increase by 133, and the number of shuttle rail cars loaded would increase by over 15,000. This would represent an increase of 35 percent over current shuttle rail activity.

The changes in grain flows, transportation costs, and ton-miles under the MO3 under Scenario 2 are summarized in Table 3-5 , Figure 18 provides a visual depiction of commodity movements by mode for Scenario 2. As in Table 3-5, Figure 3-10 depicts shipping patterns by mode for grain

shippers under MO3, Scenario 2. Specifically, the figure illustrates the highway flows of grain shipments, the location of origination points used in the transportation optimization model, river port terminals along the Columbia-Snake navigation channel (green circles) and shuttle rail terminals (orange circles). As shown, when rail rates assumed to increase by 25 percent after the breach, a larger proportion of the grain is now trucked to the Tri-Cities area, as indicated by the thick, orange-red lines in Figure 3-10.

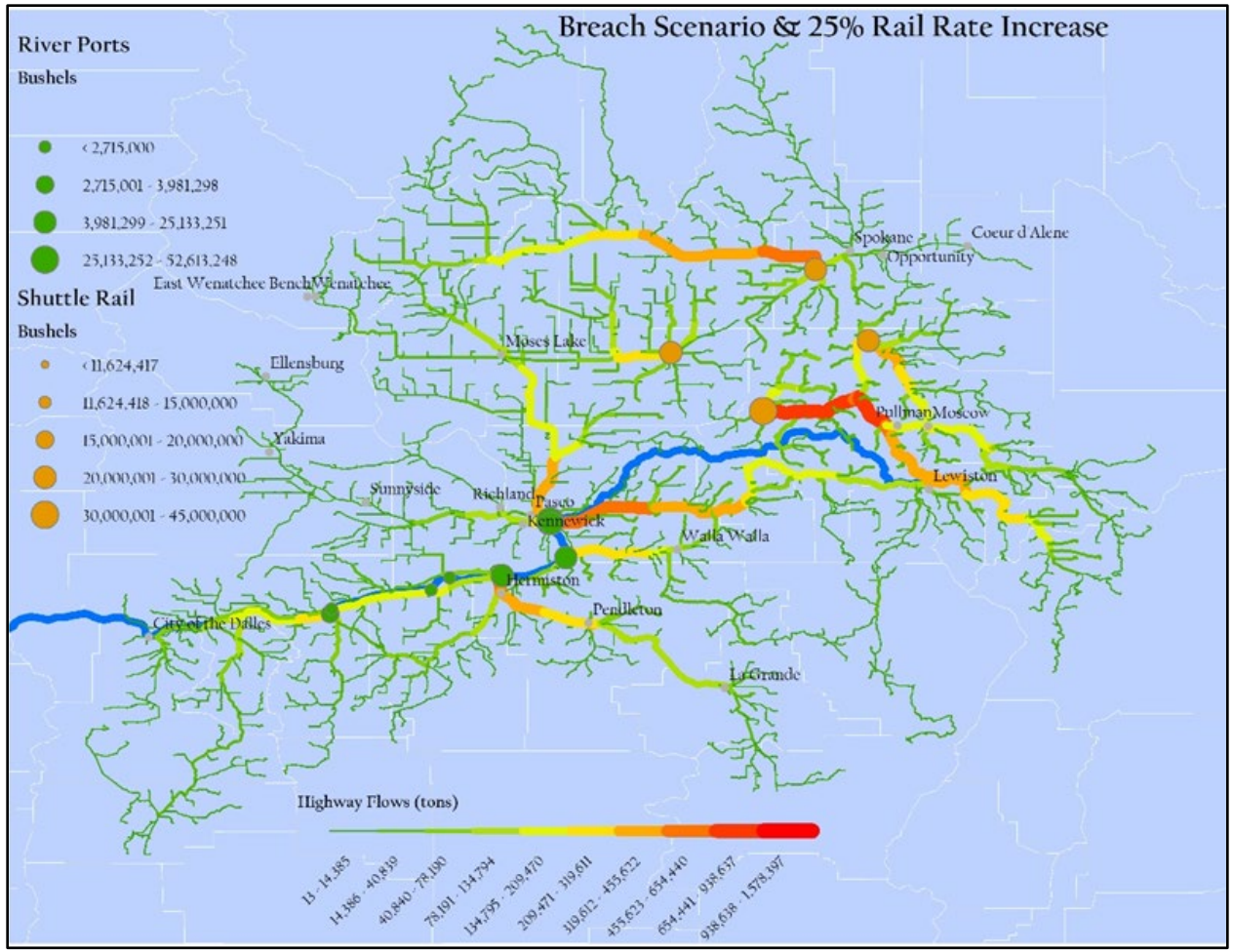
SCENARIO 3: EFFECTS OF DAM BREACH ON GRAIN TRANSPORTATION ASSUMING RAIL RATE INCREASE OF 50 PERCENT

Under Scenario 3, like in Scenario 1 and 2, it is assumed commodities that would have been transported on the lower Snake River under the No Action Alternative using the next least cost alternative. However, Scenario 3 assumes that rail rates would increase by 50 percent above No Action Alternative rates. As discussed above, rail rates increased between 35 and 40 percent during periods in the past when the lower Snake River navigation was closed due to lock maintenance. Those closures were temporary and planned (announced) and shippers adjusted volumes accordingly. Given this, increases in rail rates from a permanent closure would likely be higher given that the competitive pressure between two competing modes would no longer exist and the rail industry could exercise monopoly pricing. Therefore, this scenario represents a reasonable high estimate. As under Scenario 1 and Scenario 2, the cost increase to specific shippers would depend upon location and would vary throughout the region, depending on transportation options at each location. Generally, those grain shippers that are the farthest from alternative shipping locations (shuttle rail facilities or river ports on the Columbia River) would be the most negatively impacted. The Regional Economic Effects section describes farming effects in more detail.

Increasing rail rates by 50 percent in Scenario 3 under MO3 would result in total transportation costs of approximately $193 million, a $48 million increase in costs (in comparison to the $13 million increase under Scenario 1 and to the $31 million increase under Scenario 2), and is equivalent to 95 cents per bushel transportation costs. This would represent a 24 cent per bushel increase from the No Action Alternative (an increase of 33 percent when compared with the No Action Alternative). While this increase would represent an increase of 33 percent on average, some individual shippers may experience increases that are more than double this amount, depending on their location.

568 **Table 3-5. Multiple Objective Alternative 3 Scenario 2 (25 percent Rail Rate Increase): Changes from No Action Alternative**

Origin-Destination Type	Mode	Volume (bushels)	Total Cost	Cents/Bushel	Ton-Miles	Average Distance (miles)
Farm to Elevator (no rail)	Truck	4,201,670	$885,508	(0.02)	6,153,442.72	-4.5
Farm to Elevator (with rail)	Truck	44,722,739	$9,534,917	(0.01)	67,287,654.97	-2.1
Farm to Elevator (shuttle rail)	Truck	31,101,452	$12,077,649	0.06	138,459,240.10	15.2
Farm to River Port	Truck	(80,025,861)	-$19,069,260	0.07	(154,741,874.54)	17.3
Elevator to Elevator with Rail	Truck	498,298	$111,709	0.22	845,211.88	25.7
Elevator to Elevator Shuttle Rail	Truck	-	$0	-	-	0.0
Elevator to River Port	Truck	3,703,372	$2,258,162	0.24	29,984,454.23	59.6
Elevator with Rail to Shuttle Rail	Truck	-	$0	-	-	0.0
Elevator with Rail to Shuttle Rail	Rail	17,173,661	$2,740,914	(0.05)	17,608,509.41	-22.7
Elevator with Rail to River Port	Truck	28,047,376	$7,123,924	(0.04)	61,478,081.62	-10.2
Elevator with Rail to River Port	Rail	-	$0	-	-	0.0
Shuttle Rail Elevator to Portland	Rail	48,275,113	$38,784,812	0.12	495,088,604.69	-10.6
River Port to Portland	Barge	(48,275,113)	-$23,202,569	(0.05)	(568,883,879.43)	-68.0
Total Change from NAA		-	$31,245,767	0.15	93,279,446	-



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570 **Figure 3-9. Multiple Objective Alternative 3 Scenario 2 (25 percent rail rate increase):**
571 **Shipping Routes by Mode.**

572 Source: Transportation optimization model, parameterized to reflect current conditions.

573

The TOM model finds that the distribution of volume moving via different transportation modes would change substantially under this scenario, as the increase in rail rates would dramatically shift grain shipments away from shuttle rail lines. Instead shippers would move grain either by rail to river terminals on the Columbia River, or by truck to river terminals on the Columbia River. The total volume moving by shuttle rail to export ports would increase under Scenario 3 to 72 million bushels, which is a 1.1 percent increase compared to the No Action Alternative. The volume moving by barge (130 million bushels) would be higher than under Scenario 1 (64 million bushels), and would be slightly lower than would have occurred under the No Action Alternative (131 million bushels), representing a decrease of 0.6 percent. River ports still operating on the Columbia River at Pasco, Washington, would experience a large volume increase, mostly from shipments arriving via truck traveling longer distances to access the river ports.[8]

Total ton-miles under Scenario 3 would increase to 2.5 billion, a 5 percent increase from the No Action Alternative. Total truck ton-miles would increase dramatically to 855 million ton-miles (391 million more than under the No Action Alternative). Under MO3 Scenario 3, there would be a 33 percent increase in total transportation cost regionwide. However, some shippers may experience increases that are more than double this amount, depending on location (refer to the Regional Economic Effects section for a discussion of Costs to Agricultural Operations). Unlike Scenarios 1 and 2, modal changes under Scenario 3 would only create a small increase in volume at each of the four shuttle rail facilities. Consistent with the No Action Alternative, each shuttle rail facility would receive approximately 4 trains per month. Overall, the annual number of shuttle rail unit train trips in the region would increase by 2, and the number of shuttle rail cars loaded would increase by approximately 240. This would represent a less than 1 percent change from current shuttle rail activity.

The changes in grain flows, transportation costs, and ton-miles under the MO3 under Scenario 3 are summarized in Table 3-6, Figure 3-10 provides a visual depiction of commodity movements by mode for Scenario 3. As in Table 3-6, Figure 3-10 depicts shipping patterns by mode for grain shippers under MO3, Scenario 3. Specifically, the figure illustrates the highway flows of grain shipments, the location of origination points used in the transportation optimization model, river port terminals along the Columbia-Snake navigation channel (green circles) and shuttle rail terminals (orange circles). As shown, when rail rates assumed to increase by 50 percent after the breach, a larger proportion of the grain is now trucked to the Tri-Cities area, as indicated by the thick, dark red lines in Figure 3-10

[8] The model assumes that after freight is loaded onto rail lines, it is shipped to Portland via rail and will not be transferred to the river at Pasco or downriver. Should this option be made available, costs would be somewhat lower under this scenario.

607 **Table 3-6. Multiple Objective Alternative 3 Scenario 3 (50 Percent Rail Rate Increase): Changes from No Action Alternative**

Origin-Destination Type	Mode	Volume (bushels)	Total Cost	Cents/Bushel	Ton-Miles	Average Distance (miles)
Farm to Elevator (no rail)	Truck	20,240,269	$3,444,821	(0.06)	15,603,792	-15.4
Farm to Elevator (with rail)	Truck	82,323,807	$16,164,634	(0.02)	100,240,187	-5.9
Farm to Elevator (shuttle rail)	Truck	(22,538,215)	($4,820,439)	0.00	(34,183,387)	0.5
Farm to River Port	Truck	(80,025,861)	($14,837,301)	0.16	(84,516,494)	40.9
Elevator to Elevator with Rail	Truck	-	$0	-	-	0.0
Elevator to Elevator Shuttle Rail	Truck	1,212,417	$352,402	-	3,425,139	42.8
Elevator to River Port	Truck	19,027,852	$13,235,305	0.39	181,101,543	96.7
Elevator with Rail to Shuttle Rail	Truck	-	$0	-	-	0.0
Elevator with Rail to Shuttle Rail	Rail	22,101,943	$2,513,352	(0.24)	6,037,253	-40.8
Elevator with Rail to River Port	Truck	60,221,864	$19,928,589	0.03	209,794,207	7.1
Elevator with Rail to River Port	Rail	-	$0	-	-	0.0
Shuttle Rail Elevator to Portland	Rail	776,145	$17,944,821	0.24	(20,703,326)	-13.5
River Port to Portland	Barge	(776,145)	($6,180,280)	(0.05)	(247,902,414)	-61.8
Total Change from NAA		–	$47,745,902	$0.24	128,896,500	–

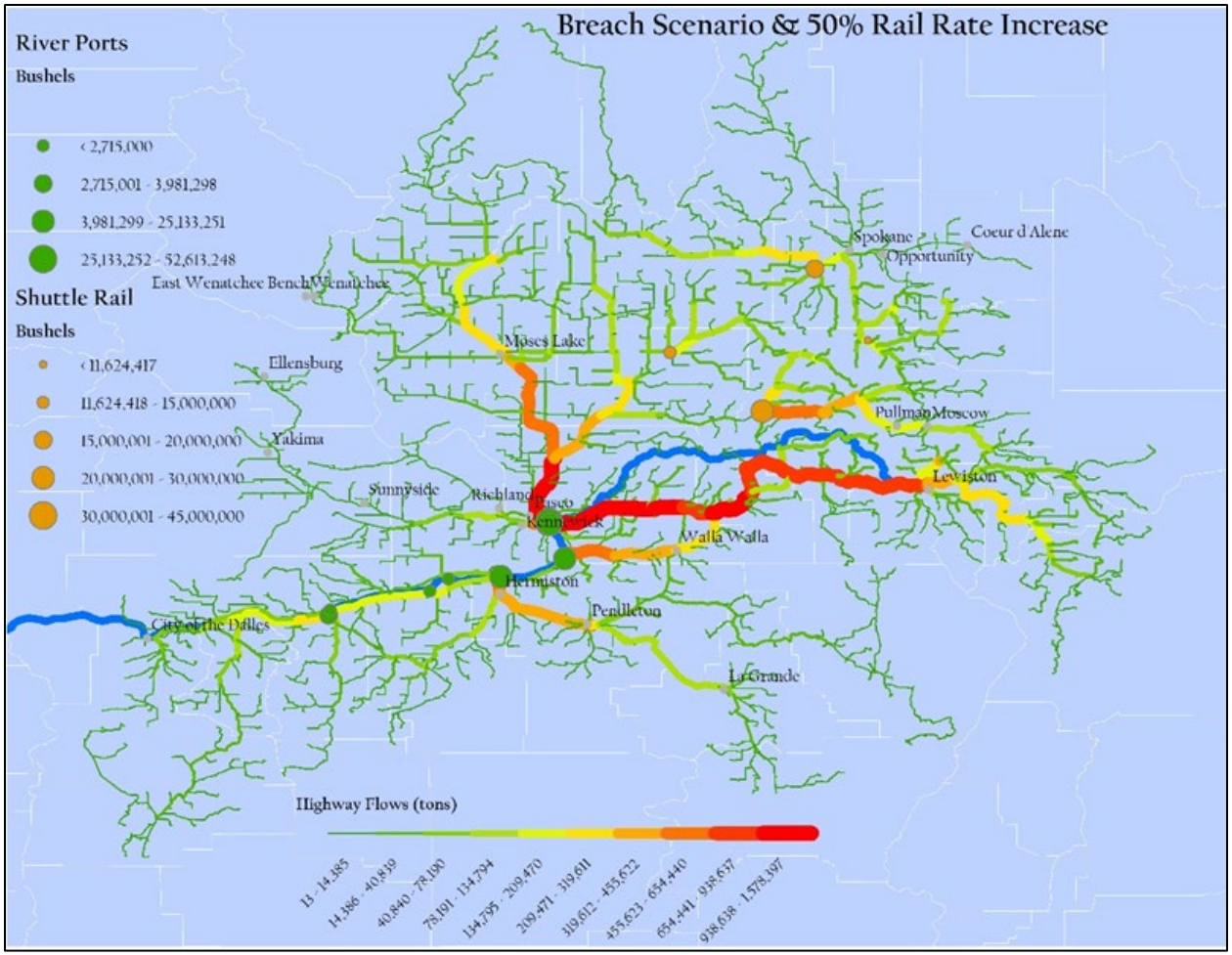


Figure 3-10. Multiple Objective Alternative 3, Scenario 3 (50 Percent Rail Rate Increase): Shipping Routes by Mode

EFFECTS ON OTHER COMMODITIES

As described above, the modeling effort associated with increased costs to transport goods focused on grain shippers because these shipments comprise the majority (more than 87 percent) of downriver shipments. However, it is worth noting that other commodities shipped on the system would also not be able to utilize the system following dam breach. The total volume of these commodities is relatively small; however, the system provides some unique services associated with these commodities.

WOOD CHIPS

Wood chips travel both upriver and down river in relatively small volumes in service of papermills that are located on or near the lower Snake River. As described in the Affected Environment section, a papermill in Lewiston receives regular shipments of wood chips that are used as a process input. While comprising a small overall volume, there would be increased costs to this industry under MO3 associated with shipping these inputs by other means (likely via truck).

FUEL/PETROLEUM PRODUCTS

Primarily an upriver movement that ends above McNary Dam, petroleum products travel via barge in the shallow system and comprise the primary upbound commodity on the lower Snake River segment (100 million tons in 2018, Waterborne Commerce 2020). Because these shipments currently terminate below Ice Harbor Dam and do not utilize the river channel, they would not be directly affected by dam removal. However, barge companies report that these shippers are very sensitive to increased risk and are concerned that potential needs for dredging facilities in the McNary pool would discourage those shippers from utilizing the system even if it continues to be made available by periodic dredging (Personal communication with Shaver Transportation Company, January 2020).

SHIPMENTS OF OVERSIZED OBJECTS

As described in the Introduction to this section, the CSNS provides a unique water route to transport oversized cargo into the interior of the U.S. Cargo transported upriver to the Port of Lewiston can then be transported on U.S. Highway 12, which has no cargo height restrictions. U.S. Highway 12 has no overpasses and similarly there are routes in Montana that have no height restrictions (Written communication with Idaho Cooperating Agencies, January 2020). While the system transports shipments of this type infrequently, it is a unique service that could not be replaced by road or rail alone.

Regional Economic Effects

As discussed above, MO3 would necessitate changing the mode of transit for commodities that would have used the lower Snake River portion of the CSNS under the No Action Alternative. Changing the mode of transportation for these goods from commercial barge to road or rail would have regional economic implications. This section discusses potential regional economic effects associated with increased costs to the agriculture industry, increased demands for infrastructure, including highways, rail lines, grain elevators, impacts to port facilities and barge companies. Iimpacts to support industries for the commercial cruise lines, and other city and local implications are described in section 3.10.3.5 of the EIS.

COSTS TO AGRICULTURAL OPERATIONS

The entities producing and shipping goods on the CSNS would also experience increased costs under MO3. While the increased expenditures to transport goods would benefit, to some degree, the road and rail industries and industries that support them, producers of commodities would need to absorb the cost increase in their operations. As described above, costs to farmers are likely to vary based on location.

In order to illustrate how specific geographic locations would differ in terms of impacts of MO3, two hypothetical farmers evaluated to illustrate how M03 would affect their shipping choices and costs related to the scenarios provided above. The first example evaluates impacts to a farmer that is located near Colfax, WA and one farmer is located near Grangeville, ID.

Example 1: Farmer Near Colfax with Many Shipping Options

The first example evaluates impacts to a farmer that is located near Colfax, WA. The Colfax farmer is located in an area where there is intense wheat production and where there are several different choices for shipping wheat to market. Under the No Action Alternative, the Colfax farmer would ship wheat using the least-cost option available, which would be to truck grain to the port at Almota on the lower Snake River at a cost of 23 cents per bushel (Figure 3-11). Once at the port of Almota, the barge rate to ship the wheat to Portland would be 46 cents per bushel, for a total shipping cost of 69 cents per bushel.

Under MO3, where the option to utilize the lower Snake River for shipping would not be available, the Colfax farmer would choose the next cheapest option, which would be to ship wheat north to the McCoy shuttle rail facility at a cost of 21 cents per bushel (Figure 3-12). The Colfax farmer would then pay 51 cents per bushel to ship the wheat directly to Portland via rail for a total cost of 72 cents per bushel. As such, under Scenario 1, the No Rail Rate Increase Scenario, the farmer's costs would increase by 3 cents per bushel (4 percent).

If the shuttle rail facility raises the rail rate by 25 percent from the No Action Alternative (Scenario 2), the Colfax farmer would continue to utilize the McCoy shuttle rate facility option (Figure 3-13), but shipping costs would increase from 72 cents per bushel to 85 cents per bushel

(21 cents from the truck travel to the shuttle rail and then 64 cents per bushel rail rate), which would represent an increase of 23 percent.

If shuttle rail facility raises the rail rate by 50 percent from the No Action Alternative, the Colfax farmer's next cheapest option would be to utilize the Lacrosse shuttle rail facility, which would increase shipping costs to $1.07 per bushel (35 cents truck cost to Lacrosse and 72 cents per bushel shuttle rail), which would represent an increase of 55 percent (Figure 3-13).

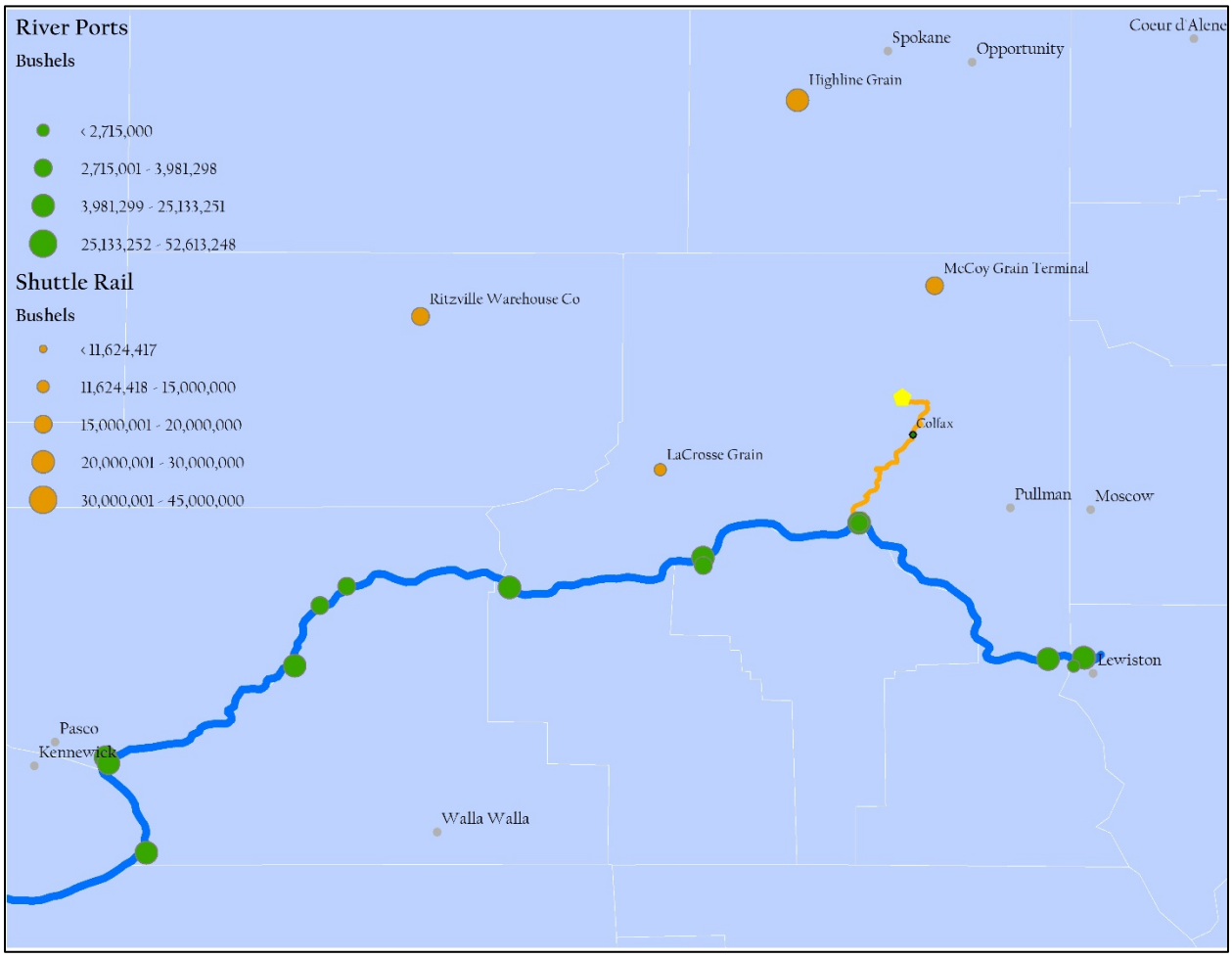
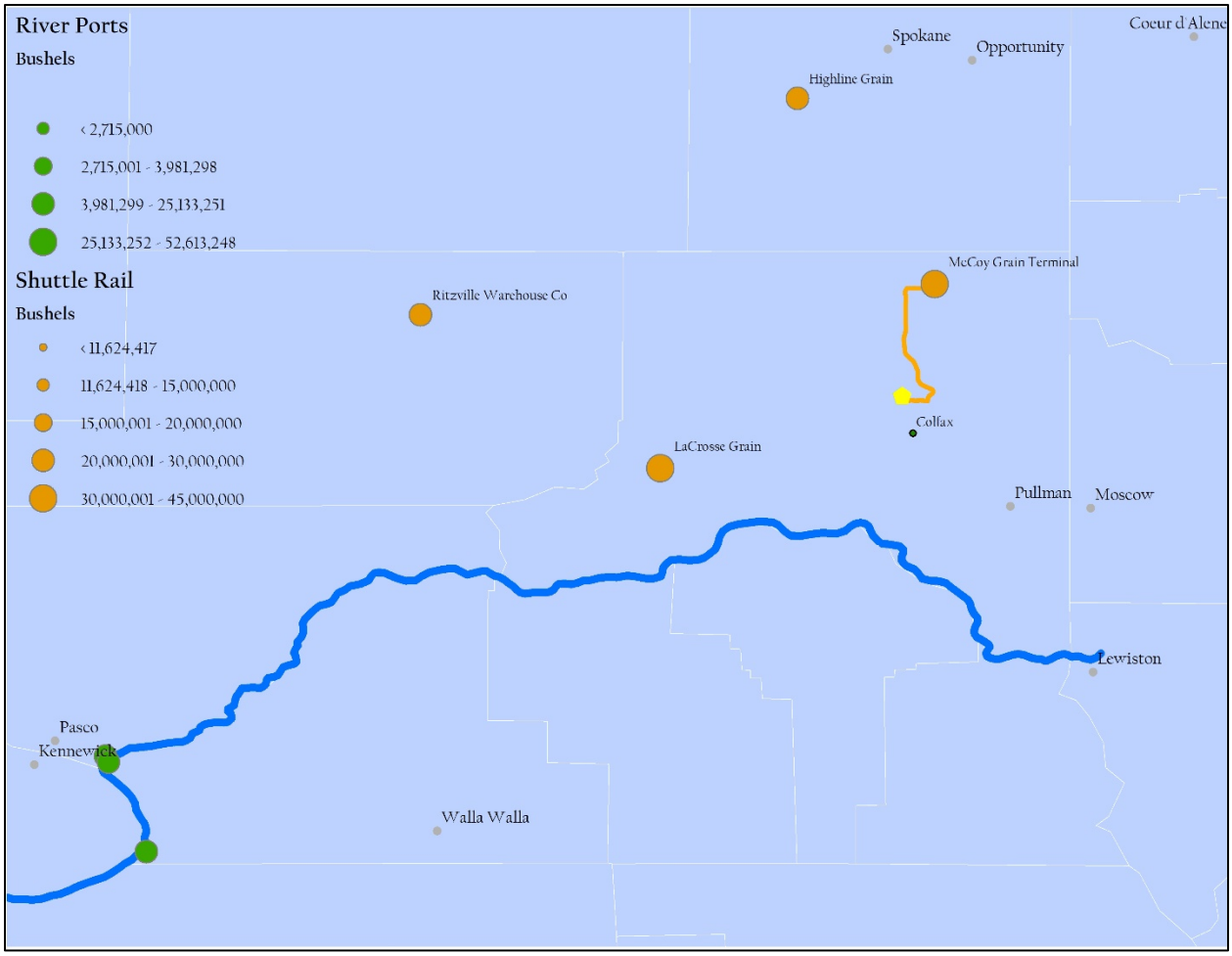


Figure 3-11. Colfax-Area Farmer Transit Route Under the No Action Scenario



688

689 **Figure 3-12. Colfax-Area Farmer Transit Route Under Scenarios 1 and 2: No Rail Rate Increase**
690 **and 25% Rail Rate Increase**

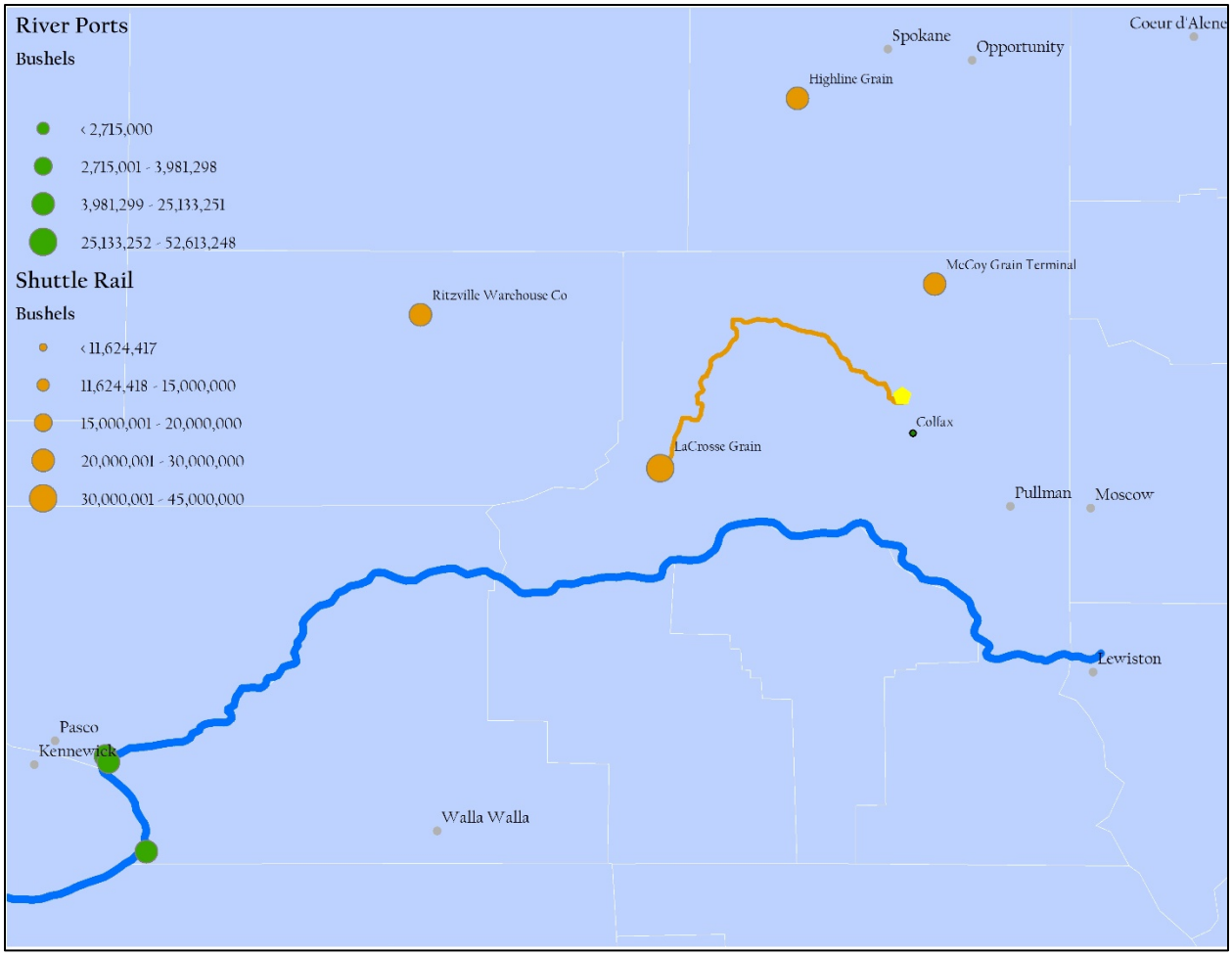


Figure 3-13. Colfax-Area Farmer Transit Route Under Scenario 3: 50% Rail Rate Increase

Example 2: Farmer near Grangeville with More Limited Shipping Options

In a second example evaluates impacts to a farmer that is located near Grangeville, ID. A farmer in Grangeville is located at the edge of wheat production in the Northwest and has relatively limited shipping options. Under the No Action Alternative, the Grangeville farmer's least cost option would be to truck wheat from the farm to the Lewiston barge terminal at a cost of 47 cents per bushel and then pay another 47 cents per bushel barge rate to move the grain to Portland for a total cost of 94 cents per bushel (Figure 23). As such, shipping costs are approximately 36 percent higher than the Colfax farmer's shipping costs under the No Action Alternative.

Under MO3 when river barge is not available on the lower Snake River, the Grangeville farmer's next best option would be to truck the wheat from the farm to the McCoy shuttle terminal at a cost of 75 cents per bushel and then to pay the 51 cents per bushel to ship the wheat via rail to Portland, for a total cost of $1.26 per bushel. As such, under Scenario 1, the No Rail Rate Increase Scenario, costs would increase by 32 cents per bushel (34 percent) (Figure 3-14).

If the railroads begin raising rates by 25 percent or 50 percent (Scenarios 2 and 3), the Grangeville farmer would be better off trucking the grain all the way to the Tri-Cities for a cost of $1.08 per bushel and then paying 36 cents per bushel to barge the grain to Portland at a total cost of $1.44 per bushel. As such, under Scenarios 2 and 3, costs would increase by 50 cents per bushel (53 percent).

The difference between the Grangeville farmer and the Colfax farmer is that the Grangeville farmer has higher transportation costs to begin with given that he is much farther from market and has limited transportation options in order gain access to those markets. Once those options are reduced, as would occur under MO3, the Grangeville farmer cost impacts would be much greater. Under MO3 when rail rates increase by 50 percent, the Grangeville farmer's costs would increase by 50 cents per bushel, compared with 39 cents per bushel for the Colfax farmer, both representing an increase in shipping costs of over 50 percent compared to the No Action Alternative.

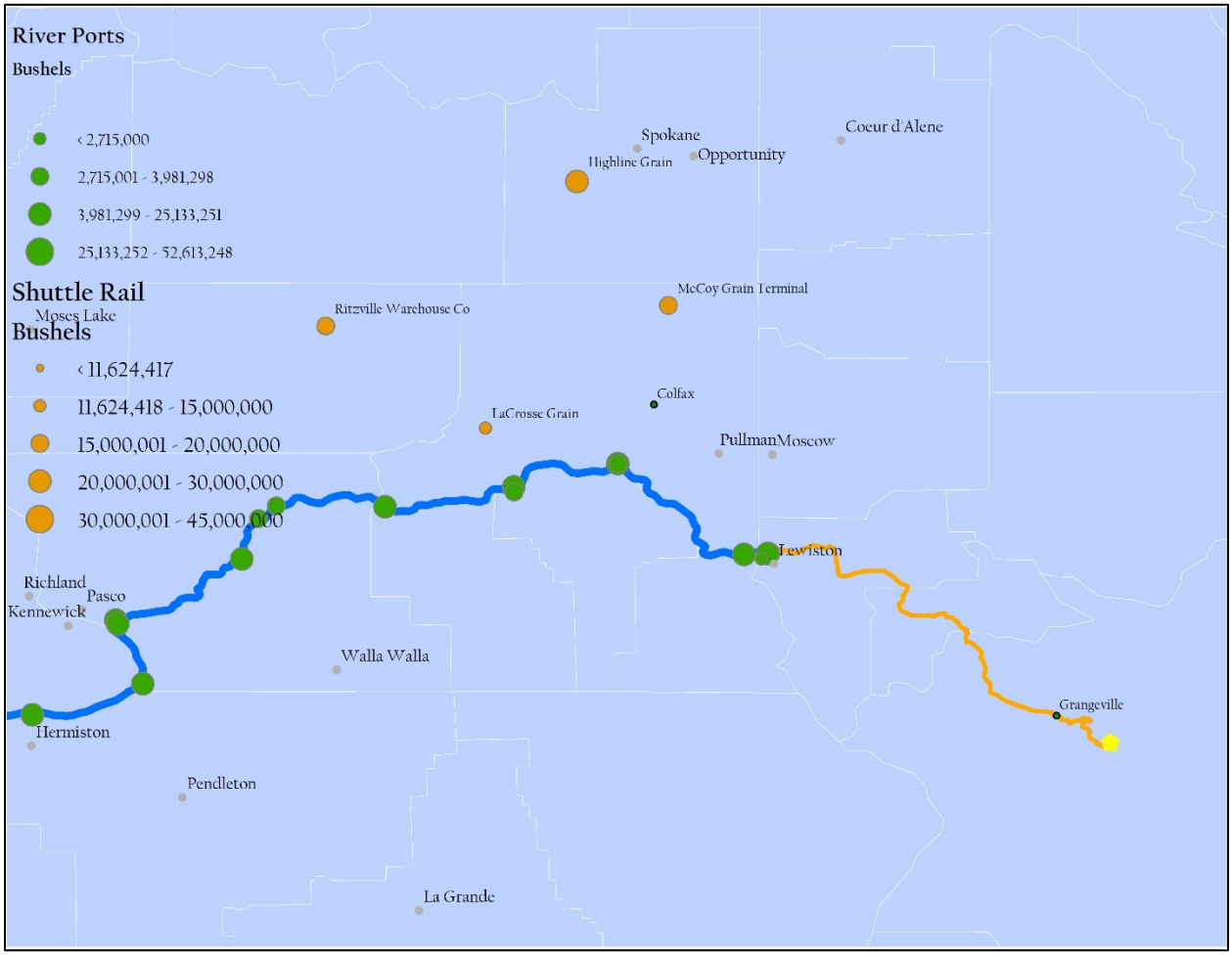


Figure 3-14. Grangeville-Area Farmer Transit Route Under the No Action Alternative

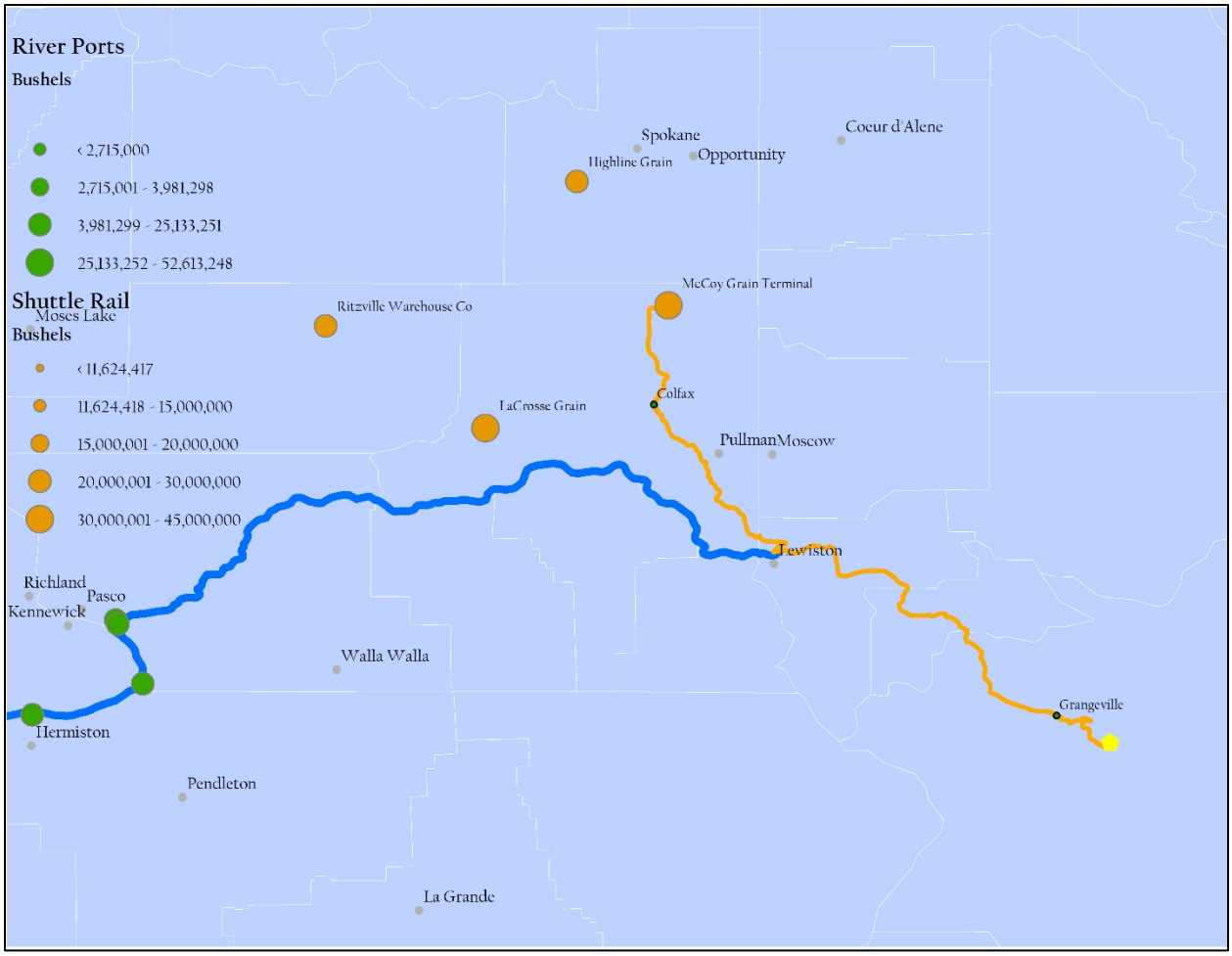


Figure 3-15. Grangeville-Area Farmer Transit Route Under Scenario 1: No Rail Rate Increase

Faced with increasing transportation costs of over 50 percent, profitability of farming in this region would be adversely affected. However, the analysis indicates the cost to transport wheat to market would still be less than costs paid by other wheat growers in the US (e.g. Dakotas and Midwest). For example, with the current total cost of producing wheat being approximately $6 per bushel, the estimated cost increase of $0.07 (average increase under Scenario 1) to $.50 per bushel (for Grangeville farmer under Scenario 2 or 3) would represent a 1 to 8 percent increase in total production costs, marginally affecting competitiveness (Figure 3-15).

The wheat grown in the Northwest is soft white wheat. This type of wheat is a preferred grain for Asian and Eastern countries, however there is no guarantee wheat grown in the Northwest will be competitive now or in the future because there are so many factors that influence international commodity markets (e.g. trade agreements, US dollar etc., global supply). In general, wheat producers are 'price takers' so keeping production costs lower are critical for remaining competitive. Favorable conditions for Northwest wheat growers that help them stay competitive are: 1) the natural environment of the Palouse region (weather, soils) is ideal for growing this type of wheat which leads to some of the highest yields per acre in the world, and

2) proximity of Northwest export ports. Currently, the cost to transport wheat to market is quite low relative to other parts of the US and world.

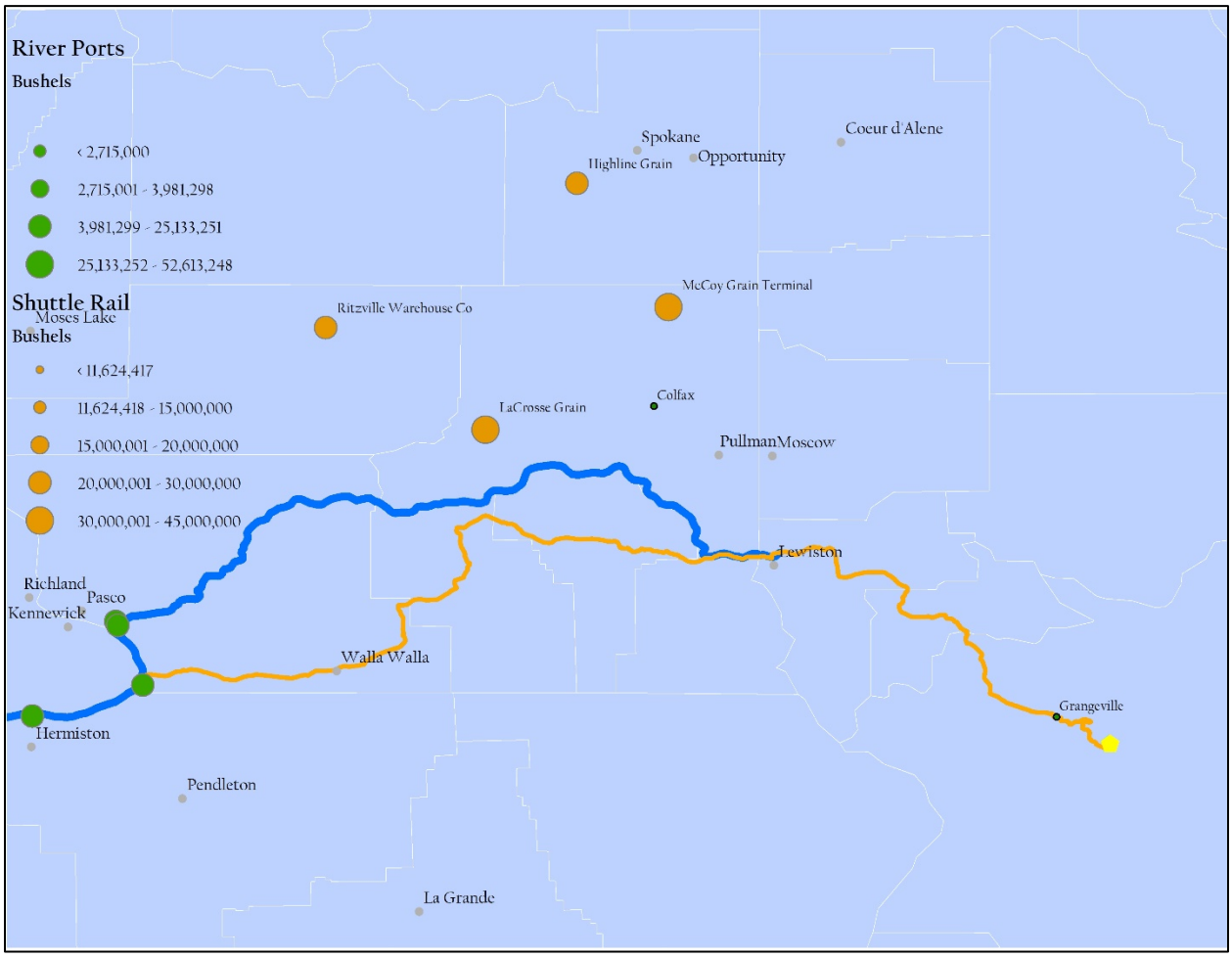


Figure 3-16 .Grangeville-area Farmer Transit Route Under Scenarios 2 and 3: 25% and 50% Rate Increase

INFRASTRUCTURE COSTS

With dam breaching and a shift of commodities from shipment on the lower Snake River to other shipping modes, demands for the region's land-based transportation and grain handling infrastructure would increase. These increases in infrastructure demands could vary widely depending on factors such as the changes in rail rates, which influence the mix of alternative transportation modes that are utilized. In our scenarios, the largest demands on rail would occur under Scenario 1, when rail rates are assumed not to increase and rail transit would be relatively more attractive. In contrast, increased highway use would be highest under Scenario 3, when rail rates are assumed to increase by 50 percent.

This section addresses impacts to the rail system, potential effects to rail car demands, highway system requirements, and grain elevator capacity requirements that may occur under the

various scenarios, as well as potential costs associated with these demands. Estimates were developed for these costs based upon input from local stakeholders, as well as published reports including the 2002 Lower Snake River Feasibility Study/EIS (2002 EIS), and the 1999 Lund Report. Both of these studies considered infrastructure investments that would be needed if the lower Snake River dams were breached.

It should be noted that the high rail demand scenario and the high highway demand scenario would not both occur. In addition, infrastructure investments are transitional costs, and would primarily be borne by private entities, including rail lines and grain shippers. Over time, prices should adjust to cover these costs. Some highway costs would be transferring to the trucking industry through fees, though most costs would likely be borne by public entities. Because of the high level of uncertainty surrounding these costs, interpretation of these them should be done with caution.

Highways and Highway Congestion

Transportation officials and regional policy planners are often concerned with how closure (or opening) of one mode option impacts truck traffic and ultimately impacts the highway system. The comparisons between how each of the TOM scenario results in impacts upon the public highway system is best captured in comparing the ton-miles between different origin-destination types in each scenario. The ton-mile more accurately captures the comparison in volume and distance across different freight modes. But often planners are also concerned with absolute number of truck trips. These comparisons may also be made utilizing the same tables and dividing the total volume (bushels) for each truck origin-destination type by 1,000 (the approximate capacity of the typical grain truck). Depending on the scenario, truck ton-miles may experience an increase of 19 percent under Scenario 1, when rail rates are not assumed to increase, to 84 percent when rail rates increase by 50 percent under MO3, when compared to the No Action Alternative. Since the TOM captures all grain movements leaving the farm, the total number of trucks for shipments leaving the farm doesn't change between each scenario given that total grain production would not be anticipated to change. But the distribution of shipments and truck trips to the various destinations after leaving the farm does change once the choice set changes. The most immediate and noticeable impact comparing the No Action Alternative to MO3 is that the number of truck trips going to the river ports decreases by 80,086 trucks as farmers now choose the next least cost option, which would be shuttle rail under Scenario 1. That would result in an additional 46,638 trucks going from the farm to elevators with rail access instead and an additional 32,495 trucks to elevators with rail access and an additional 892 trucks going from the farm to elevators without rail access. Also, under Scenario 1, an additional 498 truck trips would occur for trans-shipments between elevators without rail to those with rail that didn't occur under the no-action scenario. The net additional trips under Scenario 1 is 13,515 truck trips compared to the No Action Alternative.

Once railroads increase rail rates by 25 percent under Scenario 2, truck trips to the remaining Columbia River ports would become more attractive (compared to shuttle rail with higher rates) and shippers would begin to increase truck trips to those ports as elevator (both with and

without rail access) to river port truck shipments increase. The total net additional trips under this scenario would be 32,249 truck trips compared to the No Action Alternative, with an additional 25,711 truck trips due to elevator to river port shipments. Truck shipments to shuttle elevators would decline under Scenario 2 compared Scenario 1, but would still be higher than under the No Action Alternative.

Once railroads increase rail rates by 50 percent, the net additional trips would increase to 79,250 truck trips compared No Action Alternative, with the majority of that coming from elevator to river port movements.

Changes that would result in increased truck usage would also add to vehicular traffic and congestion. As shown in Figure 3-16 (Scenario 2 map), Highway 12 and Highway 395 appear likely to experience increases in traffic. These, in turn, would have impacts on infrastructure costs. In particular, the costs to maintain roadways may increase under MO3. In order to estimate roadway infrastructure costs:

1. Per ton-mile estimates of road resurfacing costs in Eastern Washington by truck and road type were acquired from published literature (Jessup and Casavant, 1998). These costs are inflated to 2019 dollars and are presented in Table 3-7.

2. An allocation of 70% combination truck and 30% farm truck are applied to the costs of road resurfacing per mile to produce a per ton-mile cost estimate across both truck types. Across both truck types, costs would be $0.01 per ton-mile on state roads and a $0.04 per ton-mile on county roads. It is assumed that 60 percent of increased traffic would occur on state roads and 40 percent would occur on county roads. These estimates are presented in Table 3-8.

3. Finally, to estimate total costs to road infrastructure, the total change in truck ton-miles from the TOM is applied to per ton-mile costs (Table 3-8).

Table 3-7. Costs of Road Resurfacing per Ton-mile (2019 Cents)

Road Type	Combination Truck (¢)	Farm Truck (¢)
Interstate	0.4	0.9
State Highway	1.0	2.4
Country	3.0	6.6

Costs to maintain roads in Eastern Washington due to the increased truck traffic would be approximately $2 million annually in Scenario 1. Under Scenario 2, where truck use would increase moderately, increased pavement damage costs would be approximately $4 million annually. Under Scenario 3, where truck use would increase substantially, increased pavement damage costs would be approximately $10 million annually. The increase in infrastructure costs across all MO3 Scenarios are illustrated in Table 3-9.

827 **Table 3-8. Resurfacing Cost per Truck Ton-Mile by Road Type.**

Road Type	Resurfacing Cost per Truck ton-mile (cents)	Assumed Percentage of Truck Traffic on Road Type
Interstate	-	0%
State Highway	1.4	60%
Country	4.1	40%
Weighted Damage Cost (cents/ton-mile)	2.5	-

828 Note: Resurfacing costs per truck ton-mile reflect the costs associated with an allocation of 70% combination
829 trucks and 30% farm trucks. Due to the distribution of weight on their axle, farm trucks create higher costs of road
830 surfacing per ton-mile than combination trucks.

831 **Table 3-9. Total Increase in Pavement Costs for Each MO3 Scenario.**

Scenario	Change in Truck Ton-Miles	Total Pavement Resurfacing Cost
MO3 Scenario 1	86,965,082	$2,164,375
MO3 Scenario 2	149,466,211	$3,719,894
MO3 Scenario 3	391,464,988	$9,742,727

832 ***Rail Lines and Demand for Rail Cars***

833 Depending on the price increases by rail lines under MO3, rail traffic would be anticipated to
834 increase when compared to the No Action Alternative when barges would share the
835 transportation load. The higher the increase in rail prices, the lower the increased demand for
836 rail (this is because other options, such as transit via truck to the Tri-Cities area, would be
837 relatively more affordable as rail prices increase). Rail ton-miles may increase by as much as 86
838 percent under Scenario 1, when rail rates are not assumed to increase, or by 63 percent under
839 Scenario 2 (25 percent rail rate increase). Under Scenario 3, with a 50 percent rail rate increase,
840 rail ton-miles would be anticipated to decrease by 2 percent (under Scenario 3). As such,
841 although Scenario 1 may be the most unlikely, it also defines the highest increase in demand for
842 rail.

843 *Increased capacity at shuttle rail facilities.* As discussed in the social welfare section, the
844 increase in rail demand under Scenario 1 (no rail rate increase) and Scenario 2 (25 percent rail
845 rate increase) would represent an increase in the demand for shuttle rail capacity that would
846 exceed current shuttle rail capacity. Increased capacity needs would range from approximately
847 38 million bushels under Scenario 1 (approximately the size of one shuttle rail facility) to 19
848 million bushels under Scenario 1 (less than one shuttle rail facility). Increased shuttle rail
849 capacity would not be required under Scenario 3. Costs to develop this increased capacity
850 would vary depending on the type of storage provided. Increased investments at ports around
851 the Port of Pasco would also likely be required. Based upon input from local shuttle rail facility
852 operators the cost to construct a new shuttle rail facility with the ability to move 25 million
853 bushels of wheat/barley per year is approximately 25 million per year (personal
854 communications with shuttle rail manager). Based upon this it's estimated that 1 to 2 shuttle
855 rail facilities could be needed at a cost of $25 to $50 million.

Demand for trains and rail cars. As discussed in the social welfare effects section, the number of unit trains (with approximately 110 cars per train) would be anticipated to increase under Scenario 1 (no rail rate increase) from approximately 4 trains to approximately 8 trains per month at each shuttle rail facility. Overall, the number of shuttle rail unit train trips in the region would increase by 185 annually, and the number of shuttle rail cars loaded would increase by over 20,000 under Scenario 1. This would represent an increase of 94 percent over current shuttle rail activity. Scenario 2 also anticipates increased demands are somewhat lower, at 133 trains and 14,600 rail cars. Similarly, the 2002 EIS found the unavailability of variable inputs, such as locomotives, rail cars, and train crews could lead to serious short-turn capacity constraints for mainline rail lines. However, in the long run, these services would be acquired "at prices that would not affect rail rates if rail carriers face effective competition in rail-served markets" (2002 EIS, Appendix I).

Costs to improve condition of shortline rail. Local stakeholders as well as WSDOT stated that the shortline rail lines are need of improvement, and would require significant investment to handle higher volumes. Similarly, the 2002 EIS found that shortline rail lines were in generally poor condition at the time. These rail lines were characterized as "spin-offs of low volume, low revenue/profit segments of the mainline system and maintenance tends to be deferred. Needed improvements included interchanges with mainline railroads, track upgrading, and other. Costs of shortline rail improvements were estimated to range from $30 million $36 million or $2.1 million to $2.5 million annualized over 50 years (inflated to 2019 dollars). These would be generally private investments, although public investments of the PCC could also be required.

Congestion on mainline rail lines. Concerns have been raised about congestion on the mainline rail lines, however based upon available information congestion and associated capacity constraints are likely more associated with shuttle rail facilities and/or shortline rail upgrades. Similar the 2002 EIS found that diversion of lower Snake River traffic to rail lines would increase rail traffic, but would not create substantial capacity issues along the mainline rail corridor. Even though some congestion was expected, the 2002 EIS found that BNSF and UP would be able to address capacity issues without increasing long term marginal costs or changing rates. When the EIS 2002 interviewed a representative at BNSF, BNSF asserted that existing rail capacity would sufficient to handle the increase in traffic with dam breaching (2002 EIS, Appendix I).

Effects to Ports and Barge/Towboat Companies

The analysis finds that under Scenario 1, barge volume would decrease by 64 percent on the system relative to the No Action Alternative (some volume would continue to transit the Columbia River below the breached dams). Under Scenario 2, barge traffic would also decrease by 52 percent. Reductions would be less under Scenario 3, when rail rates are the highest, when barge volumes would be reduced by 22 percent. A change in transportation mode away from barge would affect regional businesses that support port and barge activities as well as associated employment opportunities, particularly in the short term, as businesses adjust to the

new shipping conditions and employment demands. Under this scenario, adverse effects to companies reliant on barge transit, such as towing companies, could be adversely affected. As discussed in Section 3.10.2, Affected Environment, a small number of companies specialize in operating barges and tow boats on the CSNS. These operators employ approximately 450 employees, which range from captains and crews to tug boat operators, shipping handlers, to boat builders. Many crew members permanently reside in the greater Portland area, but some reside in upriver areas (Personal communications with Tidewater Barge Lines and Shaver Transportation Company, January 2020). The commercial navigation industry supports employment for a wide range of transportation and material moving occupations. Some of these positions, such as material moving workers, including freight, stock, and material movers, may be readily transferable to support for road or rail transportation activities, while others, such as boat captains, pilots and operators, and ship engineers, would not be transferable, and could result in relocation of some workers to areas downstream or to other professions not dependent on river navigation. These companies report that many of their employees are long-term, having niche experience and skills that would likely be difficult to transfer to other industries. (Personal communications with Tidewater Barge Lines and Shaver Transportation Company, January 2020). They also report that approximately 50 percent of their business is conducted on the lower Snake River, and surmise that removal of the ability to utilize the river could threaten their ability to maintain profitability.

Increased demand for rail operators as well as for truck transport and support services would increase under this alternative. Industry representatives have noted that an increased demand for trucking services would likely result in a shortage in the availability of trucks drivers in the short term (Personal communication with Port of Lewiston and industry stakeholders, December 2019).

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Draft Columbia River System Operations Environmental Impact Statement

Appendix M
Recreation

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CHAPTER 1 - INTRODUCTION

The environmental consequences analysis for recreation evaluates how changes in reservoir, river, and habitat conditions under CRSO alternatives could affect visitation, recreational opportunities, and the value of the recreation experience. The effects of CRSO alternatives for recreation are evaluated across three categories: social welfare effects (i.e., national economic development, or NED), regional economic effects (i.e., regional economic development, or RED), and other social effects. This appendix focuses on providing additional details that support the quantified effects to recreational visitation from changes in boat ramp accessibility on reservoirs and the resulting social welfare and regional economic effects. Other social effects and additional qualitative components of the recreation analysis are detailed in the environmental consequences section for the No Action Alternative and Multi-Objective Alternatives (MOs) in Section 3.11, Recreation, and in 7.5.10 for the Preferred Alternative (PA). To summarize all of the recreation effects under CRSO alternatives, including the Preferred Alternative, the summary tables and supporting descriptions that are included in Section 3.11 and Section 7.5.10 of the EIS, are also provided for each alternative as well as the No Action Alternative in this appendix.

CHAPTER 2 - REVIEW OF METHODOLOGY FOR EVALUATION OF EFFECTS TO RECREATION

The environmental consequences for recreation in this EIS are evaluated across three categories: social welfare effects, regional economic, and other social effects. These categories provide an organizing framework for evaluating direct and indirect effects, and for displaying potential effects important to stakeholders and tribes, while ensuring effects are not double-counted. The following sections provide a brief overview of the methodology used to evaluate the effects by category. As discussed above, this appendix focuses on providing additional details to support the quantitative analysis that is described in Chapter 3.

River flows and reservoir elevations may change under the action alternatives (MOs and PA) as compared to the No Action Alternative, which may cause changes in access to water-based recreation and may affect the quality of recreational experiences. Decreased access to water-based recreation—which includes fishing, boating, and swimming—would affect the amount of visitation to a site and associated benefits to visitors and communities. Under MO3 water-based recreation on the lower Snake River would change from reservoir recreation to riverine recreation, with different water-based recreation conditions in the short term during dam breaching implementation, versus the longer term.

The recreation analysis uses outputs from the H&H analysis, which simulates reservoir operations and river conditions under each MO within a Monte Carlo framework (the H&H modeling methods are described in Section 3.2). Reservoir elevation data from the H&H analysis are compared to usable boat ramp elevations. Water surface elevations are compared with minimum usable boat ramp elevations to assess the accessibility for water-based recreators and estimate effects on recreational visitor days at reservoirs.[1] A supplemental analysis applying existing information is used to quantify potential changes in recreational visitation under for the dam breach scenario of MO3.

While effects to water-based visitation from changes in boat ramp accessibility and/or lower Snake River Dam breach are quantified, effects to river activities and non-water reservoir activities are assessed qualitatively (e.g., changes in aesthetics/recreation setting due to changes in flow and water surface elevations). Potential effects to recreation-related resources and conditions, including recreational fishing, water quality, and wildlife and habitat conditions, provide information about changes to the quality of the recreation experience that may result from the action alternatives. The detailed qualitative analysis of these effects is described in Chapter 3 of the EIS.

Changes in river flows and stages during the peak recreation season (May through September), where changes in flow of 10 percent or more are anticipated are assumed to have the potential

[1] Maximum usable boat ramp elevations were also considered, but none of the H&H elevation data would extend above ramps under the MOs and PA relative to the No Action Alternative

to affect recreation. Smaller flow changes and changes in flows that would be outside of the peak recreation season are assumed to result in negligible effects to recreation.

2.1 SUPPLEMENTAL INFORMATION ON METHODOLOGY FOR QUANTIFYING OF SOCIAL WELFARE EFFECTS RELATED TO CHANGES IN RECREATIONAL ACCESS

Social welfare effects consider both the change in the number of visitors (recreational visitor days) that could occur, as well as the change in type of recreational activities and conditions that could affect the quality of recreation experience. The analysis includes an assessment of effects on a range of activities, including recreational fishing for anadromous and resident fish species, boating, rafting/paddling opportunities, swimming, hunting, and wildlife viewing. Effects to all recreationists (tribal and non-tribal) are considered in this analysis. This section provides additional detail about impacts that are quantified in Section 3.11.

The analysis considers the effects of the alternatives on recreation over the 50-year period of analysis. The 50-year period of analysis provides a long-term perspective, and enables the analysis to distinguish between short-term and long-term impacts, recognizing that the effects to recreation would likely be different, especially under MO3 in the short versus long term. The evaluation considered the effects of hydrologic changes on annual visitation in the typical water year, as well as years with higher and lower water surface elevations. Although many factors can contribute to visitation (price of gas, population growth, climate change, and others), many of which are difficult to predict, the quantitative evaluation was focused on how changes in boat ramp accessibility could affect water-based visitation, as well as how dam breach of the lower Snake River projects (under MO3 only), could affect visitation. The results are presented for the No Action and action alternatives as annual or annual equivalent effects over the 50-year period of analysis.

2.1.1 Assessing Recreational Visitation (Visits)

The H&H analysis provides summary elevation hydrographs for reservoirs and river reaches for each alternative. The hydrographs provide the 1 percent, 25 percent, 50 percent, 75 percent, and 99 percent exceedance water levels on each day of the year. The 50 percent exceedance water level (median water surface elevation) is referred to as the typical water year throughout this appendix. The 25th percentile is referred to as the high water year and the 75th percentile as the low water year The analysis focuses on modeled daily water surface elevations associated with the 50th percentile (typical water year), but considers water surface elevations at the 25th and 75th percentiles to understand the possible extent of effects under various water conditions

The recreation analysis uses the H&H hydrographs, in conjunction with minimum usable boat ramp elevations, to assess changes in accessibility of boat ramps under the MOs and PA relative to the No Action Alternative. All elevations are in National Geodetic Vertical Datum of 1929 (NGVD 29). Visitation data for the reservoir sites are readily available from Federal and state agencies, while visitation data for river reaches are limited. Therefore, changes in boat ramp

accessibility—and associated water-based recreational visitation, including fishing, boating, and swimming—are estimated quantitatively at reservoirs only.

The methodology for estimating changes in water-based visitation at reservoirs due to changes in boat ramp accessibility is outlined in the four steps below. This discussion is supported by the graphical illustrations in Figure 2-1 through Figure 2-4. Figure 2-1 shows the minimum usable elevation for one example boat ramp; example daily water surface elevations under the No Action Alternative (NAA) at the 25th, 50th, and 75th percentiles; and example daily water surface elevations under an illustrative multiple objective action alternative (MO#) at the same percentiles. Figure 2-2 through Figure 2-4 provide separate summaries for the 25th, 50th, and 75th percentiles. The data are for illustration only and do not represent real data. Further, the recreation analysis considered multiple boat ramps within a reservoir. The figures include one example ramp for simplicity.

Figure 2-1 demonstrates that water surface elevations are highest at the 25th percentile (high water year), next highest at the 50th percentile (typical water year), and lowest at the 75th percentile (low water year). The example boat ramp in the figures would be accessible on days when the water surface elevation equals or exceeds the boat ramp's minimum usable elevation (represented as a black line).

1) **Estimate boat ramp accessibility under the No Action Alternative by reservoir**. Compare minimum usable boat ramp elevations with modeled H&H water surface elevations to evaluate boat ramp accessibility by day under the No Action Alternative. For each reservoir, the number of "accessible days", or days with water surface elevations above the minimum usable boat ramp elevations, is summed across boat ramps by month. Using August from the example figures below, the boat ramp is accessible under the No Action Alternative for 24 days at the 25th percentile, 19 days at the 50th percentile, and 15 days at the 75th percentile.

2) **Calculate the change in boat ramp accessibility under each MO and the PA**. Calculate the percentage change in boat ramp accessibility by month for each action alternative (MOs and the PA) relative to the No Action Alternative. This is based on the percentage change in total days that boat ramps would be accessible in each month. Again, using August from the example figures below, the boat ramp is accessible under the MO# alternative for 23 days at the 25th percentile, 10 days at the 50th percentile, and 0 days at the 75th percentile. Therefore, boat ramp accessibility is reduced by four percent under the MO# alternative relative to the No Action Alternative at the 25th percentile, and by 47 and 100 percent at the 50th and 75th percentiles, respectively.

3) **Estimate water-based visitation (visits) by reservoir under the No Action Alternative**. Monthly water-based visitation in a typical water year (under the No Action Alternative is estimated using reported reservoir visitation data from recent years and applying the estimated proportion of water-based activities at each reservoir (fishing, boating, and swimming). This is described in Section 3 below along with supporting detail about how monthly water-based visitation is estimated for high- and low water years under the No

Action Alternative. Water-based visitation is estimated at the reservoir level because water-based visitation data are not available for individual access points with boat ramps in the basin.

4) **Estimate changes in water-based visitation (visits) by reservoir associated with changes in boat ramp accessibility under each MO and the PA**. The estimated changes in monthly boat ramp accessibility (Step 2) are multiplied by the monthly estimates of water-based visitation (Step 3) to calculate monthly changes in water-based visitation at each reservoir. Combining results across months yields annual changes. For illustrative purposes, assume 1,000 water-based visits occur in August in a typical water year at the one-ramp reservoir in our example. Applying the estimated decrease in boat ramp accessibility of 47 percent from Step 2 yields an estimated decrease of 470 visits in a typical water year. Assuming 1,200 visits occur in August in a high water year, 50 visits would be lost (four percent decrease in boat ramp accessibility from Step 2). Assuming 800 visits occur in August in a low water year, all 800 visits would be lost (100 percent decrease in boat ramp accessibility from Step 2).

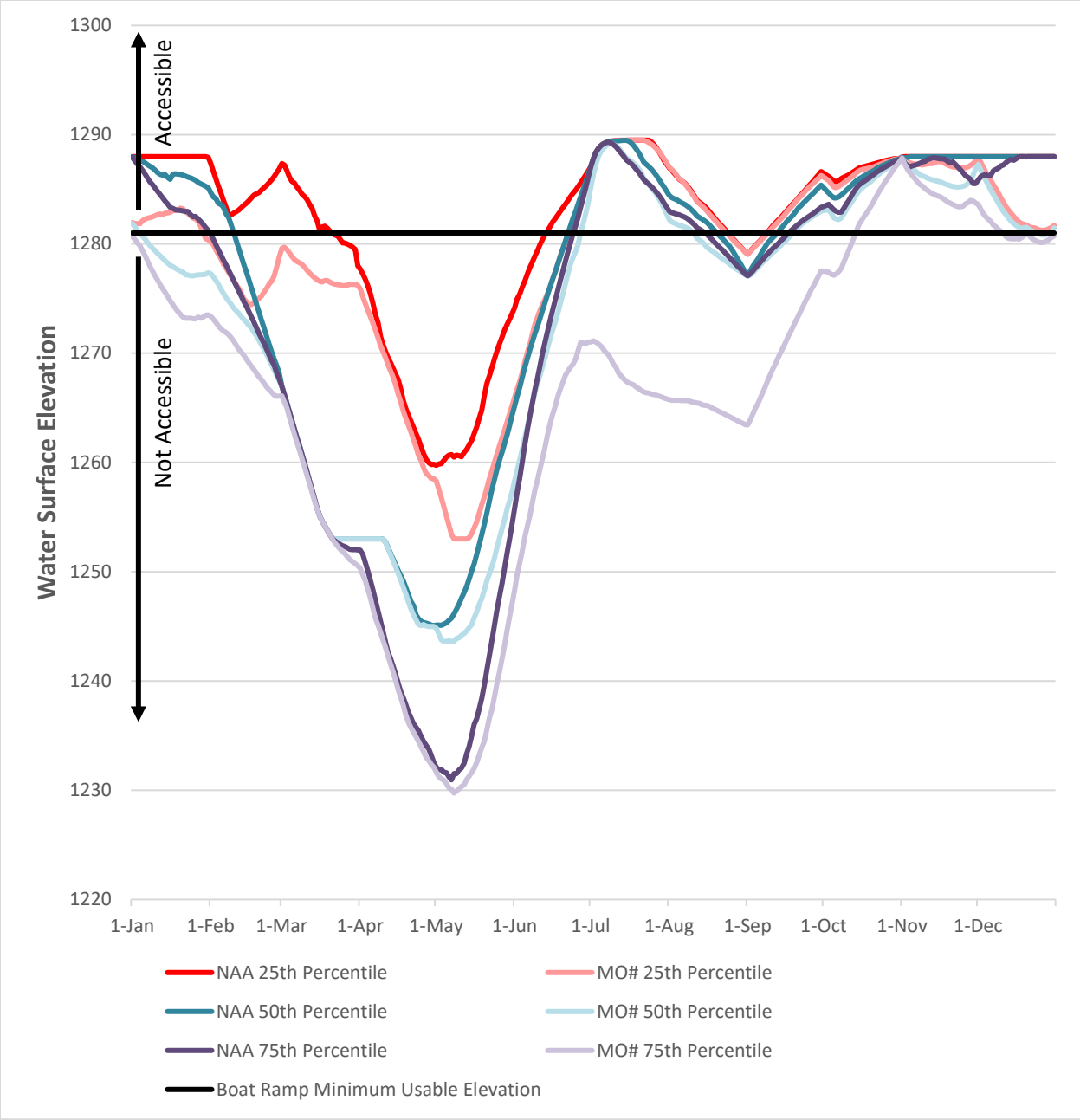

Figure 2-1. Illustration of Methodology: NAA vs. MO#, All Percentiles

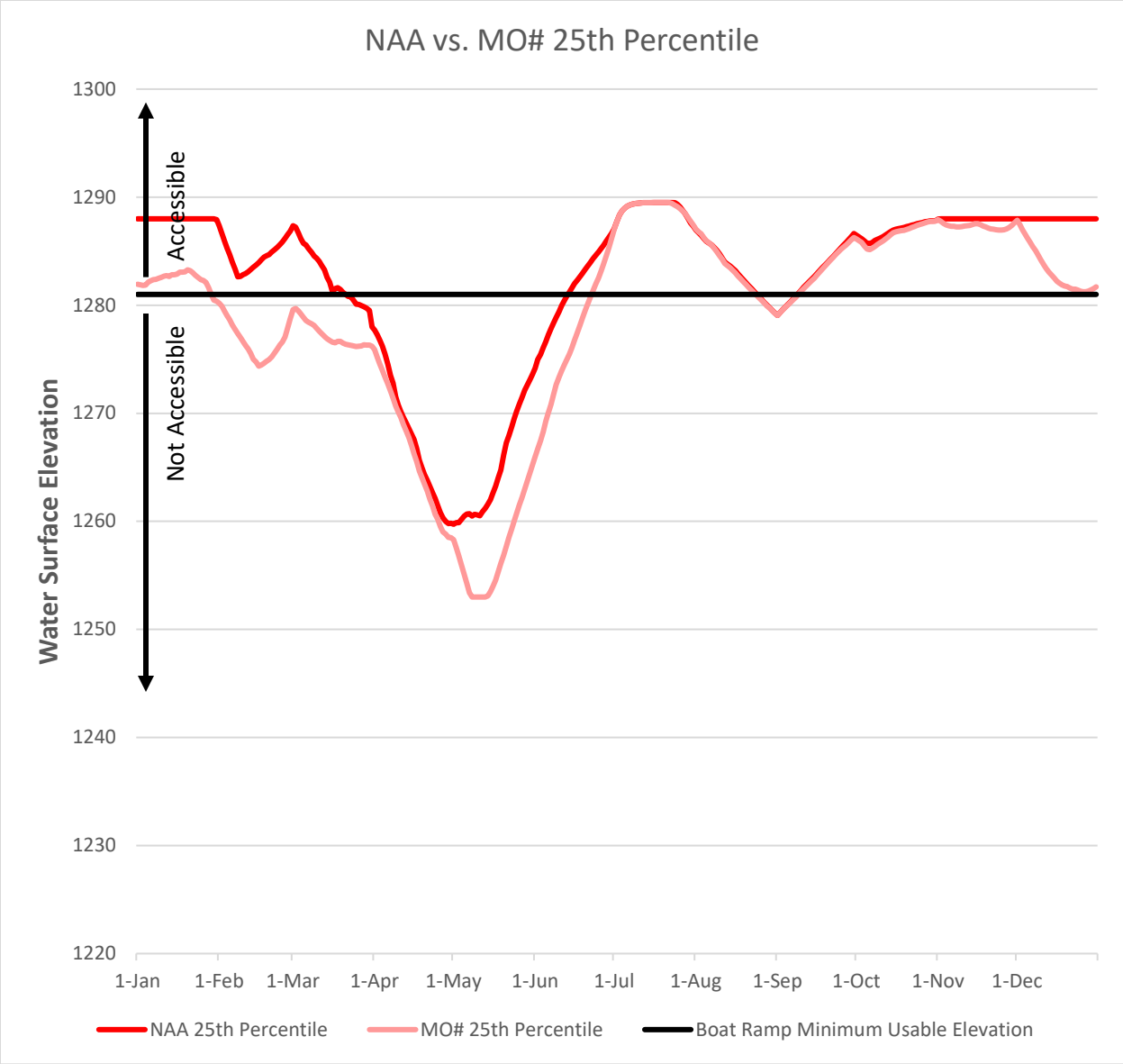

Figure 2-2. Illustration of Methodology: NAA vs. MO#, 25th Percentile

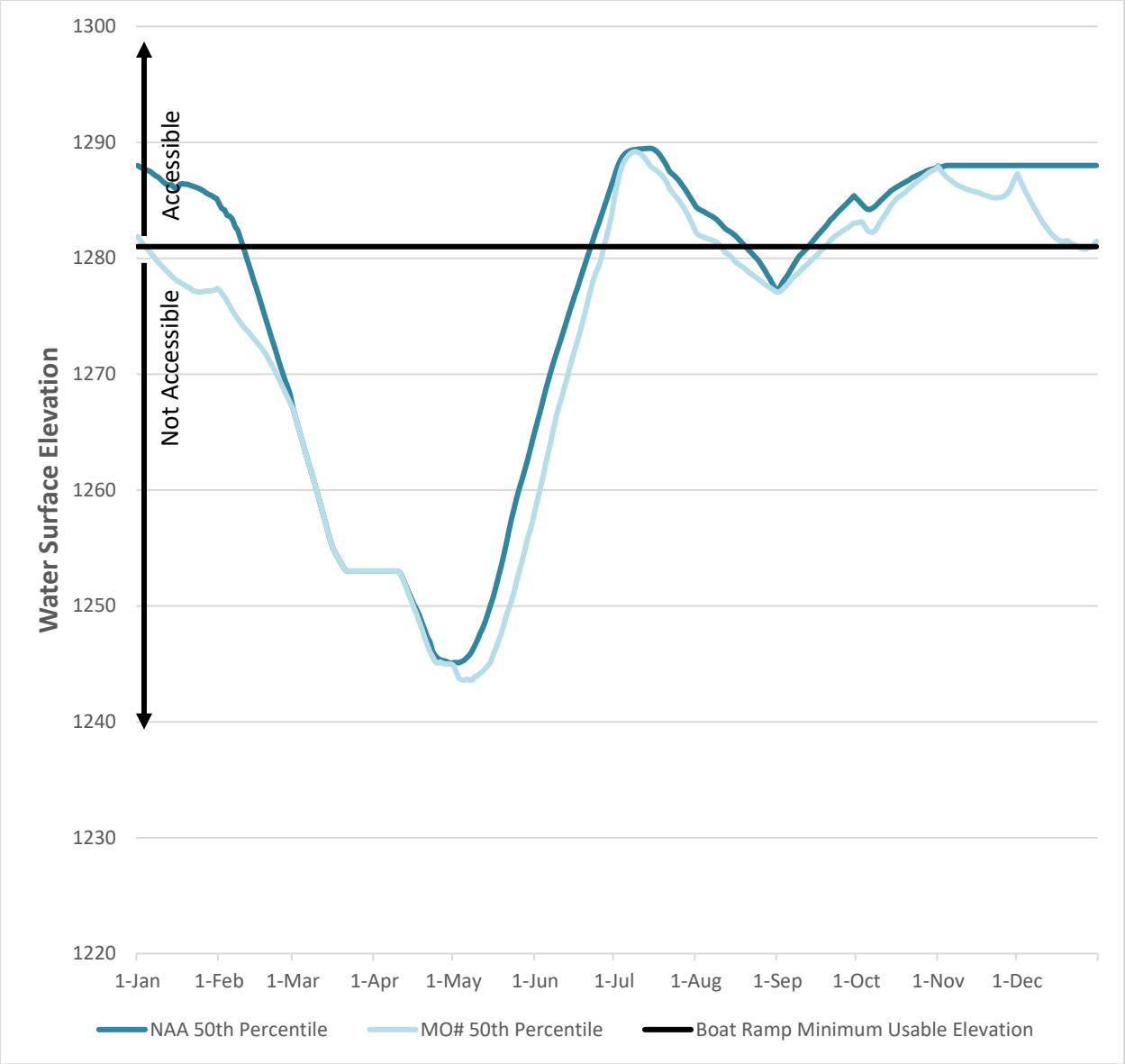

Figure 2-3. Illustration of Methodology: NAA vs. MO#, 50th Percentile

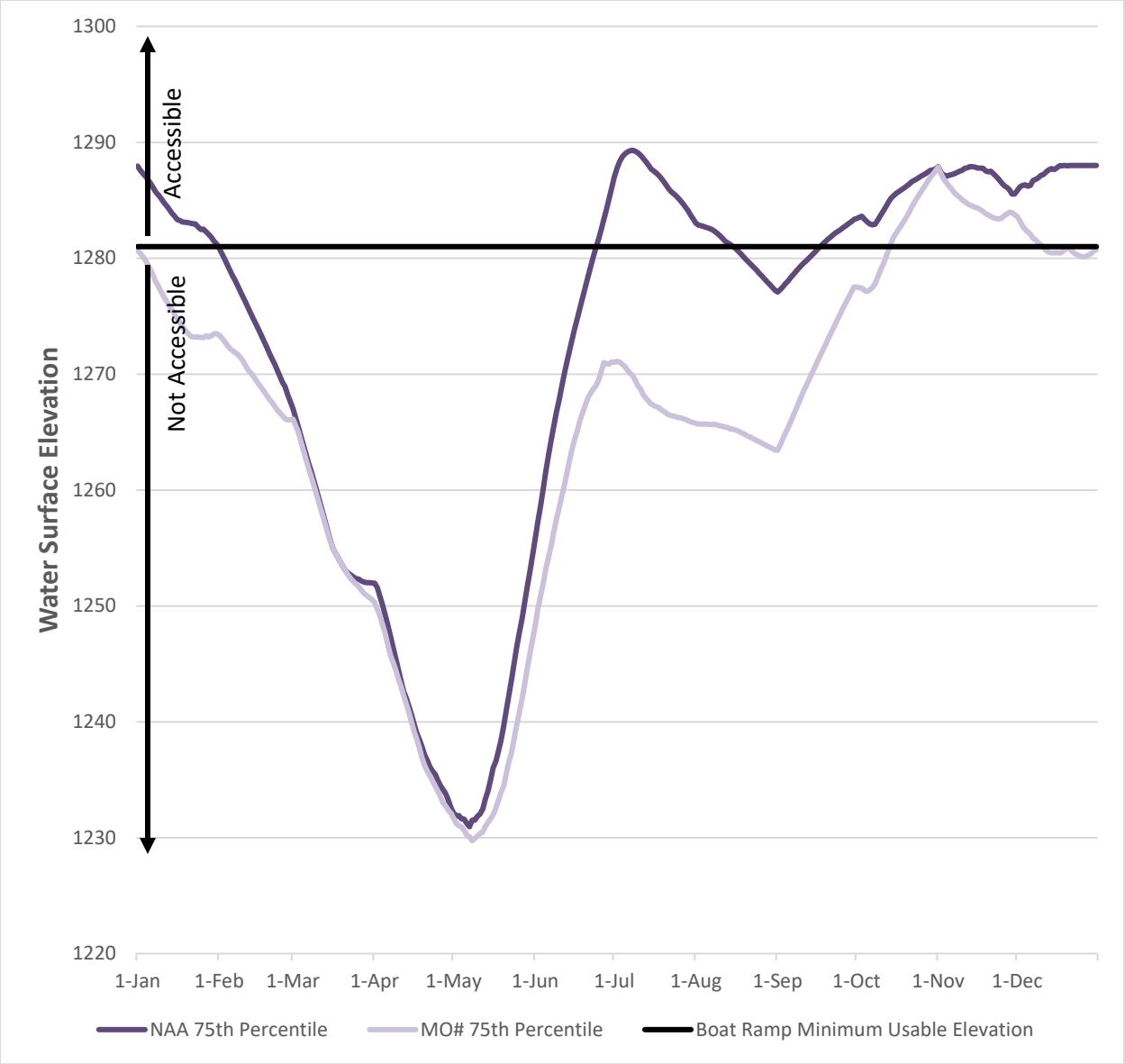

Figure 2-4. Illustration of Methodology: NAA vs. MO#, 75th Percentile

The methodology presented above includes a number of assumptions. In particular, specific data about the behavior of recreationists when faced with varying river and reservoir conditions in the basin is not known with certainty. The assumptions utilized in this analysis are conservative (i.e., they are more likely to overstate than understate effects of changes to water-based visitation). In particular, quantified effects do not take into account the potential for spatial substitution or temporal substitution.[2] Quantified effects do not take into account

[2] That is, if a particular boat ramp is made temporarily inaccessible by changes in reservoir elevations, a recreationist might use a different ramp or pursue a shore-based activity on a given trip occasion. The current methodology assumes that recreationists will forego that particular visit. Second, quantified effects do not take into account the potential for temporal substitution. That is, a recreationist may take a trip earlier or later in time to make up for a lost trip on another occasion due to an inaccessible boat ramp.

potential actions that might be taken by resource managers to make a ramp accessible under alternative water surface elevations (e.g., extending a ramp). The approach also uses boat ramp accessibility as a representation of water-based recreation activity on the reservoirs. That is, all water-based recreation is assumed to decrease when a boat ramp is inaccessible. While some water-based activities, like shore fishing and swimming, might not vary in the same manner as activities that rely directly on boat ramps (e.g., motorized boating), the assumption was supported by conversations with reservoir recreation managers (personal communication with USACE and Bureau of Recreation Natural Resource Managers 2019).[3]

Recreation visitation under MO3, particularly on the lower Snake River and at Lake Wallula would be impacted differently than what is described above. Lake Wallula (the reservoir created by McNary Dam downstream of Ice Harbor Dam) would be affected by sediment moving down from the lower Snake River during breaching activities. As discussed in the River Mechanics Appendix (Appendix C), the effects of the 2 to 7 years of sedimentation would primarily affect water-based recreation and boat ramp accessibility along the east and south sides of the Columbia River in Lake Wallula below the mouth of the Snake River. This information was used to assess the potential reductions in water-based visitation at certain recreation areas and associated economic effects affected by sedimentation at Lake Wallula.

A supplemental analysis was conducted under MO3 for the four lower Snake River projects, which would be uniquely affected by dam breaching. Recreation at the four lower Snake River projects—Lower Granite Dam and Lake, Little Goose Dam/Lake Bryan, Lower Monumental Dam/Lake Herbert G. West, and Ice Harbor Dam/Lake Sacajawea—would transition from reservoir-based recreation to river-based recreation. Recognizing that land-based recreation may return sooner than water-based recreation, the supplemental analysis quantifies potential changes in water and land-based recreation at the four lower Snake River reservoirs under MO3.

During construction activities associated with the breaching, it is likely that both land- and water-based visitors would not be able to access the area due to safety closures. After and possibly during the breaching and infrastructure drawdown period, land-based recreational activities at lower Snake River sites would likely re-occur as areas are re-opened and access is provided to curious sightseers, picnickers and hikers and other land-based activities. Therefore, the recreation evaluation estimates both reductions in land- and water-based visitation during dam breach, as well as a return of land-based visitation shortly after breaching as recreation areas become available. This information was used to assess the potential short-term changes in visitation and associated economic effects in the lower Snake River compared to current visitation under the No Action Alternative.

Potential increases in visitation associated with the new river recreational opportunities in the long-term (e.g., fishing, rafting, paddling, as well as land-based activities) are evaluated through

[3] USACE and Bureau of Recreation Natural Resource Managers. 2019. Personal communications between Paul Pence and Josh Baltz (Corps) and Eve Skillman (BOR) and Eric Horsch (Industrial Economics) regarding social welfare effects methodology. May 2019.

a review of previous studies and evaluated visitation at similar river reaches. However, the issue of recreation access is also discussed under MO3. Without the federal reservoir project, the Corps will not have a role in providing recreation facilities; therefore in order to re-establish recreation opportunities and water access in the region, there would likely be a cost impact to a government agency to provide recreational infrastructure and access roads. The river visitation estimates in the long-term are described in this appendix, consistent with the description in Section 3.11. The potential for recreational fishing in the long term and the quality of the recreational experience under MO3 are discussed qualitatively in Section 3.11.3 of the EIS.

2.1.2 Identifying Reservoirs with Changes in Visitation Related to Recreational Access

Across the MOs and PA, a change in recreational visitation due to changes in boat ramp accessibility is anticipated at 10 CRSO reservoirs (Table 2-1). This is based on the H&H modeling results as well as information related to the lower Snake River dam breaches under MO3. Analysts evaluated whether site access would be affected in any of the 25th 50th, or 75th percentile water years. Sites marked with an "X" in Table 2-1 would experience changes in 50th percentile daily water surface elevations of one foot or more, resulting in a change in boat ramp accessibility for at least seven days annually. Sites marked with "**" in Table 2-1 would experience potential effects in low water years only. Potential changes in recreational visitation resulting from smaller changes in water elevations were not evaluated because the effects, if any, are expected to be sufficiently small to not impede access. This approach was supported by conversations with reservoir recreation managers (personal communication with (USACE and Bureau of Recreation Natural Resource Managers 2019).[4]

Sites marked with an "X*" in Table 2-1 were analyzed separately using information related to the lower Snake River dam breaches under MO3. Additional non-CRSO reservoirs in the system were also assessed, but no changes in boat ramp accessibility would be anticipated because changes in water surface elevations would be negligible.

Table 2-1. Columbia River System Operations Reservoirs Where a Change in Boat Ramp Accessibility is Anticipated

CRSO Region	Reservoir	NAA	MO1	MO2	MO3	MO4	PA
Region A	Lake Koocanusa		X	X	X	X	X
Region A	Hungry Horse Reservoir		X	X	X	X	
Region A	Lake Pend Oreille					**	
Region B	Lake Roosevelt		X	X		X	X
Region B	Lake Rufus Woods						
Region C	Dworshak Reservoir		X	X			**
Region C	Lower Granite Lake				X*		
Region C	Lake Bryan				X*		

[4] USACE and Bureau of Recreation Natural Resource Managers. 2019. Personal communications between Paul Pence and Josh Baltz (Corps) and Eve Skillman (BOR) and Eric Horsch (Industrial Economics) regarding social welfare effects methodology. May 2019.

CRSO Region	Reservoir	NAA	MO1	MO2	MO3	MO4	PA
Region C	Lake Herbert G. West				X*		
Region C	Lake Sacajawea				X*		
Region D	Lake Wallula				X*		
Region D	Lake Umatilla						
Region D	Lake Celilo						
Region D	Lake Bonneville						

Notes: The sites marked with an "X" were identified as exhibiting changes in boat ramp accessibility using H&H modeling results. The sites with an asterisk (*) were analyzed separately using information related to the lower Snake River dam breaches under MO3. "**" marks potential effects in low water years only.

2.1.3 Estimating Consumer Surplus Value of Recreational Visitation

Under the No Action Alternative, social welfare effects are evaluated by estimating the economic value (i.e., consumer surplus) resulting from average annual recreational visitation at near-river sites across the basin (water- and land-based use at reservoirs and river reaches). Under the MOs and PA, social welfare effects are evaluated by estimating the change in economic value resulting from estimated changes in recreational visitation at reservoirs.

The procedures described in the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (U.S. Water Resources Council 1983) (Principals and Guidelines) outline three generally accepted methods for measuring recreational benefits: the unit day value (UDV), the travel cost method, and contingent valuation. Although completing a current site-specific travel cost or contingent value approach would be a preferred method, the study timeline eliminated these methods therefore the analysis relies upon readily available information. The recreation evaluation uses the UDV approach (Corps 2019; Water Resources Council 1983), which is a standard Corps approach to evaluate recreation consumer surplus benefits. The UDV method relies on expert and informed opinion to assign relative values to recreational visits based on the quality of recreational opportunities supported by individual recreation areas. The UDV approach provides a consistent approach across all sites in the evaluation (Chang 2019).[5]

The social welfare analysis is done in two steps. First, recreational visits are converted to recreational visitor days to account for the fact that overnight trips are longer than 1 day. Second, UDVs are applied to the estimated recreational visitor days. Additional details for these two steps are provided below.

1) ***Convert average recreational visits to recreational days.*** This is done using information maintained by the Corps and the National Park Service (NPS) on the ratio of recreation days to visits for a limited number of recreation areas (Chang 2018a; Cullinane Thomas

[5] In general, the UDV method uses estimates of economic value that are notably lower than those found in other available sources (e.g., Recreation Use Valuation Database (RUVD), Benefits Transfer Toolkit). The RUVD provides consumer surplus values from hundreds of studies for various recreational activities and locations. Consumer surplus values from the RUVD range from a median of $24 to $68 per day depending on the recreational activity in the Pacific Northwest.

2018). For reservoirs/river reaches where this ratio is not available, estimates were adapted from the closest reservoir/river reach with data.[6]

2) ***Apply UDVs to estimated recreational days from Step 1***. The UDVs are project-specific and based on existing Army Corps information. The values are developed using expert opinion and judgment, which involves assigning relative scores to individual project site areas (PSAs) based on the quality of those areas. The USACE Economic Guidance Memorandum (EGM) 19-03 (Corps 2019) provides guidelines for assigning points on a 100-point scale based on five criteria. Total possible points that can be assigned to each criterion are as follows:

   1. The quality of the recreation experience as affected by congestion (0-30 points);
   2. Availability of substitute areas in terms of travel time (0-18 points);
   3. Carrying capacity determined by level of facility development (0-14 points);
   4. Accessibility as affected by road and parking conditions (0-18 points); and
   5. Environmental quality based on aesthetics (0-20 points).

Recreation managers rate their PSAs based on the five criteria above. Each PSA is then classified as a type of site (i.e., general recreation, general hunting and fishing, specialized hunting and fishing, or other specialized recreation) and UDVs are selected based on the combination of points and site type (see Table 1 in Corps 2019). The UDV estimates were obtained from the USACE Recreation Budget Evaluation System (RecBest) (Chang 2019a).To obtain a value at the reservoir level, a weighted average was calculated across all UDVs within a project, using the PSA visitation estimates as weights.

All values were updated to 2019 dollars using the Consumer Price Index (CPI; Bureau of Labor Statistics 2019) and are presented in Table 2-2. For reservoirs/river reaches where UDV estimates were not available, estimates were adapted from nearby locations with data.[7]

Table 2-2. Unit Day Values for Columbia River Basin Reservoirs and River Reaches

CRSO Region	Reservoir/River Reach	Unit Day Value (2019$)
Region A	Kootenai River between the US-Canada border and Libby Dam and Lake Koocanusa	$9.87
Region A	Flathead River above Flathead Lake and Hungry Horse Dam and Reservoir	$9.87
Region A	Clark Fork River, Flathead River below Flathead Lake, and Flathead Lake	$9.87
Region A	Pend Oreille River and Lake Pend Oreille	$8.97
Region B	Grand Coulee Dam and Lake Roosevelt	$9.05
Region B	Chief Joseph Dam and Lake Rufus Woods	$7.95

[6] Information for Lake Koocanusa is applied to the reaches containing Flathead Lake and Hungry Horse Reservoir; information for Lake Wallula is applied to the reach containing Wanapum Lake; and information for Lake Bonneville is applied to the stretch below Bonneville Dam.

[7] See previous footnote. For Lake Roosevelt, the average UDV across all Corps sites was used.

CRSO Region	Reservoir/River Reach	Unit Day Value (2019$)
Region B	Wells Dam and Lake Pateros	ND
Region B	Rocky Reach Dam and Lake Entiat	ND
Region B	Rock Island Dam and Pool	ND
Region B	Wanapum Dam and Lake	$8.61
Region B	Priest Rapids Dam and Lake	ND
Region B	The Hanford Reach below Priest Rapids Dam	ND
Region C	Clearwater River and Dworshak Dam and Reservoir	$9.87
Region C	Snake River below Hells Canyon Dam	ND
Region C	Lower Granite Dam and Lake	$9.10
Region C	Little Goose Dam and Lake Bryan	$9.17
Region C	Lower Monumental Dam and Lake Herbert G. West	$9.85
Region C	Ice Harbor Dam and Lake Sacajawea	$8.66
Region D	McNary Dam and Lake Wallula	$8.61
Region D	John Day Dam and Lake Umatilla	$8.50
Region D	The Dalles Dam and Lake Celilo	$8.93
Region D	Bonneville Dam and Lake	$9.14
Region D	Below Bonneville Dam	$9.14

Notes: There are no visitation data for sites marked as ND (see Table 3-1 below), so no UDVs are presented.

2.2 SUPPLEMENTAL INFORMATION ON METHODOLOGY FOR CALCULATING REGIONAL ECONOMIC EFFECTS ASSOCIATED WITH CHANGES IN RECREATIONAL ACCESS

This section describes additional detail related to the methodology used to quantify regional economic effects associated with changes in recreational access. For this analysis, regional economic effects are measured in terms of changes in economic activity (jobs, labor income, and sales) related to changes in expenditures on recreational visitation by non-local visitors that are anticipated to result from changes in water access. The focus of the quantified evaluation of regional economic effects was on non-local visitors because, while local visitors are likely to continue to spend money in the affected area even if they forgo particular recreation trips, non-local visitors may divert spending to other areas if particular trips are not taken due to access issues. A majority of visitors in the study area are considered to be non-local (agencies define local by the distance travelled to sites, which is generally 30 or 60 miles, depending on agency).

Under the No Action Alternative, regional economic effects are evaluated by estimating the economic activity resulting from average annual recreational visitation at near-river sites across the basin (water- and land-based use at reservoirs and river reaches) by non-local visitors. Under the MOs and PA, regional economic effects are evaluated by estimating the change in jobs, labor income, and sales resulting from estimated changes in non-local visitation at reservoirs (results from the Social Welfare Effects evaluation).

Regional economic effects are estimated in two steps. First, recreational visitation (water- and land-based near-river visitation under the No Action Alternative or changes in recreational visitation under the MOs and PA) is multiplied by visitor spending estimates for recreation trips

in the region. Second, the broader effects of this spending on regional economic activity in terms of jobs, labor income, and sales are estimated using the input-output model, IMPLAN.[8] IMPLAN is a widely used industry-standard input-output data and software system that is used by many Federal and state agencies to estimate regional economic effects. The underlying data for IMPLAN is derived from multiple sources, including the Bureau of Economic Analysis, the Bureau of Labor Statistics, and the U.S. Census Bureau. Expenditures and the resulting regional economic effects are estimated separately for local and non-local visits using data on visitation patterns at affected sites. Additional details on the estimation of regional economic effects are provided in the steps below.

1) *Estimate expenditures associated with recreational visitation.* Estimates of recreational visitation (visits) are converted to match the units of the expenditure data shown in Table 2-3 and Table 2-4. This calculation converts visits to party trips by visitor segment for Corps projects and to party days or nights by visitor segment for Lake Roosevelt (NPS). This is done using project-specific information (e.g., share of visitation by visitor segment, party size, trip length) maintained by the Corps and NPS (Chang 2018a; USACE 2020; Cullinane Thomas 2018). The resulting estimates are then multiplied by the expenditure profiles in the tables below to estimate total expenditures by visitor segment and spending category.

The Corps' expenditure profile was developed for six visitor segments at all projects across the country from recent surveys at a range of sites. For Corps sites, local visitors live within 30 miles of the visited project, while non-locals live beyond 30 miles. The NPS' expenditure profile for Lake Roosevelt National Recreation Area was developed for six visitor segments from recent surveys. For Lake Roosevelt, local visitors live within 60 miles of the site, while non-locals live beyond 60 miles. For reservoirs/river reaches where expenditure data and supporting information were not available, estimates were adapted from nearby locations with data.[9]

Table 2-3. Corps Estimates of Typical Recreational Visitor Spending Profile: Average Spending Per Trip Per Party, 2019 Dollars

	Non-Boating Trip			Boating Trip		
Spending Category	**Local Day Visitor**	**Non-Local Day Visitor**	**Camper**	**Local Day Visitor**	**Non-Local Day Visitor**	**Camper**
Hotel	$0.00	$0.00	$2.44	$0.00	$0.00	$5.13
Camp	$0.00	$0.00	$60.36	$0.00	$0.00	$105.97
Restaurants and Bars	$11.06	$23.98	$38.98	$22.20	$31.23	$43.45
Groceries	$24.46	$26.02	$65.17	$40.51	$30.96	$68.43
Gas and oil	$26.82	$43.65	$128.11	$80.15	$130.34	$130.34
Other auto expenses	$0.59	$0.59	$0.83	$0.59	$0.59	$10.62

[8] For more information on the IMPLAN® system, visit http://www.implan.com/.

[9] Information for Lake Koocanusa is applied to the reaches containing Flathead Lake and Hungry Horse Reservoir; information for Lake Wallula is applied to the reach containing Wanapum Lake; and information for Lake Bonneville is applied to the stretch below Bonneville Dam.

Spending Category	Non-Boating Trip			Boating Trip		
	Local Day Visitor	Non-Local Day Visitor	Camper	Local Day Visitor	Non-Local Day Visitor	Camper
Other boat expenses	$0.00	$0.00	$0.00	$18.15	$18.15	$43.45
Attractions/ Entertainment and recreation fees	$4.86	$4.86	$7.41	$10.11	$10.11	$15.21
Sporting goods	$8.69	$8.69	$10.86	$18.46	$20.64	$23.90
Souvenirs/other	$6.92	$6.92	$13.03	$12.25	$14.12	$17.38
Total	**$83.38**	**$114.71**	**$327.19**	**$202.43**	**$256.13**	**$463.85**

Sources: Chang 2018b; Bender 2019.
Notes: Campers are assumed to be non-local for purposes of estimating regional economic effects separately for local and non-local visits, though campers likely include some local visitors too.

Table 2-4. NPS Estimates of Typical Recreational Visitor Spending Profile, Lake Roosevelt: Average Spending Per Day or Night Per Party, 2019 Dollars

Spending Category	Local Day Visitor	Non-Local Day Visitor	Camper In Park	Camper Out of Park	Lodging Out of Park	Other Overnight
Motel	$0.00	$0.00	$0.00	$0.00	$149.05	$0.00
Camping Fees	$0.00	$0.00	$11.95	$47.93	$0.00	$0.00
Restaurants and bars	$15.77	$23.23	$11.83	$21.03	$52.85	$13.24
Groceries and Takeaway	$11.23	$13.70	$19.74	$17.35	$23.73	$14.71
Gas	$14.93	$18.38	$13.16	$19.25	$24.17	$11.61
Local Transportation	$1.73	$2.05	$1.11	$3.69	$2.49	$1.49
Recreation Fees	$4.06	$10.13	$7.95	$9.85	$14.14	$3.41
Souvenirs and Other Expenses	$4.06	$9.11	$8.95	$16.39	$15.52	$5.30
Total	**$51.78**	**$76.60**	**$74.69**	**$282.82**	**$134.60**	**$49.76**

Sources: Cullinane Thomas 2018.
Notes: Per-day expenditures are applied to day use segments and per-night expenditures are applied to overnight users. All visitor segments other than local day visitors are assumed to be non-local for purposes of estimating regional economic effects for local and non-local visits (Cullinane Thomas et al. 2019, p. 5).

2) *Use IMPLAN to estimate regional economic effects*. Total expenditures by visitor segment and spending category from Step 1 are converted to expenditure estimates by IMPLAN sector using information maintained by the Corps and NPS (Chang 2019b; Cullinane Thomas 2019). The IMPLAN model then traces expenditures by sector through the regional economy using industry-specific multipliers to estimate the total regional economic effects in terms of jobs, labor income, and sales.

As stated above, expenditures and the resulting regional economic effects are estimated separately for local and non-local visits using data on visitation patterns at affected sites.[10] Regional economic effects are presented by CRSO region and in total for the basin. The study area for each region includes multi-county areas. IMPLAN data for these multi-county areas were used for this analysis; Table 2-5 lists the counties in each CRSO region. A county was assigned to a CRSO region if the majority of the county's area lies within the region.

Table 2-5. Counties by CRSO Region

CRSO Region A	CRSO Region B	CRSO Region C	CRSO Region D
Benewah (ID)	Adams (WA)	Adams (ID)	Benton (WA)
Bonner (ID)	Chelan (WA)	Asotin (WA)	Clark (WA)
Boundary (ID)	Douglas (WA)	Clearwater (ID)	Clatsop (OR)
Deer Lodge (MT)	Ferry (WA)	Columbia (WA)	Columbia (OR)
Flathead (MT)	Grant (WA)	Custer (ID)	Cowlitz (WA)
Granite (MT)	Lincoln (WA)	Franklin (WA)	Crook (OR)
Kootenai (ID)	Okanogan (WA)	Garfield (WA)	Deschutes (OR)
Lake (MT)	Stevens (WA)	Idaho (ID)	Gilliam (OR)
Lincoln (MT)		Latah (ID)	Grant (OR)
Mineral (MT)		Lemhi (ID)	Hood River (OR)
Missoula (MT)		Lewis (ID)	Jefferson (OR)
Pend Oreille (WA)		Nez Perce (ID)	Kittitas (WA)
Powell (MT)		Union (OR)	Klickitat (WA)
Ravalli (MT)		Valley (ID)	Lewis (WA)
Sanders (MT)		Walla Walla (WA)	Morrow (OR)
Shoshone (ID)		Wallowa (OR)	Multnomah (OR)
Silver Bow (MT)		Whitman (WA)	Sherman (OR)
Spokane (WA)			Skamania (WA)
			Umatilla (OR)
			Wahkiakum (WA)
			Wasco (OR)
			Washington (OR)
			Wheeler (OR)
			Yakima (WA)

[10] For Corps sites, *expenditures* associated with local and non-local visitation are approximated using the fraction of local and non-local *visitation* at each site. This is done because the Corps expenditure profile is generic to all sites (nationwide), whereas information about the distribution of visitor segments at Corps sites is site-specific. Visitor segments were defined as local or non-local for the purposes of this analysis as described in the note to Table 3. For Lake Roosevelt, expenditures associated with local and non-local visitation are estimated using the site-specific distribution of visitor segments and expenditure profile. Visitor segments were defined as local or non-local for the purposes of this analysis as described in the note to Table 4. For all sites, because some segments designated as non-local include local visitors, the estimates of non-local expenditures (and associated regional economic effects) may be overstated. However, any bias that may arise due to data limitations is expected to be small.

CHAPTER 3 - NO ACTION ALTERNATIVE

3.1 SUPPLEMENTAL DETAIL DESCRIBING QUANTIFIED SOCIAL WELFARE EFFECTS

Under the No Action Alternative, social welfare effects are estimated for average annual recreational visitation at near-river sites across the basin, including water- and land-based use at reservoirs and river reaches. Visitation data for 2017 and 2018 is used to estimate annual visitation for the period of analysis under the No Action Alternative, which is assumed to represent a typical year of visitation and boat ramp accessibility. Using 2017-18 visitation in future years under the No Action Alternative is supported by recent visitation trends at Lake Roosevelt and communication with recreation managers.[11]

To support the analysis of the action alternatives (i.e., estimating changes in recreational visitation at reservoirs relative to the No Action Alternative due to changes in water surface elevations and boat ramp accessibility), monthly visitation in a typical water year at CRSO reservoirs in Table 2-1 is estimated and water-based visitation is identified by applying the estimated proportion of water-based activities at each reservoir (fishing, boating, and swimming).

3.1.1 Recreational Visitation

Visitation data for 2017 and 2018 is used to estimate annual visitation for the period of analysis under the No Action Alternative. Recreational visitation data for near-river sites across the basin were compiled with assistance from Federal and states agencies. Federal site managers include the Corps, the Bureau of Reclamation (Reclamation), the NPS, the Bureau of Land Management (BLM), the United States Fish and Wildlife Service (USFWS), and the United States Forest Service (USFS). State-managed facilities in Washington, Oregon, Idaho, and western Montana are operated by Washington State Parks and Recreation Commission (WSPRC) and Washington Department of Fish and Wildlife (WDFW); Oregon Parks and Recreation Department (OPRD) and Oregon Department of Fish and Wildlife (ODFW); Idaho Department of Parks and Recreation (IDPR) and Idaho Department of Fish and Game (IDFG), and Montana Fish, Wildlife, and Parks (MFWP), respectively.

Table 3-1 presents available annual visitation estimates for 2017 and 2018 and the distribution of monthly visitation for 2018. Figure 3-1 presents a map of the reservoirs/river reaches shown in Table 3-1, along with the CRSO Regions. Consistent visitation data for years prior to 2017 are not available from all Federal and state agencies. Across the basin, total recreational visitation at sites within 1 mile of the mainstem rivers, including water- and land-based use at reservoirs and river reaches, is anticipated to be around 13 million visits annually, with most visitation

[11] While data is not available prior to 2017 for most sites, visitation at Lake Roosevelt—where NPS data is available back to 1941—has been relatively flat over recent decades despite growth in population and changes in other factors. Based on this evidence, in concert with input from the H&H Team and recreation managers that 2017 and 2018 represent relatively typical years in terms of water levels and recreational visitation, no adjustments were made to the average visitation numbers for future years.

occurring in summer months.[12] This estimate may underestimate river-based recreation as well as visitation at some state and local sites, as visitation sources for this analysis are most complete at Federal reservoir locations.

[12] Because regional visitation data from Federal and state agencies are more comprehensively collected for reservoirs and are limited for sections of river between reservoirs, total estimated visitation primarily reflects reservoir-based recreation.

560 **Table 3-1. Available Recreational Visitation Data (Visits) for Columbia River Basin Reservoirs and River Reaches[1/]**

CRSO Region, Reservoir/River Reach	2018 Monthly Recreational Visitation as a Percentage of Total Site Visitation[2/]												Annual Total Site Visits (Thousands of Visits)		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2017 Total	2018 Total	2017-2018 Average
Kootenai River between the US-Canada border and Libby Dam and Lake Koocanusa	2%	2%	2%	4%	18%	17%	18%	16%	13%	6%	2%	1%	189	198	193
Flathead River above Flathead Lake and Hungry Horse Dam and Reservoir	0%	0%	0%	0%	5%	15%	43%	28%	9%	0%	0%	0%	6	9	7
Clark Fork River, Flathead River below Flathead Lake, and Flathead Lake	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	309	323	316
Pend Oreille River and Lake Pend Oreille	1%	2%	1%	4%	13%	14%	26%	20%	12%	4%	2%	2%	975	1,020	997
Region A Total	**1%**	**2%**	**2%**	**4%**	**14%**	**15%**	**24%**	**19%**	**12%**	**5%**	**2%**	**2%**	**1,478**	**1,550**	**1,514**
Grand Coulee Dam and Lake Roosevelt	4%	4%	5%	6%	9%	13%	23%	18%	9%	4%	2%	2%	1,304	1,277	1,291
Chief Joseph Dam and Lake Rufus Woods	4%	4%	6%	8%	9%	13%	15%	12%	10%	8%	5%	5%	412	340	376
Wells Dam and Lake Pateros	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Rocky Reach Dam and Lake Entiat	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Rock Island Dam and Pool	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Wanapum Dam and Lake	2%	2%	6%	9%	12%	15%	17%	14%	12%	7%	3%	2%	322	331	327
Priest Rapids Dam and Lake	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
The Hanford Reach below Priest Rapids Dam	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Region B Total	**4%**	**4%**	**5%**	**7%**	**10%**	**13%**	**21%**	**16%**	**10%**	**5%**	**3%**	**2%**	**2,038**	**1,948**	**1,993**
Clearwater River and Dworshak Dam and Reservoir	2%	3%	5%	7%	12%	16%	20%	13%	8%	8%	4%	2%	489	430	459
Snake River below Hells Canyon Dam	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lower Granite Dam and Lake	5%	5%	6%	9%	11%	10%	11%	13%	7%	12%	6%	4%	1,938	1,882	1,910
Little Goose Dam and Lake Bryan	3%	3%	5%	4%	10%	13%	17%	13%	10%	15%	5%	3%	253	272	263
Lower Monumental Dam and Lake Herbert G. West	1%	2%	3%	9%	15%	16%	17%	14%	11%	8%	2%	1%	178	172	175
Ice Harbor Dam and Lake Sacajawea	3%	3%	4%	6%	12%	15%	21%	17%	9%	6%	3%	3%	208	213	211

CRSO Region, Reservoir/River Reach	2018 Monthly Recreational Visitation as a Percentage of Total Site Visitation[2/]												Annual Total Site Visits (Thousands of Visits)		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2017 Total	2018 Total	2017-2018 Average
Region C Total	**4%**	**4%**	**6%**	**8%**	**11%**	**12%**	**14%**	**13%**	**8%**	**11%**	**5%**	**4%**	**3,066**	**2,969**	**3,017**
McNary Dam and Lake Wallula	4%	5%	7%	9%	12%	12%	15%	10%	10%	6%	4%	4%	2,913	3,189	3,051
John Day Dam and Lake Umatilla	2%	3%	5%	9%	12%	14%	14%	11%	18%	6%	3%	2%	661	713	687
The Dalles Dam and Lake Celilo	4%	4%	6%	8%	13%	11%	14%	13%	13%	8%	4%	3%	1,052	1,101	1,076
Bonneville Dam and Lake	5%	4%	6%	8%	9%	12%	14%	13%	10%	8%	5%	6%	1,699	1,483	1,591
Below Bonneville Dam	5%	5%	6%	8%	14%	14%	14%	9%	9%	7%	5%	3%	260	293	276
Region D Total	**4%**	**4%**	**6%**	**8%**	**12%**	**12%**	**14%**	**12%**	**12%**	**7%**	**4%**	**4%**	**6,585**	**6,779**	**6,682**
Total	**4%**	**4%**	**6%**	**8%**	**12%**	**13%**	**16%**	**13%**	**10%**	**7%**	**4%**	**4%**	**13,168**	**13,246**	**13,207**

Sources: MFWP 2017-2018 and email communication; NPS 2019; other visitation data provided through personal communication with BLM, Corps, USFWS, USFS, IDPR, OPRD, and WSPRC.

Notes:

ND = no data are available. Potential impacts to recreation at reservoirs/river reaches with no data are expected to be negligible (see Table 2-1).

This table displays available data from state and Federal agencies. Other agencies (e.g., counties, municipalities, etc.) are not included in this summary.

There is no standard definition of a "visit" across agencies and there is variation in how visitation data are collected. Specifically, some agencies have defined methods for visitors who enter and exit a site multiple times during their visit and for visitors who only stop at the site for a few minutes (e.g., to use a restroom or ask for directions). With the exception of the USFWS, a visit is generally defined as a single person entering a site for recreation regardless of the length of stay or activities pursued. The USFWS estimates visitation based on unique activities pursued. For example, if a visitor takes a hike and goes hunting in a refuge, that visitor would account for a hiking visit and a hunting visit.

Visitation to National Forests and other USFS-managed lands is estimated for the entire unit. Estimates are not available for near-water sites, except for a subset of locations at Hungry Horse Reservoir, and are therefore excluded from this table. Visitation data for sites managed by Reclamation are collected by partner agencies.

[1/] Totals and percentages presented in this table combine fiscal and calendar year data across agencies. Data from BLM, Corps, and USFWS reflect fiscal years while all other agencies provide data by calendar year.

[2/] Percentages are based on available monthly data from Federal and state agencies. Some agencies only report annual data.

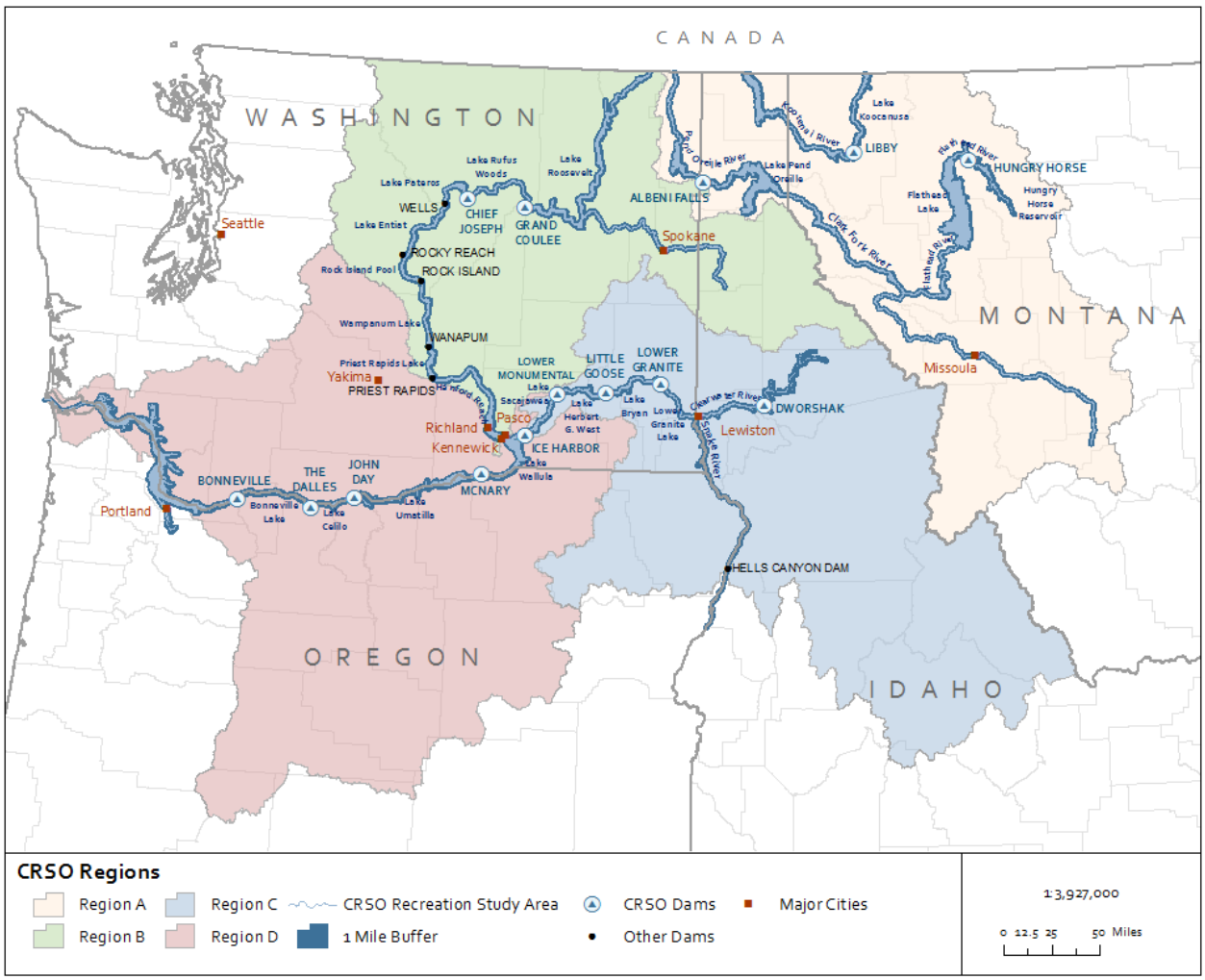

Figure 3-1. Area of Analysis for Recreation

Due to gaps in existing information, visitation estimates are not available for all sites across the basin managed by Federal and state agencies. Specifically, estimates for near-water sites managed by the USFS are only available at Hungry Horse Reservoir and only for a small portion of the total recreation sites on the reservoir. Estimates are missing from USFWS for select National Wildlife Refuges. Visitation data for sites that are not managed by Federal and state agencies are not included in Table 3-2. It is expected that fluctuations in visitor use and activities would be mirrored at sites managed by local agencies and private land owners. Table 3-3 presents visitation estimates for the individual sites that underlie Table 3-2.

Table 3-2. Average Annual Visitation (Visits) by Site, 2017-2018

Sites	Managing Agency	2017-2018 Average
Kootenai River between the US-Canada border and Libby Dam and Lake Koocanusa		
Blackwell Flats	USACE	15,952
Dispersed Use	USACE	21,925
Downstream Area	USACE	29,268
Dunn Creek	USACE	8,748

Sites	Managing Agency	2017-2018 Average
Libby Dam Left Abutment	USACE	22,926
Libby Dam Visitor Center	USACE	16,232
Ripley	USACE	1,270
Souse Gulch	USACE	26,660
Vista Point	USACE	6,694
Kootenai NWR	USFWS	43,713
Total		**193,386**
Flathead River above Flathead Lake and Hungry Horse Dam and Reservoir		
Doris Creek Campground	USFS	2,573
Emery Bay Campground	USFS	860
Lid Creek	USFS	915
Lost Johnny CAMP	USFS	510
Lost Johnny POINT Campground	USFS	1,404
Murray Bay Campground	USFS	751
Riverside Campground	USFS	216
Total		**7,229**
Clark Fork River, Flathead River below Flathead Lake, and Flathead Lake		
Wayfarers	MFWP	163,673
Big Arm	MFWP	47,487
West Shore	MFWP	33,329
Yellow Bay	MFWP	24,534
Finley Point	MFWP	24,127
Wild Horse Island	MFWP	22,615
Total		**315,764**
Pend Oreille River and Lake Pend Oreille		
Albeni Cove	USACE	10,871
Albeni Falls Dam Visitor Center	USACE	12,724
Clark Fork Drift Yard	USACE	23,377
Dispersed Use	USACE	200,723
Hawkins Point	USACE	5,488
Johnson Creek	USACE	9,121
Morton Slough	USACE	17,102
Priest River	USACE	25,155
Riley Creek	USACE	49,386
Springy Point	USACE	21,048
Trestle Creek	USACE	20,767
Vista Area Lower	USACE	32,702
Vista Area Upper	USACE	46,446
Farragut	IDPR	522,540
Total		**997,447**
Grand Coulee Dam and Lake Roosevelt		
Barstow Flats	NPS	3,282
Bradbury Beach	NPS	35,846

Sites	Managing Agency	2017-2018 Average
China Bend	NPS	40,090
Cloverleaf	NPS	2,212
Colvile Flats	NPS	23,271
Crescent Bay	NPS	36,275
Daisy	NPS	19,204
Dispersed Use	NPS	2,884
Eden Harbor	NPS	11,211
Evans	NPS	31,229
Fort Spokane	NPS	98,365
Fort Spokane Swim Beach	NPS	40,627
Fort Spokane VC	NPS	8,795
French Rocks	NPS	14,512
Gifford	NPS	33,733
Haag Cove	NPS	7,094
Hanson Harbor	NPS	24,938
Hawk Creek	NPS	41,701
Hunters	NPS	96,653
Jones Bay	NPS	7,167
Kamloops Island	NPS	20,849
Keller Ferry	NPS	65,183
Kettle Falls	NPS	248,219
Kettle River	NPS	9,313
Lincoln Mill BL	NPS	42,946
Marcus Island	NPS	32,835
Napoleon	NPS	17,010
North Gorge	NPS	5,051
Porcupine Bay	NPS	9,166
Seven Bays Marina	NPS	119,118
Sherman Creek Hatchery	NPS	0
SnagCove	NPS	20,896
Spring Canyon	NPS	118,962
St Pauls Mission	NPS	1,926
Total		**1,290,563**
Chief Joseph Dam and Lake Rufus Woods		
Brandt's Landing	USACE	23,797
Bridgeport Marina Park Boat Ramp	USACE	19,389
Chief Joseph Dam Visitor Center	USACE	1,172
Commons	USACE	1,113
Debris Basin	USACE	50,203
Dispersed Use	USACE	32,149
Foster Creek	USACE	1,609
Information & Rest Area	USACE	58,024
Lower Spillway	USACE	10,929

Sites	Managing Agency	2017-2018 Average
North Shore Trail	USACE	921
North Viewpoint	USACE	14,556
Powerhouse Viewpoint	USACE	26,296
Rocky Flats	USACE	590
Spillway Viewpoint	USACE	2,786
Willow Flats	USACE	31,867
Bridgeport	WSPRC	100,578
Total		**375,975**
Wanapum Dam and Lake		
Ginkgo Petrified Forest	WSPRC	234,281
Wanapum	WSPRC	92,546
Total		**326,826**
Clearwater River and Dworshak Dam and Reservoir		
Big Eddy Marina	USACE	15,869
Big Eddy Recreation Area	USACE	59,959
Bruce's Eddy Recreation Area	USACE	25,118
Canyon Creek Recreation Area	USACE	8,291
Cold Springs Trail	USACE	335
Dam View Camping Area	USACE	20,427
Dent Acres Recreation Area	USACE	33,861
Dispersed Use	USACE	15,150
Dworshak Dam Viewpoint	USACE	8,573
Dworshak State Park- Three Meadows Group Camp	USACE	9,231
Dworshak State Park-Freeman Creek	USACE	70,331
Dworshak Visitor Center	USACE	20,427
Grandad Recreation Area	USACE	9,371
Lake-Based Recreation Facilities	USACE	29,595
Little Meadow Creek Campground	USACE	1,978
Merry's Bay Recreation Area	USACE	3,349
Powerhouse Road Fishing Access	USACE	56,827
Harpers Bend	BLM	13,336
McKays Bend Recreation Site	BLM	14,228
Pinkhouse Recreation Site	BLM	43,046
Total		**459,297**
Lower Granite Dam and Lake		
Asotin Slough	USACE	27,905
Blyton Landing	USACE	11,910
Chestnut Beach	USACE	164,597
Chief Looking Glass Park	USACE	67,713
Chief Timothy Park	USACE	77,672
Clearwater Park	USACE	20,039
Clearwater Ramp	USACE	40,594
Dispersed Use	USACE	199,700

Sites	Managing Agency	2017-2018 Average
Evans Pond	USACE	18,211
Gateway Park	USACE	5,732
Golf Course Pond	USACE	38,827
Granite Lake Park	USACE	91,409
Granite Lake RV Park	USACE	81,738
Greenbelt Ramp	USACE	65,308
Hells Canyon Resort	USACE	19,373
Hells Gate	USACE	18,747
Lewiston Levee Recreation Trail	USACE	261,646
Lower Granite Esplanade	USACE	19,448
Lower Granite North Shore Tailrace Area	USACE	5,433
Lower Granite South Shore Visitor Center	USACE	19,671
Nisqually John Landing	USACE	17,038
Offield Landing	USACE	3,859
Southway Park	USACE	8,343
Southway Ramp	USACE	83,817
Swallows Park	USACE	240,064
Wawawai County Park	USACE	14,021
Wawawai Landing	USACE	19,445
Hells Gate	IDPR	267,805
Total		**1,910,057**
Little Goose Dam and Lake Bryan		
Boyer Park And Marina	USACE	165,762
Central Ferry Park	USACE	8,888
Dispersed Use	USACE	3,050
Illia Dunes Recreation Area	USACE	14,603
Illia Landing	USACE	3,298
Lambi Creek Recreation Area	USACE	1,973
Little Goose Esplanade	USACE	29,176
Little Goose Landing	USACE	14,525
Little Goose North Shore Tailrace	USACE	4,214
Little Goose South Shore Area	USACE	3,890
Penawawa Bay Habitat Management Unit	USACE	1,825
Rice Bar Habitat Management Unit	USACE	6,042
Willow Landing	USACE	5,416
Total		**262,659**
Lower Monumental Dam and Lake Herbert G. West		
Ayer Boat Basin	USACE	8,405
Devils Bench Recreation Area	USACE	6,418
Dispersed Use	USACE	1,100
Lyons Ferry Marina	USACE	51,677
Lyons Ferry Natural Area	USACE	1,135
Riparia Park	USACE	5,421

Sites	Managing Agency	2017-2018 Average
Texas Rapids Park	USACE	13,535
Tucannon Habitat Management Unit	USACE	7,906
Lyons Ferry	WSPRC	79,350
Total		**174,945**
Ice Harbor Dam and Lake Sacajawea		
Big Flat Habitat Management Unit	USACE	7,423
Charbonneau Marina	USACE	12,934
Charbonneau Park	USACE	44,623
Dispersed Use	USACE	4,508
Fishhook Park	USACE	28,388
Hollebebek Habitat Management Unit	USACE	5,886
Ice Harbor - South Shore Recreation Area	USACE	26,043
Ice Harbor - South Shore Road Fishing Area	USACE	26,294
Ice Harbor Dam Boat Ramp	USACE	12,638
Ice Harbor Dam Visitor Center	USACE	5,834
Indian Memorial Viewing Area	USACE	1,504
Lake Emma Recreation Area	USACE	5,023
Levey Park	USACE	7,489
Matthews Boat Ramp	USACE	1,127
Snake River Junction	USACE	7,113
Walker Pit Habitat Management Unit	USACE	8,335
Windust Park	USACE	5,371
Total		**210,531**
McNary Dam and Lake Wallula		
Burbank Heights	USACE	5,732
Chiawana Park	USACE	121,455
Columbia Park	USACE	847,172
Dispersed Use	USACE	248,347
Hood Park	USACE	138,315
Howard Amon Park	USACE	202,336
Leslie Groves Park	USACE	318,175
Martindale	USACE	5,662
McNary Beach	USACE	78,035
McNary Wildlife Nature Area	USACE	178,667
McNary Yacht Club	USACE	19,383
Oregon Boat Ramp	USACE	27,244
Pacific Salmon Visitor Information Center	USACE	14,933
Pasco Boat Basin & Marina	USACE	20,890
Sand Station Recreation Area	USACE	21,434
Spillway Park	USACE	148,834
Two Rivers Park	USACE	83,522
Walla Walla Yacht Club	USACE	6,366
Warehouse Beach	USACE	24,855

Sites	Managing Agency	2017-2018 Average
Washington Boat Ramp	USACE	15,807
West Park	USACE	33,126
Wye Park	USACE	31,032
Yakima Delta	USACE	20,050
Hat Rock State Park	OPRD	291,804
Sacajawea	WSPRC	72,857
McNary NWR	USFWS	75,000
Total		**3,051,028**
John Day Dam and Lake Umatilla		
Boardman Park	USACE	85,889
Cliffs Park	USACE	17,691
Crow Butte Park	USACE	53,464
Dispersed Use	USACE	133,475
Giles French Park	USACE	44,550
Irrigon Park	USACE	57,778
Lepage Park	USACE	36,172
Paradise Park	USACE	12,207
Philippi Park	USACE	12,425
Plymouth Campground	USACE	12,646
Plymouth Day Use	USACE	50,374
Railroad Island	USACE	6,846
Rock Creek Park	USACE	7,885
Roosevelt Park	USACE	25,638
Sundale Park	USACE	7,558
Threemile Canyon Park	USACE	7,364
Umatilla Park	USACE	115,134
Total		**687,093**
The Dalles Dam and Lake Celilo		
Avery Park	USACE	36,658
Celilo Park	USACE	90,677
Dispersed Use	USACE	9,100
Heritage Landing	USACE	45,423
Hess Park	USACE	7,803
Rufus Landing	USACE	53,182
Seufert Park	USACE	68,420
Spearfish Park	USACE	16,278
The Dalles North Shore	USACE	27,639
The Dalles Visitor Center	USACE	12,932
The Wall	USACE	30,840
Columbia Hills	WSPRC	163,998
Maryhill	WSPRC	215,802
Deschutes River State Recreation Area	OPRD	297,652
Total		**1,076,402**

Sites	Managing Agency	2017-2018 Average
Bonneville Dam and Lake		
Bonneville Fish Hatchery	USACE	190,004
Bradford Island Recreation Area	USACE	35,839
Bradford Island Visitor Center	USACE	75,662
Dispersed Use	USACE	196,958
Fort Cascades National Historic Site	USACE	14,949
Hamilton Island Recreation Area	USACE	41,084
Home Valley Park	USACE	40,086
Navigation Lock Visitor Area	USACE	3,943
North Shore Recreation Area	USACE	32,633
Pacific Crest Trail Equestrian Trailhead	USACE	17,294
Robins Island Recreation Area	USACE	28,275
Tanner Creek Recreation Area	USACE	41,572
Washington Shore Visitor Center Complex	USACE	30,219
Doug's Beach	WSPRC	24,386
Spring Creek Hatchery	WSPRC	137,597
Koberg Beach State Recreation Site	OPRD	361,600
Mayer State Park	OPRD	206,145
Viento State Park	OPRD	112,873
Total		**1,591,114**
Below Bonneville Dam		
Beacon Rock	WSPRC	276,200
Total		**276,200**

Sources: MFWP 2017-2018 and email communication; NPS 2019; other visitation data provided through personal communication with BLM, Corps, USFWS, USFS, IDPR, OPRD, and WSPRC .

Notes:

This table displays available data from state and Federal agencies. Other agencies (e.g., counties, municipalities, etc.) are not included in this summary.

A significant amount of recreation occurs on managed lands and waters outside of developed recreation areas. This dispersed use includes visitors to wildlife management areas, low-density (undeveloped) recreation areas and visitors accessing the project from adjacent lands.

Some of the most commonly pursued activities in the region include fishing, sightseeing, boating, swimming, picnicking, and camping. Table 3-3 summarizes the distribution of recreation use at reservoirs/river reaches where such data are available. The most recent information is presented, which is from 2016. As discussed later in this Appendix, this information is used to identify land- and water-based visitation for this analysis.

601 **Table 3-3. Distribution of Recreation Use by Activity for Columbia River Basin Reservoirs and River Reaches**

CRSO Region, Reservoir/River Reach	Fishing	Camping	Boating	Swimming	Picnicking	Hunting	Sightseeing	Other	Water-Based Visitation[1/]
Kootenai River between the US-Canada border and Libby Dam and Lake Koocanusa	26%	1%	0%	5%	19%	0%	17%	31%	31%
Flathead River above Flathead Lake and Hungry Horse Dam and Reservoir	ND	ND	ND	ND	ND	ND	ND	ND	ND
Clark Fork River, Flathead River below Flathead Lake, and Flathead Lake	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pend Oreille River and Lake Pend Oreille	9%	11%	6%	12%	12%	1%	14%	35%	27%
Region A Total	13%	8%	4%	10%	14%	1%	15%	34%	27%
Grand Coulee Dam and Lake Roosevelt	33%	27%	20%	7%	1%	ND	ND	12%	60%
Chief Joseph Dam and Lake Rufus Woods	34%	3%	4%	2%	7%	1%	36%	14%	40%
Wells Dam and Lake Pateros	ND	ND	ND	ND	ND	ND	ND	ND	ND
Rocky Reach Dam and Lake Entiat	ND	ND	ND	ND	ND	ND	ND	ND	ND
Rock Island Dam and Pool	ND	ND	ND	ND	ND	ND	ND	ND	ND
Wanapum Dam and Lake	ND	ND	ND	ND	ND	ND	ND	ND	ND
Priest Rapids Dam and Lake	ND	ND	ND	ND	ND	ND	ND	ND	ND
The Hanford Reach below Priest Rapids Dam	ND	ND	ND	ND	ND	ND	ND	ND	ND
Region B Total	33%	22%	17%	6%	2%	0%	7%	12%	56%
Clearwater River and Dworshak Dam and Reservoir	36%	13%	6%	5%	5%	1%	17%	17%	47%
Snake River below Hells Canyon Dam	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lower Granite Dam and Lake	13%	1%	7%	13%	9%	0%	11%	45%	33%

CRSO Region, Reservoir/River Reach	Fishing	Camping	Boating	Swimming	Picnicking	Hunting	Sightseeing	Other	Water-Based Visitation[1/]
Little Goose Dam and Lake Bryan	14%	4%	17%	15%	15%	1%	13%	20%	46%
Lower Monumental Dam and Lake Herbert G. West	19%	15%	14%	7%	10%	1%	8%	26%	40%
Ice Harbor Dam and Lake Sacajawea	27%	2%	13%	11%	14%	0%	13%	21%	51%
Region C Total	16%	3%	7%	12%	9%	1%	12%	40%	35%
McNary Dam and Lake Wallula	7%	0%	15%	4%	13%	0%	18%	43%	26%
John Day Dam and Lake Umatilla	27%	1%	21%	11%	17%	3%	10%	12%	59%
The Dalles Dam and Lake Celilo	25%	0%	14%	9%	17%	3%	15%	16%	48%
Bonneville Dam and Lake	19%	0%	2%	2%	7%	0%	52%	17%	23%
Below Bonneville Dam	ND	ND	ND	ND	ND	ND	ND	ND	ND
Region D Total	32%	20%	16%	7%	4%	0%	8%	14%	55%
Total	**23%**	**11%**	**11%**	**9%**	**7%**	**0%**	**10%**	**28%**	**43%**

Sources: Corps 2016; Le and Strawn 2017

Note: ND = no data are available. Potential impacts to recreation at reservoirs/river reaches with no data are expected to be negligible (see Table 2-1).

[1/] Water-based visitation is the sum of fishing, boating, and swimming visitation.

3.1.2 Boat Ramp Accessibility and Water-based Recreational Visitation

Four CRSO reservoirs were identified as exhibiting changes in boat ramp accessibility under one or more MO or the PA using H&H modeling results (Table 2-1) in a typical water year: Lake Koocanusa (Libby Dam) and Hungry Horse Reservoir in Region A; Lake Roosevelt (Grand Coulee Dam) in Region B; and Dworshak Reservoir in Region C.[13] To support the analysis under the MOs and PA at these sites (i.e., estimating changes in water-based visitation at reservoirs relative to the No Action Alternative due to changes in water surface elevations and boat ramp accessibility), minimum usable boat ramp elevations were required for all boat ramps at these four reservoirs.[14]

Table 3-4 presents the boat ramps at each of these four reservoirs and their minimum usable elevations. The analysis approach assumes that changes in accessibility to ramps with minimum usable elevation data would be representative of other ramps for which elevation data are unavailable. Figure 3-2 through Figure 3-5 present the locations of these boat ramps. Table 3-5 also presents the annual elevation range across all days in a typical water year (50th Percentile) for each reservoir and the name of the H&H outputs used in the analysis for each boat ramp. The closest H&H output to each ramp was used.

Table 3-4. Minimum Usable Boat Launch Elevations for Four CRSO Reservoirs with Changes in Boat Ramp Accessibility using H&H Modeling Results

Boat Ramp	Minimum Usable Elevation (Feet)	Name of Closest H&H Output Used in Analysis
Libby Dam and Lake Koocanusa (Annual Elevation Range in a Typical Water Year: 2,384 to 2,453 feet)		
Barron Creek	2,282	Libby-Pool_Elev
Peck Gulch	2,310	Libby-Pool_Elev
Souse Gulch	2,310	Libby-Pool_Elev
Koocanusa Marina	2,334	Libby-Pool_Elev
Rexford Bench	2,341	Libby-Pool_Elev
Rocky Gorge	2,370	Libby-Pool_Elev
McGillivray	2,385	Libby-Pool_Elev
McGillivray 2	2,385	Libby-Pool_Elev
Tobacco Plains	2,433	Libby-Pool_Elev
Abayance Bay Marina	ND	N/A
Gateway Boat Camp	ND	N/A
Little North Fork Falls	ND	N/A
Tobacco River	ND	N/A
Hungry Horse Dam and Reservoir (Annual Elevation Range in a Typical Water Year: 3,519 to 3,560 feet)		
Abbot Bay Boating Site (Lion Hill Gorge)	3,430	Hungry Horse-Pool_Elev

[13] As described in Table 1, the lower Snake River Reservoirs and Lake Wallula were analyzed separately using information related to the lower Snake River dam breaches under MO3. Potential effects at Lake Pend Oreille would occur in low water years only. Analysis for these sites are discussed in subsequent sections.

[14] Minimum usable boat ramp elevations are not presented for other sites in the basin where the analysis did not detect changes in boat ramp accessibility using existing information.

Boat Ramp	Minimum Usable Elevation (Feet)	Name of Closest H&H Output Used in Analysis
Lost Johnny Point Campground	3,488	Hungry Horse-Pool_Elev
Riverside Boat	3,507	Hungry Horse-Pool_Elev
Devil's Corkscrew Campground	3,517	Hungry Horse-Pool_Elev
Emery Bay Campground	3,527	Hungry Horse-Pool_Elev
Lid Creek Campground	3,529	Hungry Horse-Pool_Elev
Crossover Boat	3,539	Hungry Horse-Pool_Elev
Murray Bay Campground	3,540	Hungry Horse-Pool_Elev
Canyon Creek Boating Site	3,542	Hungry Horse-Pool_Elev
Doris Point Boating Site	3,545	Hungry Horse-Pool_Elev
Goose Head	ND	N/A
Graves Creek	ND	N/A
Painted Turtle	ND	N/A
Grand Coulee Dam and Lake Roosevelt (Annual Elevation Range in a Typical Water Year: 1245 to 1,290 feet)		
Spring Canyon	1,222	Grand Coulee-Pool_Elev
Seven Bays	1,227	Columbia River Reach 21_River Mile_616.006_Stage
Keller Ferry	1,229	Columbia River Reach 21_River Mile_616.006_Stage
Hunters Camp	1,232	Columbia River Reach 21_River Mile_680.054_Stage
Kettle Falls	1,234	Columbia River Reach 21_River Mile_720.431_Stage
Porcupine Bay	1,243	Columbia River Reach 21_River Mile_616.006_Stage
Lincoln Mill	1,245	Columbia River Reach 21_River Mile_616.006_Stage
Fort Spokane	1,247	Columbia River Reach 21_River Mile_616.006_Stage
Gifford	1,249	Columbia River Reach 21_River Mile_680.054_Stage
Bradbury Beach	1,251	Columbia River Reach 21_River Mile_680.054_Stage
Hansen Harbor	1,253	Columbia River Reach 21_River Mile_616.006_Stage
Crescent Bay	1,265	Grand Coulee-Pool_Elev
Daisy	1,265	Columbia River Reach 21_River Mile_680.054_Stage
French Rocks	1,265	Columbia River Reach 21_River Mile_680.054_Stage
Jones Bay	1,268	Columbia River Reach 21_River Mile_616.006_Stage
China Bend	1,277	Columbia River Reach 21_River Mile_720.431_Stage

Boat Ramp	Minimum Usable Elevation (Feet)	Name of Closest H&H Output Used in Analysis
Snag Cove	1,277	Columbia River Reach 21_River Mile_720.431_Stage
Evans	1,280	Columbia River Reach 21_River Mile_720.431_Stage
Napoleon Bridge	1,280	Columbia River Reach 21_River Mile_720.431_Stage
North Gorge	1,280	Columbia River Reach 21_River Mile_720.431_Stage
Hawk Creek	1,281	Columbia River Reach 21_River Mile_616.006_Stage
Marcus Island	1,281	Columbia River Reach 21_River Mile_720.431_Stage
Northport Public Boat Ramp	ND	N/A
Dworshak Dam and Reservoir (Annual Elevation Range in a Typical Water Year: 1,517 to 1,600 feet)		
Big Eddy Recreation Area	1,445	Dworshak-Pool_Elev
Dent Acres Recreation Area	1,485	Dworshak-Pool_Elev
Bruce's Eddy Recreation Area	1,490	Dworshak-Pool_Elev
Dworshak State Park-Freeman Creek	1,515	Dworshak-Pool_Elev
Grandad Recreation Area	1,530	Dworshak-Pool_Elev
Bruce's Eddy #2	1,560	Dworshak-Pool_Elev
Canyon Creek Recreation Area	1,560	Dworshak-Pool_Elev
Dent Bridge	ND	N/A
Little North Fork	ND	N/A

Sources: NPS N.d.; LibbyMT.com 2012; Pence 2019; Crandall 2019.

Notes: ND = no data are available. N/A = not applicable.

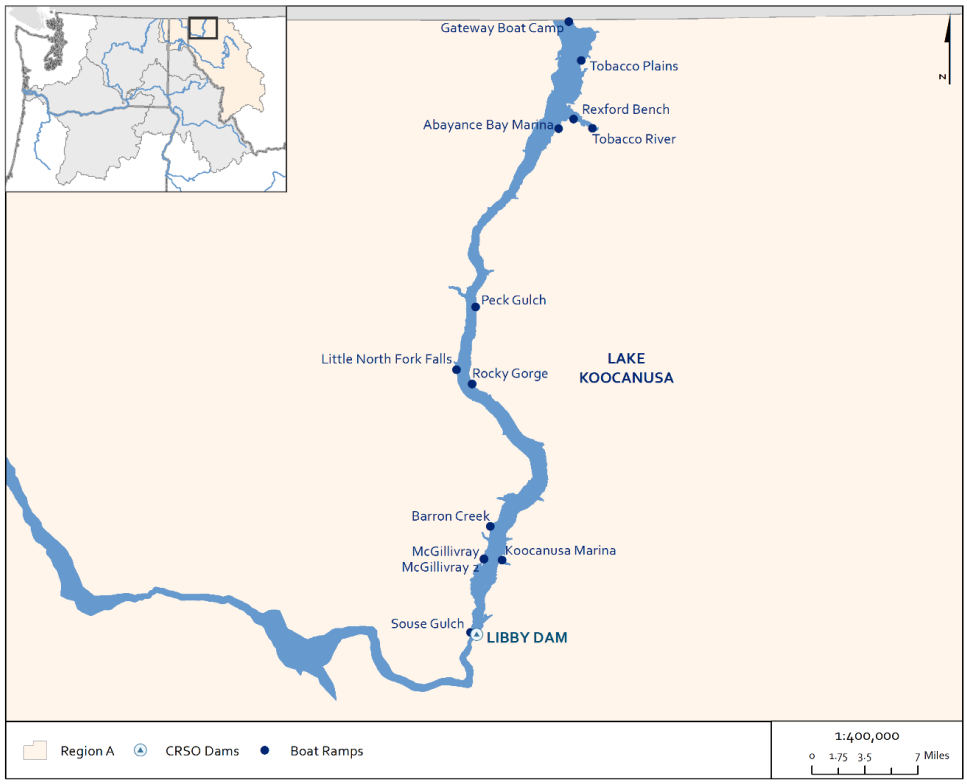

Figure 3-2. Lake Koocanusa Boat Ramps

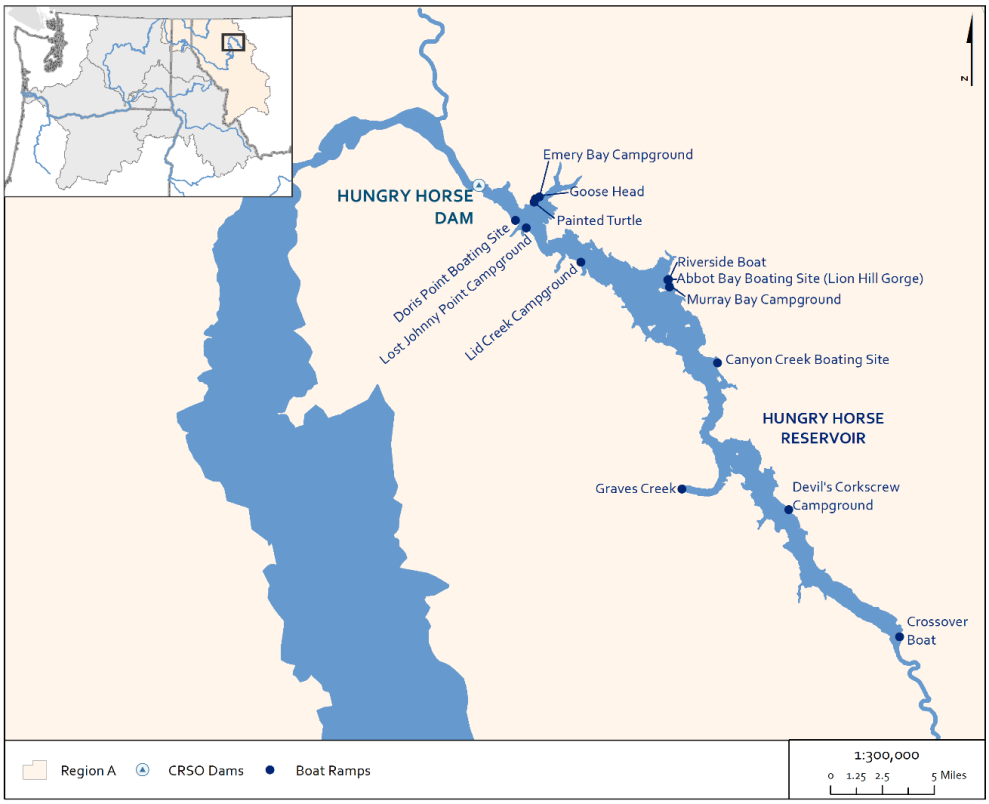

Figure 3-3. Hungry Horse Reservoir Boat Ramps

Figure 3-4. Lake Roosevelt Boat Ramps

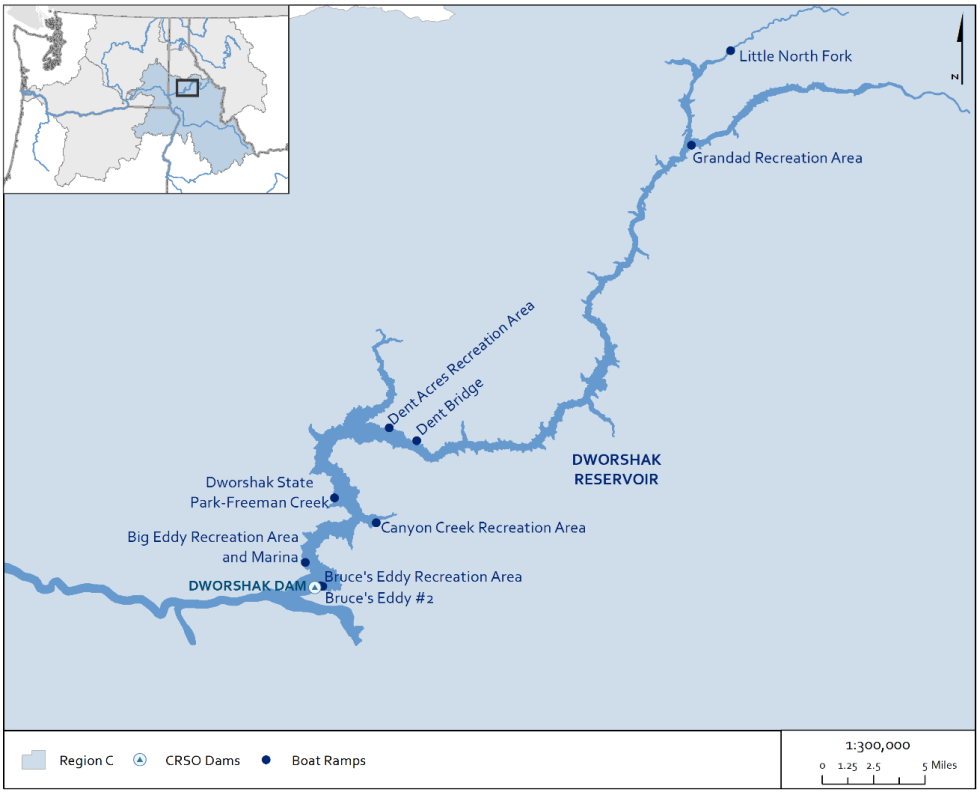

Figure 3-5. Dworshak Reservoir Boat Ramps

Water-based visitation, including fishing, boating, and swimming, is supported by the accessibility of the ramps shown above.[15] As described in Step 1 in Section 2.1.1, the minimum usable boat ramp elevations are compared with modeled H&H water surface elevations to evaluate boat ramp accessibility by day under the No Action Alternative. For each reservoir, the number of "accessible days", or days with water surface elevations above the minimum usable boat ramp elevations, is summed across boat ramps by month. The results of these calculations are presented in Table 3-5 for the No Action Alternative in the typical water year.

Table 3-5. No Action Alternative Boat Ramp Accessibility in a Typical Water Year (50th Percentile), by Month

	Libby Dam and Lake Koocanusa		Hungry Horse Dam and Reservoir		Grand Coulee Dam and Lake Roosevelt		Dworshak Dam and Reservoir	
Month	NAA Accessible Days	Percent of Days that are Accessible	NAA Accessible Days	Percent of Days that are Accessible	NAA Accessible Days	Percent of Days that are Accessible	NAA Accessible Days	Percent of Days that are Accessible
Jan	248	89%	213	69%	682	100%	124	57%
Feb	224	89%	166	59%	508	82%	112	57%
Mar	248	89%	127	41%	350	51%	124	57%
Apr	206	76%	120	40%	272	41%	120	57%
May	248	89%	151	49%	285	42%	173	80%
Jun	247	91%	287	96%	526	80%	210	100%
Jul	279	100%	310	100%	682	100%	217	100%
Aug	279	100%	310	100%	638	94%	177	82%
Sep	270	100%	300	100%	615	93%	124	59%
Oct	279	100%	310	100%	642	94%	124	57%
Nov	270	100%	294	98%	660	100%	120	57%
Dec	251	90%	276	89%	682	100%	124	57%

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps. For example, two ramps with 100 percent accessibility in a 30-day month results in 60 accessible days.

For the recreation analysis, the results in Table 3-6 are assumed to represent boat ramp accessibility in a typical water year under the No Action Alternative. Estimates of corresponding monthly water-based visitation are developed using reported reservoir visitation data from 2017-2018 (Table 3-2) and applying the estimated proportion of water-based activities at each reservoir (the summation of fishing, boating, and swimming percentages in Table 3-3).[16] Table 3-7 presents average monthly water-based visitation for each reservoir.

[15] As described in Section 2.1.1, the analysis approach uses boat ramp accessibility as a proxy for water-based recreation activity on the reservoirs. However, some water-based activities, like shore fishing and swimming, might not vary in the same manner as activities that rely directly on boat ramps (e.g., motorized boating).

[16] This approach is taken because visitation estimates and minimum usable boat ramp elevations are not comprehensively available for individual boat ramps across the basin.

Table 3-6. No Action Alternative Water-Based Visitation (Visits) in a Typical Water Year (50th Percentile), by Month

Month	Average Visitation 2017-2018	Percentage of Visitation that is Water Based	Estimated Total Water-Based Visitation (Visits)
Libby Dam and Lake Koocanusa			
Jan	1,409	31%	439
Feb	1,436	31%	447
Mar	1,805	31%	562
Apr	6,104	31%	1,900
May	19,766	31%	6,154
Jun	21,667	31%	6,746
Jul	30,117	31%	9,377
Aug	27,001	31%	8,407
Sep	20,349	31%	6,336
Oct	9,857	31%	3,069
Nov	8,007	31%	2,493
Dec	2,154	31%	671
Total	**149,673**	**31%**	**46,603**
Hungry Horse Dam and Reservoir			
Jan	0	31%	0
Feb	0	31%	0
Mar	0	31%	0
Apr	0	31%	0
May	435	31%	135
Jun	1,267	31%	394
Jul	3,703	31%	1,153
Aug	1,453	31%	452
Sep	371	31%	115
Oct	0	31%	0
Nov	0	31%	0
Dec	0	31%	0
Total	**7,229**	**31%**	**2,251**
Grand Coulee Dam and Lake Roosevelt			
Jan	40,390	60%	24,234
Feb	49,842	60%	29,905
Mar	65,191	60%	39,114
Apr	69,337	60%	41,602
May	105,161	60%	63,096
Jun	185,902	60%	111,541
Jul	319,751	60%	191,850
Aug	224,477	60%	134,686
Sep	114,846	60%	68,908
Oct	54,226	60%	32,535
Nov	31,269	60%	18,761

Month	Average Visitation 2017-2018	Percentage of Visitation that is Water Based	Estimated Total Water-Based Visitation (Visits)
Dec	30,174	60%	18,104
Total	**1,290,563**	**60%**	**774,338**
Dworshak Dam and Reservoir			
Jan	8,511	48%	4,058
Feb	13,214	48%	6,299
Mar	24,456	48%	11,659
Apr	40,229	48%	19,178
May	39,598	48%	18,877
Jun	58,992	48%	28,123
Jul	70,845	48%	33,774
Aug	48,303	48%	23,027
Sep	33,916	48%	16,169
Oct	21,837	48%	10,410
Nov	17,132	48%	8,167
Dec	11,596	48%	5,528
Total	**388,628**	**48%**	**185,269**

Note: This table includes the following sites from Table 3-3 that are on the reservoirs:
Lake Koocanusa: Blackwell Flats, Downstream Area, Dunn Creek, Libby Dam Left Abutment, Libby Dam Visitor Center, Ripley, Souse Gulch, Vista Point, and Dispersed Use;
Hungry Horse: all sites;
Lake Roosevelt: all sites; and
Dworshak: Big Eddy Marina, Big Eddy Recreation Area, Bruce's Eddy Recreation Area, Canyon Creek Recreation Area, Cold Springs Trail, Dam View Camping Area, Dent Acres Recreation Area, Dworshak Dam Viewpoint, Dworshak State Park- Three Meadows Group Camp, Dworshak State Park-Freeman Creek, Dworshak Visitor Center, Grandad Recreation Area, Lake-Based Recreation Facilities, Little Meadow Creek Campground, Merry's Bay Recreation Area, Powerhouse Road Fishing Access, and Dispersed Use.
At some recreation sites on these reservoirs, visitation data are only available at the annual level (rather than monthly). These annual data are allocated to months using the average distribution from monthly data available for other sites at the reservoirs.
Because the proportion of water-based activities is not available for Hungry Horse Reservoir, the proportion for Lake Koocanusa is applied, the closest site with this information.

Changes in boat ramp accessibility and water-based visitation were also evaluated in high- and low water years under the No Action Alternative. As noted in section 2 of this appendix, analysts evaluated whether site access would be affected in any of the 25th, 50th, or 75th percentile water years. Four reservoir sites would experience water surface elevation changes of one foot or more in any of these water years, resulting in a change in boat ramp accessibility. Potential changes in recreational visitation resulting from smaller changes in water surface elevations were not evaluated because the effects, if any, are expected to be sufficiently small to not impede access. Table 3-7 and Table 3-8 present the number of accessible days across boat ramps by month for the low and high water years for the four affected reservoirs. [17]

[17] It should be noted that that the supplemental analysis under MO3 and MO4, for the lower Snake River and Pend Oreille, respectively, are presented in Sections 6 and 7 or this appendix.

Table 3-7. No Action Alternative Boat Ramp Accessibility in High-water Year (25th Percentile), by Month

Month	Libby Dam and Lake Koocanusa		Hungry Horse Dam and Reservoir		Grand Coulee Dam and Lake Roosevelt		Dworshak Dam and Reservoir	
	NAA Accessible Days	Percent of Days that are Accessible	NAA Accessible Days	Percent of Days that are Accessible	NAA Accessible Days	Percent of Days that are Accessible	NAA Accessible Days	Percent of Days that are Accessible
Jan	248	89%	289	93%	682	100%	155	71%
Feb	224	89%	183	65%	616	100%	140	71%
Mar	248	89%	186	60%	655	96%	155	71%
Apr	240	89%	180	60%	403	61%	150	71%
May	248	89%	220	71%	386	57%	211	97%
Jun	259	96%	300	100%	601	91%	210	100%
Jul	279	100%	310	100%	682	100%	217	100%
Aug	279	100%	310	100%	663	97%	179	82%
Sep	270	100%	300	100%	635	96%	124	59%
Oct	279	100%	310	100%	642	94%	124	57%
Nov	270	100%	300	100%	660	100%	120	57%
Dec	254	91%	310	100%	682	100%	153	71%

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

Table 3-8. No Action Alternative Boat Ramp Accessibility in Low-water Year (75th Percentile), by Month

Month	Libby Dam and Lake Koocanusa		Hungry Horse Dam and Reservoir		Grand Coulee Dam and Lake Roosevelt		Dworshak Dam and Reservoir	
	NAA Accessible Days	Percent of Days that are Accessible	NAA Accessible Days	Percent of Days that are Accessible	NAA Accessible Days	Percent of Days that are Accessible	NAA Accessible Days	Percent of Days that are Accessible
Jan	248	89%	186	60%	682	100%	124	57%
Feb	156	62%	126	45%	449	73%	94	48%
Mar	129	46%	104	34%	340	50%	56	26%
Apr	90	33%	66	22%	184	28%	30	14%
May	151	54%	86	28%	181	27%	118	54%
Jun	230	85%	242	81%	480	73%	210	100%
Jul	277	99%	310	100%	682	100%	217	100%
Aug	279	100%	310	100%	618	91%	177	82%
Sep	270	100%	300	100%	591	90%	124	59%
Oct	279	100%	310	100%	642	94%	124	57%
Nov	270	100%	262	87%	660	100%	120	57%

Month	Libby Dam and Lake Koocanusa		Hungry Horse Dam and Reservoir		Grand Coulee Dam and Lake Roosevelt		Dworshak Dam and Reservoir	
	NAA Accessible Days	Percent of Days that are Accessible	NAA Accessible Days	Percent of Days that are Accessible	NAA Accessible Days	Percent of Days that are Accessible	NAA Accessible Days	Percent of Days that are Accessible
Dec	251	90%	204	66%	682	100%	124	57%

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

Table 3-9 presents average monthly water-based visitation for each reservoir in high- and low water years. Because consistent visitation data are not available for years prior to 2017, recent historical data are not available for high- and low water years. Therefore, the estimates in Table 3-9 were constructed based on percentage changes in accessibility relative to a typical water year (50th percentile). Referring back to Figure 3-1 above, more days of boat accessibility are supported during high water years (25th percentile), fewer are supported in typical water years (50th percentile), and the least are supported in low water years (75th percentile). Consistent with the basis for the analysis across alternatives (i.e., changes in boat ramp accessibility under an MO or the PA relative to the No Action Alternative lead to changes in water-based visitation), water-based visitation in the 25th and 75th percentiles under the No Action Alternative is estimated based on proportional differences in accessibility with the 50th percentile.

For example, the number of accessible days across ramps in June during a typical water year at Lake Roosevelt is 526 days (Table 3-6). There are 601 accessible days (14.3 percent more than a typical water year) during a high water year (Table 3-7) and 480 accessible days (8.7 percent less than a typical water year) during an low water year (Table 3-8). These percentage changes are applied to the estimated water-based visitation in June during a typical water year at Lake Roosevelt (111,541) to estimate water-based visitation during high- and low-level years for the same month (127,445 and 101,787, respectively). This approach is applied to all months across reservoirs to develop monthly water-based visitation estimates for high- and low water years under the No Action Alternative.

Table 3-9. No Action Alternative Water-Based Visitation (Visits) in High- (25th Percentile) and Low- (75th Percentile) Water-Level Years, by Month

Month	Estimated Total Water-Based Visitation (Visits)	
	High-water Year	Low-water Year
Libby Dam and Lake Koocanusa		
Jan	439	439
Feb	447	311
Mar	562	292
Apr	2,214	830
May	6,154	3,747
Jun	7,074	6,282

Month	Estimated Total Water-Based Visitation (Visits)	
	High-water Year	**Low-water Year**
Jul	9,377	9,310
Aug	8,407	8,407
Sep	6,336	6,336
Oct	3,069	3,069
Nov	2,493	2,493
Dec	679	671
Total	**47,252**	**42,188**
Hungry Horse Dam and Reservoir		
Jan	0	0
Feb	0	0
Mar	0	0
Apr	0	0
May	197	77
Jun	412	333
Jul	1,153	1,153
Aug	452	452
Sep	115	115
Oct	0	0
Nov	0	0
Dec	0	0
Total	**2,330**	**2,131**
Grand Coulee Dam and Lake Roosevelt		
Jan	24,234	24,234
Feb	36,263	26,432
Mar	73,200	37,997
Apr	61,638	28,142
May	85,457	40,072
Jun	127,445	101,787
Jul	191,850	191,850
Aug	139,964	130,464
Sep	71,148	66,219
Oct	32,535	32,535
Nov	18,761	18,761
Dec	18,104	18,104
Total	**880,600**	**716,597**
Dworshak Dam and Reservoir		
Jan	5,072	4,058
Feb	7,874	5,287
Mar	14,573	5,265
Apr	23,973	4,795
May	23,024	12,876
Jun	28,123	28,123

Month	Estimated Total Water-Based Visitation (Visits)	
	High-water Year	Low-water Year
Jul	33,774	33,774
Aug	23,288	23,027
Sep	16,169	16,169
Oct	10,410	10,410
Nov	8,167	8,167
Dec	6,821	5,528
Total	**201,267**	**157,478**

Note: This table includes the following sites from Table 3-2 that are on the reservoirs:
Lake Koocanusa: Blackwell Flats, Downstream Area, Dunn Creek, Libby Dam Left Abutment, Libby Dam Visitor Center, Ripley, Souse Gulch, Vista Point, and Dispersed Use;
Hungry Horse: all sites;
Lake Roosevelt: all sites; and
Dworshak: Big Eddy Marina, Big Eddy Recreation Area, Bruce's Eddy Recreation Area, Canyon Creek Recreation Area, Cold Springs Trail, Dam View Camping Area, Dent Acres Recreation Area, Dworshak Dam Viewpoint, Dworshak State Park- Three Meadows Group Camp, Dworshak State Park-Freeman Creek, Dworshak Visitor Center, Grandad Recreation Area, Lake-Based Recreation Facilities, Little Meadow Creek Campground, Merry's Bay Recreation Area, Powerhouse Road Fishing Access, and Dispersed Use.

3.1.3 Recreational Visitor Days and Consumer Surplus Values

Across the basin, total recreational visitation at sites within 1 mile of the mainstem rivers, including water- and land-based use at reservoirs and river reaches, is anticipated to be around 13 million visits annually (Table 3-2) in a typical water year under the No Action Alternative. Accounting for overnight visitation yields an estimated 14.9 million recreational days.
As described above, this conversion of visits to recreation days is calculated using a ratio of recreation days to visits available for a limited number of sites to each area. The unit day values described in Section 2.1.3 are applied to the visitation estimates in Table 3-3 to estimate the social welfare effects. The visitation is anticipated to support over $133 million in annual consumer surplus value (social welfare), primarily at CRSO reservoirs. Table 3-10 presents the social welfare effects of these recreational days by reservoir/river reach, CRSO region, and in total.

Table 3-10. Summary of Average Annual Social Welfare Effects of Recreation under the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Reservoir/River Reach	Recreational Visitor Days (Thousands)	Social Welfare Effects (Consumer Surplus)
Kootenai River between the US-Canada border and Libby Dam and Lake Koocanusa	203	$2,005,000
Flathead River above Flathead Lake and Hungry Horse Dam and Reservoir	8	$75,000
Clark Fork River, Flathead River below Flathead Lake, and Flathead Lake	332	$3,277,000
Pend Oreille River and Lake Pend Oreille	1,086	$9,746,600

CRSO Region, Reservoir/River Reach	Recreational Visitor Days (Thousands)	Social Welfare Effects (Consumer Surplus)
Region A Total	**1,629**	**$15,102,000**
Grand Coulee Dam and Lake Roosevelt	2,145	$19,411,000
Chief Joseph Dam and Lake Rufus Woods	376	$2,988,000
Wells Dam and Lake Pateros	ND	ND
Rocky Reach Dam and Lake Entiat	ND	ND
Rock Island Dam and Pool	ND	ND
Wanapum Dam and Lake	339	$2,919,000
Priest Rapids Dam and Lake	ND	ND
Region B Total	**2,860**	**$25,319,000**
Clearwater River and Dworshak Dam and Reservoir	524	$5,173,000
Snake River below Hells Canyon Dam	ND	ND
Lower Granite Dam and Lake	1,939	$17,640,000
Little Goose Dam and Lake Bryan	280	$2,568,000
Lower Monumental Dam and Lake Herbert G. West	217	$2,141,000
Ice Harbor Dam and Lake Sacajawea	252	$2,184,000
Region C Total	**3,213**	**$29,706,000**
The Hanford Reach below Priest Rapids Dam	ND	ND
McNary Dam and Lake Wallula	3,164	$27,252,000
John Day Dam and Lake Umatilla	855	$7,269,000
The Dalles Dam and Lake Celilo	1,283	$11,462,000
Bonneville Dam and Lake	1,591	$14,539,000
Below Bonneville Dam	276	$2,524,000
Region D Total	**7,169**	**$63,046,000**
Total	**14,871**	**$133,173,000**

Notes: 1) The social welfare analysis is conducted in two steps. First, recreational visits are converted to recreational visitor days to account for the fact that overnight trips are longer than 1 day. Second, UDVs are applied to the estimated recreational visitor days.2) There is no visitation data for sites marked as ND. As such, consumer surplus values may be underestimated at these sites. However, visitation at recreation at reservoirs/river reaches with no data are expected to be relatively low (see Table 2-1).

3.2 SUPPLEMENTAL DETAIL DESCRIBING QUANTIFIED REGIONAL ECONOMIC EFFECTS

Assuming that each visitor spends an average amount on recreation per day, non-local visitation at sites within 1 mile of the mainstem rivers, including water- and land-based use at reservoirs and river reaches, is anticipated to support $499 million in visitor expenditures annually in a typical water year under the No Action Alternative. Table 3-11 presents these expenditures by reservoir/river reach, CRSO region, and in total, as well as the percentage of expenditures associated with local and non-local visitors. Regional economic effects associated with non-local visitor expenditures would support approximately 6,480 annual jobs, $265 million in labor income, and $843 million in sales across the recreation study area annually under the No Action Alternative. Table 3-12 presents these regional economic effects by CRSO region and in total. Regional effects associated with local, non-local, and total visitation are presented for completeness, but the focus of the regional economic effects evaluation was on

749 non-local visitors since changes in their expenditures would result in impacts to the regional
750 economy.

751 **Table 3-11. Summary of Average Annual Visitor Expenditures under the No Action Alternative**
752 **in a Typical Water Year (2019 Dollars)**

CRSO Region, Reservoir/River Reach	Local Visitor Expenditures	Non-Local Visitor Expenditures	Total Expenditures	Percentage Non-Local[1/]
Kootenai River between the US-Canada border and Libby Dam and Lake Koocanusa	$361,000	$8,589,000	$8,950,000	96%
Flathead River above Flathead Lake and Hungry Horse Dam and Reservoir	$14,000	$321,000	$335,000	96%
Clark Fork River, Flathead River below Flathead Lake, and Flathead Lake	$590,000	$14,034,000	$14,624,000	96%
Pend Oreille River and Lake Pend Oreille	$1,864,000	$44,299,000	$46,163,000	96%
Region A Total (weighted average)	$2,829,000	$67,243,000	$70,072,000	**96%**
Grand Coulee Dam and Lake Roosevelt	$6,265,000	$50,010,000	$56,275,000	89%
Chief Joseph Dam and Lake Rufus Woods	$2,379,000	$14,546,000	$16,925,000	86%
Wells Dam and Lake Pateros	ND	ND	ND	ND
Rocky Reach Dam and Lake Entiat	ND	ND	ND	ND
Rock Island Dam and Pool	ND	ND	ND	ND
Wanapum Dam and Lake	$3,031,000	$12,218,000	$15,249,000	80%
Priest Rapids Dam and Lake	ND	ND	ND	ND
The Hanford Reach below Priest Rapids Dam	ND	ND	ND	ND
Region B Total (weighted average)	$11,603,000	$76,846,000	$88,449,000	**87%**
Clearwater River and Dworshak Dam and Reservoir	$815,000	$21,100,000	$21,915,000	96%
Snake River below Hells Canyon Dam	ND	ND	ND	ND
Lower Granite Dam and Lake	$12,428,000	$73,543,000	$85,972,000	86%
Little Goose Dam and Lake Bryan	$301,000	$11,959,000	$12,260,000	98%
Lower Monumental Dam and Lake Herbert G. West	$188,000	$8,079,000	$8,267,000	98%
Ice Harbor Dam and Lake Sacajawea	$266,000	$9,483,000	$9,749,000	97%
Region C Total (weighted average)	$14,166,000	$123,997,000	$138,162,000	**90%**
McNary Dam and Lake Wallula	$28,298,000	$114,055,000	$142,353,000	80%
John Day Dam and Lake Umatilla	$8,201,000	$22,044,000	$30,246,000	73%

CRSO Region, Reservoir/River Reach	Local Visitor Expenditures	Non-Local Visitor Expenditures	Total Expenditures	Percentage Non-Local[1/]
The Dalles Dam and Lake Celilo	$12,848,000	$34,535,000	$47,383,000	73%
Bonneville Dam and Lake	$17,542,000	$51,823,000	$69,365,000	75%
Below Bonneville Dam	$3,045,000	$8,996,000	$12,041,000	75%
Region D Total (weighted average)	$70,226,000	$231,162,000	$301,388,000	**77%**
Total (weighted average)	**$99,126,000**	**$498,945,000**	**$598,071,000**	**83%**

Notes: There is no visitation data for sites marked as ND (Table 3-2 above). As such the contribution of visitor expenditures to the regional economy is likely underestimated for these sites. However, visitation at recreation at reservoirs/river reaches with no data are expected to be relatively low (see Table 2-1).

[1/] Information for Lake Koocanusa is applied to all reservoirs and river reaches in Region A, information for Lake Umatilla is applied to the reach containing Lake Celilo; and information for Lake Bonneville is applied to the stretch below Bonneville Dam.

Table 3-12. Summary of Average Annual Regional Economic Effects of Recreation under the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Local/Non-Local	Local/Non-Local Visitation (Thousands)	Jobs	Labor Income	Sales
Region A				
Local	61	36	$1,242,000	$3,720,000
Non-Local	1,453	858	$29,530,000	$88,423,000
Total	**1,514**	**894**	**$30,772,000**	**$92,143,000**
Region B				
Local	261	127	$3,896,000	$13,323,000
Non-Local	1,732	843	$25,803,000	$88,240,000
Total	**1,993**	**970**	**$29,699,000**	**$101,563,000**
Region C				
Local	309	170	$5,385,000	$20,163,000
Non-Local	2,708	1,488	$47,136,000	$176,495,000
Total	**3,017**	**1,658**	**$52,521,000**	**$196,658,000**
Region D				
Local	1,557	882	$38,437,000	$119,690,000
Non-Local	5,125	2,905	$126,522,000	$393,982,000
Total	**6,682**	**3,787**	**$164,959,000**	**$513,672,000**
Total				
Local	2,189	1,287	$52,637,000	$167,481,000
Non-Local	11,018	6,477	$264,945,000	$843,004,000
Total	**13,207**	**7,763**	**$317,582,000**	**$1,010,485,000**

Notes: The multiplier effect is larger for the entire Basin, so total regional economic effects are greater than the summation of effects across CRSO regions. There is no visitation data for sites marked as ND. As such the contribution of visitor expenditures to the regional economy is likely underestimated for these sites. However, visitation at recreation at reservoirs/river reaches with no data are expected to be relatively low (see Table 2-1).

3.3 SUMMARY OF EFFECTS

Consistent with the summary in Section 3.11 of the EIS, Table 3-13 summarizes the estimated social welfare effects, regional economic effects, and social welfare effects associated with recreational visitation under the No Action Alternative. A more detailed discussion of qualitative effects (e.g., other social effects and fishing conditions) that are described in the table are provided in section 3.11 of the EIS, Recreation. Across the basin, total recreational visitation at sites within 1 mile of the mainstem rivers, including water- and land-based use at reservoirs and river reaches, is anticipated to be approximately 13 million visits annually.[18] This estimate may underestimate river-based recreation as well as visitation at some state and local sites, as visitation sources for this analysis are most complete at Federal reservoir locations. This recreational visitation is anticipated to support over $133 million in annual consumer surplus value (social welfare), primarily at CRS reservoirs.

Visitor expenditures by non-local visitors are anticipated to be $499 million across the study area annually under the No Action Alternative, with most of the expenditures occurring in Regions C and D. Regional economic effects associated with these non-local visitor expenditures in the basin are anticipated to result in 6,480 annual jobs, $265 million in labor income, and $843 million in sales across the recreation study area annually. To put these numbers in context, across the Basin, all economic activity supports 2.9 million jobs, $163.0 billion in labor income, and $475.5 billion in sales annually. Recreational opportunities under the No Action Alternative would continue to support social well-being and quality of life, especially in the communities surrounding and adjacent to recreational sites. Sites in rural areas likely have a larger effect on local economic activity and community identity because there is less economic diversity and relatively higher reliance on local recreation-related businesses, recreational amenities, and features.

[18] Because regional visitation data from Federal and state agencies is more comprehensively collected for reservoirs and are limited for sections of river between reservoirs (see Section 3.11.2.2 of the EIS), total estimated visitation primarily reflects reservoir-based recreation.

789 **Table 3-13. Summary of Average Annual Effects of Recreation Under the No Action Alternative (2019 Dollars)**

Region	Social Welfare Effects	Regional Economic Effects	Other Social Effects
Region A	A wide range of land- and water-based recreation would occur, with most visitation occurring at Lake Koocanusa, Hungry Horse Reservoir, and Albeni Falls/Lake Pend Oreille. Regional visitation totaling 1.5 million visits would generate annual welfare benefits of $15 million. Current conditions for fish, wildlife, and water quality would continue to support recreational experiences in the river and reservoirs.	Non-local visitor expenditures of approximately $67 million annually would860 annual jobs, $30 million in regional labor income, and $88 million in regional sales annually.	The No Action Alternative would continue to provide other social effects associated with considerable recreational opportunities in the region. Continued operation of the system would provide benefits to community well-being, cohesion, and identity similar to current conditions across the study area. However, long-term adverse effects of system operations on area tribes would continue.
Region B	A wide range of land- and water-based recreation would occur, with most visitation occurring at Lake Roosevelt, and to a lesser extent at Lake Rufus Woods. Regional visitation totaling 2.0 million annual visits would generate annual welfare benefits of $25 million.	Non-local visitor expenditures of approximately $77 million annually would support 840 annual jobs, $26 million in regional labor income, and $88 million in regional sales annually.	
Region C	A wide range of land- and water-based recreation would occur, with most visitation occurring at the four lower Snake River and Dworshak Reservoirs. About 63 percent of regional visitation occurs at Lower Granite Lake near Lewiston, ID. Regional visitation totaling 3.0 million annual visits would generate annual welfare benefits of $30 million.	Non-local visitor expenditures of approximately $124 million annually would support 1,490 annual jobs, $47 million in regional income, and $176 million in regional sales annually.	
Region D	A wide range of land- and water-based recreation would occur at reservoirs on the lower Columbia River and along the river below Bonneville Dam. About 86 percent of regional visitation occurs at Lake Wallula, Lake Celilio, and Lake Bonneville. Regional visitation totaling 6.7 million annual visits would generate annual welfare benefits of $63 million.	Non-local visitor expenditures of approximately $231 million annually would support2,910 jobs, $127 million in regional income, and $394 million in regional sales.	
Total	A wide range of land- and water-based recreation within 1 mile of mainstem rivers would result in 13 million annual visits to the region. This visitation would generate annual welfare benefits of $133 million.	Non-local visitor expenditures of approximately $499 million annually would support for 6,480 jobs, $265 million in income, and $843 million in regional sales annually.	

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CHAPTER 4 - MULTIPLE OBJECTIVE ALTERNATIVE 1

Anticipated changes in water surface elevations under MO1 would affect boat ramp accessibility and water-based visitation relative to the No Action Alternative at Lake Koocanusa (Libby Dam) and Hungry Horse Reservoir in Region A, Lake Roosevelt in Region B, and Dworshak Reservoir in Region C. Changes in water surface elevations at other reservoirs in the basin would not affect accessibility or visitation. Over time, visitors may adjust their behavior to adapt to changes in accessibility, such as utilizing different sites on the system, which could reduce the adverse effects to visitation described in this section.

4.1 SUPPLEMENTAL DETAIL DESCRIBING QUANTIFIED SOCIAL WELFARE EFFECTS

The tables below present the changes in water-based visitation and social welfare effects under MO1 relative to the No Action Alternative. As discussed above, this appendix focuses on providing additional details to support the quantitative analysis that is described in Chapter 3. Additional qualitative analysis is not repeated in this Appendix; please refer to Section 3.11 of the EIS for a complete description of the effects of MO1 on recreation.

Table 4-1 presents the percentage change in the number of accessible days across boat ramps by month for the four reservoirs affected under MO1 relative to the No Action Alternative in a typical water year, as well as the associated change in water-based visitation. Table 4-2 and Table 4-3 present these results using the 25th percentile H&H results (high water year) and 75th percentile results (low water year). Table 4-4 presents the annual changes in recreation days and associated social welfare effects in a typical water year by reservoir, CRSO region, and in total.

Table 4-1. Change in Boat Ramp Accessibility and Water-Based Visitation (Visits) under MO1 Relative to the No Action Alternative in a Typical Water Year (50th Percentile), by Month

Month	NAA Accessible Days	MO1 Accessible Days	Percentage Change in Accessible Days	Estimated Change in Water-Based Visitation (Visits)[1/]
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	224	224	0%	0
Mar	248	236	-5%	(27)
Apr	206	180	-13%	(240)
May	248	248	0%	0
Jun	247	248	0%	27
Jul	279	279	0%	0
Aug	279	279	0%	0
Sep	270	270	0%	0
Oct	279	279	0%	0
Nov	270	270	0%	0
Dec	251	253	1%	5
Total	**3,049**	**3,014**	**-1%**	**(234)**

Month	NAA Accessible Days	MO1 Accessible Days	Percentage Change in Accessible Days	Estimated Change in Water-Based Visitation (Visits)[1/]
Hungry Horse Dam and Reservoir				
Jan	213	186	-13%	0
Feb	166	129	-22%	0
Mar	127	113	-11%	0
Apr	120	90	-25%	0
May	151	137	-9%	(13)
Jun	287	277	-3%	(14)
Jul	310	310	0%	0
Aug	310	310	0%	0
Sep	300	300	0%	0
Oct	310	282	-9%	0
Nov	294	209	-29%	0
Dec	276	186	-33%	0
Total	**2,864**	**2,529**	**-12%**	**(26)**
Grand Coulee Dam and Lake Roosevelt				
Jan	682	668	-2%	(497)
Feb	508	445	-12%	(3,709)
Mar	350	350	0%	0
Apr	272	269	-1%	(459)
May	285	284	0%	(221)
Jun	526	527	0%	212
Jul	682	682	0%	0
Aug	638	633	-1%	(1,056)
Sep	615	612	0%	(336)
Oct	642	642	0%	0
Nov	660	660	0%	0
Dec	682	682	0%	0
Total	**6,542**	**6,454**	**-1%**	**(6,066)**
Dworshak Dam and Reservoir				
Jan	124	124	0%	0
Feb	112	112	0%	0
Mar	124	124	0%	0
Apr	120	120	0%	0
May	173	173	0%	0
Jun	210	210	0%	0
Jul	217	217	0%	0
Aug	177	157	-11%	(2,602)
Sep	124	135	9%	1,434
Oct	124	124	0%	0
Nov	120	120	0%	0

Month	NAA Accessible Days	MO1 Accessible Days	Percentage Change in Accessible Days	Estimated Change in Water-Based Visitation (Visits)[1/]
Dec	124	124	0%	0
Total	**1,749**	**1,740**	**-1%**	**(1,168)**
Basin-Wide Total	**14,204**	**13,737**	**-3%**	**(7,494)**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation is calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-6.

Table 4-2. Change in Boat Ramp Accessibility and Water-Based Visitation (Visits) under MO1 Relative to the No Action Alternative in a High-water Year (25th Percentile), by Month

Month	NAA Accessible Days	MO1 Accessible Days	Percentage Change in Accessible Days	Estimated Change in Water-Based Visitation (Visits) [1/]
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	224	224	0%	0
Mar	248	248	0%	0
Apr	240	240	0%	0
May	248	248	0%	0
Jun	259	262	1%	82
Jul	279	279	0%	0
Aug	279	279	0%	0
Sep	270	270	0%	0
Oct	279	279	0%	0
Nov	270	270	0%	0
Dec	254	253	0%	(3)
Total	**3,098**	**3,100**	**0%**	**79**
Hungry Horse Dam and Reservoir				
Jan	289	247	-15%	0
Feb	183	168	-8%	0
Mar	186	160	-14%	0
Apr	180	120	-33%	0
May	220	199	-10%	(19)
Jun	300	300	0%	0
Jul	310	310	0%	0
Aug	310	310	0%	0
Sep	300	300	0%	0
Oct	310	294	-5%	0
Nov	300	270	-10%	0
Dec	310	279	-10%	0
Total	**3,198**	**2,957**	**-8%**	**(19)**
Grand Coulee Dam and Lake Roosevelt				

Month	NAA Accessible Days	MO1 Accessible Days	Percentage Change in Accessible Days	Estimated Change in Water-Based Visitation (Visits) [1/]
Jan	682	682	0%	0
Feb	616	521	-15%	(5,592)
Mar	655	507	-23%	(16,540)
Apr	403	381	-5%	(3,365)
May	386	388	1%	443
Jun	601	601	0%	0
Jul	682	682	0%	0
Aug	663	658	-1%	(1,056)
Sep	635	632	0%	(336)
Oct	642	642	0%	0
Nov	660	660	0%	0
Dec	682	682	0%	0
Total	**7,307**	**7,036**	**-4%**	**(26,446)**
Dworshak Dam and Reservoir				
Jan	155	155	0%	0
Feb	140	140	0%	0
Mar	155	155	0%	0
Apr	150	150	0%	0
May	211	211	0%	0
Jun	210	210	0%	0
Jul	217	217	0%	0
Aug	179	177	-1%	(260)
Sep	124	135	9%	1,434
Oct	124	124	0%	0
Nov	120	120	0%	0
Dec	153	153	0%	0
Total	**1,938**	**1,947**	**0%**	**1,174**
Basin-Wide Total	**15,541**	**15,040**	**-3%**	**(25,211)**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-7.

Table 4-3. Change in Boat Ramp Accessibility and Water-Based Visitation (Visits) under MO1 Relative to the No Action Alternative in a Low-water Year (75th Percentile), by Month

Month	NAA Accessible Days	MO1 Accessible Days	Percentage Change in Accessible Days	Estimated Change in Water-Based Visitation (Visits) [1/]
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	156	171	10%	30

Month	NAA Accessible Days	MO1 Accessible Days	Percentage Change in Accessible Days	Estimated Change in Water-Based Visitation (Visits) [1/]
Mar	129	145	12%	36
Apr	90	99	10%	83
May	151	152	1%	25
Jun	230	230	0%	0
Jul	277	278	0%	34
Aug	279	279	0%	0
Sep	270	270	0%	0
Oct	279	279	0%	0
Nov	270	270	0%	0
Dec	251	252	0%	3
Total	**2,630**	**2,673**	**2%**	**210**
Hungry Horse Dam and Reservoir				
Jan	186	124	-33%	0
Feb	126	103	-18%	0
Mar	104	81	-22%	0
Apr	66	60	-9%	0
May	86	83	-3%	(3)
Jun	242	234	-3%	(11)
Jul	310	310	0%	0
Aug	310	310	0%	0
Sep	300	300	0%	0
Oct	310	190	-39%	0
Nov	262	180	-31%	0
Dec	204	160	-22%	0
Total	**2,506**	**2,135**	**-15%**	**(14)**
Grand Coulee Dam and Lake Roosevelt				
Jan	682	559	-18%	(4,371)
Feb	449	415	-8%	(2,002)
Mar	340	336	-1%	(447)
Apr	184	177	-4%	(1,071)
May	181	175	-3%	(1,328)
Jun	480	480	0%	0
Jul	682	682	0%	0
Aug	618	610	-1%	(1,689)
Sep	591	591	0%	0
Oct	642	642	0%	0
Nov	660	660	0%	0
Dec	682	682	0%	0
Total	**6,191**	**6,009**	**-3%**	**(10,907)**
Dworshak Dam and Reservoir				
Jan	124	124	0%	0

Month	NAA Accessible Days	MO1 Accessible Days	Percentage Change in Accessible Days	Estimated Change in Water-Based Visitation (Visits) [1/]
Feb	94	94	0%	0
Mar	56	56	0%	0
Apr	30	30	0%	0
May	118	118	0%	0
Jun	210	210	0%	0
Jul	217	213	-2%	(623)
Aug	177	155	-12%	(2,862)
Sep	124	135	9%	1,434
Oct	124	124	0%	0
Nov	120	120	0%	0
Dec	124	124	0%	0
Total	**1,518**	**1,503**	**-1%**	**(2,050)**
Basin-Wide Total	**12,845**	**12,320**	**-4%**	**(12,761)**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation is calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-8.

Table 4-4. Changes in Annual Social Welfare Effects of Water-Based Recreation under MO1 Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Reservoir/River Reach	Changes in Recreational Visitor Days	Social Welfare Effects (Consumer Surplus)
Region A Total (Lake Koocanusa and Hungry Horse Reservoir)	**(274)**	**($3,000)**
Lake Koocanusa	(246)	($2,000)
Hungry Horse Reservoir	(28)	($0)
Region B Total (Lake Roosevelt)	**(10,081)**	**($91,000)**
Region C Total (Dworshak Reservoir)	**(1,333)**	**($13,000)**
Region D Total	**0**	**$0**
Total	**(11,688)**	**($107,000)**

Notes: The social welfare analysis is conducted in two steps. First, recreational visits are converted to recreational visitor days to account for the fact that overnight trips are longer than 1 day. Second, UDVs are applied to the estimated recreational visitor days. Impacts are estimated based on changes in water surface elevations at reservoirs. Changes in water surface elevations at other reservoirs in the basin not shown would not affect accessibility or visitation.

4.2 SUPPLEMENTAL DETAIL DESCRIBING QUANTIFIED REGIONAL ECONOMIC EFFECTS

The tables below present the regional economic effects under MO1 relative to the No Action Alternative. Table 4-5 presents the average annual changes in water-based visitor expenditures in a typical water year by reservoir, CRSO region, and in total, as well as the percentage of expenditures associated with non-local visitors. Table 4-6 presents the regional economic

effects associated with these changes in expenditures by CRSO region and in total. Regional effects associated with local, non-local, and total visitation are presented for completeness, but the focus of the regional economic effects evaluation was on non-local visitors since changes in their expenditures would result in impacts to the regional economy.

Table 4-5. Changes in Visitor Expenditures under MO1 Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Reservoir/River Reach	Local Visitor Expenditures	Non-Local Visitor Expenditures	Total Expenditures	Percentage Non-Local
Region A Total (Lake Koocanusa and Hungry Horse Reservoir)	**($0)**	**($12,000)**	**($12,000)**	**96%**
Lake Koocanusa	($0)	($10,000)	($11,000)	96%
Hungry Horse Reservoir	($0)	($1,000)	($1,000)	96%
Region B Total (Lake Roosevelt)	**($29,000)**	**($235,000)**	**($265,000)**	**89%**
Region C Total (Dworshak Reservoir)	**($2,000)**	**($54,000)**	**($56,000)**	**96%**
Region D Total	**$0**	**$0**	**$0**	**77%**
Total (weighted average)	**($32,000)**	**($300,000)**	**($332,000)**	**90%**

Notes: Impacts are estimated based on changes in water surface elevations at reservoirs. Changes in water surface elevations at other reservoirs in the basin would not affect accessibility or visitation. Table does not reflect effects that are described qualitatively, and may underestimate effects at some sites.

Table 4-6. Changes in Regional Economic Effects of Recreation under MO1 Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Local/Non-Local	Local/Non-Local Visitation	Jobs	Labor Income	Sales
Region A				
Local	(11)	(0)	($0)	($0)
Non-Local	(250)	(0)	($5,000)	($15,000)
Total	**(261)**	**(0)**	**($5,000)**	**($16,000)**
Region B				
Local	(675)	(0)	($9,000)	($30,000)
Non-Local	(5,391)	(3)	($76,000)	($236,000)
Total	**(6,066)**	**(3)**	**($85,000)**	**($266,000)**
Region C				
Local	(43)	(0)	($1,000)	($3,000)
Non-Local	(1,124)	(1)	($21,000)	($76,000)
Total	**(1,168)**	**(1)**	**($21,000)**	**($79,000)**
Region D				
Local	0	0	$0	$0
Non-Local	0	0	$0	$0
Total	**0**	**0**	**$0**	**$0**

CRSO Region, Local/Non-Local	Local/Non-Local Visitation	Jobs	Labor Income	Sales
Total				
Local	(729)	(0)	($15,000)	($44,000)
Non-Local	(6,765)	(4)	($139,000)	($404,000)
Total	**(7,494)**	**(4)**	**($154,000)**	**($447,000)**

Notes: Regional economic effects of recreational expenditures are included for each study region, but some "leakage" effects occur in other areas from each region. As such, the total regional economic effects are larger for the total basin than the sum of the individual regions. Also, the table does not reflect effects that are described qualitatively, and may underestimate effects at some sites.

4.3 SUMMARY OF EFFECTS

Consistent with the summary in Section 3.11 of the EIS, Recreation, Table 4-7 summarizes social welfare effects, regional economic effects, and social welfare effects associated with changes in recreation conditions under MO1. Detailed discussion of qualitative effects (e.g., quality of the recreational experience, fishing conditions, other social effects) described in the table are provided in Section 3.11, of the EIS, Recreation.

Overall effects of MO1 on recreational visitation are anticipated to be negligible to minor, with the exception of moderate adverse effects to recreational fishing in the Clearwater Reach below Dworshak Dam in August and September. Table 4-7 presents a summary of MO1 effects, including the anticipated changes in average annual recreational visitation, social welfare, and regional economic effects by region and in total relative to the No Action Alternative. Across the basin, total recreational visitation and associated social welfare effects are anticipated to decrease by less than 1 percent annually (approximately 7,500 water-based visits and $107,000 in consumer surplus value) in a typical year associated with changes in boat ramp access. Expenditures associated with non-local visitation would decrease by $300,000 annually across the region, a change of 0.1 percent compared to the No Action Alternative. Regional economic effects of this change in expenditures would be negligible. The largest reservoir effects are anticipated at Lake Roosevelt in Region B, the most visited of the four reservoirs.

There would be negligible to minor benefits to fish populations. Effects to the quality of fishing, hunting, wildlife viewing, swimming, and water sports at river recreation sites in the region under MO1 would be negligible. However, there is the potential for moderate adverse effects to recreational fishing along the Clearwater River in August and September due to increased turbidity from changes in outflows from Dworshak Dam.

Over time, visitors may adjust their behavior to adapt to changes in accessibility and site quality, such as utilizing different sites on the system, which could reduce effects to visitation.

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Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
Region A	A reduction of less than 300 water-based recreational visits (less than 1 percent of regional water-based visitation) would occur at Lake Koocanusa and Hungry Horse Reservoirs in a typical water year associated with changes in boat ramp access. In high-water-level years, water-based visitation would increase by less than 0.2 percent at these two reservoirs and would increase by less than 0.5 percent in low-water-level years. Annual social welfare benefits would decrease by $2,700 in a typical water year. Negligible effects to the quality of recreation experiences.	Expenditures associated with non-local recreational visits would decrease by $12,000 across the region (less than 0.1 percent) associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be negligible.	Negligible change from No Action
Region B	A reduction of approximately 6,100 water-based visits at Lake Roosevelt (less than 1 percent of water-based visitation at the site) would occur in a typical water year. In years with high or low water, visitation would decrease by 3 to 1.5 percent, respectively. Annual social welfare benefits would decrease by approximately $91,000 in a typical water year. Negligible effects to the quality of recreation experiences.	Expenditures associated with non-local recreational visits would decrease by $235,000 across the region (0.3 percent) associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be negligible.	Negligible to minor decrease in recreationist well-being when compared No Action due to potential reduction in visitor days and potential minor decreases in wildlife viewing.
Region C	A reduction of approximately 1,000 water-based visits at Dworshak Reservoir (less than one percent of water-based visitation at the site) would occur in a typical water year. Visitation would increase by less than one percent in high water years and decrease by 1.3 percent in low water years. Annual social welfare benefits would decrease by approximately $13,000 in a typical water year. Negligible to minor effects to quality of fishing, hunting, wildlife viewing, swimming, and water sports associated with changing river and reservoir conditions may occur. There is the potential for moderateadverse effects to recreational fishing along the Clearwater River in August and September due to increased turbidity from changes in outflows from Dworshak Dam.	Expenditures associated with non-local recreational visits would decrease by $54,000 across the region (less than 0.1 percent) associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be negligible.	Negligible change from No Action, with a localized exception along the Clearwater River in Region C where recreational anglers may be unable to fish due to increased turbidity.
Region D	No changes in reservoir visitation associated with changes in boat ramp access. Minor effects to quality of fishing, hunting, wildlife viewing, swimming, and water sports associated with changing river and reservoir conditions may occur.	No changes in visitor expenditures or regional effects associated with changes in boat ramp access.	No change from No Action.

Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
Total	Negligible effects to reservoir visitation (7,500 fewer visits, representing approximately 0.1 percent of total visitation compared to the No Action Alternative) in a typical water year, with decreases in social welfare of approximately $107,000 annually associated with changes in boat ramp access. Negligible to minor effects in most areas to quality of fishing, hunting, wildlife viewing, swimming, and water sports associated with changing river and reservoir conditions may occur. There is the potential for moderate adverse effects to recreational fishing along the Clearwater River in Region C.	Expenditures associated with non-local recreational visits would decrease by $300,000 across the region (a change of less than 0.1 percent from No Action) in a typical water year associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be negligible (approximately $404,000 less in sales, four fewer jobs, and $139,000 less in labor income).	Recreation would continue to provide other social effects associated with considerable recreational opportunities in the region. Continued operation of the system would provide benefits to community well-being, cohesion, and identity. Negligible change from No Action in most locations, with the exception o potential minor effects to recreationists in Region B, and major adverse localized social effects to anglers in the Clearwater River in Region C, and potential minor effects to recreationists in Region B.

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CHAPTER 5 - MULTIPLE OBJECTIVE ALTERNATIVE 2

Anticipated changes in water surface elevations under MO2 would affect boat ramp accessibility and water-based visitation relative to the No Action Alternative at Lake Koocanusa (Libby Dam) and Hungry Horse Reservoir in Region A, Lake Roosevelt in Region B, and Dworshak Reservoir in Region C. Changes in water levels at other reservoirs in the basin would not affect accessibility or visitation. Over time, visitors may adjust their behavior to adapt to changes in accessibility, such as utilizing different sites on the system, which could reduce effects to visitation.

5.1 SUPPLEMENTAL DETAIL DESCRIBING QUANTIFIED SOCIAL WELFARE EFFECTS

The tables below present the changes in water-based visitation and social welfare effects under MO2 relative to the No Action Alternative. As discussed above, this appendix focuses on providing additional details to support the quantitative analysis that is described in Chapter 3. Additional qualitative analysis is not repeated in this Appendix.

Table 5-1 presents the percentage change in the number of accessible days across boat ramps by month for the four reservoirs affected under MO2 relative to the No Action Alternative in a typical water year, as well as the associated change in water-based visitation. Table 5-2 and Table 5-3 present these results using the 25th percentile H&H results (high water year) and 75th percentile results (low water year). Table 5-4 presents the average annual changes in recreation days and associated social welfare effects in a typical water year by reservoir, CRSO region, and in total.

Table 5-1. Change in Boat Ramp Accessibility and Water-Based Visitation (Visits) under MO2 Relative to the No Action Alternative in a Typical Water Year (50th Percentile), by Month

Month	NAA Accessible Days	MO2 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	224	224	0%	0
Mar	248	238	-4%	(23)
Apr	206	184	-11%	(203)
May	248	248	0%	0
Jun	247	246	0%	(27)
Jul	279	279	0%	0
Aug	279	279	0%	0
Sep	270	270	0%	0
Oct	279	279	0%	0
Nov	270	264	-2%	(55)
Dec	251	248	-1%	(8)
Total	**3,049**	**3,007**	**-1%**	**(316)**

Month	NAA Accessible Days	MO2 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Hungry Horse Dam and Reservoir				
Jan	213	195	-8%	0
Feb	166	114	-31%	0
Mar	127	108	-15%	0
Apr	120	90	-25%	0
May	151	143	-5%	(7)
Jun	287	277	-3%	(14)
Jul	310	310	0%	0
Aug	310	310	0%	0
Sep	300	300	0%	0
Oct	310	310	0%	0
Nov	294	298	1%	0
Dec	276	278	1%	0
Total	**2,864**	**2,733**	**-5%**	**(21)**
Grand Coulee Dam and Lake Roosevelt				
Jan	682	658	-4%	(853)
Feb	508	438	-14%	(4,121)
Mar	350	350	0%	0
Apr	272	266	-2%	(918)
May	285	286	0%	221
Jun	526	529	1%	636
Jul	682	682	0%	0
Aug	638	633	-1%	(1,056)
Sep	615	601	-2%	(1,569)
Oct	642	642	0%	0
Nov	660	660	0%	0
Dec	682	682	0%	0
Total	**6,542**	**6,427**	**-2%**	**(7,658)**
Dworshak Dam and Reservoir				
Jan	124	113	-9%	(360)
Feb	112	84	-25%	(1,575)
Mar	124	91	-27%	(3,103)
Apr	120	90	-25%	(4,795)
May	173	156	-10%	(1,855)
Jun	210	210	0%	0
Jul	217	217	0%	0
Aug	177	175	-1%	(260)
Sep	124	124	0%	0
Oct	124	124	0%	0
Nov	120	120	0%	0
Dec	124	124	0%	0
Total	**1,749**	**1,628**	**-7%**	**(11,947)**

Month	NAA Accessible Days	MO2 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Basin-Wide Total	**14,204**	**13,795**	**-3%**	**(19,942)**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-6.

Table 5-2. Change in Boat Ramp Accessibility and Water-Based Visitation (Visits) under MO2 Relative to the No Action Alternative in a High-water Year (25th Percentile), by Month

Month	NAA Accessible Days	MO2 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	224	224	0%	0
Mar	248	248	0%	0
Apr	240	240	0%	0
May	248	248	0%	0
Jun	259	255	-2%	(109)
Jul	279	279	0%	0
Aug	279	279	0%	0
Sep	270	270	0%	0
Oct	279	279	0%	0
Nov	270	265	-2%	(46)
Dec	254	248	-2%	(16)
Total	**3,098**	**3,083**	**0%**	**(171)**
Hungry Horse Dam and Reservoir				
Jan	289	233	-19%	0
Feb	183	156	-15%	0
Mar	186	124	-33%	0
Apr	180	120	-33%	0
May	220	194	-12%	(23)
Jun	300	297	-1%	(4)
Jul	310	310	0%	0
Aug	310	310	0%	0
Sep	300	300	0%	0
Oct	310	310	0%	0
Nov	300	300	0%	0
Dec	310	310	0%	0
Total	**3,198**	**2,964**	**-7%**	**(27)**
Grand Coulee Dam and Lake Roosevelt				
Jan	682	682	0%	0
Feb	616	560	-9%	(3,297)
Mar	655	524	-20%	(14,640)

Month	NAA Accessible Days	MO2 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Apr	403	404	0%	153
May	386	403	4%	3,764
Jun	601	610	1%	1,908
Jul	682	682	0%	0
Aug	663	658	-1%	(1,056)
Sep	635	630	-1%	(560)
Oct	642	642	0%	0
Nov	660	660	0%	0
Dec	682	682	0%	0
Total	**7,307**	**7,137**	**-2%**	**(13,727)**
Dworshak Dam and Reservoir				
Jan	155	140	-10%	(491)
Feb	140	112	-20%	(1,575)
Mar	155	124	-20%	(2,915)
Apr	150	141	-6%	(1,438)
May	211	195	-8%	(1,746)
Jun	210	210	0%	0
Jul	217	217	0%	0
Aug	179	177	-1%	(260)
Sep	124	124	0%	0
Oct	124	124	0%	0
Nov	120	120	0%	0
Dec	153	153	0%	0
Total	**1,938**	**1,837**	**-5%**	**(8,425)**
Basin-Wide Total	**15,541**	**15,021**	**-3%**	**(22,351)**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-7.

Table 5-3. Change in Boat Ramp Accessibility and Water-Based Visitation (Visits) under MO2 Relative to the No Action Alternative in a Low-water Year (75th Percentile), by Month

Month	NAA Accessible Days	MO2 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	156	161	3%	10
Mar	129	147	14%	41
Apr	90	105	17%	138
May	151	154	2%	74
Jun	230	230	0%	0
Jul	277	277	0%	0

Month	NAA Accessible Days	MO2 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Aug	279	279	0%	0
Sep	270	270	0%	0
Oct	279	279	0%	0
Nov	270	263	-3%	(65)
Dec	251	248	-1%	(8)
Total	**2,630**	**2,661**	**1%**	**191**
Hungry Horse Dam and Reservoir				
Jan	186	166	-11%	0
Feb	126	100	-21%	0
Mar	104	75	-28%	0
Apr	66	60	-9%	0
May	86	81	-6%	(4)
Jun	242	229	-5%	(18)
Jul	310	310	0%	0
Aug	310	310	0%	0
Sep	300	300	0%	0
Oct	310	310	0%	0
Nov	262	265	1%	0
Dec	204	209	2%	0
Total	**2,506**	**2,415**	**-4%**	**(22)**
Grand Coulee Dam and Lake Roosevelt				
Jan	682	550	-19%	(4,690)
Feb	449	390	-13%	(3,473)
Mar	340	326	-4%	(1,565)
Apr	184	176	-4%	(1,224)
May	181	178	-2%	(664)
Jun	480	484	1%	848
Jul	682	682	0%	0
Aug	618	604	-2%	(2,955)
Sep	591	513	-13%	(8,740)
Oct	642	606	-6%	(1,824)
Nov	660	660	0%	0
Dec	682	682	0%	0
Total	**6,191**	**5,851**	**-5%**	**(24,287)**
Dworshak Dam and Reservoir				
Jan	124	99	-20%	(818)
Feb	94	36	-62%	(3,262)
Mar	56	31	-45%	(2,351)
Apr	30	30	0%	0
May	118	93	-21%	(2,728)
Jun	210	200	-5%	(1,339)
Jul	217	217	0%	0

Month	NAA Accessible Days	MO2 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Aug	177	173	-2%	(520)
Sep	124	124	0%	0
Oct	124	124	0%	0
Nov	120	120	0%	0
Dec	124	124	0%	0
Total	**1,518**	**1,371**	**-10%**	**(11,018)**
Basin-Wide Total	**12,845**	**12,298**	**-4%**	**(35,137)**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation is calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-8.

Table 5-4. Changes in Average Annual Social Welfare Effects of Recreation under MO2 Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Reservoir/River Reach	Changes in Recreational Days	Social Welfare Effects (Consumer Surplus)
Region A Total (Lake Koocanusa and Hungry Horse Reservoir)	**(354)**	**($3,497)**
Lake Koocanusa	(332)	($3,280)
Hungry Horse Reservoir	(22)	($217)
Region B Total (Lake Roosevelt)	**(12,727)**	**($115,180)**
Region C Total (Dworshak Reservoir)	**(13,635)**	**($134,571)**
Region D Total	**0**	**$0**
Total	**(26,717)**	**($253,249)**

Notes: The social welfare analysis is conducted in two steps. First, recreational visits are converted to recreational visitor days to account for the fact that overnight trips are longer than 1 day. Second, UDVs are applied to the estimated recreational visitor days. Impacts are estimated based on changes in water surface elevations at reservoirs. Changes in water surface elevations at other reservoirs in the basin not shown would not affect accessibility or visitation.

5.2 SUPPLEMENTAL DETAIL DESCRIBING QUANTIFIED REGIONAL ECONOMIC EFFECTS

The tables below present the regional economic effects under MO2 relative to the No Action Alternative. Table 5-5 presents the average annual changes in expenditures associated with water-based recreation in a typical water year by reservoir, CRSO region, and in total, as well as the percentage of expenditures associated with non-local visitors. Table 5-6 presents the regional economic effects associated with these changes in expenditures by CRSO region and in total. Regional effects associated with local, non-local, and total visitation are presented for completeness, but the focus of the regional economic effects evaluation was on non-local visitors since changes in their expenditures would result in impacts to the regional economy.

Table 5-5. Changes in Visitor Expenditures under MO2 Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Reservoir/River Reach	Local Visitor Expenditures	Non-Local Visitor Expenditures	Total Expenditures	Percentage Non-Local
Region A Total (Lake Koocanusa and Hungry Horse Reservoir)	**($1,000)**	**($15,000)**	**($16,000)**	**96%**
Lake Koocanusa	($1,000)	($14,000)	($15,000)	96%
Hungry Horse Reservoir	($0)	($1000)	($1,000)	96%
Region B Total (Lake Roosevelt)	**($37,000)**	**($297,000)**	**($334,000)**	**89%**
Region C Total (Dworshak Reservoir)	**($21,000)**	**($549,000)**	**($570,000)**	**96%**
Region D Total	**$0**	**$0**	**$0**	**77%**
Total (weighted average)	**($59,000)**	**($861,000)**	**($920,000)**	**93%**

Notes: Impacts are estimated based on changes in water surface elevations at reservoirs. Changes in water surface elevations at other reservoirs in the basin would not affect accessibility or visitation. Table does not reflect effects that are described qualitatively, and may underestimate effects at some sites.

Table 5-6. Changes in Regional Economic Effects of Recreation under MO2 Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Local/Non-Local	Local/Non-Local Visitation	Jobs	Labor Income	Sales
Region A				
Local	(14)	(0)	$0	($1,000)
Non-Local	(324)	(0)	($7,000)	($20,000)
Total	**(337)**	**(0)**	($7,000)	($21,000)
Region B				
Local	(853)	(0)	($12,000)	($37,000)
Non-Local	(6,805)	(3)	($95,000)	($298,000)
Total	**(7,658)**	**(4)**	($107,000)	($336,000)
Region C				
Local	(444)	(0)	($8,000)	($30,000)
Non-Local	(11,503)	(7)	($210,000)	($782,000)
Total	**(11,947)**	**(7)**	($218,000)	($813,000)
Region D				
Local	0	0	$0	$0
Non-Local	0	0	$0	$0
Total	**0**	**0**	$0	$0
Total				
Local	(1,310)	(1)	($31,000)	($94,000)
Non-Local	(18,632)	(11)	($434,000)	($1,336,000)
Total	**(19,942)**	**(12)**	($465,000)	($1,430,000)

Notes: Regional economic effects of recreational expenditures are included for each study region, but some "leakage" effects occur in other areas from each region. As such, the total regional economic effects are larger for the total basin than the sum of the individual regions. Also, the table does not reflect effects that are described qualitatively, and may underestimate effects at some sites.

5.3 SUMMARY OF EFFECTS

Consistent with the summary in Section 3.11 of the EIS, Recreation, Table 5-7 summarizes social welfare effects, regional economic effects, and social welfare effects associated with changes in recreation conditions under MO2. Detailed discussion of qualitative effects described in the table (e.g., quality of the recreational experience, fishing conditions, other social effects) are provided in Section 3.11, of the EIS, Recreation.

Overall effects of MO2 on recreation are anticipated to be minor in the short and long term following implementation. Table 5-7 presents a summary of MO2 effects, including the anticipated changes in average annual recreational visitation, social welfare, and regional economic effects by region and in total relative to the No Action Alternative. Across the basin, total visitation and associated social welfare effects are anticipated to decrease by less than 1 percent (0.2 percent) annually in a typical water year (approximately 20,000 visits and $253,000 in consumer surplus value) under MO2. Non-local visitor expenditures would decrease by $861,000 across the basin. The total economic effects of this change in regional expenditures would be minor. The largest effects are anticipated at Dworshak Reservoir in Region C, the second-most visited of the four reservoirs that are anticipated to have effects on boat ramp accessibility.

Resident fish entrainment would increase in Region A, which could result in minor effects in the quality of fishing experiences there. In addition, decreases in fish abundance for several anadromous fish species could result in minor effects in recreational fishing experiences under MO2 in Regions B, C, and D. There would be additional minor adverse effects associated with increased algal bloom frequency in some areas, as well as effects to wetlands and waterbird habitat that could adversely affect wildlife viewing, and swimming at reservoir and river recreation sites in the region under MO2. If recreationists reduce recreation trips to this region due to declines in recreation experiences, additional effects could occur.

975 **Table 5-7. Changes in Economic Effects of Recreation Under Multiple Objective Alternative 2 Relative to the No Action Alternative**

Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
Region A	A minor reduction of less than 350 water-based recreational visits associated with changes in access to boat ramps (less than 1 percent of regional water-based visitation) would occur at Lake Koocanusa and Hungry Horse Reservoirs in a typical water year. In high-water-level years, water-based visitation would decrease by 0.4 percent at these two reservoirs and would increase by 0.4 percent in low water years. Annual social welfare benefits would decrease by $3,500 in a typical water year. Resident fish species may be adversely impacted from higher winter flows anticipated under MO2. There would be additional minor adverse effects to the water quality and waterbird populations.	Expenditures associated with non-local recreational visits would decrease by $15,000 across the region (less than 0.1 percent change from the No Action Alternative). Regional economic effects of this change in expenditures would be negligible. If recreationists reduce recreation trips to this region due to declines in recreation experiences, additional effects could occur.	Minor decrease in water-based recreation visitor days causing slight reduction in well-being of reservoir recreationist. Potential adverse impacts to fish species could decrease recreational fishing opportunity and reduce well-being of recreationists who value fishing, as well as.
Region B	A reduction of approximately 7,700 water-based visits at Lake Roosevelt (less than 1 percent of water-based visitation at the site) would occur in a typical water year associated with changes in boat ramp access. In years with high or low water, visitation would decrease by 2 to 3 percent. Annual social welfare benefits would decrease by approximately $115,000 in a typical water year. Decreases in fish abundance for several anadromous fish species could adversely affect recreational fishing experiences below Chief Joseph Dam.	Expenditures associated with non-local recreational visits would decrease by $297,000 across the region (0.4 percent changes from the No Action Alternative). Regional economic effects of this change in expenditures would be minor. If recreationists reduce recreation trips to this region due to declines in recreation experiences, additional effects could occur.	Decreased water-based recreation access at Lake Roosevelt could have adverse effects on recreationists. Potential adverse impacts to fish species, particularly below Chief Joseph Dam, could decrease recreational fishing opportunity and reduce well-being of recreationists who value fishing, as well as tribes.

Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
Region C	A minor reduction of approximately 12,000 water-based visits at Dworshak Reservoir (6.5 percent of water-based visitation at the site) would occur in a typical water year associated with changes to boat ramp access. Visitation would decrease by 4.2 percent in high-water-level years and 7.0 percent in low-water-level years, compared to high-water and low-water No Action water years. Annual social welfare benefits would decrease by approximately $135,000 in a typical water year. Decreases in fish abundance for several anadromous fish species could adversely affect recreational fishing experiences. Minor additional adverse effects to quality of fishing, hunting, wildlife viewing, swimming, and water sports associated with changes in water quality and wetland habitat conditions on the Snake River.	Expenditures associated with non-local recreational visits would decrease by $549,000 across the region (0.4 percent change from the No Action Alternative) associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be minor. If recreationists reduce recreation trips to this region due to declines in recreation experiences, additional effects could occur.	Decreased water-based recreational access at Doworshak Reservoir could have adverse effects on recreationists. Potential adverse impacts to fish species could decrease recreational fishing opportunity and reduce well-being of recreationists who value fishing, as well as tribes. Similarly adverse effects to hunting, wildlife viewing, swimming, and related activities would reduce the well-being of recreationists who value these activities, as well as tribes.
Region D	No changes in reservoir visitation would occur associated with changes to boat ramp access. Decreases in fish abundance for several anadromous fish species could adversely affect recreational fishing experiences. Negligible to minor adverse effects to quality of fishing, hunting, wildlife viewing, swimming, and water sports would occur associated with minor changes in river conditions on the lower Columbia River.	No changes in visitor expenditures or regional effects associated with changes in boat ramp access. If recreationists reduce recreation trips to this region due to declines in recreation experiences, reductions in regional recreation expenditures could occur.	No change in boat ramp access. Potential adverse impacts to fish species could decrease recreational fishing opportunity and fishing recreationists' well-being.

Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
Total	Negligible to minor adverse effects to reservoir visitation (20,000 fewer visits, representing approximately 0.2 percent of total visitation) in a typical water year, with consumer surplus value losses of approximately $253,000 annually. Minor adverse effects to quality of fishing, hunting, wildlife viewing, swimming, and water sports associated with changing river conditions in river segments below reservoirs.	Expenditures associated with non-local recreational visits would decrease by $861,000 across the region (0.2 percent change from the No Action Alternative) in a typical water year associated with boat ramp access. Regional economic effects of this change in expenditures are likely to be minor (11 fewer jobs, and $434,000 less in labor income, and approximately $1.3 million less in sales). If recreationists reduce recreation trips to this region due to declines in recreation experiences, additional effects could occur.	Although changes in access to recreation sites would be minor under MO2, adverse effects to fish species may have adverse effects on fishing experiences under this alternative, which, in turn, could have adverse effects on the well-being of those recreationists who value these fish, particularly area tribes.

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CHAPTER 6 - MULTIPLE OBJECTIVE ALTERNATIVE 3

Anticipated changes in water surface elevations under MO3 would affect boat ramp accessibility and water-based visitation relative to the No Action Alternative at Lake Koocanusa (Libby Dam) and Hungry Horse Reservoir in Region A. The breaching of the four lower Snake River projects would have major adverse effects on current recreation in the short term at the four lower Snake River projects in Region C and Lake Wallula in Region D. In the longer-term, near-natural river conditions could return, which would draw visitors to the region to experience water- and land-based activities associated with the riverine environment. Changes in water levels at other reservoirs in the basin would not affect accessibility or visitation.

6.1 SUPPLEMENTAL DETAIL DESCRIBING QUANTIFIED SOCIAL WELFARE EFFECTS

The sections below present the changes in visitation and social welfare effects by region under MO3 relative to the No Action Alternative. As discussed above, this appendix focuses on providing additional details to support the quantitative analysis on water-based visitation that is described in Chapter 3. In addition, the lower Snake River recreational evaluation under MO3 is also provided in this section.

Table 6-1 presents the percentage change in the number of accessible days across boat ramps by month for the two reservoirs in Region A affected under MO3 relative to the No Action Alternative in a typical water year, as well as the associated change in water-based visitation. Table 6-2 and Table 6-3 present these results using the 25th percentile H&H results (high water year) and 75th percentile results (low water year). The social welfare effects associated with these changes in water-based visitation are presented in Table 6-5 along with effects in other regions.

Table 6-1. Change in Boat Ramp Accessibility and Water-Based Visitation (Visits) under MO3 Relative to the No Action Alternative in a Typical Water Year (50th Percentile), by Month

Month	NAA Accessible Days	MO3 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits)[1/]
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	224	224	0%	0
Mar	248	238	-4%	(23)
Apr	206	184	-11%	(203)
May	248	248	0%	0
Jun	247	246	0%	(27)
Jul	279	279	0%	0
Aug	279	279	0%	0
Sep	270	270	0%	0
Oct	279	279	0%	0
Nov	270	264	-2%	(55)
Dec	251	248	-1%	(8)

Month	NAA Accessible Days	MO3 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits)[1/]
Total	**3,049**	**3,007**	**-1%**	**(316)**
Hungry Horse Dam and Reservoir				
Jan	213	186	-13%	0
Feb	166	124	-25%	0
Mar	127	111	-13%	0
Apr	120	90	-25%	0
May	151	136	-10%	(13)
Jun	287	276	-4%	(15)
Jul	310	310	0%	0
Aug	310	310	0%	0
Sep	300	300	0%	0
Oct	310	210	-32%	0
Nov	294	200	-32%	0
Dec	276	186	-33%	0
Total	**2,864**	**2,439**	**-15%**	**(29)**
Basin-Wide Total	**5,913**	**5,446**	**-8%**	**(345)**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-6.

Table 6-2. Change in Boat Ramp Accessibility and Water-Based Visitation under MO3 Relative to the No Action Alternative in a High-water Year (25th Percentile), by Month

Month	NAA Accessible Days	MO3 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation[1/]
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	224	224	0%	0
Mar	248	248	0%	0
Apr	240	240	0%	0
May	248	248	0%	0
Jun	259	255	-2%	(109)
Jul	279	279	0%	0
Aug	279	279	0%	0
Sep	270	270	0%	0
Oct	279	279	0%	0
Nov	270	265	-2%	(46)
Dec	254	248	-2%	(16)
Total	**3,098**	**3,083**	**0%**	**(171)**

Month	NAA Accessible Days	MO3 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation[1/]
Hungry Horse Dam and Reservoir				
Jan	289	243	-16%	0
Feb	183	168	-8%	0
Mar	186	158	-15%	0
Apr	180	120	-33%	0
May	220	197	-10%	(21)
Jun	300	300	0%	0
Jul	310	310	0%	0
Aug	310	310	0%	0
Sep	300	300	0%	0
Oct	310	293	-5%	0
Nov	300	270	-10%	0
Dec	310	279	-10%	0
Total	**3,198**	**2,948**	**-8%**	**(21)**
Basin-Wide Total	**6,296**	**6,031**	**-4%**	**(192)**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-9.

Table 6-3. Change in Boat Ramp Accessibility and Water-Based Visitation (Visits) under MO3 Relative to the No Action Alternative in a Low-water Year (75th Percentile), by Month

Month	NAA Accessible Days	MO3 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	156	161	3%	10
Mar	129	147	14%	41
Apr	90	105	17%	138
May	151	154	2%	74
Jun	230	230	0%	0
Jul	277	277	0%	0
Aug	279	279	0%	0
Sep	270	270	0%	0
Oct	279	279	0%	0
Nov	270	263	-3%	(65)
Dec	251	248	-1%	(8)
Total	**2,630**	**2,661**	**1%**	**191**
Hungry Horse Dam and Reservoir				
Jan	186	124	-33%	0

Month	NAA Accessible Days	MO3 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Feb	126	99	-21%	0
Mar	104	78	-25%	0
Apr	66	60	-9%	0
May	86	83	-3%	(3)
Jun	242	234	-3%	(11)
Jul	310	310	0%	0
Aug	310	310	0%	0
Sep	300	300	0%	0
Oct	310	190	-39%	0
Nov	262	172	-34%	0
Dec	204	136	-33%	0
Total	**2,506**	**2,096**	**-16%**	**(14)**
Basin-Wide Total	**5,136**	**4,757**	**-7%**	**177**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-9.

Region B – Grand Coulee and Chief Joseph Dams

Changes in water surface elevations are expected to be sufficiently minor as not to affect recreational access and visitation at reservoirs in Region B.

Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor Dams

Breaching the dams at the four lower Snake River projects in Region C —Lower Granite Dam, Little Goose Dam, Lower Monumental Dam, and Ice Harbor Dam—would return the lower Snake River to free-flowing conditions. This substantial change in reservoir and river conditions would affect existing developed and dispersed recreation areas and associated recreational activities. Water-based recreation activities would change from lake or flat-water activities to river-oriented recreation along the lower Snake River. Given the magnitude of these changes, the shift in usage patterns could take years to settle.

Fishing activities, as well as other recreation types, would be considerably reduced in the shorter-term during and immediately following breach, but could rebound in the long term as anadromous fish populations improve. The largest increases in the number of salmon and steelhead are projected under MO3. Therefore, fishing for these anadromous species could increase in the long term in Region C relative to the No Action Alternative. The value for trips could also increase due to increased abundance and diversity of wild fish.

Construction and demolition activities at these projects during the breaching activities would limit access during breaching. Most of the existing facilities were developed around the reservoirs. Pre-dam river stages under dam breaching would range from approximately 8 to 100 feet below current water surface elevations. Existing water-based recreation facilities, such as boat ramps, swimming beaches, and moorage facilities, were designed to operate within very specific ranges of water elevations (generally within 5 feet of full pool). If dam breaching

were to occur, none of these facilities could continue to be used without modification or relocation because river stages would be substantially lower than would be anticipated under the No Action Alternative. Some facilities, such as marinas and moorage facilities, would likely be incompatible with river conditions under MO3.

Many lower Snake River recreation areas have upland facilities such as picnic shelters, concrete walks, and interpretive signs that are located near the existing reservoirs. Although the activities that occur at these facilities are not water-dependent, the proximity of water enhances the recreation experience. Some of these facilities, such as picnic tables, could be moved closer to the river. However, other more permanent facilities such as shade structures and parking areas may not be able to be relocated because of the need to allow natural riparian functions to develop along the newly exposed river shorelines. The fish viewing facilities at the four dams would no longer be functional under the new river conditions. Fish viewing opportunities could occur at outdoor interpretive displays. Some sites would simply cease to be used because the features that attracted people would be eliminated, while other sites would be abandoned because they would be so high above or far away from the river that access would be difficult and possibly dangerous.

Dispersed recreation use would likely be reduced in the short term, but would likely return after the breaching activities and in the long term as the river and shoreline stabilize and natural features form. The action of dam breaching itself may draw some curious visitors in the short term. Many of the recreational activities that presently occur at existing dispersed sites could occur at new dispersed sites.

Lake or flatwater-oriented recreation activities, including water skiing, sailing, motorboating (in fiberglass boats), fishing for some warm-water species, and sightseeing in tour boats that cruise between Portland and Lewiston, would no longer be possible if breaching were to occur. Some activities that occur on lakes, such as fishing, swimming, hiking, camping, and wildlife viewing, could still occur. Breaching the dams would also expand opportunities in the long-term for river recreation activities, such as drift boating, rafting, and kayaking that require, or are more favorable under, riverine conditions.

The four lower Snake River projects currently support 0.9 million annual water-based visits, 1.7 million land-based visits, with a total of 2.6 million annual visits overall (i.e., including water- and land-based visits; Table 3-2). This is converted to 2.7 million annual recreational visitor days using the methodology described in section 2.1.3 of this appendix. This visitation supports $8.9 million and $24.5 million in annual consumer surplus value (social welfare), for water-based and all visitation, respectively.

In the short term, major effects to social welfare would occur associated with the construction and breaching activities, with a large reduction in consumer surplus value of up to $24.5 million with major reductions in both land- and water-based visitors to the area (Table 6-5).

After the construction and breaching activities conclude, it is possible that some of the existing land-based visitation would return, with the potential for up to 1.7 million visitors (land-based

visitors pre breach). However, the loss of water-based recreation on the lower Snake reservoirs would result in major adverse effects in the short-term post dam breach, a decrease in consumer surplus of $8.9 million (-36%), compared to $24.5 million under the No Action Alternative.

In the long term, both water-based and land-based river recreation would become re-established. The future physical condition of the river is uncertain, which would affect its suitability for supporting specific types of recreational activities (e.g., river rafting). In addition, it is uncertain how the environment might be managed to achieve other resource goals (e.g., fishing regulations and restrictions associated with the ESA-listed species, particularly Chinook salmon), and the effect these management decisions would have on recreation activities. To provide an estimate of the range of potential recreational use levels that may occur in the long-term under MO3 in the lower Snake River area, this section reviews existing data and past efforts to estimate these effects. The estimates developed suggest that a wide range of potential changes to river-based recreational visitation could occur following dam breach. Information sources for this estimate include the 2002 *Lower Snake River Juvenile Salmon Migration Feasibility Report and Environmental Impact Statement* (2002 EIS) and visitation estimates to other similar rivers in the region.

2002 Lower Snake River Juvenile Salmon Migration Feasibility Report / Environmental Impact Statement

For the 2002 Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Study (2002 EIS*)*, a contingent behavior survey was conducted to estimate how non-fishing recreation use would change if the four lower Snake River dams were breached. Using results from this survey, visitation after dam breach was estimated to be 1.5 million to 2.7 million annual recreational visitor days after full recovery of the natural river system, excluding fishing use. Estimates of fishing visitation specifically for the lower Snake River following dam breach were not estimated (Corps 2002a, p. I3-65 to I3-66).[19]

To provide an updated visitation level, the visitation was adjusted for changes in the target survey populations since the study was conducted. The following counties were used to assess the changes in population from 1998 to 2018. Rural Washington would include the following counties: Adams, Asotin, Benton, Columbia, Franklin, Garfield, Grant, Spokane, Walla, and Whitman. Rural Oregon would include the following counties: Union, Umatilla, and Wallowa. Rural Idaho would include the following counties: Adams, Idaho, Latah, Lewis, and Nez Perce. Based on population adjustments, the updated visitation would range from approximately 1.9 million to 3.4 million (Table 6-4).[20]

[19] The range reflects uncertainty about how to extrapolate the survey results, so two different methods were used (Corps 2002a, p. I3-61).

[20] This population adjustment was made based on personal communication with the study author (personal communication with J. Loomis, December 2019) and is consistent with increased participation in non-fishing river activities (e.g., rafting) since the study was done (White et al. 2016).

The Corps had a number of concerns about the survey methods and results from the contingent behavior survey from the 2002 EIS (Corps 2002a, Section 3.2.9). In 2002, the Corps' was concerned that the "potential recreation benefits associated with dam breaching may be significantly overstated." (Corps 2002a, p. I3-74), and these concerns remain. First, the result was much higher than visitation estimates to other free-flowing river/unimpounded river stretches. Second, the results suggested that visitors from California would account for over 30 percent of the visits to a near natural lower Snake River, even though data for other free-flowing rivers/unimpounded river stretches suggested that would be unlikely. Other concerns pertained to representativeness (the target survey response rate was not met), and the associated potential for nonresponse and strategic bias.[21]

Given the Corps' concerns, Table 6-4 also presents adjusted visitation estimates from the 2002 EIS without California visitors. Without California, visitation estimates would range from approximately 1.2 million to 1.9 million, depending on whether the estimates were adjusted to current levels and the extrapolation method used. Visitation to the lower Snake River would be limited by the availability of infrastructure to access river recreational opportunities.

Table 6-4. Visitation Estimates for the Lower Snake River in the Long-Term, With and Without Adjusting for Population Growth (excludes recreational fishing), from 2002 EIS

2002 Contingent Behavior Study Region	Total Recreation Visitor Days Demanded, 2002 EIS	Percentage Change in Population (1998-2018)	Total Recreation Visitor Days Demanded, Population-Adjusted
Rural Washington, Estimate 1	406,372	132%	535,066
Rural Washington, Estimate 2	317,280		417,760
Rural Oregon, Estimate 1	3,914	111%	4,331
Rural Oregon, Estimate 2	10,382		11,487
Rural Idaho, Estimate 1	36,846	111%	40,804
Rural Idaho, Estimate 2	29,739		32,933
Rest of Washington, Estimate 1	426,746	130%	556,631
Rest of Washington, Estimate 2	545,190		711,125
Rest of Oregon, Estimate 1	311,071	125%	390,232
Rest of Oregon, Estimate 2	396,671		497,615
Rest of Idaho, Estimate 1	24,328	142%	34,663
Rest of Idaho, Estimate 2	109,127		155,487
Montana, Estimate 1	14,188	119%	16,889
Montana, Estimate 2	49,157		58,514
California, Estimate 1	299,162	120%	358,739
California, Estimate 2	1,268,226		1,520,788

[21] Nonresponse bias arises when respondents differ in meaningful ways from nonrespondents (e.g., respondents were more likely to report changes in visitation to the lower Snake River after dam removal than nonrespondents). Thus, bias would exist when extrapolating survey responses to the target population. Strategic bias can arises when respondents think they can shape future decisions based on their survey responses. For example, respondents who support dam breach (possibly for reasons beyond its impact to their recreation) might exaggerate the number of visits they would take post breaching (and vice versa for those opposed).

2002 Contingent Behavior Study Region	Total Recreation Visitor Days Demanded, 2002 EIS	Percentage Change in Population (1998-2018)	Total Recreation Visitor Days Demanded, Population-Adjusted
Total, Estimate 1	**1,522,627**		**1,937,354**
Total, Estimate 2	**2,725,772**		**3,405,709**
Total, Estimate 1 (without California)	**1,223,465**		**1,578,615**
Total, Estimate 2 (without California)	**1,457,546**		**1,884,921**

Sources: 2002 EIS estimates from Table 3.2-7 (Corps 2002a, p. I3-61). Estimates 1 and 2 reflect uncertainty about how to extrapolate the survey results, so two different methods were used (Corps 2002a, p. I3-61). County-level population data for 1998, the year of the contingent behavior survey, from State and County Intercensal Tables: 1990-2000 (U.S. Census Bureau 2016); county-level population data for 2018, most recent data available, from American FactFinder (U.S. Census Bureau 2019).

Visitation to Other Similar Rivers in the Region

The 2002 EIS evaluated a number of potential additional comparison sites, including areas along the Main Salmon River, Middle Fork of the Salmon River, and the Hells Canyon stretch of the Snake River. As stated in the 2002 EIS, "it appears that a near-natural lower Snake River would offer a very different type of recreation experience to the region's premier whitewater rivers, such as the Main Salmon River, the Middle Fork of the Salmon River, and the Hells Canyon stretch of the Snake River. In addition to whitewater, these rivers also offer a wilderness experience and spectacular scenery. In terms of accessibility, the range of activities offered, and scenery, a near-natural lower Snake River would appear to have more in common with the lower Deschutes River, the Grand Ronde River, or the lower Salmon River. It would, however, be much larger than these rivers, with about 10 times the flow of the lower Deschutes and Grand Ronde Rivers, and about 5 times the flow of the lower Salmon River. In addition, visitation data for these rivers is limited (Corps 2002b, p. 5.13-18)." The 2002 EIS concluded that "a near-natural lower Snake River would be a fairly unique recreation resource primarily because of its size, accessibility, and the available range of existing recreation facilities and activities" (Corps 2002b, p. 5.13-18).

Despite the limitations, an approach for estimating recreational visitation, primarily for fishing, to the lower Snake River after dam removal would be to consider estimates of current visitation to other rivers in the region. The Hanford Reach of the Columbia River and the North Fork of the Clearwater River have been identified by Corps personnel as reasonable sites to evaluate as potentially comparable to future dam breach conditions on the lower Snake River. The Hanford Reach, which is located below Priest Rapids Dam on the Columbia River in Washington, and the North Fork of the Clearwater, which is located above Dworshak Reservoir in Idaho, are somewhat similar to a near-natural lower Snake River in terms of size, accessibility, and proximity to local users.

For the Hanford Reach, WDFW has estimates of fishing effort for select anadromous species (about 30,000-55,000 trips per year)[22] and traffic count data for some boat launches in this reach, but no comprehensive estimates of use. The USFWS does not have visitation numbers for the Hanford Reach National Monument (Haas 2019), a significant recreation site in the reach. For the 2002 EIS, it was estimated that the Hanford Reach had 50,000 annual recreational fishing visits (Foster Wheeler Environmental and Harris, 2001). Since the Hanford Reach is approximately 50 miles long, this would be equivalent to approximately 1,000 annual fishing visits per mile.

Recreational visitation data are available from the BLM for sites they manage along the Clearwater River, but visitation data are not available for other sites. The partial visitation data totaled about 80,000 visits in 2018. This would be comparable to the 100,000 visits estimated for this area when the 2002 EIS was written (Foster Wheeler Environmental and Harris, 2001). Since the North Fork of the Clearwater is approximately 135 miles long, visitation per mile would be similar to the 1,000 visits per mile for the Hanford Reach.

Estimating Visitation in the Long-Term

As discussed above, the sources available for estimating recreational use levels and activities along the lower Snake River after dam removal under MO3 suggest a wide range of estimates of potential recreational visitation that may occur post dam breach. Applying the current estimates of visitation rates to the Hanford or Clearwater Rivers to the 140-mile lower Snake River without any other adjustments would yield an estimate of approximately 140,000 annual visits that would be anticipated in the lower Snake River in the long-term. However, data for this estimate are primarily fishing related. As such, using estimates from these proxy sites may considerably underestimate future recreational activity on the lower Snake River.

In contrast, applying the results of the contingent behavior study conducted for the 2002 EIS would yield an estimate that would range from approximately 1.2 to 3.4 million annual visits (adjusted and unadjusted for population) under MO3 in the long-term, depending on whether or not California estimates are included. As described above, the Corps has expressed concerns that the 2002 EIS may have overstated recreation benefits from dam breach.

Because the contingent behavior survey in the 2002 EIS specifically focused on non-fishing visitation, it would underestimate that type of recreation. Recreational fishing visitation could be possible in the long-term although there is uncertainty around it being an allowable activity, given the current measures to regulate, protect, and support ESA-listed fish populations and habitat in the region. However, in the long-term, there is the potential for recreational fishing in the lower Snake River. One approach to estimate long-term visitation post dam breach would be to combine the proxy site estimates of 0.1 million, which primarily capture fishing visitation, with the visitation estimates from the general recreation survey (contingent behavior survey) from the 2002 EIS. By doing this, long-term visitation in the lower Snake River could range from 1.3 to 3.5 million following dam breach for all types of recreational activities (water- and land-

[22] ODFW and WDFW (2018) and NMFS (2014).

based activities). In comparison to the current water-based and land based visitation on the lower Snake River under the No Action Alternative of approximately 2.7 million recreational visitor days, the long-term visitation estimates would suggest that visitation to the river reach (both water-based and land-based recreation) could range from 50 percent lower to 30 percent higher than under the No Action Alternative. As described above, visitation to the lower Snake River could be limited by and dependent upon visitors' ability to access the recreational opportunities.

Region D – McNary, John Day, The Dalles, and Bonneville Dams

Breaching the dams at the four lower Snake River projects would release substantial amounts of sediment, almost all of which would be deposited in Lake Wallula behind McNary Dam within the first 2 to 7 years. Seven recreation sites in Lake Wallula—located along the east and south sides of the Columbia River below the mouth of the Snake River—could be affected by this sedimentation permanently. These sites include Hat Rock State Park, Hood Park, McNary Yacht Club, Sacajawea State Park, Walla Walla Yacht Club, Warehouse Beach, and McNary National Wildlife Refuge. Some boat launches and beaches may be buried in sediment, which would adversely affect visitation to those areas, while other areas may experience new vegetation and wetland conditions. In order to address these effects, local entities may need to remove sediment materials, extend boat launches, and/or modify the recreation sites to adapt to sediment and potentially new vegetation and wetland conditions, depending on the localized effect and desired recreation conditions.

The seven affected sites in Lake Wallula support 163,000 water-based visits during a typical water year (5.6 percent of total Region D visitation) (Table 3-3 and Table 3-4), which support $1.5 million in annual consumer surplus value (social welfare) (Table 6-5). This social welfare may be considerably reduced immediately after breaching of the dams and last for up to several years until any issues associated with the sediment and recreational access are addressed. Some types of visitation may increase, and some visitors may experience increased fishing success if the abundance of key recreational species (Snake River runs of spring-run Chinook and steelhead) increases in Region D. Further, after the breaching, visitors may adapt to the conditions by visiting recreation areas downstream or in other places not directly impacted by the sedimentation.

Summary

Table 6-5 presents the average annual changes in recreation days and associated social welfare effects in a typical water year by reservoir, CRSO region.

Table 6-5. Changes in Annual Social Welfare Effects of Recreation under MO3 Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Reservoir/River Reach	Changes in Recreational Visitor Days	Social Welfare Effects (Consumer Surplus)
Region A Total (Lake Koocanusa and Hungry Horse Reservoir)	**(<1,000)**	**($4,000)**
Lake Koocanusa	(<1,000)	($3,000)
Hungry Horse Reservoir	(0)	($0)
Region B Total (Lake Roosevelt)	**0**	**$0**
Region C Total in the Short-Term (Four Lower Snake River Reservoirs)[1/]	**(2.7 million)**	**($24,532,000)**
Region C Total in the Long-Term (Four Lower Snake River Reservoirs)	Uncertain - may range from reduction of 1.4 million to gain of 0.8 million recreational visitor days	not estimated
Region D Total (Lake Wallula) in the Short-Term[1/]	**(169,000)**	**($1,456,000)**
	Uncertain; visitation would be return if sediment is removed and/or wetland and vegetation conditions are established and recreational access is re-established in Lake Wallula	

Notes: Changes in water levels at other reservoirs in the basin would not affect accessibility or visitation.
[1/] Social welfare effects presented for Regions C and D represent short-term effects. The long-term impacts to visitation is uncertain. Some adaptation is likely over time. To the extent that increases in anadromous fish populations draw additional fishing visits to the region, increases in regional economic expenditures and effects would increase in the long term.

6.2 SUPPLEMENTAL DETAIL DESCRIBING QUANTIFIED REGIONAL ECONOMIC EFFECTS

The tables below present the regional economic effects under MO3 relative to the No Action Alternative. Table 6-6 presents the average annual changes in expenditures associated with recreation in a typical water year by reservoir, CRSO region, and in total, as well as the percentage of expenditures associated with non-local visitors. Table 6-7 presents the regional economic effects associated with these changes in expenditures by CRSO region and in total. Regional effects associated with local, non-local, and total visitation are presented for completeness, but the focus of the regional economic effects evaluation was on non-local visitors since changes in their expenditures would result in impacts to the regional economy.

Short-term adverse effects of dam breach on current reservoir recreation facilities and visitation would be major, with water levels falling substantially below No Action Alternative conditions and limitations for recreational access during the breach and construction period. A wide range of businesses that serve visitors would be adversely affected in the short term when recreationists forego trips to the region. Some facilities, such as marinas and moorage facilities, that serve water-based visitors would likely be incompatible with river conditions under MO3, and employment at these businesses would likely be eliminated.

In the short-term during construction activities, a decrease of 2.3 million water- and land-based visitors in Region C could result in decreased visitor spending of $103 million (Table 6-6), a decrease of 83 percent compared to non-local visitor spending under the No Action Alternative. Reduced visitor spending would result in a decrease of approximately 1,230 jobs, $39 million in labor income, and $147 million in sales during this construction period.

After the construction and breaching period is over, access would be re-opened to some of the recreation areas, and it is likely that a portion of the land-based visitors, such as site-seers, hikers, and others, would visit the region after construction while the reservoirs transition to river conditions. A reduction in only the water-based visitors at the reservoirs (land-based visitation would remain), compared to No Action Alternative, would result in a decrease of 820,000 non-local visitors and $37.4 million in visitor spending in the region.[23] The decreased non-local water-based visitor spending would lead to decreases in 450 jobs and $14 million in labor income and $53 million in sales compared to the No Action Alternative.

Although the specific response of visitors to new river conditions is uncertain, the establishment of near-natural river conditions would result in changes to regional economic effects over time. In particular, new opportunities for land- and water-based river recreation and possibly anadromous recreational fishing may offset visitation losses in Region C associated with reservoir or flatwater-oriented recreation activities, and recreational opportunities may even increase in the long term relative to the No Action Alternative. Again, river recreation in the long-term would be dependent on the development of recreational facilities and infrastructure to facilitate access. Tourism businesses, such as retail, rental businesses, and service providers, would likely have to adapt to the new type of visitor who may demand different types of activities, services, gear, and retail merchandise.

Reduced water quality due to increased sedimentation in Region D at water-based recreation sites in Lake Wallula may render sections of this area unusable to recreationists for a period of time following dam breach (approximately 2 to 7 years). Non-local visitor expenditures associated with water-based visitation at affected sites could decrease by up to $6.1 million under MO3 (Table 6-6). The specific site conditions may not preclude visitation entirely, which would render this estimate higher than would be likely. However, were it to occur, this change would represent a decrease of 2.6 percent of non-local visitor expenditures on recreation in Region D relative to the No Action Alternative. Regional economic effects of this change in regional expenditures, should they occur, would be a reduction of 80 jobs, $3 million in labor income, and $10 million in sales when compared to the No Action Alternative. Effects would likely be most acute in the short term. Over time, Lake Wallula visitation would likely rebound to levels similar to the No Action Alternative and could increase if visitation from the lower Snake River is diverted to this area. As noted above, potential long term increases in

[23] Non-local water-based visitors are calculated as the average 2017-2018 visitation to the site multiplied by the percentage of visitation that is water based at the site and the percentage of non-local visitation at the site. The site-level results are then summed across sites. 820,000 non-local water-based visitors represent 36 percent of total non-local water- and land-based visitors. Thus, expenditures and associated regional economic effects would be 36 percent of the values reported for non-local visitors.

anadromous fish populations could increase fishing activities in Region D, which may draw additional visitors.

Table 6-6. Changes in Visitor Expenditures under MO3 Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Reservoir/River Reach	Local Visitor Expenditures	Non-Local Visitor Expenditures	Total Expenditures	Percentage Non-Local
Region A Total (Lake Koocanusa and Hungry Horse Reservoir)	**($1,000)**	**($15,000)**	**($16,000)**	**96%**
Lake Koocanusa	($1,000)	($14,000)	($15,000)	96%
Hungry Horse Reservoir	($0)	($1,000)	($1,000)	96%
Region B Total (Lake Roosevelt)	**$0**	**$0**	**$0**	**89%**
Region C Total (Four Lower Snake River Reservoirs) – Short-Term[1/]	**($13,282,000)**	**($102,965,000)**	**($116,248,000)**	**89%**
Region C Total (Four Lower Snake River Reservoirs) – Long-Term[1/]	The long-term impacts to visitation, visitor expenditures, and regional economic effects are uncertain. Near-natural river conditions and increases in anadromous fish populations would draw visitation to the region in the long-term, and the increased visitor expenditures and regional economic effects would partially or fully offset losses in the short-term, with the potential to increase in the long-term relative to the No Action Alternative.			
Region D Total (Lake Wallula)[1/]	**($1,511,000)**	**($6,091,000)**	**($7,603,000)**	**80%**

Notes: Changes in water levels at other reservoirs in the basin would not affect accessibility or visitation.

[1/] Changes in expenditures and regional economic effects presented for Regions C and D represent short-term effects associated with the reduction of all land- and water-based visitation at the four lower Snake River projects and some of the visitation at Lake Wallula.

Table 6-7. Changes in Regional Economic Effects of Recreation under MO3 Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Local/Non-Local	Local/Non-Local Visitation	Jobs	Labor Income	Sales
Region A				
Local	(14)	(0)	$0	$0
Non-Local	(331)	(0)	($1,000)	($3,000)
Total	**(345)**	**(0)**	($1,000)	($3,000)
Region B				
Local	0	0	($71,000)	($222,000)
Non-Local	0	0	($566,000)	($1,771,000)
Total	**0**	**0**	($637,000)	($1,993,000)
Region C[1/]				
Short-Term Effects				
Local	(292,298)	(159)	$0	$0
Non-Local	(2,265,893)	(1,233)	$0	$0

CRSO Region, Local/Non-Local	Local/Non-Local Visitation	Jobs	Labor Income	Sales
Total	**(2,558,191)**	**(1,392)**	$0	$0
Long-Term Effects	The long-term impacts to visitation, visitor expenditures, and regional economic effects are uncertain. Near-natural river conditions and increases in anadromous fish populations would draw visitation to the region in the long-term, and the increased visitor expenditures and regional economic effects would partially or fully offset losses in the short-term, with the potential to increase in the long-term relative to the No Action Alternative.			
Region D[1/]				
Local	(32,393)	(19)	$0	$0
Non-Local	(130,558)	(77)	$0	$0
Total	**(162,951)**	**(96)**	$0	$0

Notes: The multiplier effect is larger for the entire Basin, so total regional economic effects are greater than the summation of effects across CRSO regions.

[1/] Changes in expenditures and regional economic effects presented for Regions C and D represent short-term effects associated with the reduction of all land- and water-based visitation at the four lower Snake River projects and some of the visitation at Lake Wallula.

6.3 SUMMARY OF EFFECTS

Consistent with the summary table provided in Section 3.11 of the EIS, Table 6-8 summarizes social welfare effects, regional economic effects, and social welfare effects associated with changes in recreation conditions under MO3. Detailed discussion of qualitative effects (i.e., quality of the recreation experience, fishing condition, other social effects) described in the table are provided in Section 3.11, of the EIS, Recreation.

Adverse effects of MO3 on recreational visitation at the four lower Snake River projects in Region C are anticipated to be major due to dam breach and construction activities. Some land-based visitation would return to the region following the construction activities once areas are opened to recreation. With about one-third of the current visitation associated with water-based activities, the loss of this visitation would be large and adverse. However, as the river returns to natural conditions, river-based recreation would increase over time, given recreational access and infrastructure is developed; the exact long-term beneficial impacts to visitation and social welfare are uncertain, although the losses in reservoir recreation would be offset by increases in river recreation visitors, and may eventually increase to levels and values greater than under the No Action Alternative.

Water quality effects are expected to be major at Lake Wallula in Region D in the short term due to temporary sedimentation effects associated with dam breach; water-based visitation would be adversely affected.

An increased quantity and quality of recreational fishing trips for key anadromous species, namely Snake River runs of salmon and steelhead, could occur. However, while Section 3.5, *Aquatic Habitat, Aquatic Invertebrates, and Fish*, describes increased abundance of these

species under MO3, other factors may limit their long-term success (e.g., ceased hatchery operations on the lower Snake River).

Table 6-8 presents a summary of MO3 effects, including the anticipated changes in average annual recreational visitation, social welfare, and economic effects by region and in total relative to the No Action Alternative. Across the basin in the short-term, total recreational visitation and associated social welfare effects could decrease by up to 21 percent in the study area (approximately 2.7 million visitor days and $26.0 million across all locations).

Expenditures associated with 2.4 million non-local recreational visits could decrease by up to $109 million across the basin in the short-term during the breaching and construction activities (representing 22 percent of non-local visitor expenditures on recreation across the basin under the No Action Alternative). The decrease of 2.4 million non-local visitors would result in decreases in 1,420 jobs, $59 million in labor income, and $189 million less in sales. The largest effects would be anticipated at the four lower Snake River projects in Region C and Lake Wallula in Region D due to dam breach and associated sedimentation effects.

Changes in other social effects could be substantial, as communities that are economically dependent on visitation to these five projects could be adversely affected, particularly in the short term. Users of these projects could experience diminished physical, mental, and social health benefits associated with the reduced quantity or quality of recreational activities (staying home or diverting recreational use to less-preferred sites), particularly in the short term. The effects to social welfare, regional economic, and other social effects could be moderated, at least to some extent, through adaptation of recreationists to new conditions over time (e.g., recreationists converting to river-oriented recreation). Restoration of riverine conditions and increases in anadromous fish species to the lower Snake River has been a long-term objective of area tribes, who would experience benefits to their ability to utilize the area recreationally and exercise treaty rights, in addition to other cultural and spiritual benefits.

1352 **Table 6-8. Changes in Economic Effects of Recreation Under Multiple Objective Alternative 3 Relative to the No Action Alternative**

Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
Region A	A reduction of less than 350 water-based recreational visits (less than 1 percent of regional water-based visitation) would occur at Lake Koocanusa and Hungry Horse Reservoirs in a typical water year. In high-water-level years, water-based visitation would decrease by 0.4 percent at these two reservoirs and would increase by 0.4 percent in low-water-level years. Annual social welfare benefits would decrease by $3,600 in a typical water year associated with access to boat ramps. Negligible effects on the quality of fishing experiences.	Expenditures associated with non-local recreational visits would decrease by $15,000 across the region (less than 0.1 percent change from the No Action Alternative). Regional economic effects of this change in expenditures would be negligible. If recreationists reduce recreation trips to this region due to declines in recreation experiences, additional effects could occur.	Negligible change in well-being of water-based recreation visitors due to slight decrease in recreation days. Negligible difference in the well-being of recreationists that value recreational fishing and tribes.
Region B	No changes in reservoir visitation would occur associated with access to boat ramps. Increased effort or enjoyment of recreational fishing for anadromous fish could occur over time as populations increase. Changes in the quality of recreational experience are anticipated to be long term and beneficial.	No changes in visitor expenditures or regional effects associated with access to boat ramps. To the extent that increases in anadromous fish populations draw additional fishing visits to the region, increases in regional economic expenditures and effects could increase in the long term.	No change from No Action
Region C	Overall, long-term beneficial (e.g., riverine-oriented recreation) and adverse (e.g., lake or flatwater-oriented recreation) effects are anticipated."	In the short-term, non-local visitor expenditures would decrease by $103 million during construction and breaching activities, resulting in major adverse effects to regional economic conditions (decrease in 1,230 jobs and $39 million in labor income). After the construction and breaching period is over, access would be re-opened to some of the recreation areas. A reduction in only the reservoir water-based visitors compared to No Action Alternative would result in a major decrease in non-local visitor expenditures of $37 million, with associated decreases in 450 jobs, $14 million in income, and $53 million in sales.	Major changes in other social effects would occur, which could be both beneficial and adverse. Communities that benefit economically from recreational visits could be adversely affected, particularly in the short term. However, restoration of riverine conditions and increases in anadromous fish species could benefit recreationists who value river-based recreation activities, as well as possibly recreational fishing and related economic opportunities.

Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
	Due to dam breaching and construction activities, there would be major short-term adverse effects to all water- and land-based reservoir visitation from construction closures in the short-term at the 4 lower Snake River projects. This could result in a decrease of 2.7 million annual recreational visitor days on average $25 million in social welfare in the short term. Some land-based visitation would return in the short term as access to lower Snake River areas is reopened. The reduction of only water-based reservoir recreation compared to No Action Alternative at the lower Snake river would result in a decrease of 0.9 million visitors and $8.9 million in social welfare. In the long-term, as riverine conditions return, river recreation would increase, with benefits to visitation and social welfare values. Access to the lower Snake River would be dependent on the development of new recreation facilities and water access points. Additional costs would be incurred to provide recreational infrastructure. Increased enjoyment of recreational fishing for anadromous fish could occur over time as fish populations increase. The long-term river visitation estimates (land- and water-based) suggest that recreation values could range from 50 percent lower to 30 percent higher than under the No Action Alternative (1.3 million to 3.5 million visitor days).	Over time, river recreation would grow, along with the quality of the recreational experience. The newly-created river conditions would draw a different pattern of visitors to the region, with different types of visitor spending compared with reservoir visitors. Depending on the numbers and type of visitor, tourism economic activity may partially or fully offset the loss in economic activity associated with reservoir recreation, with the potential for greater economic activity in the region relative to the No Action Alternative.	The restoration of the Snake River has been a long-term objective of area tribes, who would experience benefits to their ability to utilize the area recreationally and exercise treaty rights, in addition to other cultural and spiritual benefits. Adverse effects to resident fish species would have adverse effects on fishing experiences in Region C, which, in turn, would have adverse effects on the well-being of those tribes in Region C who value the affected resident fish. Natural landscapes and the transition to a natural river state would likely provide social benefits to many people, as well as educational and scientific research opportunities associated with this unique area. Recreationists who recreational activities depend on reservoir conditions could experience reduced well-being associated with the reduced availability of reservoir recreation within Region C.

Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
Region D	Due to sedimentation effects associated with dam breach, 163,000 annual water-based visits could be lost at seven Lake Wallula recreation sites (5.6 percent of total Region D visitation) in the short term (2 to 7 years). Annual social welfare benefits would decrease by $1.5 million associated with this change. Some visitation could be replaced or improved through a transition to river-based recreation over time. Short-term adverse and long-term beneficial effects are anticipated. Increased effort or enjoyment of recreational fishing for anadromous fish could occur over time as populations increase.	Expenditures associated with non-local recreational visits would decrease by $6.1 million (2.6 percent), particularly in the short term (2 to 7 years). Regional economic effects of this change in expenditures would be minor (80 fewer jobs, $3 million less labor income, and $10 million less sales). Some adaptation is likely over time. To the extent that increases in anadromous fish populations draw additional fishing visits to the region, increases in regional economic expenditures and effects would increase in the long term.	In the short run, there could be decrease water-based recreation visitor days at Lake Wallula decreasing these recreationists well-being. Over the long term, depending upon modifications made at several Lake Wallula facilities, well-being of reservoir recreationist would improve. In additional, increased opportunity for recreational fishing for anadromous fish occur improving the well being of recreationists that value this type of fishing.
Total	In Region A, a reduction of less than 1 percent in regional water-based visitation would occur at Lake Koocanusa and Hungry Horse Reservoirs in a typical water year. Negligible changes in water-based visitation in Region B and Region D. Overall in Region C, long-term beneficial (e.g., riverine-oriented recreation) and adverse (e.g., lake or flatwater-oriented recreation) effects are anticipated. A number of recreation areas on Lake Wallula would be adversely affected by sedimentation from breaching. Basin-wide visitation could decrease by up to 21 percent (approximately 2.7 million recreational visitor days and $26 million in annual social welfare benefits). Increased enjoyment of recreational fishing for anadromous fish could occur over time as fish populations increase. The long-term river visitation estimates (land- and water-based) suggest that recreation values could range from 50 percent lower to 30 percent higher than under the No Action Alternative (1.3 million to 3.5 million visitor days).	Expenditures associated with non-local recreational visits could decrease by up to $109 million across the region (22 percent decrease compared to the No Action Alternative), in the short term, primarily associated with closures during dam breaching activities. Regional economic effects of this change in expenditures would be major, with 1,420 fewer jobs, $59 million less labor income, and $189 million less in sales. In the long-term, depending on the numbers and type of visitor, tourism economic activity may partially or fully offset the loss in economic activity associated with reservoir recreation, with the potential for greater economic activity in the region relative to the No Action Alternative. Increases in anadromous fish populations could draw additional fishing visits to the region in the long term with benefits to regional economic conditions.	Negligible changes in OSE in Regions A and B compared to the No Action Alternative. In Regions C and D major changes in OSEs could occur, which could be adverse in the short-term and beneficial in the long-term at the 4 lower Snake River projects and Lake Wallula.

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CHAPTER 7 - MULTIPLE OBJECTIVE ALTERNATIVE 4

In a typical water year, anticipated changes in water surface elevations under MO4 would affect boat ramp accessibility and water-based visitation relative to the No Action Alternative at Lake Koocanusa (Libby Dam), Hungry Horse Reservoir in Region A and Lake Roosevelt in Region B. Changes in water levels at other reservoirs in the basin in a typical water year would not affect accessibility or visitation. In low water years, changes in water surface elevations would also affect boat ramp accessibility and water-based visitation relative to the No Action Alternative at Lake Pend Oreille in Region A. high water year

7.1 SUPPLEMENTAL DETAIL DESCRIBING QUANTIFIED SOCIAL WELFARE EFFECTS

The tables is this section present the changes in water-based visitation and social welfare effects under MO4 relative to the No Action Alternative for Lake Koocanusa, Hungry Horse Reservoir, and Lake Roosevelt. As discussed above, this appendix focuses on providing additional details to support the quantitative analysis that is described in Chapter 3 (Section 3.11). In addition, a description of the potential effects at Lake Pend Oreille is included in this section.

While the analysis does not detect changes in boat ramp accessibility at Lake Pend Oreille using available data for Federal- and state-managed boat ramps, major adverse effects to recreation are possible under MO4 in low water years. In low water years, water surface elevations at Lake Pend Oreille (Albeni Falls) would be 1 to 3 feet lower between July and September under MO4 relative to the No Action Alternative. While the analysis does not detect changes in boat ramp accessibility from these changes in water levels at Federal- and state-managed boat ramps, major adverse effects to recreation associated with impaired lake aesthetics (e.g., exposed mud flats) and reduced functionality of fixed docks and other infrastructure are possible under MO4 in low water years (i.e. low water measured at 75th percentile). There are over 2,000 fixed docks, city and county-managed boat ramps, and other infrastructure in Lake Pend Oreille that are sensitive to changing lake levels. The Lake Pend Oreille area is an important regional tourist destination in Region A, supporting as many as one million visits annually. A substantial proportion of this visitation occurs in summer months and is water-based. According to Bonner County Assessor's Office, there are approximately 3,100 waterfront property owners on Lake Pend Oreille and the River, many of whom are seasonal visitors.[24] The Lake Pend Oreille, Pend Oreille River, Priest Lake and Priest River Commission (Lakes Commission) reports that accessibility impacts can occur from just a one foot drop in lake elevation. For example, the Lakes Commission reports that at least 80 percent of lakefront homes have fixed infrastructure that makes mooring a boat difficult and unsafe in low-water conditions. There are also 20 marinas on the lake (Lakes Commission 2019). [25] The Lakes Commission provided cost information for various infrastructure modifications that would be needed to accommodate

[24] Written communication with The Lake Pend Oreille, Pend Oreille River, Priest Lake and Priest River Commission, October 2019.
[25] Written communication with The Lake Pend Oreille, Pend Oreille River, Priest Lake and Priest River Commission, October 2019.

lower water levels at Lake Pend Oreille. Using this information, the cost of extending fixed and floating docks to accommodate lower water levels was estimated to be approximately $4,500 per fixed dock and $1,575 per floating dock (both inclusive of a 50 percent contingency). As such, costs to extend fixed docks could exceed $9 million (Lakes Commission 2019). There would be additional costs for modifying other types of infrastructure including pedestrian ramps at launches, commercial marinas, community marinas, boat up restaurants, and fueling docks. As such, a one to three-foot decline in water surface elevations has the potential to have a major adverse effect on recreational visitation in low water level years. These effects would reduce the social welfare benefits associated with recreational visitation at Lake Pend Oreille.

Table 7-1 presents the percentage change in the number of accessible days across boat ramps by month for Lake Koocanusa, Hungry Horse Reservoir, and Lake Roosevelt under MO4 relative to the No Action Alternative in a typical water year, as well as the associated change in water-based visitation. No changes in boat-ramp accessibility were detected at the state and federal boat ramps at Lake Pend Oreille so Lake Pend Oreille was not provided in these tables. Table 7-2 and Table 7-3 present these results using the 25th percentile H&H results (high water year) and 75th percentile results (low water year). Table 7-4 presents the average annual changes in recreation days and associated social welfare effects in a typical water year by reservoir, CRSO region, and in total.

Table 7-1. Change in Boat Ramp Accessibility and Water-Based Visitation (Visits) under MO4 Relative to the No Action Alternative in a Typical Water Year (50th Percentile), by Month

Month	NAA Accessible Days	MO4 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	224	224	0%	0
Mar	248	238	-4%	(23)
Apr	206	200	-3%	(55)
May	248	248	0%	0
Jun	247	249	1%	55
Jul	279	279	0%	0
Aug	279	279	0%	0
Sep	270	270	0%	0
Oct	279	279	0%	0
Nov	270	270	0%	0
Dec	251	252	0%	3
Total	**3,049**	**3,036**	**0%**	**(21)**
Hungry Horse Dam and Reservoir				
Jan	213	186	-13%	0
Feb	166	124	-25%	0
Mar	127	111	-13%	0
Apr	120	90	-25%	0
May	151	135	-11%	(14)

Month	NAA Accessible Days	MO4 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Jun	287	275	-4%	(16)
Jul	310	310	0%	0
Aug	310	310	0%	0
Sep	300	300	0%	0
Oct	310	210	-32%	0
Nov	294	200	-32%	0
Dec	276	186	-33%	0
Total	**2,864**	**2,437**	**-15%**	**(31)**
Grand Coulee Dam and Lake Roosevelt				
Jan	682	558	-18%	(4,406)
Feb	508	422	-17%	(5,063)
Mar	350	350	0%	0
Apr	272	269	-1%	(459)
May	285	241	-15%	(9,741)
Jun	526	466	-11%	(12,723)
Jul	682	682	0%	0
Aug	638	593	-7%	(9,500)
Sep	615	585	-5%	(3,361)
Oct	642	642	0%	0
Nov	660	660	0%	0
Dec	682	674	-1%	(212)
Total	**6,542**	**6,142**	**-6%**	**(45,466)**
Basin-Wide Total	**12,455**	**11,615**	**-7%**	**(45,517)**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-6.

Table 7-2. Change in Boat Ramp Accessibility and Water-Based Visitation under MO4 Relative to the No Action Alternative in a High-water Year (25th Percentile), by Month

Month	NAA Accessible Days	MO4 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation[1/]
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	224	224	0%	0
Mar	248	248	0%	0
Apr	240	240	0%	0
May	248	248	0%	0
Jun	259	261	1%	55
Jul	279	279	0%	0
Aug	279	279	0%	0
Sep	270	270	0%	0

Month	NAA Accessible Days	MO4 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation[1/]
Oct	279	279	0%	0
Nov	270	270	0%	0
Dec	254	252	-1%	(5)
Total	**3,098**	**3,098**	**0%**	**49**
Hungry Horse Dam and Reservoir				
Jan	289	241	-17%	0
Feb	183	168	-8%	0
Mar	186	156	-16%	0
Apr	180	120	-33%	0
May	220	196	-11%	(22)
Jun	300	300	0%	0
Jul	310	310	0%	0
Aug	310	310	0%	0
Sep	300	300	0%	0
Oct	310	293	-5%	0
Nov	300	270	-10%	0
Dec	310	279	-10%	0
Total	**3,198**	**2,943**	**-8%**	**(22)**
Grand Coulee Dam and Lake Roosevelt				
Jan	682	678	-1%	(142)
Feb	616	454	-26%	(9,537)
Mar	655	493	-25%	(18,104)
Apr	403	394	-2%	(1,377)
May	386	344	-11%	(9,298)
Jun	601	529	-12%	(15,268)
Jul	682	682	0%	0
Aug	663	658	-1%	(1,056)
Sep	635	632	0%	(336)
Oct	642	642	0%	0
Nov	660	660	0%	0
Dec	682	682	0%	0
Total	**7,307**	**6,848**	**-6%**	**(55,118)**
Basin-Wide Total	**13,603**	**12,889**	**-5%**	**(55,090)**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-7.

Table 7-3. Change in Boat Ramp Accessibility and Water-Based Visitation (Visits) under MO4 Relative to the No Action Alternative in a Low-water Year (75th Percentile), by Month

Month	NAA Accessible Days	MO4 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) 1/2/
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	156	171	10%	30
Mar	129	145	12%	36
Apr	90	101	12%	101
May	151	155	3%	99
Jun	230	232	1%	55
Jul	277	278	0%	34
Aug	279	279	0%	0
Sep	270	270	0%	0
Oct	279	279	0%	0
Nov	270	270	0%	0
Dec	251	249	-1%	(5)
Total	**2,630**	**2,677**	**2%**	**350**
Hungry Horse Dam and Reservoir				
Jan	186	124	-33%	0
Feb	126	100	-21%	0
Mar	104	79	-24%	0
Apr	66	60	-9%	0
May	86	82	-5%	(4)
Jun	242	230	-5%	(16)
Jul	310	310	0%	0
Aug	310	308	-1%	(3)
Sep	300	221	-26%	(30)
Oct	310	186	-40%	0
Nov	262	180	-31%	0
Dec	204	141	-31%	0
Total	**2,506**	**2,021**	**-19%**	**(53)**
Grand Coulee Dam and Lake Roosevelt				
Jan	682	497	-27%	(6,574)
Feb	449	411	-8%	(2,237)
Mar	340	337	-1%	(335)
Apr	184	177	-4%	(1,071)
May	181	147	-19%	(7,527)
Jun	480	374	-22%	(22,478)
Jul	682	446	-35%	(66,388)

Month	NAA Accessible Days	MO4 Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/2/]
Aug	618	394	-36%	(47,288)
Sep	591	433	-27%	(17,703)
Oct	642	593	-8%	(2,483)
Nov	660	660	0%	0
Dec	682	642	-6%	(1,062)
Total	**6,191**	**5,111**	**-17%**	**(175,146)**
Basin-Wide Total	**11,327**	**9,809**	**-13%**	**(174,849)**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-8.

[2/] As described in this section, there could be major adverse effects to recreation at Lake Pend Oreille in Region A in low water years (Section 3.11.3.6 of the EIS).

Table 7-4. Changes in Annual Social Welfare Effects of Recreation under MO4 Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Reservoir/River Reach	Changes in Recreational Visitor Days	Social Welfare Effects (Consumer Surplus)
Region A Total (Lake Koocanusa and Hungry Horse Reservoir)[1/]	**(54)**	**($535)**
Lake Koocanusa	(22)	($215)
Hungry Horse Reservoir	(32)	($320)
Lake Pend Oreille[2/]	Potential for major adverse effects to visitation and social welfare at Lake Pend Oreille in low water years.	
Region B Total (Lake Roosevelt)[1/]	**(75,562)**	**($683,839)**
Region C Total (Dworshak Reservoir)	**0**	**$0**
Region D Total	**0**	**$0**

Notes: The social welfare analysis is conducted in two steps. First, recreational visits are converted to recreational visitor days to account for the fact that overnight trips are longer than 1 day. Second, UDVs are applied to the estimated recreational visitor days. Impacts are estimated based on changes in water surface elevations at reservoirs. Changes in water surface elevations at other reservoirs in the basin not shown would not affect accessibility or visitation.

[1/] In low water years, water-based visitation would decrease by over 175,000 visits at Lake Roosevelt (Table 6-7). This would lead to an average annual decrease of $2.6 million in social welfare.

[2/] The analysis does not detect changes in boat ramp accessibility at Federal- and state-managed boat ramps at Lake Pend Oreille. However, during low water years under MO4 between July and September major adverse impacts to recreation could occur.

7.2 SUPPLEMENTAL DETAIL DESCRIBING QUANTIFIED REGIONAL ECONOMIC EFFECTS

The tables below present the regional economic effects under MO4 relative to the No Action Alternative. Table 7-4 presents the average annual changes in expenditures associated with recreation in a typical water year by reservoir, CRSO region, and in total, as well as the

percentage of expenditures associated with non-local visitors. Table 7-5 presents the regional economic effects associated with these changes in expenditures by CRSO region and in total. Regional effects associated with local, non-local, and total visitation are presented for completeness, but the focus of the regional economic effects evaluation was on non-local visitors since changes in their expenditures would result in impacts to the regional economy. low water year. As discussed above, the analysis does not detect changes in boat ramp accessibility at Federal- and state-managed boat ramps at Lake Pend Oreille. However, during low water years under MO4 between July and September major adverse impacts to recreation associated with impaired lake aesthetics (e.g., exposed mud flats) and reduced functionality of fixed docks and other infrastructure could occur. Because the Lake Pend Oreille area is an important tourism destination, reductions in visitation would affect the local economy, including the potential to adversely affect a wide range of businesses that serve visitors.

As a result of changes in boat ramp accessibility in a typical water year, recreational expenditures associated with non-local visitation at Lake Koocanusa and Hungry Horse in Region A would decrease annually by $2,300 under MO4. Recreational expenditures associated with non-local visitation at Lake Roosevelt in Region B would decrease annually by $1.8 million under MO4 in a typical water year. These changes represent less than 1 percent of non-local recreational expenditures in the basin under the No Action Alternative. Because most changes in visitation would occur along the northern portion of Lake Roosevelt, communities reliant on recreation in that area—including Northport, Kettle Falls, and Colville—could be adversely affected. No changes to visitation are anticipated in Region C or D under MO4 relative to the No Action Alternative.

Overall, the change in non-local visitor regional expenditures in a typical water year would result in approximately 22 fewer jobs, $780,000 less in labor income, and $2.2 million less in sales. Most of the effects would be in Region B, where about 89 percent of affected visitation is non-local. In a low water year, decreased expenditures associated with non-local visitation in Region B (Lake Roosevelt) would lead to 74 fewer jobs, $2.2 million less in labor income, and $6.9 million less sales, a major adverse effect.

Table 7-5. Changes in Visitor Expenditures under MO4 Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Reservoir/River Reach	Local Visitor Expenditures	Non-Local Visitor Expenditures	Total Expenditures	Percentage Non-Local
Region A Total (Lake Koocanusa and Hungry Horse Reservoir)	**($0)**	**($2,000)**	**($2,000)**	**96%**
Lake Koocanusa	($0)	($1,000)	($1,000)	96%
Hungry Horse Reservoir	($0)	($1,000)	($1,000)	96%
Lake Pend Oreille	Potential for major adverse effects to visitor expenditures and regional economic effects at Lake Pend Oreille in low water years			
Region B Total (Lake Roosevelt)	**($221,000)**	**($1,762,000)**	**($1,983,000)**	**89%**

CRSO Region, Reservoir/River Reach	Local Visitor Expenditures	Non-Local Visitor Expenditures	Total Expenditures	Percentage Non-Local
Region C Total (Dworshak Reservoir)	**$0**	**$0**	**$0**	**96%**
Region D Total	**$0**	**$0**	**$0**	**77%**

Notes: Impacts are estimated based on changes in water surface elevations at reservoirs. Changes in water surface elevations at other reservoirs in the basin would not affect accessibility or visitation. Table does not reflect effects that are described qualitatively, and may underestimate visitation at some sites.

Table 7-6. Changes in Regional Economic Effects of Recreation under MO4 Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Local/Non-Local	Local/Non-Local Visitation	Jobs	Labor Income	Sales
Region A[1/]				
Local	(2)	(0)	$0	$0
Non-Local	(49)	(0)	($1,000)	($3,000)
Total	**(52)**	**(0)**	($1,000)	($3,000)
Potential for major adverse effects to visitor expenditures and regional economic effects at Lake Pend Oreille in low water years (these effects are not included in the regional economic effects in the rows above)				
Region B[1/]				
Local	(5,062)	(2)	($71,000)	($222,000)
Non-Local	(40,404)	(19)	($566,000)	($1,771,000)
Total	**(45,466)**	**(22)**	($637,000)	($1,993,000)
Region C				
Local	0	0	$0	$0
Non-Local	0	0	$0	$0
Total	**0**	**0**	$0	$0
Region D				
Local	0	0	$0	$0
Non-Local	0	0	$0	$0
Total	**0**	**0**	$0	$0

Notes: The multiplier effect is larger for the entire Basin, so total regional economic effects are greater than the summation of effects across CRSO regions.

[1/] In low water years, water-based visitation would decrease by over 175,000 visits at Lake Roosevelt (Table 6-7). Decreased expenditures associated with non-local visitors would lead to 74 fewer jobs, $2.2 million less in labor income, and $6.9 million less sales. Further, major adverse effects to recreation may occur at Lake Pend Oreille in Region A in low water years (Section 3.11.3.6 of the Draft EIS). Note: Table does not reflect effects that are described qualitatively, and may underestimate visitation at some sites.

7.3 SUMMARY OF EFFECTS

Consistent with the summary in Section 3.11 of the EIS, Recreation, Table 7-6 summarizes social welfare effects, regional economic effects, and social welfare effects associated with changes in recreation conditions under MO4. Detailed discussion of qualitative effects (fishing conditions, quality of recreational experience, other social effects) described in the table are provided in Section 3.11, of the EIS, Recreation.

Overall, MO4 is anticipated to result in minor to moderate adverse effects in a typical water year, as well as beneficial effects on recreational visitation over the long term. Moderate adverse effects could occur at Lake Roosevelt during typical water years, while localized major adverse effects could occur during low water years from the *McNary Flow Target* measure. During low water years, water-based visitation could decrease at Lake Pend Oreille in Region A due to adverse impacts to lake aesthetics (e.g., exposed mud flats) and reduced functionality of fixed docks, some city- and county-owned boat ramps, and other infrastructure. Major adverse impacts to visitation could occur, resulting in decreased social welfare and regional economic activity during low water years. Over time, visitors may adjust their behavior to adapt to changes in accessibility and site quality, such as utilizing different sites on the system. These long-term adaptations could reduce effects of changes in visitation. At Lake Pend Oreille during low water years, active management, such as boat dock extensions and possibly dredging would likely be needed to reduce the effects of low water.

Table 7-6 presents a summary of MO4 effects, including the anticipated changes in average annual recreational visitation, social welfare, and regional economic effects by region and in total relative to the No Action Alternative. Across the basin, total recreational visitation is anticipated to decrease annually by 0.4 percent (46,000 visits) and associated social welfare effects by $0.7 million associated with reductions in access to boat ramps in a typical water year. The change in non-local visitor regional expenditures in a typical water year would result in approximately 22 fewer jobs, $780,000 less in labor income, and $2.2 million less in sales. In low water years, decreased expenditures associated with non-local visitation in Region B would lead to 74 fewer jobs, $2.2 million less in labor income, and $6.9 million less sales. The largest adverse effects are anticipated at Lake Roosevelt in Region B in low water years and at Lake Pend Oreille in Region A in low water years. Some increased shoreline erosion may also occur in Region B.

Resident fish entrainment would increase in Region A, which could adversely affect the quality of fishing experiences there. However, anadromous fish species would benefit under this alternative, which could benefit recreationists in Regions B, C, and D. There would be negligible to minor adverse effects to the quality of hunting, wildlife viewing, swimming, and water sports at river recreation sites in the region under MO4.

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Region	Social Welfare Effects	Regional Economic Effects (2019 dollars)	Other Social Effects
Region A	A reduction of less than 100 water-based recreational visits (0.1 percent of regional water-based visitation) would occur at Lake Koocanusa and Hungry Horse Reservoirs in a typical water year associated with boat ramp access. Changes would be similar under low- and high-water-level years. Social welfare changes would be negligible associated with changes in boat ramp access. During low water level years, water-based visitation could decrease at Lake Pend Oreille due to adverse impacts to lake aesthetics and reduced functionality of fixed docks, some city- and county-owned boat ramps, and other infrastructure. During low water years, major adverse impacts to social welfare could occur. Adverse effects to resident fish species would have adverse effects on recreational fishing experiences. Minor effects associated with increases in invasive species could adversely affect the quality of fishing, hunting, wildlife viewing, swimming, and water sports at recreation sites in the region.	Expenditures associated with non-local recreational visits would decrease by $2,300 across the region associated with boat ramp access (less than 0.01 percent). Regional economic effects of this change in expenditures would be negligible. If recreationists reduce recreation trips to this region due to declines in recreation experiences, additional effects could occur. Effects to water levels at Lake Pend Oreille in low water years could have a major adverse effect on tourism and regional spending.	During low water years only, social effects could occur to residents and communities at Lake Pend Oreille from decreased visitation and tourism activity. Adverse effects to resident fish species would have adverse effects on fishing experiences and the well-being of recreationists who value affected resident fish, particularly area tribes.

Region	Social Welfare Effects	Regional Economic Effects (2019 dollars)	Other Social Effects
Region B	A reduction of approximately 45,000 water-based visits at Lake Roosevelt (5.9 percent of water-based visitation at the site) would occur in a typical water year associated with boat ramp access, a moderate adverse effect. Annual social welfare benefits would decrease by approximately $684,000 in a typical water year associated with changes in boat ramp access. Visitation would decrease by about 6 percent in high-water-level years and decrease by around 24 percent in low- water years (about 175,000 visits), a major adverse effect, resulting in an average annual decrease of $2.6 million in social welfare. Changes in the quality of recreational experience are anticipated to be adverse as well as beneficial. In-river survival and abundance of wild salmon would increase, which would benefit river as well as reservoir recreationists in areas accessible to wild salmon. However, increased entrainment risk for some resident species (bull trout, kokanee, rainbow trout, burbot) could adversely affect the destination fishery at Lake Roosevelt.	Expenditures associated with non-local recreational visits would decrease by $1.8 million across the region (2.3 percent compared to the no Action Alternative) associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be minor to moderate in typical water years. In low water years, decreased expenditures associated with non-local visitation would lead to 74 fewer jobs, $2.2 million less in labor income, and $6.9 million less sales; localized major adverse effects could occur at Lake Roosevelt. To the extent that increases in anadromous fish populations draw visitors to the region, regional economic expenditures and effects would increase.	Adverse social effects could occur residents and communities at Lake Roosevelt from decreased visitation and tourism activity, primarily during low water years. The Spokane Tribe and the Confederated Tribes of the Colville Reservation could experience adverse effects from change in water-based recreation visitation, and related decrease in tourism activity and expenditures. Likewise decreased well-being of water-based recreation visitors could occur due to the sizable reduction in recreation days during a low water year. However, slight improvements in anadromous fish populations would contribute to improved well-being for recreationists who value these populations, while resident species and related recreational fisheries could be adversely affected.

Region	Social Welfare Effects	Regional Economic Effects (2019 dollars)	Other Social Effects
Region C	No changes to reservoir visitation related to changes in boat ramp access. Changes in the quality of recreational experience are anticipated to be adverse as well as beneficial. In-river survival and abundance of wild salmon would increase, which would benefit river recreationists. However, there may also be increased gas bubble trauma for bull trout and other resident fish.	No measurable changes in visitor expenditures or regional effects associated with boat ramp access. To the extent that increases in anadromous fish populations draw visitors to the region, regional economic expenditures and effects would increase.	No change from No Action for boat ramp access. Improvements in anadromous fish populations would contribute to improved well-being for recreationists who value these populations, while resident species and related recreational fisheries could be negatively affected.
Region D	No changes to reservoir visitation related to changes in boat ramp access. Changes in the quality of recreational experience are anticipated to be adverse as well as beneficial. In-river survival and abundance of wild salmon would increase, which would benefit river recreationists. Minor improvements in wildlife viewing may occur. However, drawdown to MOP could reduce sturgeon habitat.	No measurable changes in visitor expenditures or regional effects associated with boat ramp access. To the extent that increases in anadromous fish populations draw visitors to the region, regional economic expenditures and effects would increase.	No change from No Action for boat ramp access. Slight improvement in well-being for recreationists who value potential increase in anadromous fish populations and opportunities for wildlife viewing, however also potential for slight decrease in well-being for recreationists that value sturgeon.

Region	Social Welfare Effects	Regional Economic Effects (2019 dollars)	Other Social Effects
Total	Minor to moderate adverse effects to reservoir visitation associated with boat ramp access (46,000 fewer visits, representing approximately 0.3 percent of total visitation) in a typical water year, with annual social welfare losses of approximately $684,000 annually. Most changes occur in Region B, where 89 percent of visitation is non-local. In low water years, major adverse social welfare effects could occur at Lake Roosevelt—a 24 percent decrease in water-based visitation (about 175,000 visits), resulting in an average annual decrease of $2.6 million in social welfare compared to the no Action Alternative. In addition, major adverse effects could occur in low water years at Lake Pend Oreille due to accessibility impacts to multiple facilities and infrastructure. Changes in the quality of recreational experience are anticipated to be adverse as well as beneficial. In-river survival and abundance of wild salmon would increase, which would benefit river recreationists. Minor improvements in wildlife viewing may occur. However, adverse effects to resident fish may also occur.	Expenditures associated with non-local recreational visits would decrease by $1.8 million across the region (a change of less than 1 percent from No Action) associated with changes in boat ramp access in a typical water year. Economic effects of this change in expenditures would be 22 fewer jobs, $780,000 less labor income, and $2.2 million less sales. In low water level years, localized major adverse regional economic effects could occur at Lake Roosevelt—a 24 percent decrease in water-based visitation, leading to 74 fewer jobs, $2.2 million less in labor income, and $6.9 million less sales in Region B. In addition, major adverse effects to regional economic conditions could occur in low water years at Lake Pend Oreille due to accessibility impacts to multiple facilities and infrastructure. To the extent that increases in anadromous fish populations draw visitors to the region, regional economic expenditures and effects would increase.	Adverse social effects could occur to residents and communities at Lake Roosevelt and Lake Pend Oreille from decreased visitation and tourism activity during low water years. Generally, improvements in anadromous fish populations would contribute to improved well-being for recreationists in Regions C and D. Some adverse effects associated with decreases in resident fish populations in Region A.

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CHAPTER 8 - PREFERRED ALTERNATIVE

In a typical water year, anticipated changes in water surface elevations under the PA would affect boat ramp accessibility and water-based visitation relative to the No Action Alternative at Lake Koocanusa (Libby Dam) in Region A and Lake Roosevelt in Region B. Changes in water levels at other reservoirs in the basin in a typical water year would not affect accessibility or visitation. In low water years, changes in water surface elevations would also affect boat ramp accessibility and water-based visitation relative to the No Action Alternative at Dworshak Reservoir in Region C. Over time, visitors may adjust their behavior to adapt to changes in accessibility, such as utilizing different sites on the system, which could reduce effects on visitation.

8.1 SUPPLEMENTAL DETAIL DESCRIBING QUANTIFIED SOCIAL WELFARE EFFECTS

The tables below present the changes in water-based visitation and social welfare effects under the PA relative to the No Action Alternative. Table 7-7 presents the percentage change in the number of accessible days across boat ramps by month for the two reservoirs affected under the PA relative to the No Action Alternative in a typical water year, as well as the associated change in water-based visitation. Table 8-1 and Table 8-2 present these results using the 25th percentile H&H results (high water year) and 75th percentile results (low water year), respectively. Table 8-3 presents the average annual changes in recreation days and associated social welfare effects in a typical water year by reservoir, CRSO region, and in total.

Table 8-1. Change in Boat Ramp Accessibility and Water-Based Visitation (Visits) under the PA Relative to the No Action Alternative in a Typical Water Year (50th Percentile), by Month

Month	NAA Accessible Days	PA Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	224	224	0%	0
Mar	248	236	-5%	(27)
Apr	206	180	-13%	(240)
May	248	242	-2%	(149)
Jun	247	247	0%	0
Jul	279	279	0%	0
Aug	279	279	0%	0
Sep	270	270	0%	0
Oct	279	279	0%	0
Nov	270	270	0%	0
Dec	251	251	0%	5
Total	**3,049**	**3,005**	**-1%**	**(416)**
Grand Coulee Dam and Lake Roosevelt				
Jan	682	682	0%	0
Feb	508	504	-1%	(235)

Month	NAA Accessible Days	PA Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Mar	350	350	0%	0
Apr	272	272	0%	0
May	285	287	1%	443
Jun	526	529	1%	636
Jul	682	682	0%	0
Aug	638	638	0%	0
Sep	615	609	-1%	(672)
Oct	642	642	0%	0
Nov	660	660	0%	0
Dec	682	682	0%	0
Total	**6,542**	**6,437**	0%	**171**
Dworshak Dam and Reservoir (No change)				
Basin-Wide Total	**9,591**	**9,542**	**-1%**	**(245)**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-6.

Table 8-2. Change in Boat Ramp Accessibility and Water-Based Visitation (Visits) under the PA Relative to the No Action Alternative in a High-water Year (25th Percentile), by Month

Month	NAA Accessible Days	PA Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Libby Dam and Lake Koocanusa (No change)				
Grand Coulee Dam and Lake Roosevelt				
Jan	682	682	0%	0
Feb	616	616	0%	0
Mar	655	635	-3%	(2,235)
Apr	403	413	2%	1,529
May	386	411	6%	5,535
Jun	601	614	2%	2,757
Jul	682	682	0%	0
Aug	663	658	-1%	(1,056)
Sep	635	629	-1%	(672)
Oct	642	642	0%	0
Nov	660	660	0%	0
Dec	682	682	0%	0
Total	**7,307**	**7,324**	0%	**5,858**
Dworshak Dam and Reservoir (No change)				

Month	NAA Accessible Days	PA Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Basin-Wide Total	**7,307**	**7,324**	**0%**	**5,858**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-7.

Table 8-3. Change in Boat Ramp Accessibility and Water-Based Visitation (Visits) under the PA Relative to the No Action Alternative in a Low-water Year (75th Percentile), by Month

Month	NAA Accessible Days	PA Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Libby Dam and Lake Koocanusa				
Jan	248	248	0%	0
Feb	156	156	0%	0
Mar	129	130	1%	2
Apr	90	90	0%	0
May	151	139	-8%	(298)
Jun	230	226	-2%	(109)
Jul	277	276	0%	(34)
Aug	279	279	0%	0
Sep	270	270	0%	0
Oct	279	279	0%	0
Nov	270	270	0%	0
Dec	251	251	0%	3
Total	**2,630**	**2,614**	**-1%**	**(438)**
Grand Coulee Dam and Lake Roosevelt				
Jan	682	682	0%	0
Feb	449	445	-1%	(235)
Mar	340	339	0%	(112)
Apr	184	179	-3%	(765)
May	181	180	-1%	(221)
Jun	480	483	1%	636
Jul	682	682	0%	0
Aug	618	615	0%	(633)
Sep	591	580	-2%	(1,232)
Oct	642	642	0%	0
Nov	660	660	0%	0
Dec	682	682	0%	0
Total	**6,191**	**6,169**	0%	**(2,563)**
Dworshak Dam and Reservoir				
Jan	124	122	-2%	(65)
Feb	94	84	-11%	(562

Month	NAA Accessible Days	PA Accessible Days	Percentage Change in Accessible Days	Change in Water-Based Visitation (Visits) [1/]
Mar	56	49	-13%	(658)
Apr	30	30	0%	0
May	118	118	0%	0
Jun	210	210	0%	0
Jul	217	217	0%	0
Aug	177	177	0%	0
Sep	124	124	0%	0
Oct	124	124	0%	0
Nov	120	120	0%	0
Dec	124	124	0%	0
Total	**1,518**	**1,499**	-1%	**(1,286)**
Basin-Wide Total	**10,339**	**10,282**	**-1%**	**(4,287)**

Note: The number of "accessible days" is a summation across boat across ramps within a month. Therefore, the number of accessible days reflects the number of days within a month and the number of boat ramps.

[1/] Change in water-based visitation calculated as the percentage change in accessible days multiplied by the NAA visitation presented in Table 3-8.

Table 8-4. Changes in Average Annual Social Welfare Effects of Recreation under the PA Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Reservoir/River Reach	Changes in Recreational Visitor Days	Social Welfare Effects (Consumer Surplus)
Region A Total (Lake Koocanusa)	**(437)**	**($4,000)**
Region B Total (Lake Roosevelt)	**285**	**$3,000**
Region C Total	**0**	**$0**
Region D Total	**0**	**$0**
Total	**(152)**	**($2,000)**

Notes: The social welfare analysis is conducted in two steps. First, recreational visits are converted to recreational visitor days to account for the fact that overnight trips are longer than 1 day. Second, UDVs are applied to the estimated recreational visitor days. Impacts are estimated based on changes in water surface elevations at reservoirs. Changes in water surface elevations at other reservoirs in the basin not shown would not affect accessibility or visitation.

8.2 SUPPLEMENTAL DETAIL DESCRIBING QUANTIFIED REGIONAL ECONOMIC EFFECTS

The tables below present the regional economic effects under the PA relative to the No Action Alternative. Table 8-4 presents the average annual changes in expenditures associated with recreation in a typical water year by reservoir, CRSO region, and in total, as well as the percentage of expenditures associated with non-local visitors. Table 8-5 presents the regional economic effects associated with these changes in expenditures by CRSO region and in total. Regional effects associated with local, non-local, and total visitation are presented for completeness, but the focus of the regional economic effects evaluation was on non-local visitors since changes in their expenditures would result in impacts to the regional economy.

Table 8-5. Changes in Visitor Expenditures under the PA Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Reservoir/River Reach	Local Visitor Expenditures	Non-Local Visitor Expenditures	Total Expenditures	Percentage Non-Local
Region A Total (Lake Koocanusa)-short term	**($1,000)**	**($18,000)**	**($19,000)**	**96%**
Region A Total (Lake Koocanusa)-long term				
Region B Total (Lake Roosevelt)	**$1,000**	**$7,000**	**$7,000**	**89%**
Region C Total	**$0**	**$0**	**$0**	**90%**
Region D Total	**$0**	**$0**	**$0**	**77%**
Total (weighted average)	**$0**	**($12,000)**	**($12,000)**	**100%**

Notes: Changes in water levels at other reservoirs in the basin would not affect accessibility or visitation. Table does not reflect effects that are described qualitatively, and may underestimate visitation at some sites.

Table 8-6. Changes in Regional Economic Effects of Recreation under the PA Relative to the No Action Alternative in a Typical Water Year (2019 Dollars)

CRSO Region, Local/Non-Local	Local/Non-Local Visitation	Jobs	Labor Income	Sales
Region A				
Local	(17)	(0)	$0	($1,000)
Non-Local	(399)	(0)	($8,000)	($24,000)
Total	**(416)**	**(0)**	($8,000)	($25,000)
Region B				
Local	19	0	$0	$1,000
Non-Local	152	0	$2,000	$6,000
Total	**171**	**0**	$2,000	$7,000
Region C				
Local	0	0	$0	$0
Non-Local	0	0	$0	$0
Total	**0**	**0**	$0	$0
Region D				
Local	0	0	$0	$0
Non-Local	0	0	$0	$0
Total	**0**	**0**	$0	$0
Total				
Local	2	0	$0	$0
Non-Local	(247)	(0)	($7,000)	($25,000)
Total	**(245)**	**(0)**	($7,000)	($25,000)

Notes: Regional economic effects of recreational expenditures are included for each study region, but some "leakage" effects occur in other areas from each region. As such, the total regional economic effects are larger for the total basin than the sum of the individual regions. Also, the table does not reflect effects that are described qualitatively, and may underestimate effects at some sites.

8.3 SUMMARY OF EFFECTS

Consistent with the summary in Section 3.11 of the EIS, Recreation, Table 8-6 summarizes social welfare effects, regional economic effects, and social welfare effects associated with changes in recreation conditions under the Preferred Alternative. Detailed discussion of qualitative effects described in the table (e.g., quality of recreational experience, fishing conditions, other social effects) are provided in Section 3.11, of the EIS, Recreation.

Overall effects of the Preferred Alternative on recreational visitation are anticipated to range from negligible, or basically no effect, to moderate adverse, to major beneficial, depending on the Region. Table 8-6 presents a summary of the Preferred Alternative effects, including the anticipated changes in average annual recreational visitation, social welfare, and regional economic effects by region and in total relative to the No Action Alternative. Across the basin, total recreational visitation and associated social welfare effects are anticipated to decrease by less than 0.1 percent annually (approximately 250 visits and $2,000) in a typical water year associated due to changes in boat ramp access. Expenditures associated with non-local visitation would decrease by $12,000 annually across the region, a change of less than 0.1 percent compared to the No Action Alternative. Regional economic effects of this change in expenditures would be negligible. Effects to the quality of hunting, wildlife viewing, swimming, and water sports at river recreation sites in the region under the Preferred Alternative would be generally negligible.

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Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
Region A	A decrease of approximately 400 water-based recreational visits would occur at Lake Koocanusa (less than 1.0 percent of water-based visitation at the site) in a typical year associated with changes in boat ramp access. In high-water-level years, water-based visitation would not change at Lake Koocanusa and would decrease by about 1.0 percent in low-water-level years. Annual social welfare benefits would decrease by $4,300 in a typical water year. Negligible effects to the quality of recreation experiences would occur.	Expenditures associated with non-local recreational visits would decrease by $18,000 across the region (less than 0.1 percent) associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be negligible.	Negligible change resulting in no noticeable effect to recreationist well-being when compared No Action.
Region B	An increase of approximately 200 water-based visits at Lake Roosevelt (less than 0.1 percent of water-based visitation at the site) would occur in a typical year. In years with high or low water, visitation would decrease by less than 1.0 percent. Annual social welfare benefits would increase by approximately $2,600 in a typical water year. Negligible effects to the quality of recreation experiences would occur.	Expenditures associated with non-local recreational visits would increase by $7,000 across the region (less than 0.1 percent) associated with changes in boat ramp access. Regional economic effects of this change in expenditures would be negligible.	Negligible change resulting in no noticeable effect to recreationist well-being when compared No Action
Region C	No changes in reservoir visitation associated with changes in boat ramp access in a typical water year or high-water-level year. A reduction of approximately 1,300 water-based visits at Dworshak Reservoir (less than one percent of water-based visitation at the site) would occur in a low-water-level year. Annual social welfare benefits would not change in typical or high-water-level years, but would decrease by about $14,000 in a low-water-level year. Moderate adverse to major beneficial effects to quality of fishing may occur. Impacts to hunting, wildlife viewing, swimming, and water sports associated with changing river and reservoir conditions are likely to be negligible.	No changes in visitor expenditures or regional effects associated with changes in boat ramp access in most years. Regional effects of potential changes in expenditures during low-water-levels years would be negligible.	No change to visitor well-being associated with access to reservoir-based recreation. Moderate adverse to major beneficial change in recreationist well-being when compared No Action.

Region	Social Welfare Effects (2019 dollars)	Regional Economic Effects (2019 dollars)	Other Social Effects
Region D	No changes in reservoir visitation associated with changes in boat ramp access. Moderate adverse to major beneficial effects to quality of fishing may occur. Impacts to hunting, wildlife viewing, swimming, and water sports associated with changing river and reservoir conditions are likely to be negligible.	No changes in visitor expenditures or regional effects associated with changes in boat ramp access.	No change to visitor well-being associated with access to reservoir-based recreation. Moderate adverse to major beneficial change in recreationist well-being when compared No Action.

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Appendix N
Water Supply Physical and Socioeconomic Methods and Analysis

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Acronyms and Abbreviations

BPA	Bonneville Power Administration
bu	bushel
CDL	Cropland Data Layer
cfs	cubic feet per second
CRSO	Columbia River System Operations
CSKT	Confederated Salish and Kootenai Tribes
cwt	hundredweight (equal to 100 pounds)
EIS	environmental impact statement
H&H	hydrology and hydraulics
ID	Idaho State
IMPLAN	impact analysis for planning
lb	pound
MAF	million acre-feet
M&I	municipal and industrial
MO1	Multiple Objective Alternative 1
MO2	Multiple Objective Alternative 2
MO3	Multiple Objective Alternative 3
MO4	Multiple Objective Alternative 4
MT	Montana State
NAA	No Action Alternative
NASS	National Agricultural Statistics Service
NEPA	National Environmental Policy Act
NGVD29	National Geodetic Vertical Datum of 1929
OR	Oregon State
P&Gs	Principles and Guidelines
Reclamation	U.S. Bureau of Reclamation
ResSim	reservoir simulation model (power/flood model)
Corps	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WA	Washington State

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CHAPTER 1 - INTRODUCTION

1.1 BACKGROUND

The mainstem Columbia River, lower Snake River, Clearwater River, Kootenai River, Pend Oreille River, and Flathead River (the study rivers) provide water for millions of people and irrigated agriculture in Oregon, Washington, Idaho, and Montana. Water is pumped from the reservoirs of 9 of the 14 Federal projects: Grand Coulee, Lower Granite, Lower Monumental, Little Goose, Ice Harbor, McNary, John Day, The Dalles, and Bonneville. Annually, about 7 million acre-feet (MAF) of water is supplied for irrigation, drinking water, and other municipal and industrial (M&I) needs (U.S. Geological Survey [USGS] 2017).

This appendix describes both the physical and socioeconomic existing conditions relating to water supply. It also describes the environmental consequences resulting from the Alternatives in Chapter 2 of the main EIS document. The physical existing condition description quantifies the irrigated lands and M&I needs associated with potentially affected areas. The socioeconomic existing condition description outlines social and economic conditions that could potentially be affected by changes to the physical existing condition for water supply.

The purpose of the water supply analysis is to evaluate the effects of operational and structural measure changes on current water supply obligations as described in the No Action Alternative. This should not be confused with the future water supply measures that are intended to explore the effect on the flow and stage in the rivers of diverting additional water.

1.1.1 Irrigation

About 1,393,000[1] acres are irrigated with water diverted within the study area. Growers in the potentially affected areas depend on irrigation to produce a wide variety of crops including alfalfa, small grains, vegetables, fruits, and wine grapes.

About five percent[2] of the Columbia Basin's Water is diverted for agriculture. Irrigation water is diverted directly from the rivers, from the pools behind the storage and run-of-river projects, and pumped from groundwater wells. Diversions can vary from year to year and month to month in response to varying weather and hydrologic conditions. A portion of the diverted water can travel back into the rivers and are known as irrigation return flows.

Though not all of these areas would be affected by potential changes to operations and maintenance of the Columbia River System, irrigation throughout the projects is described here for context.

[1] Calculated using place-of-use polygons from the individual states for acres irrigated with water from the Columbia, lower Snake, Clearwater, Kootenai, Pend Oreille, and Flathead Rivers. Includes 720,000 acres in the Columbia Basin Project.

[2] Calculated using 30-year average from 1981 to 2010 inflow to The Dalles 133 million acre-feet (Northwest River Forecast Center 2018) and 7.1 million acre-feet of diversion for entire study area (Bonneville Power Administration [BPA] 2011).

1.1.1.1 Federal Irrigation Projects

Grand Coulee and Hungry Horse, operated by the U.S. Bureau of Reclamation (Reclamation), are the only projects of the 14 that are authorized to store water for irrigation. Grand Coulee stores water for the Columbia Basin Project; Hungry Horse does not currently store water for irrigation despite its authorization to do so.

At Grand Coulee, the water is pumped approximately 300 feet vertically from behind the dam at Lake Roosevelt to a feeder canal that delivers water to Banks Lake, where it is stored and eventually released and distributed by canal to irrigators within the Columbia Basin Project. The Columbia Basin Project has water rights and previous National Environmental Policy Act (NEPA) compliance to deliver 3.248 MAF[3] of irrigation water to 720,000 acres[4] in Grant, Adams, Walla Walla, and Franklin Counties. Some of these acres have not yet been developed, so past measured deliveries are smaller than this volume. The Burbank pumps in the McNary Reservoir also supply about 23,000 acre-feet of water to the Columbia Basin Project.

The Chief Joseph Project, operated by Reclamation, pumps water from the Columbia River below the Corps' Chief Joseph Dam. The project was authorized over many years (versus all at once, which is more common) with authorizations totaling 33,050 acres (some of these acres have been transferred outside of the Federal project). Currently, 97,920[5] acre-feet of water are delivered to 28,800 Federal project acres.[6]

1.1.1.2 Non-Federal Irrigation Withdrawals

Non-Federal parties divert water for irrigation at many locations within the study area. Extensive areas of irrigated agriculture have developed near the pools behind the four lower Columbia River dams (Bonneville, John Day, The Dalles, and McNary) and the pool behind Ice Harbor Dam on the lower Snake River. The dams are not authorized to store water for irrigation. Rather, they are run-of-river projects that maintain elevated pool levels primarily for power generation and navigation. The exception is John Day, which maintains a slightly higher pool elevation than is needed for navigation to ensure that irrigation pumps can operate. Both small pumps and large-scale pumping plants that serve multiple users withdraw water from the pools for pumping to fields. This water is diverted under natural or live flow rights issued by the States.

[3] There are water rights for 3.318 MAF, but 70,000 acre-feet is used for M&I.
[4] Includes acres for Odessa (Reclamation 2013) and Lake Roosevelt Incremental Storage Agreement (Reclamation 2009).
[5] 28,800 acres multiplied by the current delivery rate of 3.4 acre-feet per acre.
[6] Distinction is made between federally owned acres for this project because it was part of the determination of the remaining undeveloped acres from the original authorization.

1.1.2 Municipal and Industrial

Use of water from the study area to meet municipal and industrial water supply needs is approximately 0.5 percent[7] of the annual flow in the Columbia River Basin, which is about 10 times smaller than the amount used for irrigation. Some cities and industries divert water from the river system, but these diversions are small to the point of being immeasurable when compared to the total flow in the system. Most of this water is diverted under flow rights issued by the States.

The largest municipal and industrial water withdrawals from the lower Snake and lower Columbia rivers are concentrated on or near the Lower Granite and McNary reservoirs. Water users withdrawing directly from the McNary Pool include the cities of Hermiston, Richland, Kennewick, and Pasco. Industrial water users, including the Port of Umatialla, also have intakes nearby. The City of Lewiston and Potlach Corporation have water supply intakes on the Clearwater above Lower Granite. The Columbia Basin Project has water rights to deliver 70,000 acre-feet of M&I water to its patrons.

1.2 ALTERNATIVES

The Environmental Impact Statement (EIS) evaluates possible effects from four Multiple Objective alternatives (MO1–MO4) and a No-Action alternative. Each Multiple Objective alternative was assessed relative to the No-Action following similar criteria. Each Multiple Objective alternative contained measures (or actions) that were analyzed to meet the objective of the alternative. For complete descriptions of operational changes associated with each alternative, see Chapter 2 of the main EIS document.

Table 1-1 highlights the potential actions that could affect physical water supply resources, which alternative measures these potential actions are associated with, the locations that could be potentially affected, the potential temporal scope of effects, and the metric or measure that will be used to assess the effect.

Table 1-1. Potential Cause-and-Effect Analysis for Physical Water Supply

Alternative Measure(s)	Potential Action	Potential Effect	Location of Potential Effect	Temporal Scope of Potential Effect	Metric Used to Assess Environmental Effect
MO1.O8, MO2.O9, MO3.O11, MO4.O13	Change to upstream Storage Correction Method as applied to Grand Coulee storage reservation diagram	Change in reservoir pool elevations	Grand Coulee/ Lake Roosevelt – Pump Generators	January through April	Pool elevations, operational range of the pump generators, pump capacity to pump water to Banks Lake.

[7] Calculated using 650,000 acre-feet (USGS 2017) from the counties using M&I water in the study area and 133 MAF from Northwest River Forecast Center (2018).

Alternative Measure(s)	Potential Action	Potential Effect	Location of Potential Effect	Temporal Scope of Potential Effect	Metric Used to Assess Environmental Effect
MO1.O9, MO2.O10, MO3.O12, MO4.O14	Change in the Grand Coulee Dam draft rate used in planning drawdown	Change in reservoir pool elevations	Grand Coulee/ Lake Roosevelt – Pump Generators	Winter to spring	Pool elevations, operational range of the pump generators, pump capacity to pump water to Banks Lake.
MO1.O10, MO2.O11, MO3.O13, MO4.O15	Change in operational constraints for ongoing Grand Coulee Maintenance of power plants and spillways.	Change in reservoir pool elevations	Grand Coulee/ Lake Roosevelt – Pump Generators	Winter to Spring	Pool elevations, operational range of the pump generators, pump capacity to pump water to Banks Lake.
MO1.O11, MO2.O12, MO4.O16	New draft requirements to protect against rain-induced flooding.	Change in reservoir pool elevations	Grand Coulee/ Lake Roosevelt – Pump Generators	Mid-December through March	Pool elevations, operational range of the pump generators, pump capacity to pump water to Banks Lake.
MO3.S1	Removal of earthen embankments and adjacent structures.	Change in reservoir pool elevations	Pumps at the following project pools: Ice Harbor, Lower Monumental, Little Goose, and Lower Granite projects	Year round	Irrigation and M&I pumps elevations, pump capacity, reservoir pool water surface elevations.
MO3.S1	Removal of earthen embankments and adjacent structures	Change in groundwater elevations	Groundwater wells within 1 mile of the following project pools: Ice Harbor, Lower Monumental, Little Goose, and Lower Granite projects	Year round	Well locations, well depths, operational range of wells, well pumping capacity.
MO4.O7	Maintenance of minimum 220/200 thousand cubic feet per second spring flow objective at McNary	Change in reservoir pool elevations	Grand Coulee	May 1 to June 15/ June 16 to July 31	Pool elevations, operational range of the pump generators, pump capacity to pump water to Banks Lake.

Alternative Measure(s)	Potential Action	Potential Effect	Location of Potential Effect	Temporal Scope of Potential Effect	Metric Used to Assess Environmental Effect
MO4.O8	Reservoir drawdown to Minimum Operating Pool	Change in reservoir pool elevations	John Day	Year round	Pool elevations
MO4.O8	Reservoir drawdown to Minimum Operating Pool	Change in groundwater elevations	John Day	Year round	Pool elevations

1.3 AREA OF ANALYSIS

The scope of this study is limited to the Regions in the study area where operational or structural changes in the alternatives may potentially affect the ability to supply water for irrigation and municipal and industrial (M&I) purposes. Only the reaches where the analysis showed a physical change were further analyzed for socioeconomic effects.

The hydrology and hydraulics (H&H) models assume that current the diversion volume[8] of water for irrigation and M&I is delivered in all years and in all alternatives. So, the flow in the river in all years and all alternatives reflects what would occur when all current irrigation and M&I demands are met and would not appear to be affected. As long as water surface elevations do not change substantially, it is assumed that these deliveries can be made with current infrastructure. However, changes in pool elevation such that water could not physically be diverted could affect the ability to deliver water. In addition, pool elevations could also affect efficiency, or the energy required to pump water both from surface and groundwater pumps.

The area of analysis for physical and socioeconomic water supply does not include Banks Lake or the Columbia Basin Project. Effects on the Columbia River from pumping water to Banks Lake are considered, but how water is managed in Banks Lake or delivered to the Columbia Basin Project is not considered. Additional information is provided in Chapter 5 of this appendix.

In addition, socioeconomic impacts were not evaluated for increased pumping from Grand Coulee or increased water supply from Hungry Horse or for the Chief Joseph Dam Project for the water supply measures. The details of how and where this water would be used is unknown and additional NEPA would be needed prior to implementation. Additional information is provided in Chapter 5 of this appendix.

[8] This includes all diversions for irrigation and M&I including both Federal and non-Federal obligations.

CHAPTER 2 - METHODS

2.1 OVERVIEW

This analysis primarily uses modeled or described[9] water surface elevation in the affected reaches to determine impacts. Both the ability to pump from the rivers or reservoirs behind the dams and groundwater wells can be affected by the water surface elevation in the rivers and reservoirs. John Day and Lower Snake reaches in this study are impounded behind dams that are considered run-of-river, which means that they do not store a lot of water and their water surface elevation does not change substantially. Grand Coulee elevations vary seasonally and annually due to varying flood, irrigation, and ecological operations.

2.2 PROCESS

A water supply study team was convened to develop evaluation criteria, collect data, and to review analysis results. The team consisted of at least one person from the co-lead agencies and representatives from about 15 of the cooperating agencies that had expressed interest in Water Supply in their Memorandum of Understanding.

During alternatives development, the team met regularly to discuss the scope of analysis and to develop an analysis plan. The team also met regularly as data was being collected, processed, and assessed for use in the analysis. Meetings were less frequent as the team waited for H&H modeling results and began documenting background information and early analysis. The team was given multiple opportunities to review written products as the analysis was developed and finalized through the spring and summer of 2019. Comments were tracked and responses were documented. Every effort was made to incorporate comments, but some comments could not addressed be due to data limitations or relevance to the NEPA process.

2.3 DATA COLLECTION AND PREPARATION

The study team collected a large amount of data for this analysis that included water use statistics for each state, diversion location and place of use, delivery efficiency estimates, and crop types. Because the study area covers many states and a large geographic area, it was necessary to use multiple data sets from a variety of sources. The data sets were compared and combined to ensure the most complete set of data could be used for analysis.

The analysis required data on the diversion point and lands associated with surface water delivery and data on the diversion point and lands associated with groundwater wells within one mile of the river. Data collection occurred concurrently with the development of EIS alternatives and measures. Additional information about the data collection and processing can be found in a technical memorandum that describes the development of this data (Reclamation 2019).

[9] Not all proposed water surface elevations were modeled, so sometimes the descriptions in the measures themselves were used to analyze affects.

2.3.1 Surface Water Data

Both M&I and Agricultural water can be delivered from surface water. Most of the surface water from the study area rivers is delivered via pumps and intakes in the rivers or reservoirs. The states' geospatial water right datasets provided diversion locations that were used as surrogates for the surface water pumps. Each state collects and maintains their water right information differently. In cases where diversion type data were missing, water source data (e.g. surface vs. groundwater sources) were used to estimate diversion types and fill in missing data. Points of diversion classified by diversion type and/or water source were summarized from agricultural and municipal and industrial uses.

The points of diversion for each reach were linked to agricultural lands via place-of-use data (spatial data that indicates where the water can be used). Obvious data problems, such as a single county-sized place-of-use in Oregon, or places-of-use[10] far from their associated reach, were edited by removing them from the dataset to avoid mis-representing the place-of-use.

Many places-of-use are based upon property boundaries, and not all lands within the area are cultivated. In order to limit places-of-use to agricultural lands and determine the number of acres irrigated from each reach, the places-of-use were clipped to the extent of mapped crops, called crop-delimited (in other words, place of use areas that did not overlay crops were excluded). The places-of-use were spatially overlain on the CropLand Data Layers (CDLs) for 2013 to 2017 (U.S. Department of Agriculture [USDA] National Agricultural Statistics Service Cropland Data Layer, 2013–2017). The CDLs are pixel-based spatial datasets where each 30 m^2 pixel was classified as a different crop type based upon the light reflectance signatures of different crops. The USDA releases a new layer each year that is based upon satellite measurements of surface reflectance throughout the year. Any pixels within the places-of-use that supported crops in at least one of the five years were classified as irrigated lands. The crop-delimited places-of-use were then totaled to estimate the total acres of land irrigated from each reach and classified by combined water sources and diversion types.

Additionally, by overlaying the place-of-use dataset and the CDLs, the number of acres of individual crops that were grown in each irrigated area were determined for each year and averaged over the five years. Linking the place-of-use back to the point of diversion allowed the crop types to be summarized by each socioeconomic region.

States' water rights databases are often not a reliable method for obtaining the amount of water delivered because often only the maximum delivery rate is reported, which would overestimate the amount of water actually delivered. The following two methods were used to define water diverted for irrigation and M&I.

Irrigation depletion (diversion minus return flow) was summarized from the 2010 Modified Flows Study (Bonneville Power Administration [BPA] 2011) for the reaches that were within the

[10] Place-of-use are the lands where diverted water can be applied. These are defined by the States under water rights.

study area. Modified Flows is a process where unregulated streamflow is adjusted by removing irrigation diversion and adding in return flows. The diversions and return flows that are used in the 2010 dataset are representative of average conditions from 2000 to 2008. These diversions are summarized for the study area in the No Action alternative section.

M&I use was summarized from the USGS water use study data (USGS 2018). The team obtained the county-level water use dataset, which was the finest resolution dataset from the USGS, and used it to summarize the amount of surface water used for both M&I and irrigation within counties overlapping the study area.

2.3.2 Groundwater Data

The study area included groundwater points of diversion (wells) that were up to one mile away from the study rivers. These data points were identified using the points of diversion and water use datasets. Information on well pumping rates were incomplete, so the volume of groundwater withdrawals potentially affected was not assessed.

2.4 ALTERNATIVE ANALYSIS

Four Multiple Objective alternatives were analyzed for this EIS, compared to a No-Action alternative, to understand the effect to water delivery and associated lands.

2.4.1 Physical Analysis

Water supply in the affected reaches is largely driven by a threshold surface water elevation, where the reservoir pool elevation has historically been high enough for the pumps to be able to operate. If the pool or river stage elevations drop below the historical operational minimum, they may still be able to operate, but may be less efficient, or they may not be able to operate at all. This analysis only considers negative effects to efficiencies in reaches where pool elevations drop below historical operating elevations but are still able to operate.

Modeled water surface elevation in the affected reaches using ResSim (see Appendix B: Hydrology and Hydraulics Data Analysis) is used as a key indicator to assess environmental consequences of the measures. Where the models did not explicitly simulate proposed changes in measures, the description of elevation changes in the measures was used. For example, in the Ice Harbor pool, the minimum operating elevation is 437 feet based on National Geodetic Vertical Datum of 1929 (NGVD29). Pumps in this pool were designed to work with this minimum operating pool. If the pool is lowered because the dam is removed (as is proposed in MO3), these pumps will no longer be able to operate.

The models assume that the same amount of water will be diverted from the river reaches in each year. The amount that is diverted is representative of current diversions as defined in the 2010 Modified Flows study (BPA 2011). This results in the same amount of water being diverted in each year, regardless of conditions, and therefore generally indicates no impact to water

supply deliveries since that water is in fact delivered in each year in the models. The model results then reflect the flow and stage that would result from diverting that water in all years.

Another step in the analysis was considered to take in to account possible changes in water surface elevation that could impact the ability for a pump to operate. In many cases within in the study area, irrigation developed in places where other operations (navigation and power generation) required stable pool elevations. So, the pumps in these regions rely on operating ranges that have not historically changed. The analysis used the information in the measures that stated if a pool elevation would be decreased to determine if the pumps may no longer be able to operate or could be less efficient. Similar assessments were conducted for areas where water is diverted from rivers.

For pumping from Lake Roosevelt to Banks Lake, a monthly pumping rate (Figure 2-1) representative of current water rights (Table 2-1) and environmental compliance is used.

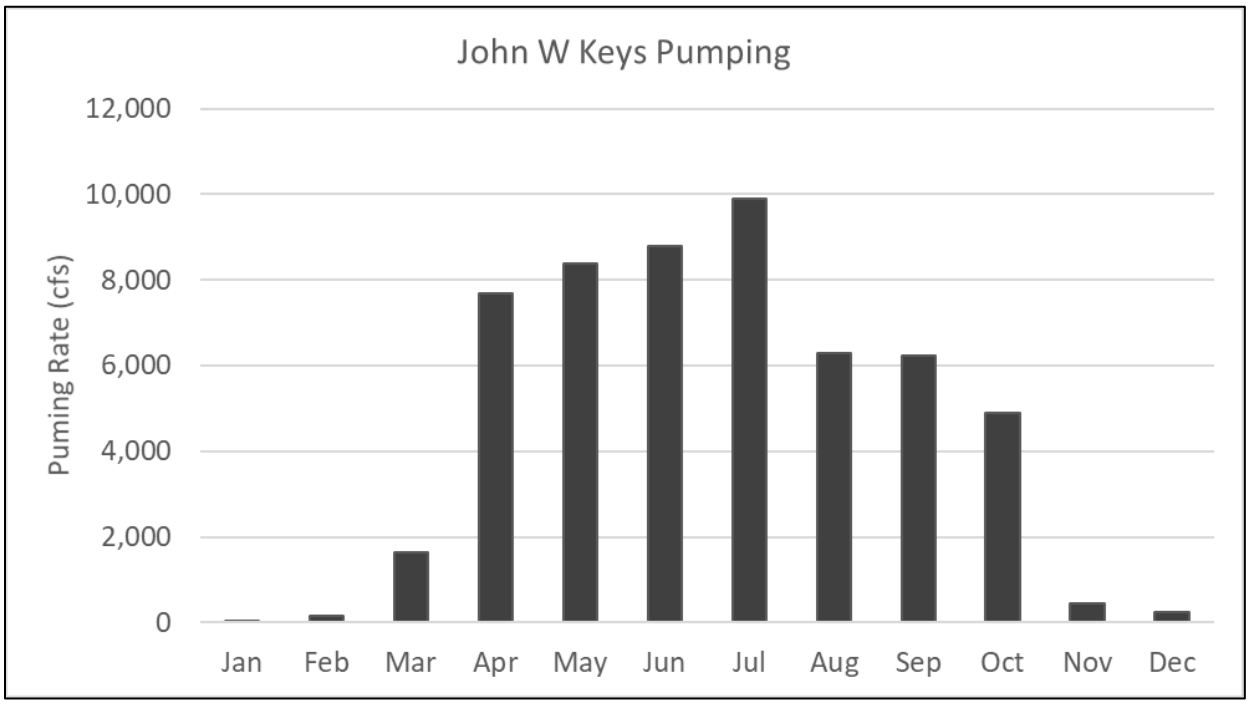


Figure 2-1. Monthly Pumping Rate Used in No Action Models and for Comparison in Analysis

Table 2-1. Water Rights to Pump Water from Lake Roosevelt to Banks Lake for Columbia Basin Project

Certificate Number	Acres	Duty (acre-feet/acre)	Volume (acre-feet)	Additional Information
S3-01622C	590,000	4.83	2,910,000	60,000 acre-feet is used for M&I
S3-28586	50,000	4.08	214,000	10,000 acre-feet is used for M&I
S4-33091P	70,000	2.34	164,000	–
S3-30486	10,000	3.00	30,000	–
Total	***772,525***	**–**	***3,318,000***	**–**

Potential effects to groundwater were analyzed qualitatively using the assumption that groundwater wells within one mile of the rivers and reservoirs could be hydraulically connected to the local aquifers. Wells close to the surface feature will experience more of an effect than those further away; however, the aquifer would need to be hydraulically connected for there to be any effect. Though there was not sufficient data to quantitively asses the degree of connectivity or the effect it would have on wells, qualitative statements were made if it was possible that wells could be effected given changes in surface water elevations from the No Action.

2.4.2 Socioeconomic Analysis

The socioeconomic analysis was driven by the physical water supply effects; if changes to the water surface elevations affect the ability of the pumps to continue to deliver water to the irrigated lands, this, in turn, affects crop production values for those lands. The irrigated lands receiving water from these pumps were estimated using the USDA Cropland Data Layer as discussed above. These acreage estimates were the basis for cropland land acreages and cropping patterns in the socioeconomic analysis. The potential socioeconomic effects related to M&I water deliveries were also analyzed based on the changes to physical water diversions.

The proposed alternatives were analyzed using two economic measures: 1) the social welfare effects, or direct impacts; and 2) the regional economic impacts. A regional impact analysis is distinctly different from the social welfare analysis. The regional impact analysis is a measure of regional activity, whereas the social welfare analysis is a measure of economic benefits to the nation as a whole. Additionally, the socioeconomic analysis evaluated the alternatives for other social effects.

The results of the social welfare analysis and the regional impact analysis are not directly comparable because they do not measure the same effects. The social welfare analysis measures net benefits, which represent the value of a resource or resource-related activity to society. The regional impact analysis measures regional impacts, which are flows of money (or employment) into or out of a defined region. The regional impacts from an action may result in substantial increases in income or employment within a specific region but may generate little or no benefits to society at the national level. It is also possible that an action may result in reduced regional output and income in a particular area, while generating positive benefits to the nation as a result of potential environmental enhancement activities or other improvements which are not translated into actual money flows.

The regional effects analysis includes not only the initial or direct impact on the primary affected industries, but also the secondary impacts resulting from those industries providing inputs to the directly affected industries as well. This analysis also includes the changes in economic activity stemming from household spending of income earned by those employed in the sectors of the economy that are impacted either directly or indirectly. These secondary impacts are often referred to as “multiplier effects.”

The modeling package used to assess the regional economic impacts stemming from the expenditures associated with each alternative was IMPLAN (IMpact analysis for PLANning). IMPLAN is an economic input-output modeling system that estimates the effects of economic

changes in a defined analysis area. The regional effects include employment, output (sales), and labor income. Employment measures the number of jobs (full time and part time) related to each industry sector of the regional economy. Labor income is the sum of employee compensation[11] and proprietor income[12]. Industry output (sales) represent the value of goods and services produced by businesses within a sector of the economy.

IMPLAN is a static model that estimates impacts for a snapshot in time (annual model) when the impacts are expected to occur, based on the makeup of the economy at the time of the underlying IMPLAN data (this analysis used 2017 data, the most current at the time of the analysis). IMPLAN measures the initial impact to the economy but does not consider long-term adjustments as labor and capital move into alternative uses. This approach is used to compare the alternatives. Realistically, the structure of the economy will adapt and change; therefore, the IMPLAN results can only be used to compare relative changes between the No Action Alternative and the action alternatives and cannot be used to predict or forecast future employment, labor income, or output (sales).

Input-output models measure commodity flows from producers to intermediate and final consumers. Purchases for final use (final demand) drive the model. Industries produce goods and services for final demand and purchase goods and services from other producers. These other producers, in turn, purchase goods and services. This buying of goods and services (indirect purchases) continues until leakages from the analysis area (imports and value added) stop the cycle. These indirect and induced effects (the effects of household spending) can be mathematically derived using a set of multipliers. The multipliers describe the change in output for each regional industry caused by a 1-dollar change in final demand.

This analysis used 2017 IMPLAN data for the counties which encompass the Study Areas. IMPLAN data files for the analysis area are compiled from a variety of sources including the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, and the U.S. Census Bureau.

2.4.2.1 Acres Affected by Socioeconomic Region

The socioeconomic analysis for water supply is based on the acres shown in Table 2-2. These data were summarized by reach and county to estimate the number of acres by crop using surface water or groundwater from each reach to more accurately estimate the water supply socioeconomic impacts for each alternative.

[11] IMPLAN defines employee compensation as "the total payroll cost of wage and salary employees to the employer. This includes wages and salaries, all benefits (e.g., health, retirement) and payroll taxes (both sides of social security, unemployment insurance taxes, etc.).

[12] IMPLAN definition of proprietor income: proprietor income consists of payments received by self-employed individuals and unincorporated business owners. This includes current-production income of sole proprietorships, partnerships, and tax-exempt cooperatives

Table 2-2. CDL Estimated Crop Acres by County and Water Supply Socioeconomic Region (annual averages, 2013–2017)

Water Supply Socioeconomic Region	County and State	Alfalfa	Other Hay	Small Grains	Irrigated Vegetables	Fruit Crops	Grapes	Total
Lower Granite	Nez Perce, ID	6	11	5	2	0	0	24
Little Goose	Garfield, WA	0	1	11	4	0	0	17
Little Goose	Whitman, WA	20	9	16	1	0	0	46
Total	**–**	***25***	***21***	***32***	***7***	***0***	***0***	***86***
Lower Monumental	Columbia, WA	9	20	159	0	0	0	189
Lower Monumental	Franklin, WA	3	0	5	0	2	0	11
Lower Monumental	Walla Walla, WA	72	10	361	28	0	2	474
Ice Harbor	Franklin, WA	450	25	3,874	4,140	1,628	209	10,326
Ice Harbor	Walla Walla, WA	1,355	188	10,359	7,963	14,170	2,801	36,836
Total	**–**	***1,889***	***244***	***14,758***	***12,131***	***15,801***	***3,013***	***47,835***

2.4.2.2 Analysis Area

The river reaches and associated counties were combined into 5 analysis regions for describing water supply related socioeconomic effects; 1) Ice Harbor and Lower Monumental, 2) Lower Granite and Little Goose, and 3) John Day. The socioeconomic regions were determined based on the economic relationships which are shared among counties and the types of farm operations. Table 2-3 summarizes the river reaches, counties, and analysis regions.

Table 2-3. Water Supply Socioeconomic Analysis Areas

Reach Name	Region Name	County	State	County and State Included in the Socioeconomic Analysis Region	Modeled Socioeconomic Region Name
Libby, Hungry Horse and Albeni Falls	Region A	Bonner	ID	Bonner, ID	Bonner
Grand Coulee	Region B	Adams Franklin Grant Lincoln	WA WA WA WA	Adam, WA Franklin, WA Grant, WA Lincoln, WA	Columbia Basin
Lower Granite	Region C	Nez Perce Asotin	ID WA	Nez Perce, ID Garfield, WA Whitman, WA Asotin, WA	Lower Granite and Little Goose
Little Goose	Region C	Garfield Whitman	WA WA		
Ice Harbor	Region C	Franklin Walla Walla	WA WA	Columbia, WA Franklin, WA Walla Walla, WA	Ice Harbor and Lower Monumental
Lower Monumental	Region C	Columbia Franklin Walla Walla	WA WA WA		
John Day	Region D	Benton Klickitat Morrow Umatilla	WA WA OR OR	Benton, WA Klickitat, WA Morrow, OR Umatilla, OR	John Day

CHAPTER 3 - PHYSICAL EFFECTS ANALYSIS

3.1 NO-ACTION ANALYSIS

The No-Action Alternative simulates the state of the system in 25 years if current operations were not changed. The No-Action Alternative serves as a point of comparison, or baseline, for the other alternatives. As such, it is processed and analyzed following the same consistent methodology as the other alternatives. The No Action Alternative represents a continued supply of water to existing users as it has in the recent past. It is assumed in the model that an average diversion every year is representative of current conditions. Regardless of conditions, water supply from surface water resources is not impacted in the No Action.

Aquifers typically have some hydrogeologic connectivity to nearby lakes and streams, and depending on the degree of connectivity, changes in the surface feature may cause changes in the aquifer. For there to be effects to groundwater deliveries, the elevations in the streams and reservoirs would have to drop below historical elevations. For the No Action, it is not anticipated that the elevations in any of the streams or reservoirs will affect nearby groundwater wells because the operation is representative of the historical range.

3.1.1 Region A – Libby, Hungry Horse, Albeni Falls

In Region A, approximately 675,000 acre-feet of water is diverted on average annual basis for irrigation with a portion of that water returning to the rivers as return flows (BPA 2011). In the counties surrounding Region A, approximately 31,000 acre-feet of water is diverted for M&I purposes from both surface and groundwater (USGS 2018; Table 3-1). Figure 3-1 shows the areas irrigated from water diverted from study area H&H reaches in Region A (Reclamation 2019). The numbers on the reaches correspond to ResSim model reaches. There are approximately 1,390 diversions in these reaches and 4,430 wells within 1 mile of the river, as counted from the point of diversion files described in Chapter 2 of this appendix.

Table 3-1. Summary of M&I Use by County for Surface and Groundwater in Counties that Border the CRSO Reaches in Region A

County	State	Surface Water (acre-feet)	Groundwater (acre-feet)
Boundary County	ID	1,000	300
Lincoln County	MT	1,800	1,800
Lake County	MT	400	3,600
Flathead County	MT	2,700	13,700
Bonner County	ID	2,700	3,000
Total	**–**	***8,600***	***22,400***

Source: USGS (2018)

Note: Kootenai County was not included because most of the M&I use was near Coeur d'Alene in that county, which is not within the study area.

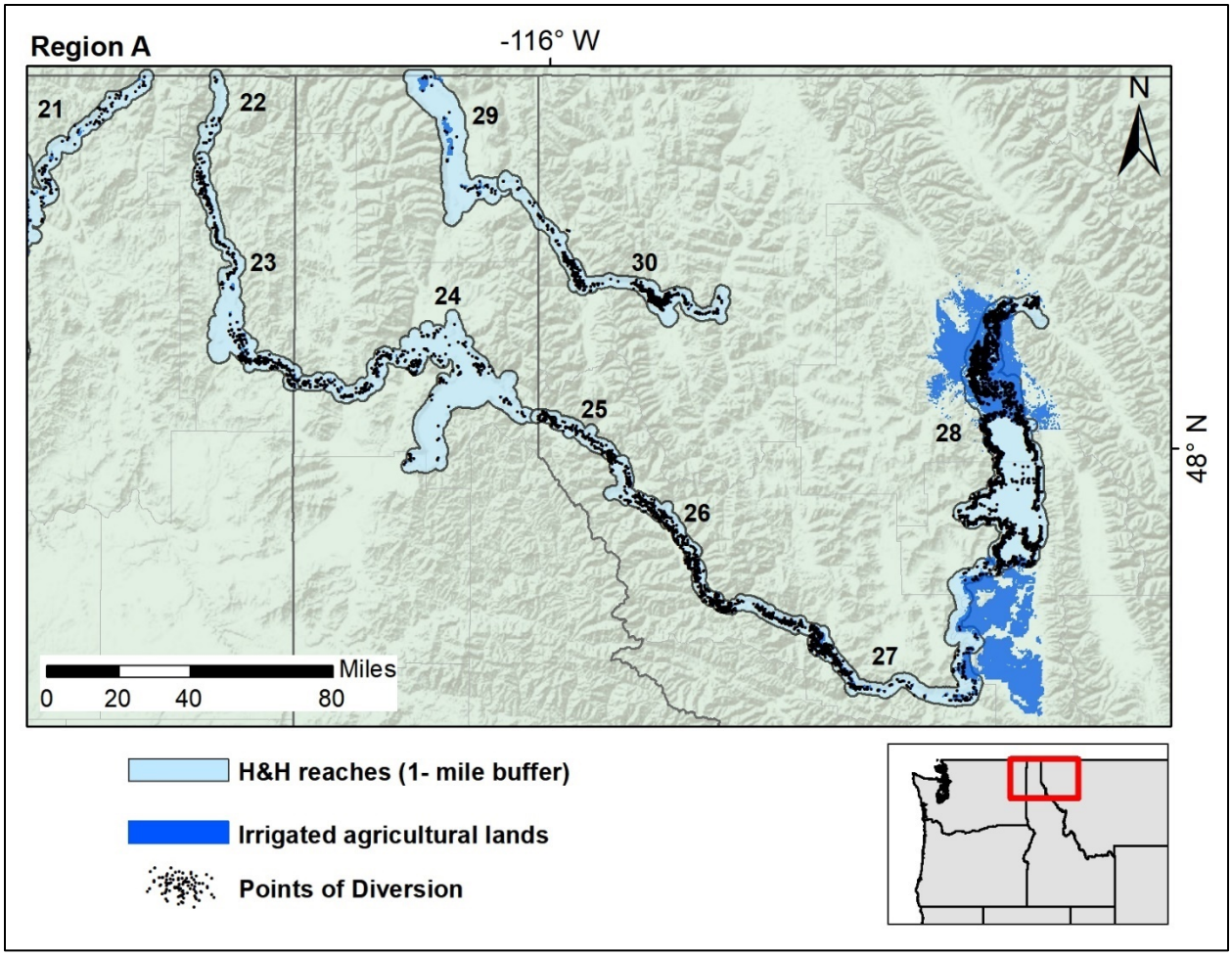


Figure 3-1. Points of Diversion and Land Irrigated from Water Diverted from Study Area H&H Reaches in Region A

3.1.2 Region B – Grand Coulee, Chief Joseph

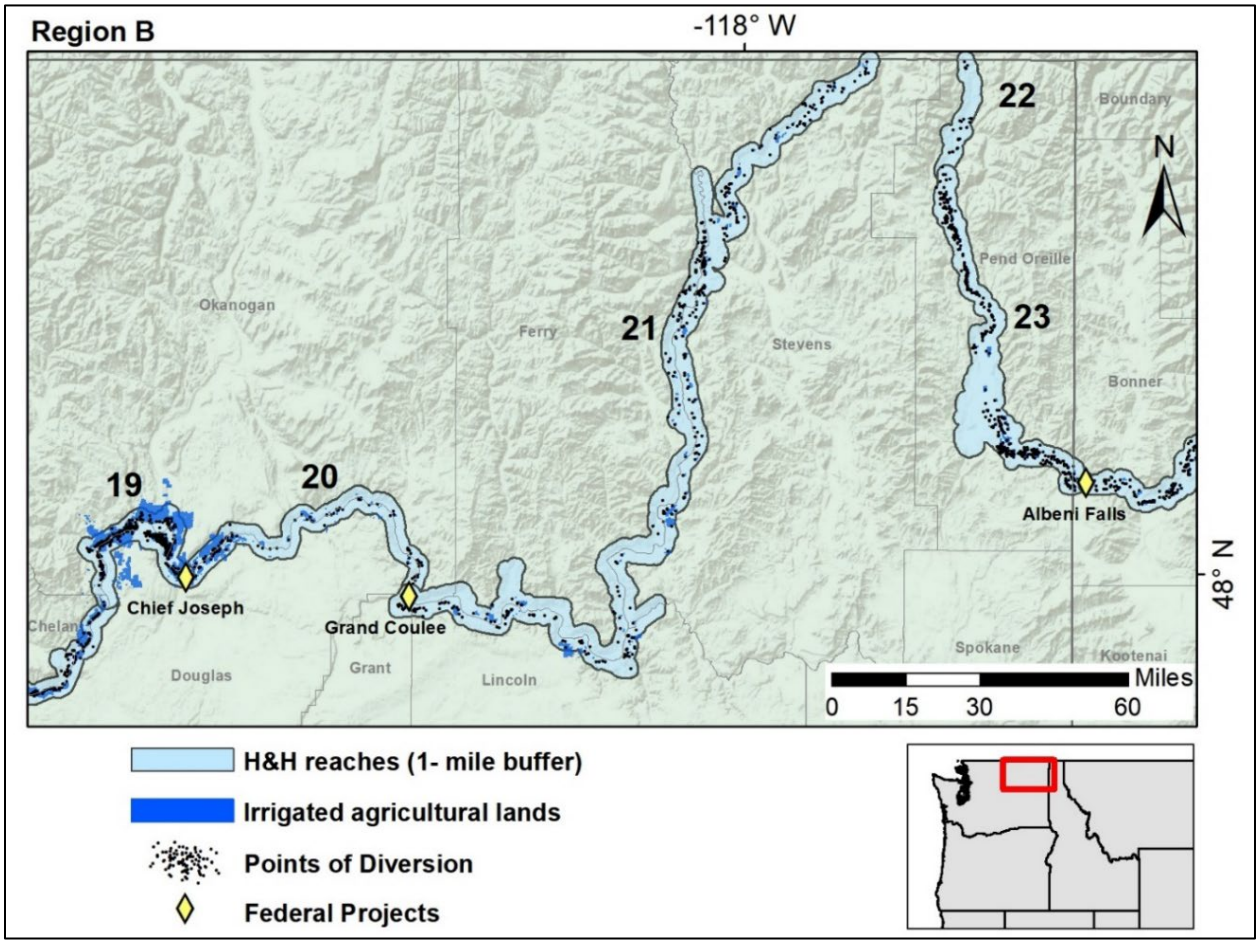
In Region B, a volume of 3.318[13] million acre-feet is pumped annually from Lake Roosevelt for irrigation and M&I purposes on the Columbia Basin Project. An additional 16,860 acre-feet is diverted on average annual basis from the countries surrounding Region B for M&I purposes from both surface and groundwater (USGS 2018; Table 3-2). Figure 3-2 shows the areas irrigated from water diverted from study area H&H reaches in Region B (Reclamation 2019). The numbers on the reaches correspond to ResSim model reaches. There are approximately 200 diversions in these reaches and 370 wells within 1 mile of the river, as counted from the point of diversion files described in Chapter 2 of this appendix.

[13] The full water right value is used in the No Action even though portions are still under development since they are reasonably certain to occur within the EIS project horizon.

552 **Table 3-2. Summary of M&I Use by County for Surface and Groundwater in Counties that**
553 **Border the CRSO Reaches in Region B**

County	State	Surface Water (acre-feet)	Groundwater (acre-feet)
Lincoln County	WA	–	3,100
Ferry County	WA	80	1,500
Stevens County	WA	80	10,600
Grant County	WA	600	900
Total	**–**	***760***	***16,100***

554 Source: USGS (2018)
555 Note: Douglas County, WA, was not included because most of the M&I use was near Wenatchee in that county,
556 which is not within the study area. Okanagan County, WA, was also removed because only a very small corner of
557 the county bordered the Columbia River and there did not appear to be any M&I activity in the area.



558
559 **Figure 3-2. Points of Diversion and Land Irrigated from Water Diverted from Study Area H&H**
560 **Reaches in Region B**

3.1.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor

In Region C, approximately 316,000 acre-feet of water is diverted on average annual basis for irrigation with a portion of that water returning to the river as return flows (BPA 2011). In the counties surrounding Region C, approximately 21,330 acre-feet is diverted for M&I purposes (USGS 2018; Table 3-3). Figure 3-3 shows the areas irrigated from water diverted from study area H&H reaches in Region C (Reclamation 2019). The numbers on the reaches correspond to ResSim model reaches. There are approximately 80 diversions in these reaches and 200 wells within 1 mile of the river, as counted from the point of diversion file described in Chapter 2 of this appendix.

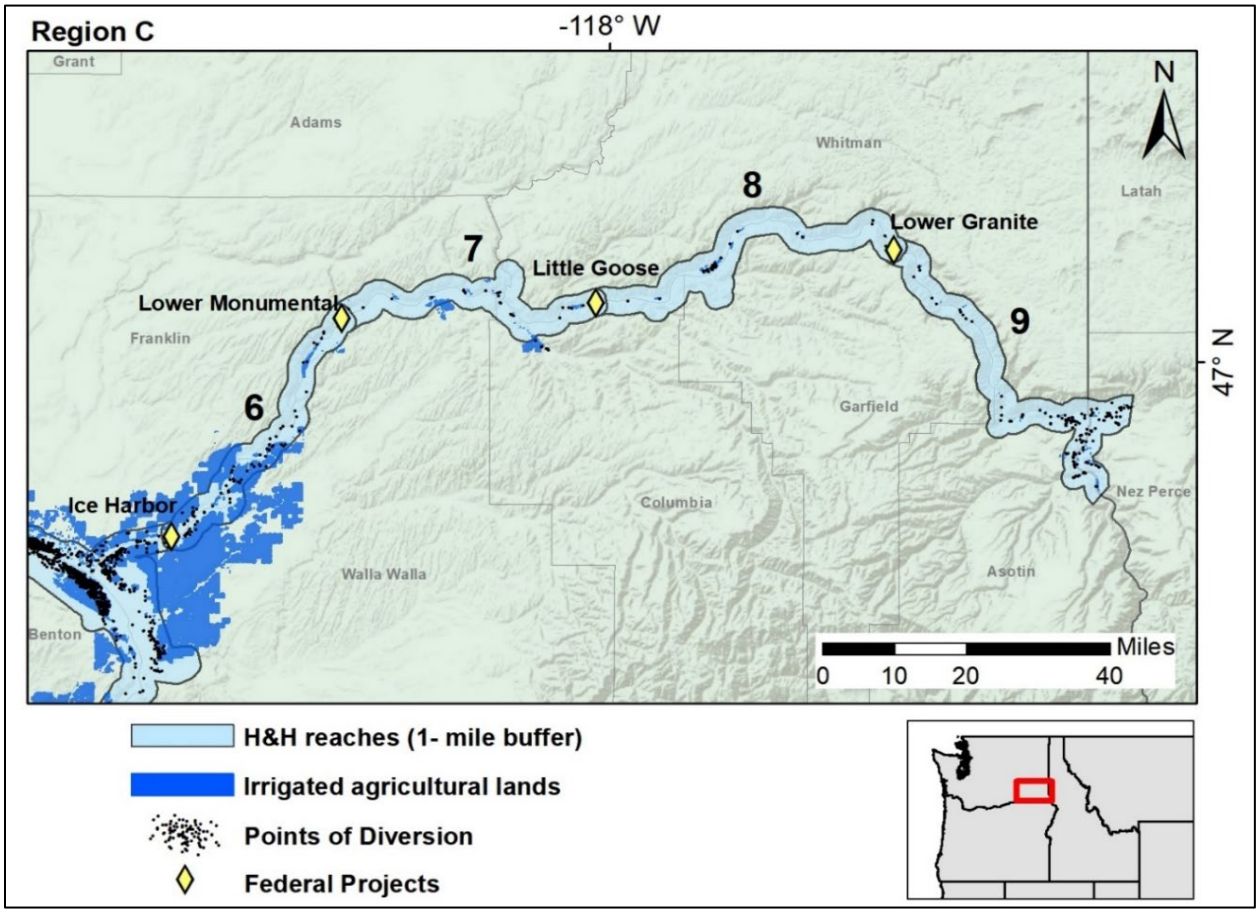


Figure 3-3. Points of Diversion and Land Irrigated from Water Diverted from Study Area H&H Reaches in Region C

Table 3-3. Summary of M&I Use by County for Surface and Groundwater in Counties that Border the CRSO Reaches in Region C

County	State	Surface Water (acre-feet)	Groundwater (acre-feet)
Asotin County	WA	30	6,200
Nez Perce County	ID	9,200	5,100
Garfield County	WA	–	800
Total	***–***	***9,230***	***12,100***

Source: USGS (2018)

Note: Did not include Columbia County, WA, Whitman County, WA, and Franklin County, WA because there did not appear to be any M&I activity along the Lower Snake. Removed Walla Walla County, WA, because most of the M&I activity was in the city of Walla Walla, which is not in the study area.

3.1.4 Region D – McNary, John Day, The Dalles, Bonneville

In Region D, approximately 530,000 acre-feet of water is diverted on average annual basis for irrigation with a portion of water returning to the river as return flows (BPA 2011). In the counties surrounding Region D, about 34,400 acre-feet are diverted for M&I purposes (USGS 2018; Table 3-4). Figure 3-4 shows the areas irrigated from water diverted from study area H&H reaches in Region D (Reclamation 2019). The numbers on the reaches correspond to ResSim model reaches. There are approximately 240 diversions in these reaches and 1,850 wells within 1 mile of the river, as counted from the point of diversion file described in Chapter 2 of this appendix.

Table 3-4. Summary of M&I Use by County for Surface and Groundwater in Counties that Border the CRSO Reaches in Region D

County	State	Surface Water (acre-feet)	Groundwater (acre-feet)
Benton County	WA	14,500	2,900
Klickitat County	WA	2,400	4,600
Morrow County	OR	5,000	5,000
Umatilla County	OR	5,000	1,500
Total	***–***	***21,900***	***12,500***

Source: USGS (2018)

Note: Walla Walla County is excluded because most of the drinking water is likely in the City of Walla Walla. The Port of Umatilla and the City of Umatilla are the only entities used for Umatilla County (data from Oregon Water Resources Department water use reports).

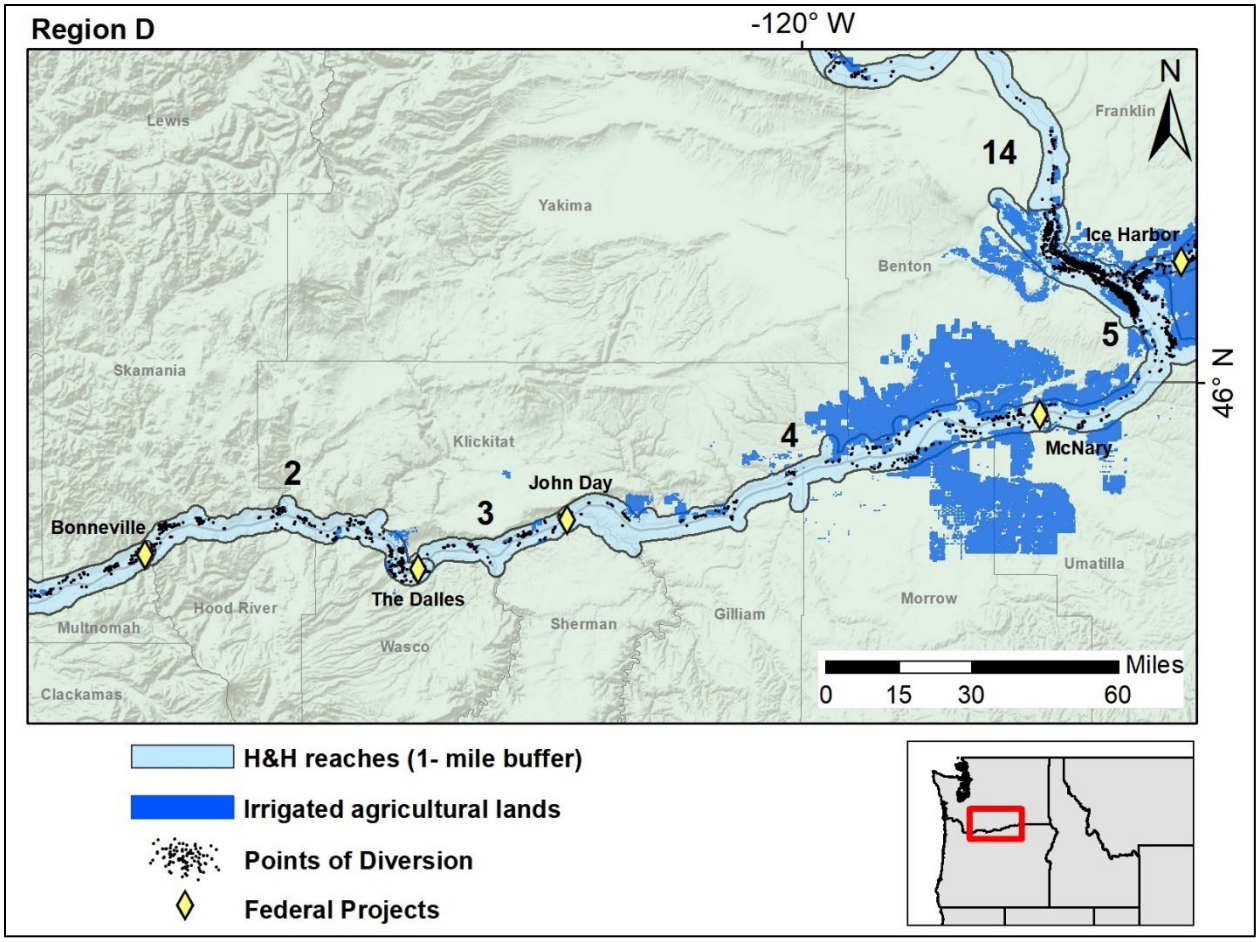


Figure 3-4. Points of Diversion and Land Irrigated from Water Diverted from Study Area H&H Reaches in Region D

3.2 MULTIPLE OBJECTIVE ALTERNATIVE 1

The H&H models assumed that current level diversions will be diverted in all years, which indicates that the volume of water needed for water supply will be available for diversion in all years. Because of is assumption, the flow and stage in the MO1 model results reflect meeting those diversions in all years, and the effect of diverting the water is included in the analysis for the resources including H&H, water quality, and fish that use those model results. There are possible negligible effects to pumping costs for MO1 if pool elevations or river stages drop below current pump configurations. Those locations are identified in this section, but are effects are not quantified because of limited data.

3.2.1 Region A – Libby, Hungry Horse, Albeni Falls

The H&H model results for MO1 were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see Chapter 3 - Table 3-4). Table 3-5 describes the H&H effects that could affect the physical ability to divert water and whether there a possible effect to water supply.

Table 3-5. Summary of H&H and Water Supply Effects for MO1 in Region A

Indicator	H&H effect	Water Supply effect
Lake Koocanusa (Libby Dam reservoir)	Lake levels higher than No Action Alternative (NAA) year-round	No effect
Libby Dam outflow	Lower Dec flows in some years, but not lower than lowest winter flows in NAA. Higher than NAA in Nov, Jan, and Feb.	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels. Elevation is controlled by downstream lake, so likely no change to pumping costs.
Hungry Horse reservoir	Lower lake levels than NAA.	No effect because there are no water supply diversions for irrigation or M&I directly from the pool.
Hungry Horse Dam (outflow)	Lower outflow than NAA in April, May, and June, but not lower than summer lowest. Higher than NAA in July, Aug, and Sep.	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels. Change in flow translates to immeasurable difference in head, so no impact to pumping costs.
Lake Pend Oreille	No change	No effect

3.2.2 Region B – Grand Coulee, Chief Joseph

The H&H model results for MO1 were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see Chapter 3 - Table 3-4). Table 3-6 describes the H&H effects that could affect the physical ability to divert water and whether there a possible effect to water supply.

Table 3-6. Summary of H&H and Water Supply Effects for MO1 in Region B

Indicator	H&H effect	Water Supply effect
Lake Roosevelt (Grand Coulee Dam Reservoir)	Lower lake elevations than NAA in Dec, Jan, and April 10.	No effect to the ability to deliver water because it assumed that pumps can operate given that lake levels are not lower than lowest NAA elevation. Possible minor effect to pumping costs in some years in the spring. These are quantified for John W Keys pumping plant, but not for other small surface or groundwater users on the Lake because there is not enough information about the pumps.
Grand Coulee Dam outflow	Lower Feb, Mar, Apr, May, Jun, Jul, Aug flows than NAA. Higher than NAA in Dec.	No effect to the ability to deliver water because the pool at Chief Joseph is not changing from NAA, so water surface and groundwater elevations are not affected regardless of outflow from Grand Coulee.
Rufus Woods Lake (Chief Joseph Dam reservoir)	No change from NAA	No effect

3.2.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor

The H&H model results for MO1 were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see

Chapter 3 – Table 3-4). Table 3-7 describes the H&H effects that could affect the physical ability to divert water and whether there is a possible effect to water supply.

Table 3-7. Summary of H&H and Water Supply Effects for MO1 in Region C

Indicator	H&H effect	Water Supply effect
Dworshak Reservoir	Lower lake elevations than NAA in Jun, Jul, Aug and higher than NAA in Sep.	No effect because there is not irrigation or M&I diverting from the pool.
Dworshak Dam outflow	Higher outflows than NAA in Jun, Jul, and Sep; lower than NAA in Aug. Lowest outflow is not lower than NAA in the summer.	No irrigation or M&I above Lewiston, so no effect.
Lower Granite Dam Reservoir	Higher pool elevations than NAA	No effect
Little Goose Dam Reservoir	Higher pool elevations than NAA	No effect
Lower Monumental Dam Reservoir	Higher pool elevations than NAA	No effect
Ice Harbor Dam Reservoir	Higher pool elevations than NAA	No effect

3.2.4 Region D – McNary, John Day, The Dalles, Bonneville

The H&H model results for MO1 were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see Chapter 3 – Table 3-4). Table 3-8 describes the H&H effects that could affect the physical ability to divert water and whether there is a possible effect to water supply.

Table 3-8. Summary of H&H and Water Supply Effects from MO1 in Region D

Indicator	H&H effect	Water Supply effect
McNary Dam outflow	Lower than NAA in May and June	No effect to the ability to deliver water because the pool at John Day is higher from NAA, so water surface and groundwater elevations are not affected regardless of outflow from McNary.
Lake Umatilla (John Day Dam Reservoir)	Higher pool elevations than NAA	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels.
The Dalles Reservoir	No change from NAA	No effect
Bonneville Reservoir	No change from NAA	No effect

3.3 MULTIPLE OBJECTIVE ALTERNATIVE 2

The H&H models assumed that current level diversions will be diverted in all years, which indicates that the volume of water needed for water supply will be available for diversion in all years. Because of is assumption, the flow and stage in the MO2 model results reflect meeting those diversions in all years, and the effect of diverting the water is analyzed for the resources

including H&H, water quality, and fish that use those model results. There are possible negligible effects of changes to pumping costs for MO2 if pool elevation or river stages drop below current pump configurations. Those locations are identified in this section, but are impacts are not quantified because of limited data.

3.3.1 Region A – Libby, Hungry Horse, Albeni Falls

The H&H model results for MO2 were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see Chapter 3 - Table 3-4). Table 3-9 describes the H&H effects that could affect the physical ability to divert water and whether there a possible effect to water supply.

Table 3-9. Summary of H&H and Water Supply Effects for MO2 in Region A

Indicator	H&H effect	Water Supply effect
Lake Koocanusa (Libby Dam reservoir)	Lake levels lower than NAA in winter (about 20 feet) and higher than NAA in summer (about 1 foot). However, lower elevations are not lower than lowest elevation in NAA.	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels. Possible negligible effect to winter pumping costs; these effects are not quantified in this analysis because there is not enough information about these pumps
Libby Dam outflow	Lower Jan and Feb flows than NAA. Higher than NAA in Nov and Dec. Lower flows than NAA in Jul, Aug, and Sep, but not lower than lowest outflow in NAA.	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels. Elevation is controlled by downstream lake, so likely no change to pumping costs.
Hungry Horse reservoir	Lower lake levels than NAA.	No effect because there are no water supply diversions for irrigation or M&I directly from the reservoir.
Hungry Horse Dam (outflow)	Lower outflow than NAA in April, May, June, Jul, Aug, and Sep, lower than NAA in many years; lowest flow 100 cfs lower than lowest NAA summer flow but not lower than lowest annual flow. Higher than NAA in Jan and Feb.	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels. Change in flow translates to immeasurable difference in head, so no impact to pumping costs.
Lake Pend Oreille	No change	No effect

3.3.2 Region B – Grand Coulee, Chief Joseph

The H&H model results for MO2 were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see Chapter 3 - Table 3-4). Table 3-10 describes the H&H effects that could affect the physical ability to divert water and whether there a possible effect to water supply.

650 **Table 3-10. Summary of H&H and Water Supply Effects for MO2 in Region B**

Indicator	H&H effect	Water Supply effect
Lake Roosevelt (Grand Coulee Dam Reservoir)	Lower lake elevations than NAA in Dec, Jan, April 10, and Sep.	No effect to the ability to deliver water because it assumed that pumps can operate given that lake levels are not lower than lowest NAA elevation. Possible negligible effect to pumping costs. These are quantified for John W Keys pumping plant, but not for other small surface or groundwater users on the Lake because there is not enough information about the pumps.
Grand Coulee Dam outflow	Lower Feb, Mar, Apr, May, Jun, Jul, Aug flows than NAA. Higher than NAA in Dec.	No effect to the ability to deliver water because the pool at Chief Joseph is not changing from NAA, so water surface and groundwater elevations are not affected regardless of outflow from Grand Coulee.
Rufus Woods Lake (Chief Joseph Dam reservoir)	No change from NAA	No effect

651 ### 3.3.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor

652 The H&H model results for MO2 were used to determine if there could be an impact to the
653 ability to deliver water based on physical limitations for surface or groundwater pumps (see
654 Chapter 3 – Table 3-4). Table 3-11 describes the H&H effects that could affect the physical
655 ability to divert water and whether there is a possible effect to water supply.

656 **Table 3-11. Summary of H&H and Water Supply Effects for MO2 in Region C**

Indicator	H&H effect	Water Supply effect
Dworshak Reservoir	Lower lake elevations than NAA in Jan, Feb, Mar, Apr, Jun, Jul, Aug.	No effect because there is not irrigation or M&I diverting from the pool.
Dworshak Dam outflow	Higher outflows than NAA in Jan, Feb, and May; lower than NAA in Mar, Apr, Jun, Jul, and Aug. Lowest outflow is not lower than NAA in the summer.	No irrigation or M&I above Lewiston, so no effect.
Lower Granite Dam Reservoir	Higher pool elevations than NAA	No effect
Little Goose Dam Reservoir	Higher pool elevations than NAA	No effect
Lower Monumental Dam Reservoir	Higher pool elevations than NAA	No effect
Ice Harbor Dam Reservoir	Higher pool elevations than NAA	No effect

657 ### 3.3.4 Region D – McNary, John Day, The Dalles, Bonneville

658 The H&H model results for MO2 were used to determine if there could be an impact to the
659 ability to deliver water based on physical limitations for surface or groundwater pumps (see
660 Chapter 3 – Table 3-4). Table 3-12 describes the H&H effects that could affect the physical
661 ability to divert water and whether there is a possible effect to water supply.

Table 3-12. Summary of H&H and Water Supply Effects from MO2 in Region D

Indicator	H&H effect	Water Supply effect
McNary Dam outflow	Lower than NAA in May and Jun.	No effect to the ability to deliver water because the pool at John Day is higher from NAA, so water surface and groundwater elevations are not affected regardless of outflow from McNary.
Lake Umatilla (John Day Dam Reservoir)	Broader range of pool elevations than NAA	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels.
The Dalles Reservoir	No change from NAA	No effect
Bonneville Reservoir	No change from NAA	No effect

3.4 MULTIPLE OBJECTIVE ALTERNATIVE 3

MO3 included measures that could impact delivery of current water supply in Region C. This alternative included measures to remove dams in the region of the Lower Snake river, where water is diverted for irrigation of lands in Washington and is anticipated to have a major effect on water supply.

The H&H models assumed that current level diversions will be diverted in all years, which indicates that the volume of water needed for water supply will be available for diversion in all years. Because of is assumption, the flow and stage in the MO3 model results reflect meeting those diversions in all years, and the effect of diverting the water is carried forward to the resources including H&H, water quality, and fish that use those model results. There are possible negligible effects of changes to pumping costs for MO3 if pool elevation or river stages drop below current pump configurations. Those locations are identified in this section, but are impacts are not quantified because of limited data.

3.4.1 Region A – Libby, Hungry Horse, Albeni Falls

The H&H model results for MO3 were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see Chapter 3 - Table 3-4). Table 3-13 describes the H&H effects that could affect the physical ability to divert water and whether there a possible effect to water supply.

Table 3-13. Summary of H&H and Water Supply Effects for MO3 in Region A

Indicator	H&H effect	Water Supply effect
Lake Koocanusa (Libby Dam reservoir)	Lake levels lower than NAA in winter (about 20 feet) and higher than NAA in summer (about 1 foot). However, lower elevations are not lower than lowest elevation in NAA.	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels. Possible negligible effect to winter pumping costs; these effects are not quantified in this analysis because there is not enough information about these pumps

Indicator	H&H effect	Water Supply effect
Libby Dam outflow	Higher than NAA in Nov and Dec. Lower flows than NAA in Jan, Feb, Jul, Aug, and Sep, but not lower than lowest outflow in NAA.	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels. Elevation is controlled by downstream lake, so likely no change to pumping costs.
Hungry Horse reservoir	Lower lake levels than NAA.	No effect because there are no water supply diversion for irrigation or M&I directly from the reservoir.
Hungry Horse Dam (outflow)	Lower outflow than NAA in April, May, and June, but not lower than summer lowest. Higher than NAA in Jul. Aug, and Sep.	Possible negligible effect to the ability to deliver water in the summer months due to lower stage as a result of lower outflows; since pump elevations are unknown, this effect is not quantified. Change in flow translates to immeasurable difference in head, so no impact to pumping costs.
Lake Pend Oreille	No change	No effect

3.4.2 Region B – Grand Coulee, Chief Joseph

The H&H model results for MO3 were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see Chapter 3 - Table 3-4). Table 3-14 describes the H&H effects that could affect the physical ability to divert water and whether there a possible effect to water supply.

Table 3-14. Summary of H&H and Water Supply Effects for MO3 in Region B

Indicator	H&H effect	Water Supply effect
Lake Roosevelt (Grand Coulee Dam Reservoir)	Similar lake elevations to NAA.	No effect to the ability to deliver water because it assumed that pumps can operate given that lake levels are not lower than lowest NAA elevation. Estimated changes to pumping costs are quantified for John W Keys pumping plant.
Grand Coulee Dam outflow	Lower Feb, Mar, Apr, May, Jun, Jul, Aug flows than NAA. Higher than NAA in Dec.	No effect to the ability to deliver water because the pool at Chief Joseph is not changing from NAA, so water surface and groundwater elevations are not affected regardless of outflow from Grand Coulee.
Rufus Woods Lake (Chief Joseph Dam reservoir)	No change from NAA	No effect

3.4.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor

MO3 included a structural measure (S1) that could impact water supply in this region by removing the lower four Snake River Dams. Currently and in the NAA, water is provided out of the pools of these facilities and groundwater that results from the pools. The pumps that supply this water would no longer be operational once the dams are removed and the nearby groundwater elevations could be significantly impacted. Chapter 4 of this appendix analyzes the socioeconomic effects of these impacts. Table 3-15 summarized the impacts in Region C.

Table 3-15. Summary of H&H and Water Supply Effects for MO3 in Region C

Indicator	H&H effect	Water Supply effect
Dworshak Reservoir	No change from NAA	No effect
Dworshak Dam outflow	No change from NAA	No effect
Lower Granite Dam Reservoir	Dam breached	Major effect
Little Goose Dam Reservoir	Dam breached	Major effect
Lower Monumental Dam Reservoir	Dam breached	Major effect
Ice Harbor Dam Reservoir	Dam breached	Major effect

3.4.3.1 Irrigation

There are approximately 48,000 acres currently being irrigated from surface water and groundwater in Region C with average diversions estimated to be around 316,000 acre-feet (the diversions encompass those from the Palouse, Lower Snake, and Clearwater, so are likely a high estimate of diversion for the possibly affected acres). Currently and in the NAA, water provided out of the pools of these facilities and by nearby groundwater, and the pumps and wells that supply this water would no longer be operational once these dams are removed. [Add Corps analysis to here]

3.4.3.2 Municipal and Industrial

There are M&I pumps in the Lewiston area that will likely be impacted by this measure, along with other small M&I uses along the river. The co-lead agencies identified a total of 16 points of diversion from surface water whose water rights purpose was indicated to be M&I. These points may use up to 9,230 acre-feet per year (USGS 2018).

The Corps of Engineers evaluated 15 pumps on Lower Granite Reservoir and indicated that they used approximately 40,000 acre-feet per year in 1996 (Corps 2002), with the largest user being the Potlatch Corporation (now Clearwater Paper). It is unclear if this number is total consumptive use or just the amount diverted. Over the last 10 years, the Clearwater Paper company has been reducing its use by treating the water and returning it to the river (Clearwater Paper 2019), which could account for the overall reduction in usage in the area.

3.4.3.3 Groundwater

Groundwater will likely be impacted by this measure with groundwater elevations having the potential to drop the entire height of previous water levels, up to 100 feet. This would impact well users in the region. The co-lead agencies identified approximately 200 groundwater points of diversion that could be used for M&I or irrigation.

The Corps of Engineers evaluated wells in this region for the 2004 EIS. They found a similar number of wells, 228, that were recorded in the region. Of the 228, they found that 180 were functioning and within the study area, which is 79 percent. They analyzed 38 of the 180 wells using well log data combined with topographic features, well depth, stratigraphy, surface elevation to determine the wells that could be affected by changes in the river water surface

elevation (Corps 2002). They found that 15 of them would need to be modified to continue operation under the dam breaching condition, which is 40 percent of those evaluated (38 wells). Extrapolating that number to the 200 groundwater points of diversion within the study area results in 63 wells that could be affected in the region.

3.4.4 Region D – McNary, John Day, The Dalles, Bonneville

The H&H model results for MO3 were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see Chapter 3 - Table 3-4). Table 3-16 describes the H&H effects that could affect the physical ability to divert water and whether there a possible effect to water supply.

Table 3-16. Summary of H&H and Water Supply Effects for MO3 in Region D

Indicator	H&H effect	Water Supply effect
McNary Dam outflow	Lower than NAA in May and Jun	No effect to the ability to deliver water because the pool at John Day is higher from NAA, so water surface and groundwater elevations are not affected regardless of outflow from McNary
Lake Umatilla (John Day Dam Reservoir)	Broader range of pool elevations than NAA	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels.
The Dalles Reservoir	No change from NAA	No effect
Bonneville Reservoir	No change from NAA	No effect

Following the removal of the Lower Snake Dams, there will likely be sediment that is transported through the McNary and John Day pools (see the River Mechanics section in Chapter 3 for more information). The river mechanics modeling showed that at the location of the large pumps used for the Umatilla lands near river mile 295, there would be fine-grained material that would reach the pumps. However, it should not impact that pumps ability to operate given that the intakes are 3 to 4 feet in diameter. Farther upstream, there are some private pumps that may be impacted by the fine-grained material. Though it would not impede their ability to deliver water, it would require more frequent maintenance.[14]

3.5 MULTIPLE OBJECTIVE ALTERNATIVE 4

The H&H models assumed that current level diversions will be diverted in all years, which indicates that the volume of water needed for water supply will be available for diversion in all years. Because of is assumption, the flow and stage in the MO4 model results reflect meeting those diversions in all years, and the effect of diverting the water is carried forward to the resources including H&H, water quality, and fish that use those model results. There are possible negligible effects of changes to pumping costs, particularly in Region D at John Day, for MO4 as pool elevation or river stages drop below current pump configurations. There are possible negligible effects of changes to pumping costs if pool elevation or river stages drop

[14] Based on conversations with Reclamation's Umatilla Field Office Manager.

below current pump configurations. Those locations are identified in this section, but are impacts are not quantified because of limited data.

3.5.1 Region A – Libby, Hungry Horse, Albeni Falls

The H&H model results for MO4 were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see Chapter 3 - Table 3-4). Table 3-17 describes the H&H effects that could affect the physical ability to divert water and whether there a possible effect to water supply.

Table 3-17. Summary of H&H and Water Supply Effects for MO4 in Region A

Indicator	H&H effect	Water Supply effect
Lake Koocanusa (Libby Dam reservoir)	Lake levels higher than NAA in winter and lower than NAA in Jul, Aug, Sep.	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels. Possible negligible effect to winter pumping costs; these effects are not quantified in this analysis because there is not enough information about these pumps
Libby Dam outflow	Lower Nov and Dec flows in some years, but not lower than lowest winter flows in NAA. Higher than NAA in Jan, Feb, and Jul.	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels Elevation is controlled by downstream lake, so likely no change to pumping costs.
Hungry Horse reservoir	Lower lake levels than NAA.	No effect because there is not irrigation or M&I diverting from the pool.
Hungry Horse Dam (outflow)	Lower outflow than NAA in April, May, and June, but not lower than summer lowest. Higher than NAA in Jul, Aug, and Sep.	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels. Change in flow translates to immeasurable difference in head, so no impact to pumping costs.
Lake Pend Oreille	Lower summer lake levels than NAA.	Possible effect to the ability to deliver summer water supplies if pumps are configured to operate at historical elevations; not enough information is available to analyze this effect. If pumps are configured to operate year-round, there should be no impact to the ability to pump but pumping costs may increase.

3.5.2 Region B – Grand Coulee, Chief Joseph

The H&H model results for MO4 were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see Chapter 3 - Table 3-4). Table 3-18 describes the H&H effects that could affect the physical ability to divert water and whether there a possible effect to water supply.

765 **Table 3-18. Summary of H&H and Water Supply Effects for MO4 in Region B**

Indicator	H&H effect	Water Supply effect
Lake Roosevelt (Grand Coulee Dam Reservoir)	Lower lake elevations than NAA in Dec, Jan, April 10, Jul, Aug, and Sep.	No effect to the ability to deliver water because it assumed that pumps can operate given that lake levels are not lower than lowest NAA elevation. Possible negligible effect to pumping costs. These are quantified for John W Keys pumping plant, but not for other small surface or groundwater users on the Lake because there is not enough information about the pumps.
Grand Coulee Dam outflow	Lower Feb, Mar, Apr, May, Jun, Jul, Aug flows than NAA. Higher than NAA in Dec and Jan.	No effect to the ability to deliver water because the pool at Chief Joseph is not changing from NAA, so water surface and groundwater elevations are not affected regardless of outflow from Grand Coulee.
Rufus Woods Lake (Chief Joseph Dam reservoir)	No change from NAA	No effect

766 ### 3.5.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor

767 The H&H model results for MO4 were used to determine if there could be an impact to the
768 ability to deliver water based on physical limitations for surface or groundwater pumps (see
769 Chapter 3 - Table 3-4). Table 3-19 describes the H&H effects that could affect the physical
770 ability to divert water and whether there a possible effect to water supply.

771 **Table 3-19. Summary of H&H and Water Supply Effects for MO4 in Region C**

Indicator	H&H effect	Water Supply effect
Dworshak Reservoir	No change from NAA	No effect
Dworshak Dam outflow	No change from NAA	No effect
Lower Granite Dam Reservoir	Higher pool elevations than NAA	No effect
Little Goose Dam Reservoir	Higher pool elevations than NAA	No effect
Lower Monumental Dam Reservoir	Higher pool elevations than NAA	No effect
Ice Harbor Dam Reservoir	Higher pool elevations than NAA	No effect

772 ### 3.5.4 Region D – McNary, John Day, The Dalles, Bonneville

773 The H&H model results for MO4 were used to determine if there could be an impact to the
774 ability to deliver water based on physical limitations for surface or groundwater pumps (see
775 Chapter 3 - Table 3-4). Table 3-20 describes the H&H effects that could affect the physical
776 ability to divert water and whether there a possible effect to water supply.

777 **Table 3-20. Summary of H&H and Water Supply Effects for MO4 in Region D**

Indicator	H&H effect	Water Supply effect
McNary Dam outflow	Higher than NAA	No effect
Lake Umatilla (John Day Dam Reservoir)	Summer pool elevations 1.5 feet lower than NAA	No effect to the ability to deliver irrigation and M&I water from surface and groundwater. Increased pumping costs due to lower pool elevations.
The Dalles Reservoir	No change from NAA	No effect
Bonneville Reservoir	No change from NAA	No effect

MO4 included an operational measure that could impact water supply from the John Day pool (08) by lowering the minimum pool during the irrigation season by 1.5 to 261.0 feet (NGVD29). A decrease in water surface elevation by 1.5 feet would not be outside the range of recent historical operations, so it is possible that most if not all of the pumps would still be operational. However, anecdotal information suggests that there are some pumps that might need modification to continue operation. Data is not available to analyze the number of pumps requiring modification or the degree of modification required, so the cost of this modification is not analyzed. For those pumps that can still operate, the cost to pump that water would likely increase due to the additional head required for pumping, which was analyzed.

This measure could also impact groundwater because the head would be lower for the irrigation season than NAA operations. The 1.5 feet of head difference could lower groundwater levels up to 1.5 feet, but the effect may be less.

3.6 PREFERRED ALTERNATIVE

The H&H models assumed that current level diversions will be diverted in all years, which indicates that the volume of water needed for water supply will be available for diversion in all years. Because of is assumption, the flow and stage in the Preferred Alternative model results reflect meeting those diversions in all years, and the effect of diverting the water is carried forward to the resources including H&H, water quality, and fish that use those model results. There are possible negligible effects of changes to pumping costs if pool elevation or river stages drop below current pump configurations. Those locations are identified in this section, but are impacts are not quantified because of limited data.

3.6.1 Region A – Libby, Hungry Horse, Albeni Falls

The H&H model results for the Preferred Alternative were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see section 7.5.1). Table 3-21 describes the H&H effects that could affect the physical ability to divert water and whether there a possible effect to water supply.

Table 3-21. Summary of H&H and Water Supply Effects for Preferred Alternative in Region A

Indicator	H&H effect	Water Supply effect
Lake Koocanusa (Libby Dam reservoir)	Lake levels higher than NAA in summer and lower in spring	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels. Possible negligible effect to spring pumping costs; these effects are not quantified in this analysis because there is not enough information about these pumps
Libby Dam outflow	Outflows are generally higher than NAA	No effect to the ability to deliver water.
Hungry Horse reservoir	Lower lake levels than NAA in fall and higher in summer.	No effect because there is not irrigation or M&I diverting from the pool.

Indicator	H&H effect	Water Supply effect
Hungry Horse Dam (outflow)	In Jul, Aug, and Sep, monthly average outflow would be lower than NAA by less than 1,000 cfs	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels. Change in flow translates to immeasurable difference in head, so no impact to pumping costs.
Lake Pend Oreille	No change from NAA	No effect

3.6.2 Region B – Grand Coulee, Chief Joseph

The H&H model results for the Preferred Alternative were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see section 7.5.1). Table 3-22 describes the H&H effects that could affect the physical ability to divert water and whether there a possible effect to water supply.

Table 3-22. Summary of H&H and Water Supply Effects for Preferred Alternative in Region B

Indicator	H&H effect	Water Supply effect
Lake Roosevelt (Grand Coulee Dam Reservoir)	Lower lake elevations than NAA in Feb through May	No effect to the ability to deliver water because it assumed that pumps can operate given that lake levels are not lower than lowest NAA elevation. Possible negligible effect to pumping costs. These are quantified for John W Keys pumping plant, but not for other small surface or groundwater users on the Lake because there is not enough information about the pumps.
Grand Coulee Dam outflow	Lower Apr, May, Jun, Jul, Aug outflows than NAA. Higher than NAA in Dec and Jan.	No effect to the ability to deliver water because the pool at Chief Joseph is not changing from NAA, so water surface and groundwater elevations are not affected regardless of outflow from Grand Coulee.
Rufus Woods Lake (Chief Joseph Dam reservoir)	No change from NAA	No effect

3.6.3 Region C – Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor

The H&H model results for the preferred were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see section 7.5.1). Table 3-23 describes the H&H effects that could affect the physical ability to divert water and whether there a possible effect to water supply.

Table 3-23. Summary of H&H and Water Supply Effects for Preferred Alternative in Region C

Indicator	H&H effect	Water Supply effect
Dworshak Reservoir	Lower pool elevations than NAA in Jan, Feb, Mar in driest years	No effect because there is not irrigation or M&I diverting from the pool.
Dworshak Dam outflow	Lower outflows than NAA in Feb and Mar.	No effect to the ability to deliver water because it is assumed that pumps can operate given that outflows are not lower than lowest NAA levels. Change in flow translates to immeasurable change in head, so no change to pumping costs.

Indicator	H&H effect	Water Supply effect
Lower Granite Dam Reservoir	Higher pool elevations than NAA	No effect
Little Goose Dam Reservoir	Higher pool elevations than NAA	No effect
Lower Monumental Dam Reservoir	Higher pool elevations than NAA	No effect
Ice Harbor Dam Reservoir	Higher pool elevations than NAA	No effect

3.6.4 Region D – McNary, John Day, The Dalles, Bonneville

The H&H model results for MO4 were used to determine if there could be an impact to the ability to deliver water based on physical limitations for surface or groundwater pumps (see section 3.5.1). Table 3-24 describes the H&H effects that could affect the physical ability to divert water and whether there a possible effect to water supply.

Table 3-24. Summary of H&H and Water Supply Effects for Preferred Alternative in Region D

Indicator	H&H effect	Water Supply effect
McNary Dam outflow	Higher than NAA.	No effect.
Lake Umatilla (John Day Dam Reservoir)	Higher than NAA	No effect.
The Dalles Reservoir	Higher than NAA	No effect
Bonneville Reservoir	Higher than NAA	No effect

CHAPTER 4 - SOCIOECONOMIC EFFECTS ANALYSIS

This section presents estimates of the social welfare effects and the regional economic impacts resulting from physical water supply impacts to irrigation and M&I water supply. Based on the physical analysis, only Region C and D were analyzed for the No Action because those are the only regions with expected changes. The social welfare effects for each alternative are described below followed by the details related to the Regional Economic Impacts for each alternative.

4.1 SOCIAL WELFARE ANALYSIS

The following section describes the social welfare effects for each alternative. The social welfare effects measure the economic benefits resulting from an alternative from a societal or national perspective.

4.1.1 No Action Alternative

4.1.1.1 Region A – Libby, Hungry Horse, Albeni Falls

Water supply effects related to socioeconomics are not expected in this area because no physical water supply effects were measured or expected.

4.1.1.2 Region B – Grand Coulee, Chief Joseph

The effects for the Multiple Objective alternatives conditions were estimated as the increment between the No Action Alternative and the Multiple Objective alternatives conditions. Therefore, effects were not estimated for the No Action Alternative.

4.1.1.3 Region C - Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor

SOCIAL WELFARE EFFECTS - IRRIGATION

The U.S. Army Corps of Engineers (Corps) 2002 report analyzed dam removal and the impact on water supply. Several system modifications were considered that would allow for the continuation of water deliveries to existing farmlands. The report concluded that modifying the existing pump system was cost prohibitive. For the regional analysis the report assumed that most of the irrigated acres receiving water from the current pumps would no longer be irrigated. The report assumed that 21 percent of the irrigated land might support the development of alternative water supplies to replace lost irrigation water and the replacement water would be used to irrigate some of the fruit orchards and vineyards. The development cost for the replacement water would need to be included as part of the alternative to assess the net benefits of irrigation under this scenario.

The current analysis also assumed that all irrigated acres (approximately 47,926 acres) receiving water from the current pumps would no longer be irrigated (with condition) and would convert to dryland pasture (without condition). This assumption was based on conversations with

several extension agents in Washington and Oregon. It was assumed that there isn't a suitable substitute water source and the annual rainfall is not sufficient to support a dryland crop rotation such as a wheat/fallow operation. There was also concern that soil acidity may impact a dryland wheat/fallow operation on lands that were previously supporting fruit orchards and vineyards.

The Principles and Guidelines (P&Gs) describe two methods for evaluating the social welfare effects associated with irrigation, farm budget analysis and land value analysis. The land value method is based on the use of land values as a measure of the land's income-producing capability from farm production. The P&Gs land value method call for a with and without comparison of irrigated and non-irrigated lands. When using land values to estimate the social welfare effects of irrigation water, the land values used for estimating the value of the water must be based only on the land's income-producing capability from crop production so other factors not related to irrigation water supply are excluded from the social welfare effects.

Appraisers generally refer to land values based on the land's income producing capability as "value in use" rather than a market value (American Society of Farm Managers and Rural Appraisers, 2000). This guidance is supported in the discipline and is documented in the Commodity Cost and Returns Handbook (American Agricultural Economics Association, 2000) which was written to provide uniform best practices for university farm budget analyses.

Farmland market values, which are generally based on sales data, are often greater than the value in use due to the expectation or potential for the land to be used for non-agricultural purposes either currently or at some point in the future (American Agricultural Economics Association, 2000). Therefore, the social welfare effects may be overstated if market values are used without making adjustments to remove potential values associated with non-agricultural influences.

Young and Loomis (2014) describe the comprehensive treatment of the methods employed to value water used in irrigated crop production including the 'land value method'. Young and Loomis (2014) caution that when using this approach that

> "if any of the market value is attributable to potential real appreciation from nonagricultural (residential, industrial, or recreational) demands for the land, this factor should be accounted for by deducting the premium attributable to potential nonagricultural demand from the imputed irrigation gains. Because of the difficulty in estimating such a premium without formal econometric techniques, the land value method must be used with caution whenever this factor is judged to be significant."

The market value of land often differs from the agricultural use value and includes premiums unrelated to irrigation water. The differences may occur when market values are influenced by non-agricultural activities such as urban development. Because of these differences extensive data collection and rigorous statistical modeling is often required to estimate the economic value of irrigation water using the market land values.

Without statistical modeling to isolate the various factors, such as the value of farm production, from USDA published farmland values may not correctly reflect the social welfare effect of irrigation water supply. It's also not clear if the USDA values include the value of irrigation systems or permanent plantings. The USDA data are available on a statewide level so these data do not reflect local conditions. Farmland values are greatly influenced by soil types and other local conditions.

Greenbelt laws encourage the retention of farmland by limiting property taxes to the land's agricultural use value rather than the market value which may include a speculative component. In Washington State assessors follow the requirements set out in the Open Space Taxation Act enacted in 1970 when determining the land values for taxation purposes. In this act it stipulates that agricultural land must be valued based on "current use" rather than at their "highest and best use." As described in the Washington State Department of Revenue's manual entitled "Current Use and Designated Forestland Administration (Washington Department of Revenue, 2018), the assessed value of agricultural land is determined using an income approach based on the earning or productivity of the land. A net cash rental or lease is the preferred method for estimating the earning or productive capacity of the land. Therefore, the productive capacity measure is equivalent to a land value analysis as defined in the P&Gs.

Almost 80 percent of the lands in the study are in Walla Walla, County. The Walla Walla County assessor's office maintains an extensive public dataset related to assessed values along with GIS mapping. Based on these available data and the location of the lands Walla Walla county assessor data was considered representative for the area.

The analysis used two datasets to estimate the benefit values. The first estimate relied on Walla Walla County assessor estimates of current use values (based on cash rental rates) for Class 1 land. The second estimate used USDA farmland value survey estimates for Washington.

The approach to estimate a per acre benefit value involved two steps. First the difference between land value with irrigated land and without irrigated was determined. Second the per acre value was converted to annual equivalent value.

The productive value of land varies depending upon quality and location. Land parcels are classified based on quality and productivity. This analysis used Class 1 lands for estimating the productive use of irrigated land (with condition) and dryland pasture use values (without condition).

The County of Walla Walla assessor's office provided the estimates used to derive their land values. These estimates were based on a current use value based on a 10-year average. The county estimates assumed a 40 percent owner's share of income and expenses. This analysis estimates NED benefits by adjusting the data to reflect a 100 percent owner's share to account for 100 percent of the revenues and expenses attributed to the land. The County of Walla Walla assumed a 0.0379 percent capitalization factor to adjust the current use value. These calculations are shown in Table 4-1.

Table 4-1. Irrigated Land Value Using Assessor Data

Assessor Data Category	Irrigated Land Value
Owner's share of Income (100%)	$575.00
Depreciation of equipment	$123.94
Owner's share of the Expenses (100%)	$123.94
Estimated net Income attributable to the land	$327.13
Net Income/state cap. rate (0.0379%)	$8,631.39
Plus Irrigation System value (depreciated)	$702.00
Current Use Value	$9,333
Annualized value	$353.74

Note the estimated per acre cash rental rate for dryland pasture based on the Walla Walla assessor data was less than $2 per acre, therefore this analysis assumed zero dollars per acre for dryland. Also, the USDA[15] farm land values were $7,690 and $766 per acre for irrigated and dryland respectively. These values were assumed to be present value numbers and were therefore annualized assuming 50-year project life and 2.75 percent discount rate.

The social welfare effect or economic value for irrigation water (per acre) is the difference between the Class 1 value less the dryland value in 2019 dollars ($353.74/acre). The per acre value was multiplied by the total number of acres (47,926 acres) under the No Action conditions. The present value of this annual amount was discounted over the 50-year period using the discount rate of 2.75 (2020 Federal planning rate). The present value equals $458,099,362 (annual equivalent value is $16,953,343). By contrast using the USDA farmland values the present value equals $331,770,447 (annual equivalent value is $12,278,162). These calculations are shown in Table 4-3.

Table 4-2. Benefit Values Assuming a Dryland Pasture is the Without Condition

Data Source	Price Level	With Condition (irrigated crops)	Without Condition (dryland pasture)	Benefit Value (With minus Without)
Assessor data	2019	$353.74/acre	$0.00/acre	$353.74/acre
USDA farmland data	2019	$284.53/acre	$28.34/acre	$256.19/acre

Table 4-3. Irrigation Water Supply Social Welfare Effects Under the No Action Conditions

Data Source	Irrigated Crops (acres)	Price Level	Benefit Value per Acre	Total Benefit Value Annual Equivalent	Total Benefit Value Present Value
Assessor data	47,926	2019	$353.74	$16,953,343	$458,099,362
USDA data	47,926	2019	$256.19	$12,278,162	$331,770,447

SOCIAL WELFARE EFFECTS – MUNICIPAL AND INDUSTRIAL

In Region C, approximately 21,330 acre-feet of M&I water diversions were estimated in the physical water supply affected environment section of this EIS. Two approaches were used to

[15] USDA, National Agricultural Statistics Service, Census of Agriculture.

estimate the social welfare effects of the M&I water supply, the use of water market transaction data and the cost of an alternative water source that would provide the water supply. Generally, the M&I benefits are measured based on the willingness to pay or the dollar amount that an entity is willing to pay to obtain an acre foot water.

First the observed market transaction values were analyzed to derive the value of the M&I water supply. The observed data were obtained from the Water Transfer Data Base presented by the Bren School. This dataset relied on observation from various issues of the Water Strategist publication. The dataset includes water trades involving agriculture, urban, recreational, and environmental uses between 1987 and 2009. Water trades for urban use in Washington and Idaho were used. While the dataset was limited in the number of observations it was used to show a comparison to the social welfare affects estimated using construction cost estimates for pump station and private well modifications.

A second approach for estimating the M&I benefits was based on an approach described in the P&Gs involving using the cost of the most likely alternative. In other words, using the cost of the water supply alternative that would be implemented in the absence of the project as an estimate of benefits. This approach is acceptable only if the alternative is viable in terms of engineering feasibility and financial feasibility. For this approach the estimated cost of pump modifications, found in the 2002 Corps report, were utilized.

The effects were estimated as the increment between the No Action and the Action conditions, therefore pumping costs were not estimated under the No Action condition.

4.1.1.4 Region D – McNary, John Day, The Dalles, Bonneville

The effects were estimated as the increment between the No Action and the Action conditions, therefore pumping costs were not estimated under the No Action condition.

4.1.2 Multiple Objective Alternative 1

MO1 did not affect the ability to deliver water in Regions A, C, or D therefore there were not estimated changes as compared to No-Action.

4.1.2.1 Region B – Grand Coulee, Chief Joseph

SOCIAL WELFARE EFFECTS - IRRIGATION

This analysis assumes that the currently irrigated lands would remain in production. This level of production would require increased pumping costs. Due to the drawdown, pump efficiencies would change, requiring more energy to pump the same quantity of water to the irrigated lands. The analysis assumes an increase to pumping costs of $7,000 annually.

The annual pumping costs, which represent the additional pumping cost over the No Action Alternative, were discounted over the 50-year period of record using the 2020 Federal planning

rate (2.75 percent). The annual equivalent value equals $7,000 ($189,000). This value represents a decrease in net farm income across the region under MO1.

4.1.3 Multiple Objective Alternative 2

MO2 did not affect the ability to deliver water in Regions A, C, or D therefore there were not estimated changes as compared to No-Action.

4.1.3.1 Region B – Grand Coulee, Chief Joseph

SOCIAL WELFARE EFFECTS - IRRIGATION

This analysis assumes that the currently irrigated lands would remain in production. This level of production would require increased pumping costs. Due to the drawdown, pump efficiencies would change, requiring more energy to pump the same quantity of water to the irrigated lands. The analysis assumes an increase to pumping costs of $10,000 annually.

The annual pumping costs, which represent the additional pumping cost over the No Action Alternative, were discounted over the 50-year period of record using the 2020 Federal planning rate (2.75 percent). The annual equivalent value equals $10,000 ($270,000). This value represents a decrease in net farm income across the region under MO2.

4.1.4 Multiple Objective Alternative 3

MO3 did not affect the ability to deliver water in Regions A or D therefore there were not estimated changes as compared to No-Action.

4.1.4.1 Region B – Grand Coulee, Chief Joseph

SOCIAL WELFARE EFFECTS IRRIGATION

This analysis assumes that the currently irrigated lands would remain in production. This level of production would require increased pumping costs. Due to the drawdown, pump efficiencies would change, requiring more energy to pump the same quantity of water to the irrigated lands. The analysis assumes an increase to pumping costs of $3,000 annually.

The annual pumping costs, which represent the additional pumping cost over the No Action Alternative, were discounted over the 50-year period of record using the 2020 Federal planning rate (2.75 percent). The annual equivalent value equals $3,000 ($81,000). This value represents a decrease in net farm income across the region under MO3.

4.1.4.2 Region C - Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor

SOCIAL WELFARE EFFECTS - IRRIGATION

Assuming the entire 47,926 acres were no longer irrigated, the present value of the lost social welfare benefit under MO3 is $458,099,362 (annual equivalent value is $16,953,343). This calculation is described in the No Action alternative section. By contrast using the USDA farmland values the present value of the lost social welfare benefit equals 331,770,447 (annual equivalent value is $12,278,162). These estimates are in 2019 dollars.

SOCIAL WELFARE EFFECTS – MUNICIPAL AND INDUSTRIAL

The M&I social welfare effects were first estimated using observed market data. Urban water use transfers were taken from the Water Transfer database, these observations are shown in Table 4-4. These values were indexed to 2019 dollars using the Consumer Price Index.

Table 4-4. Urban (M&I water supply) Transfers in Various Years for Washington and Idaho

Year	State	Average Annual Water Transfer (acre-feet)	Total Price	Price per acre-foot	Consumer Price Index	Indexed (2019 dollars) $/acre-foot
1993	ID	39	$273	$7.00	1.761146	12.33
1998	ID	3000	$1,575,000	$525.00	1.560731	819.38
1999	ID	3000	$19,500	$6.50	1.477423	9.6
1999	ID	300	$15,000	$50.00	1.527313	76.37
2001	WA	2597	$101,263	$38.99	1.436816	56.02
2002	WA	137	$5,343	$39.00	1.414383	55.16
2004	WA	920	$236,860	$257.46	1.346928	346.78
1992	WA	2000	$340,000	$170.00	1.813129	308.23
1995	WA	4592.58	$1,082,380	$235.68	1.669554	393.48
2004	WA	63.45	$31,725	$500.00	1.346928	673.46
2005	WA	1.5	$834	$556.00	1.302729	724.32

Source: Obtained from https://www.bren.ucsb.edu/news/water_transfers.htm

As shown in Table 4-5, a weighted average M&I per acre water value was derived. The M&I water values were weighted using the estimated surface water and groundwater M&I diversions discussed in the physical water supply affected environment section of this EIS.

Table 4-5. Weighted Average Per Acre-Foot M&I Value

State	Estimated M&I diversions (acre-feet)	Percent	State Average Value ($/acre-foot)	Weighted Average Value ($/acre-foot)
WA	7,030	33%	$365.35	$120.41
ID	14,300	67%	$229.42	$153.81
Total	**21,330**		**–**	**$274.22**

The physical water supply analysis estimated that 21,330 acre-feet of water is diverted for M&I purposes. The social welfare effect (annual equivalent) is estimated as $5,849,112 ($274.22 per acre multiplied by 21,330 acre-feet).

The second approach to value the social welfare effects of the M&I water supply relied upon the estimated costs of pump and well modifications taken from the 2002 Corps report. This analysis assumes that these modifications were found feasible in terms of engineering and financing. These costs were estimated in 1998 dollars and indexed to 2019 using Reclamation's construction cost trends for pumping plants. A summary of these costs are shown in Table 4-6.

Table 4-6. Summary of M&I Water Supply Modification Construction Costs

Supply	Low	High
Original Costs (1998 dollars)		
M&I pump stations	$11,514,000	$55,214,000
Private wells	$67,042,000	$67,042,000
Total	$78,556,000	$122,256,000
Indexed (2019 dollars)		
M&I pump stations	$19,368,613	$92,879,850
Private wells	$112,776,667	$112,776,667
Total	$132,145,280	$205,656,518
Annualized Value (2.075% discount rate and 50-year period of analysis)	$4,894,782.68 ($2,229.10 per acre-foot)	$7,617,706.53 ($357.14 per acre-foot)

To estimate the social welfare effects the cost estimates were annualized assuming a 50-year period of analysis and a 2.075 percent discount rate (2020 Federal planning rate). As shown in Table 4-6, the annualized social welfare effects range from $4,894,782.38 and $7617,706.53. On a per acre foot basis the social welfare effects range from $2,229.48 and $357.14.

It should be recognized that the physical quantities of water are based on the water right. This may lead to an overestimated of the actual water used. The estimates of social welfare effects of M&I water may be overstated.

4.1.5 Multiple Objective Alternative 4

MO4 did not affect the ability to deliver water in Regions A or C therefore there were not estimated changes as compared to No-Action.

4.1.5.1 Region B – Grand Coulee, Chief Joseph

SOCIAL WELFARE EFFECTS - IRRIGATION

This analysis assumes that the currently irrigated lands would remain in production. This level of production would require increased pumping costs. Due to the drawdown, pump efficiencies would change, requiring more energy to pump the same quantity of water to the irrigated lands. The analysis assumes an increase to pumping costs of $72,000 annually.

The annual pumping costs, which represent the additional pumping cost over the No Action Alternative, were discounted over the 50-year period of record using the 2020 Federal planning rate (2.75 percent). The annual equivalent value equals $72,000 ($1,945,500). This value represents a decrease in net farm income across the region under MO4.

4.1.5.2 Region D – McNary, John Day, The Dalles, Bonneville

SOCIAL WELFARE EFFECT - IRRIGATION

This analysis assumes that the currently irrigated lands (approximately 212,225 acres) would remain in production. This level of production will require increased pumping costs. Due to the drawdown, pump efficiencies were assumed to change which required more energy to pump the same quantity of water to the irrigated lands.

The additional power requirement was estimated based on a sample of pumps as described in [reference}. Available pump information and use rates were used to the estimate energy requirement to maintain the operability post drawdown.

The cost of the additional power requirement was valued using power prices for pumping which were obtained from the Power and Transmission analyses. These prices are forecasted by county for a 20-year period under the MO4 conditions (shown in Table 4-7 and Table 4-8). A weighted average pumping rate for each state (Washington and Oregon) was estimated using the estimated acres for each county (Table 4-9). Table 4-5 shows these weights.

Table 4-7. Estimated Pumping Rates for Washington Counties Under MO4

County	Klickitat, WA	Benton, WA	Weighted WA State Price	Klickitat, WA	Benton, WA	Weighted WA State Price
	Min	Min	Min	Max	Max	Max
Year	$/kilowatt-hour (2019 dollars)					
1	0.0661	0.0594	0.0601	0.0707	0.0636	0.0644
2	0.066	0.0591	0.0598	0.070	0.0633	0.0641
3	0.065	0.0588	0.0595	0.070	0.0630	0.0638
4	0.065	0.0585	0.0592	0.069	0.0627	0.0634
5	0.064	0.0582	0.0589	0.069	0.0624	0.0631
6	0.064	0.0579	0.0586	0.069	0.0621	0.0628
7	0.064	0.0576	0.0583	0.068	0.0618	0.0625
8	0.063	0.0572	0.0579	0.068	0.0614	0.0621
9	0.063	0.0568	0.0575	0.067	0.0610	0.0617
10	0.062	0.0564	0.0571	0.067	0.0606	0.0612
11	0.062	0.0561	0.0567	0.066	0.0601	0.0608
12	0.062	0.0557	0.0563	0.066	0.0597	0.0604
13	0.061	0.0553	0.0559	0.065	0.0593	0.0600
14	0.061	0.0549	0.0556	0.065	0.0589	0.0596
15	0.060	0.0545	0.0552	0.064	0.0585	0.0592
16	0.060	0.0542	0.0548	0.064	0.0581	0.0588

County	Klickitat, WA	Benton, WA	Weighted WA State Price	Klickitat, WA	Benton, WA	Weighted WA State Price
	Min	Min	Min	Max	Max	Max
Year	$/kilowatt-hour (2019 dollars)					
17	0.059	0.0538	0.0544	0.064	0.0577	0.0584
18	0.059	0.0534	0.0540	0.063	0.0573	0.0580
19	0.059	0.0531	0.0537	0.063	0.0569	0.0576
20	0.058	0.0527	0.0533	0.062	0.0565	0.0572
Annual Rate of Change			-0.63%	Annual Rate of Change		-0.62%

1076 **Table 4-8. Estimated Pumping Rates for Oregon Counties Under MO4**

County	Morrow, OR	Umatilla, OR	Weighted OR State Price	Morrow, OR	Umatilla, OR	Weighted OR State Price
	Min	Min	Min	Max	Max	Max
Year	$/kilowatt-hour (2019 dollars)					
1	0.0598	0.0685	0.0648	0.0637	0.0710	0.0679
2	0.0594	0.0681	0.0644	0.0634	0.0706	0.0675
3	0.0590	0.0677	0.0640	0.0630	0.0702	0.0671
4	0.0587	0.0674	0.0637	0.0626	0.0698	0.0667
5	0.0583	0.0670	0.0633	0.0622	0.0694	0.0663
6	0.0579	0.0666	0.0629	0.0618	0.0690	0.0659
7	0.0576	0.0662	0.0625	0.0614	0.0686	0.0655
8	0.0572	0.0657	0.0621	0.0610	0.0681	0.0651
9	0.0568	0.0653	0.0617	0.0606	0.0676	0.0647
10	0.0564	0.0648	0.0613	0.0602	0.0672	0.0642
11	0.0560	0.0644	0.0608	0.0598	0.0667	0.0638
12	0.0556	0.0639	0.0604	0.0594	0.0663	0.0633
13	0.0553	0.0635	0.0600	0.0590	0.0658	0.0629
14	0.0549	0.0631	0.0596	0.0586	0.0654	0.0625
15	0.0545	0.0626	0.0592	0.0582	0.0649	0.0620
16	0.0541	0.0622	0.0588	0.0578	0.0645	0.0616
17	0.0538	0.0618	0.0584	0.0574	0.0640	0.0612
18	0.0534	0.0614	0.0580	0.0570	0.0636	0.0608
19	0.0530	0.0609	0.0576	0.0566	0.0631	0.0604
20	0.0527	0.0605	0.0572	0.0562	0.0627	0.0599
	Annual Rate of Change		-0.65%	Annual Rate of Change		-0.66%

1077 **Table 4-9. Average Acres by County**

County, State	Acres	Percent
Klickitat, WA	13,561	11.05%
Benton, WA	109,144	88.95%
WA Total	122,705	100.00%
Morrow, OR	38,010	42.46%
Umatilla, OR	51,509	57.54%
OR State Total	89,519	100.00%

A range of pumping rates (minimum and maximum estimates) were used to calculate the initial pumping cost or the pumping cost for the first year of the 50-year period of analysis. The average rate of change was calculated for the pumping rates provided by the Power and Transmission analysis. This rate of change was applied to the initial pumping cost estimate to estimate the additional pumping costs over the 20-year period, as shown in Table 4-10. To accommodate a 50-year period of analysis the forecasted prices were extended to 50 years. The pumping costs beyond the 20-year period were held constant at the year 20 estimate to the end of the 50-year period of analysis.

Table 4-10. Estimated Power Rate and Additional Pumping Costs for Year 1, and Average Annual Rate Increase of the 20-year Period

	WA		OR	
Rate	**Min**	**Max**	**Min**	**Max**
Year 1 Power rate estimate	$0.06010	$0.06440	$0.06480	$0.06790
Year 1 Total additional Cost	$80,151	$90,553	$201,645	$211,291
Average Annual Rate increase	-0.6300%	-0.6200%	-0.6500%	-0.6600%

The annual pumping costs which represent the additional pumping cost over the No Action alternative were discounted over the 50-year period of record using the 2020 Federal planning rate (2.75 percent). The present values are shown in Table 4-11 along with the annual equivalent and the estimated per acre increase. These values represent a decrease in net farm income across the region under MO4. The change in social welfare is equal to these estimated differences in pumping costs between the alternatives across the 50-year period of analysis.

Table 4-11. Estimated Social Welfare Effects Under MO4

Value	Total (WA and OR)	Acres	$/acre
Min Present Value	$7,014,604.52	–	–
Min Annual Equivalent	$259,827.70	212,226	$1.23
Max Present Value	$7,496,225.31	–	–
Max Annual Equivalent	$277,667.08	212,226	$1.31

SOCIAL WELFARE EFFECTS - MUNICIPAL AND INDUSTRIAL

The physical effects to M&I were not estimated under the MO4 conditions.

4.1.6 Preferred Alternative

4.1.6.1 Region A – Libby, Hungry Horse, Albeni Falls

Preferred Alternative did not affect the ability to deliver water therefore there were not estimated changes as compared to No-Action.

4.1.6.2 Region B – Grand Coulee, Chief Joseph

Effects to Lake Roosevelt pool elevation could result increased pumping costs.

SOCIAL WELFARE EFFECTS - IRRIGATION

This analysis assumes that the currently irrigated lands would remain in production. This level of production would require increased pumping costs. Due to the drawdown, pump efficiencies would change, requiring more energy to pump the same quantity of water to the irrigated lands. The analysis assumes an increase to pumping costs of $1,000 annually.

The annual pumping costs, which represent the additional pumping cost over the No Action Alternative, were discounted over the 50-year period of record using the 2020 Federal planning rate (2.75 percent). The annual equivalent value equals $1,000 ($27,000). This value represents a decrease in net farm income across the region under the Preferred Alternative. This is considered a negligible effect as compared to No Action.

4.1.6.3 Region C - Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor

Preferred Alternative did not affect the ability to deliver water therefore there were not estimated changes as compared to No-Action.

4.1.6.4 Region D – McNary, John Day, The Dalles, Bonneville

Preferred Alternative did not affect the ability to deliver water therefore there were not estimated changes as compared to No-Action.

4.2 REGIONAL ECONOMIC IMPACTS

The results of the social welfare analysis and the regional impact analysis are not directly comparable because they do not measure the same effects. The regional economic effects are a measure of regional activity as a result of the action. Regional economic effects are distinctly different than then the social welfare effects which measure economic benefits from a national perspective.

4.2.1 No Action Alternative

4.2.1.1 Region A – Libby, Hungry Horse, Albeni Falls

Water supply effects related to socioeconomics are not expected in this area.

4.2.1.2 Region B – Grand Coulee, Chief Joseph

The effects for the Multiple Objective alternatives conditions were estimated as the increment between the No Action Alternative and the Multiple Objective alternatives conditions. Therefore effects were not estimated for the No Action Alternative.

4.2.1.3 Region C - Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor

REGIONAL ECONOMIC IMPACTS - IRRIGATION

The regional impact analysis estimated impacts in two separate analysis areas within Region C. The Ice Harbor and Lower Monumental socioeconomic region included the following counties located in Washington State; Columbia County, Franklin County, and Walla Walla County. The Lower Granite and Little Goose socioeconomic region included Nez Perce County in Idaho and Asotin, Garfield, and Whitman counties in Washington.

The available water rights place of use and point of diversion data was used to identify the lands that receive water from these reaches as discussed in the affected environment section of this EIS. In this analysis the changes in gross value of agriculture production based on potential changes to cropping patterns or the additional cost required to continue using the existing pumps to maintain baseline acres and cropping patterns were estimated based on the physical water assumptions. These potential regional effects were inputs to the IMPLAN model.

Data was not available to estimate the gross value for all the crops grown in the regions. If certain crops are grown only on a small percentage of total acres, they can be represented by a more extensively grown crop in the same general category of crops (i.e., hay, small grains, orchard, vegetables, etc.). Crop aggregation is the process by which the crops grown in the study area are grouped into representative crops. The aggregation is based on the availability of data on crop acres, prices, and yields. The representative crops chosen for the Ice Harbor and Lower Monumental region were alfalfa, winter wheat, corn, potatoes, apples, and wine grapes.

In the Lower Granite and Little Goose region alfalfa and wheat are the primary crops. Less than 90 acres were identified as receiving deliveries and therefore potentially impacted by the alternatives.

The CDLs were used to determine the number of acres for each crop. Table 4-12 shows these crops and the representative crop modeled for each socioeconomic area.

Table 4-12. Crops and Representative Crop Modeled for Each Socioeconomic Area in Region C

Crop		Socioeconomic Area		
		Ice Harbor and Lower Monumental		Lower Granite and Little Goose
Crop Category	**Crop**	**Acres**	**Percent of Category**	**Acres**
Hay	–	2,134	–	46
	Alfalfa	1,889	88.52%	25
	Other Hay	245	11.48%	21
Small Grains	–	14,761	–	32
	Winter Wheat	9,747	66.03%	–
	Corn	4,014	27.19%	–
	Spring Wheat	–	–	–
	All Other	1,000	6.77%	–

Crop		Socioeconomic Area		
		Ice Harbor and Lower Monumental		Lower Granite and Little Goose
Crop Category	**Crop**	**Acres**	**Percent of Category**	**Acres**
Irrigated Vegetables	–	12,131	–	7
	Potatoes	8,238	67.91%	–
	Sweet Corn	1,785	14.71%	–
	All Other	2,108	17.38%	–
Fruit Crops	–	15,801	–	0
	Apples	11,454	72.49%	–
	Other Tree Crops	3,734	23.63%	–
	All Other	613	3.88%	–
Grapes	*Grapes*	3,013	100.00%	0
Total		**47,840**	**–**	**86**

Source: USDA CDL, 2013–2017.

The crop yields, shown in Table 4-13, were obtained from USDA National Agricultural Statistics Service (NASS) and the USDA Farm and Ranch Survey. In the Ice Harbor and Lower Monumental socioeconomic region alfalfa yields for Walla Walla county were used to derive an average yield (2013-2017) to represent the area. Walla Walla county was used because the majority alfalfa is grown in Walla Walla county and data was not available for the other counties. In this region average yields for potatoes, apples, and grapes were derived using Washington state yields because county level data were not published for these crops. The irrigated winter wheat and corn yields were taken from the Farm and Ranch Survey (2008 and 2013) because irrigated yields are not collected on an annual basis by NASS.

Published yields were not available for the Lower Granite and Little Goose socioeconomic region.

Table 4-13. Crop Yields for Ice Harbor and Lower Monumental Socioeconomic Area

Year	Alfalfa[1] (tons)	Winter Wheat[3] (Bu)	Corn[3] (Bu)	Pototoes[2] (cwt)	Apples[2] (lbs)	Grapes[2] (tons)
2008	–	94	185	–	–	–
2013	7.60	111	209	600	38,600	4.67
2014	6.00	–	–	615	48,400	4.73
2015	7.35	–	–	590	36,800	4.53
2016	6.20	–	–	625	44,400	5.19
2017	7.30	–	–	605	45,500	4.32
Average	**6.89**	**102.5**	**197**	**607**	**42,740**	**4.69**

Sources:
1 Walla Walla county (USDA NASS, Quick Stats Database)
2 Washington State (USDA NASS, Quick Stats Database.)
3 Washington state irrigated winter wheat yield (Farm and Ranch Survey, 2013 and 2008)
bu = bushel; cwt = hundredweight (equal to 100 pounds); lb = pound

State prices were obtained from USDA NASS for each representative crop as shown in Table 4-14. Because county level prices are not published state level prices were used in this analysis.

Table 4-14. Crop Prices for Washington State

Crop	Unit	2013	2014	2015	2016	2017	2013–2017 Average
Hay, Alfalfa	$/ton	200	213	171	135	157	**175.20**
Wheat, Winter	$/bu	6.87	6.42	5.31	4.1	4.72	**5.48**
Corn	$/bu	5.29	4.9	4.3	4.7	4.05	**4.56**
Potatoes	$/cwt	8.25	7.6	7.7	7.7	6.92	**7.63**
Apples	$/lb	0.362	0.268	0.394	0.341	0.338	**0.341**
Grapes	$/ton	1,110	1,110	1,150	1,160	1,210	**1,148**

Data source: USDA NASS, Quick Stats Database.
bu = bushel; cwt = hundredweight (equal to 100 pounds); lb = pound

Results – Ice Harbor and Lower Monumental

The gross value of production was calculated for each representative crop and was run through IMPLAN to estimate the regional impacts for the alternative. The regional impacts include estimated employment, labor income, and output (sales) stemming from the gross value of production. Table 4-15 shows the estimated gross value of production for the crops grown in the Ice Harbor and Lower Monumental socioeconomic region and the corresponding IMPLAN region.

The No Action Alternative would result in approximately 4,800 jobs (full time and part time jobs) within the Ice Harbor and Lower Monumental study area as shown in Table 4-16. These jobs are the result of gross farm income generated from crop production on approximately 47,840 acres of farmland. Labor income resulting from the implementation of the No Action Alternative would equal $232,000,000. Output would equal $460,500,000.

Table 4-15. Irrigated Cropping Pattern, Estimated Gross Farm Income, and Associated IMPLAN Sector for Ice Harbor and Lower Monumental Socioeconomic Area–No Action Alternative

Representative Crops	Acres	Yield	Price	Gross Value	IMPLAN Sector
Irrigated Alfalfa	2,134	6.89 tons	$201.20/ton	$2,958,223	All other crops
Irrigated Winter Wheat	10,747	102.5 bu	$5.48/bu	$6,041,015	Grain farming
Corn	4,014	197 bu	$4.65/by	$3,677,383	Grain farming
Potatoes	12,131	607 cwt	$7.63/cwt	$56,213,352	All other crops
Apples	15,801	42740 lbs	$0.34/lb	$230,013,500	Fruit farming
Grapes	3,013	4.688 tons	$1,148.00/ton	$16,212,745	All other crops
Total	47,840	–	–	$315,116,219	–

bu = bushel; cwt = hundredweight (equal to 100 pounds); lb = pound

Table 4-16. Estimated Regional Impacts for Ice Harbor and Lower Monumental Socioeconomic Area–No Action Alternative

Impact Type	Employment	Labor Income	Output
Direct Effect	3,278	170,366,904	315,116,219
Indirect Effect	871	34,601,086	58,189,100
Induced Effect	673	26,923,088	87,216,323
Total Effect	4,822	231,891,079	460,521,642

SUBREGION - LOWER GRANITE AND LITTLE GOOSE

Effects in this region were not modeled due to the small number of acres, (less than 90 acres) that were shown to be impacted. This small number of acres would have a positive effect to employment, labor income, and output (sales) however it is too small to measure using IMPLAN.

REGIONAL ECONOMIC IMPACTS - MUNICIPAL AND INDUSTRIAL

The effects were estimated as the increment between the No Action and the Action conditions, therefore pumping costs were not estimated under the No Action condition

4.2.1.4 Region D – McNary, John Day, The Dalles, Bonneville

REGIONAL ECONOMIC IMPACTS

The physical effects to M&I were not shown in this region.

4.2.2 Multiple Objective Alternative 1

MO1 did not affect the ability to deliver water in Regions A, C, or D therefore there were not estimated changes as compared to No-Action.

4.2.2.1 Region B – Grand Coulee, Chief Joseph

Increased pumping costs would result in lower net farm income across the region, which translates to farm households having less money to spend within the regional economy. IMPLAN was used to estimate the regional effects (employment, labor income, and output) resulting from less money being spent within the study area by farm households. The increased pumping cost was modeled in IMPLAN as a household income change. The lost employment, labor income, and output would result from an increase in pumping costs that is expected to range from $7,000 (annual equivalent), as described in Section 4.1 Social Welfare Analysis above. The average annual employment impact was estimated to be a decrease in employment (less than one job), labor income ($1,000), and output or sales ($3,700). These losses are the result of less household spending within the region because income was assumed to decrease as a result of increased pumping costs.

4.2.3 Multiple Objective Alternative 2

MO2 did not affect the ability to deliver water in Regions A, C, or D therefore there were not estimated changes as compared to No-Action.

4.2.3.1 Region B – Grand Coulee, Chief Joseph

REGIONAL ECONOMIC EFFECTS ANALYSIS

Increased pumping costs would result in lower net farm income across the region, which translates to farm households having less money to spend within the regional economy. IMPLAN was used to estimate the regional effects (employment, labor income, and output) resulting from less money being spent within the study area by farm households. The increased pumping cost was modeled in IMPLAN as a household income change. The lost employment, labor income, and output would result from an increase in pumping costs that is expected to range from $10,000 (annual equivalent), as described in Section 4.1 Social Welfare Analysis above. The average annual employment impact was estimated to be a decrease in employment (less than one job), labor income ($1,500), and output or sales ($5,000). These losses are the result of less household spending within the region because income was assumed to decrease as a result of increased pumping costs.

4.2.4 Multiple Objective Alternative 3

MO3 did not affect the ability to deliver water in Regions A or D therefore there were not estimated changes as compared to No-Action.

4.2.4.1 Region B – Grand Coulee, Chief Joseph

REGIONAL ECONOMIC EFFECTS ANALYSIS

Increased pumping costs would result in lower net farm income across the region, which translates to farm households having less money to spend within the regional economy. IMPLAN was used to estimate the regional effects (employment, labor income, and output) resulting from less money being spent within the study area by farm households. The increased pumping cost was modeled in IMPLAN as a household income change. The lost employment, labor income, and output would result from an increase in pumping costs that is expected to range from $3,000 (annual equivalent), as described in Section 4.1 Social Welfare Analysis above. The average annual employment impact was estimated to be a decrease in employment (less than one job), labor income ($500), and output or sales ($1,500). These losses are the result of less household spending within the region because income was assumed to decrease as a result of increased pumping costs.

4.2.4.2 Region C - Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor

REGIONAL ECONOMIC IMPACTS - IRRIGATION

The 2002 Corps report analyzed dam removal and the impact on water supply. This analysis considered several system modifications that would allow for the continuation of water deliveries to existing farmlands. The report concluded that modifying the existing pump system was cost prohibitive. For the regional analysis the report assumed that most of the irrigated acres receiving water from the current pumps would no longer be irrigated. The report assumed that 21 percent of the irrigated land might support the development of alternative water supplies to replace lost irrigation water. According to the report the replacement water would be used to irrigate some of the fruit orchards and vineyards.

This analysis assumed that all irrigated acres receiving water from the current pumps would no longer be irrigated. This assumption was based on conversations with several extension agents in Washington and Oregon. The analysis assumed that there isn't a suitable substitute water source and the annual rainfall would not support a dryland crop rotation such as a wheat/fallow operation. There was also concern that soil acidity may impact a dryland wheat/fallow operation on lands that were previously supporting fruit orchards and vineyards. A decrease in agricultural production would result in less local expenditures related to farm inputs, wages, and household income.

Results - Ice Harbor and Lower Monumental

Assuming the entire 47,840 acres were no longer irrigated gross value of production would decline by approximately $313,695,365 as described in the No Action alternative.

Decreased production would result in the loss of employment, labor income, and output (sales) in the region equal to what was estimated under the No Action alternative. Approximately 4,800 jobs (full time and part time jobs) within the Ice Harbor and Lower Monumental were estimated be lost. The implementation of MO3 would decrease labor income by $232,000,000. Output would decline by $460,000,000.

Results - Lower Granite and Little Goose

Assuming the entire 90 acres, shown in the No Action alternative, was no longer irrigated gross value of production would decline. Published yields and prices were not available in this area to measure the gross value of production.

A decrease in agricultural production on these 90 acres would result in the loss of employment, labor income, and output (sales). These losses were too small to quantify.

REGIONAL ECONOMIC IMPACTS – MUNICIPAL AND INDUSTRIAL

The physical water supply analysis estimated that 21,330 acre-feet of water is diverted for M&I purposes. These impacts were estimated to occur in the Lower Granite and Little Goose region.

The social welfare effect (annual equivalent) is estimated as $5,849,112 ($274.22 per acre multiplied by 21,330 acre-feet). This value was estimated based on the wholesale price of M&I water therefore it was modeled in IMPLAN as a loss in household income change. This decrease in household income has a negative impact on the regional economy in terms of jobs, labor income, and output (sales). These impacts were estimated as a loss of 55 jobs, $2,261,000 of labor income, and $7,518,000 of output (sales) annually.

4.2.5 Multiple Objective Alternative 4

MO4 did not affect the ability to deliver water in Regions A or C therefore there were not estimated changes as compared to No-Action.

4.2.5.1 Region B – Grand Coulee, Chief Joseph

REGIONAL ECONOMIC EFFECTS ANALYSIS

Increased pumping costs would result in lower net farm income across the region, which translates to farm households having less money to spend within the regional economy. IMPLAN was used to estimate the regional effects (employment, labor income, and output) resulting from less money being spent within the study area by farm households. The increased pumping cost was modeled in IMPLAN as a household income change. The lost employment, labor income, and output would result from an increase in pumping costs that is expected to range from $72,000 (annual equivalent), as described in Section 4.1 Social Welfare Analysis above. The average annual employment impact was estimated to be a decrease in employment (less than one job), labor income ($11,000), and output or sales ($38,000). These losses are the result of less household spending within the region because income was assumed to decrease as a result of increased pumping costs.

4.2.5.2 Region D – McNary, John Day, The Dalles, Bonneville

REGIONAL ECONOMIC IMPACTS - IRRIGATION

This analysis assumes that the currently irrigated lands would remain in production however due to changes in pumping efficiencies, as a result of the drawdown, increased pumping costs were required to maintain irrigation needs. This additional power requirement results in additional estimated annual energy costs ranging from $260,000-277,000 (annual equivalent) for the entire study area as described in Section 4.1 Social Welfare Analysis above. In this analysis the additional cost required to continue using the existing pumps to maintain baseline acres and cropping patterns were inputs to the IMPLAN model.

Increased pumping costs would result in lower net farm income across the region which translates to farm households having less money to spend within the regional economy.

IMPLAN was used to estimate the regional impacts (employment, labor income, and output) resulting from less money being spent within the study area by farm households. The increased pumping cost was modeled in IMPLAN as a household income change.

Table 4-17 shows the lost employment, labor income, and output resulting from an increase in pumping costs ranging from $260,000 to $277,860 (annual equivalent) as described in Section 4.1 Social Welfare Analysis above. The average annual employment impact was estimated to be a decrease in employment (less than 5 jobs), labor income ($55,000-$59,000), and output ($176,000-$188,000). These losses are the result of less household spending within the region because income was assumed to decrease as a result of increased pumping costs.

Table 4-17. Estimated Regional Impacts for John Day Socioeconomic Area – MO4

Impact Type	Decrease in Employment	Labor Income	Output
Direct Effect	0	0	0
Indirect Effect	0	0	0
Induced Effect	Less than 5	$55,000-$59,000	$176,000-$188,000
Total Effect	Less than 5	$55,000-$59,000	$176,000-$188,000

REGIONAL ECONOMIC IMPACTS – MUNICIPAL AND INDUSTRIAL

The physical effects to M&I were not shown in this region.

4.2.6 Preferred Alternative

4.2.6.1 Region A – Libby, Hungry Horse, Albeni Falls

Preferred Alternative did not affect the ability to deliver water therefore there were not estimated changes as compared to No-Action.

4.2.6.2 Region B – Grand Coulee, Chief Joseph

Effects to Lake Roosevelt pool elevation could result increased pumping costs.

REGIONAL ECONOMIC EFFECTS ANALYSIS

Increased pumping costs would of $1,000 annual would result no measurable regional economic effects compared to the No Action alternative.

4.2.6.3 Region C - Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor

Preferred Alternative did not affect the ability to deliver water therefore there were not estimated changes as compared to No-Action.

4.2.6.4 Region D – McNary, John Day, The Dalles, Bonneville

Preferred Alternative did not affect the ability to deliver water therefore there were not estimated changes as compared to No-Action.

CHAPTER 5 - DISCUSSION OF OTHER WATER SUPPLY RELATED TOPICS

5.1 WATER SUPPLY MEASURES

The future water supply measures were added to MO1, MO3, and MO4 to evaluate the effects of diverting that water on the flow and stage in the river and reservoirs associated with the 14 Federal Projects (see Chapter 2 of the main EIS document for a complete description). The scope of the future water supply measure analysis is limited to effects on the water surface elevation and river flows in the study area and reservoirs, not the physical or socioeconomic effects of delivering that water. In other words, the effects of these measures are analyzed in the resources that are affected by water surface elevation and river flows in the study area, not in the water supply sections of this EIS.

Hungry Horse Additional Water Supply – In 2015, the Montana State Legislature ratified the Confederated Salish and Kootenai Tribes (CSKT)- Montana Compact that allows the CSKT to divert up to 229,383 acre-feet per year with 128,158 acre-feet per year allowed for consumptive use or depletion (Montana 2019). The Compact allocated up to 90,000 acre-feet of water stored in Hungry Horse to meet this need. Prior to this agreement, there had been other requests for water by the State and other interested parties, but the parties have agreed to the terms in the Compact and no other requests are currently pending.

The Compact must be approved by Congress and the Montana Water Court before it can become effective. Because approvals for the Compact are still being implemented, it is not known exactly when or what amounts of water from Hungry Horse will be used and how much will be consumptively used. To analyze the most extreme effects of using this water, MO1, MO3, and MO4 included an operational future water supply measure to release 90,000 acre-feet of water from Hungry Horse in July, August, and September and divert all of it downstream where it would be consumptively used (O13, O15, and O20, respectively).

The modeling of the Compact for this EIS was designed to capture the maximum impacts to Hungry Horse. Previous modeling work conducted by Reclamation (2012) shows possible methods of implementation, but by covering the extremes in this EIS, flexibility is provided for the actual implementation.

The modeling showed how release of this stored water from Hungry Horse would affect the reservoir and downstream reaches. It generally resulted in Hungry Horse being approximately four feet lower than the No Action on September 30 and flows being 500 cubic feet per second (cfs) higher in July, August, and September downstream of the dam. The impacts on other resources are discussed in their respective sections of this EIS.

Lake Roosevelt Additional Water Supply - Reclamation's Columbia Basin Project was originally authorized by Congress for 1,095,000 acres of irrigated land but has developed or has current plans to develop 772,525 acres. To serve the 254,475 additional acres with an estimated 4.5 acre-feet per acre, 1.154 million acre-feet of additional water would need to be pumped from the Columbia River.

MO1, MO3, and MO4 included an operational future water supply measure to pump an additional 1.154 MAF from Lake Roosevelt for additional water supply to the Columbia Basin Project (O12, O14, and O17, respectively). Figure 5-1 shows the total pumped monthly volume that was modeled to simulate delivering that water. This amount of water was delivered in each model year to analyze the downstream effects of the delivery. Additional NEPA would be required prior to delivering this water to the Columbia Basin Project, further analysis would need to be done to determine the impacts and the methods that would be used to deliver this water.

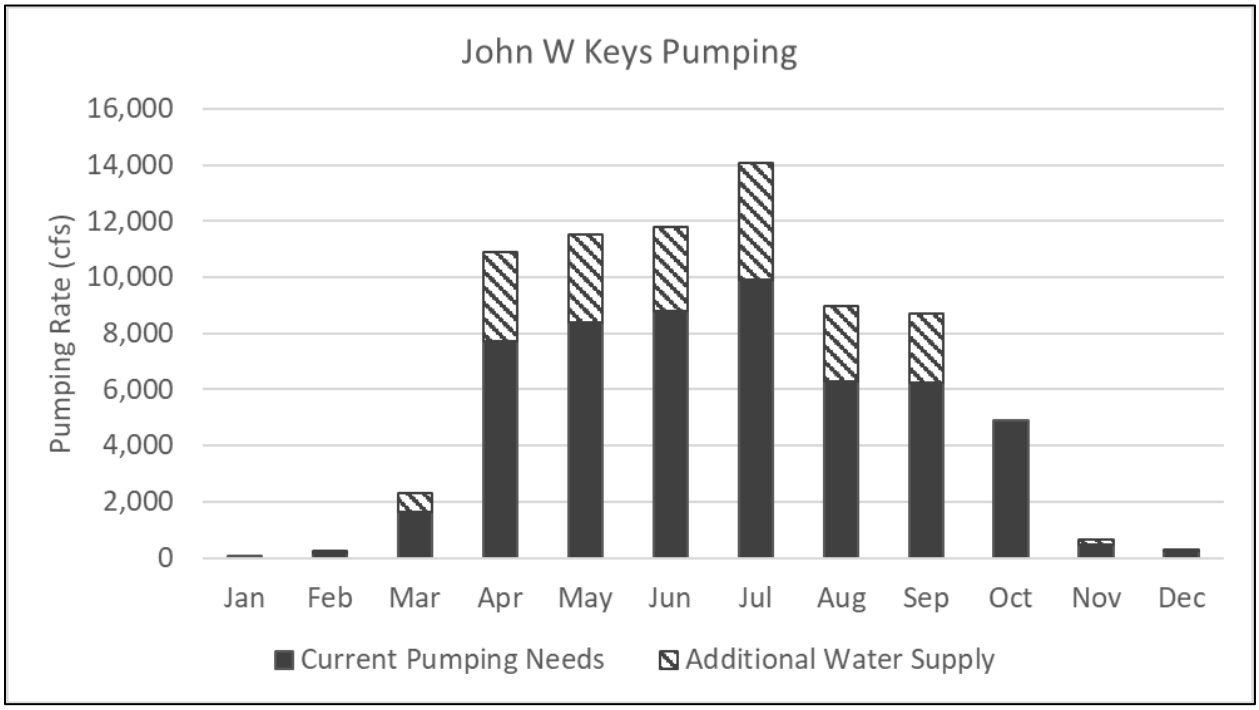


Figure 5-1. Monthly Pumping Requirement from Lake Roosevelt for Current Water Supply (solid bars) and Additional Water Supply (dashed bars)

The modeling showed how delivery of this water from Lake Roosevelt would affect the downstream reaches. Diverting this additional water did not have an effect on Lake Roosevelt elevations; however, it did result in outflows being slightly lower during the irrigation season. The impacts on other resources are discussed in their respective sections of this EIS.

Chief Joseph Dam Project Additional Water Supply - Reclamation's Chief Joseph Dam Project is an irrigation project that was authorized with the construction of the Corps' Chief Joseph Dam. Although they share the same name, they are separate projects. The irrigation project was authorized in phases over many years with authorizations totaling 33,050 acres. To date, 2,821 acres were authorized but have not been developed. To serve the additional acres with an estimated 3.4 acre-feet per acre, approximately 9,600 acre-feet of water would need to be diverted from the Columbia River.

MO1, MO3, and MO4 included an operational future water supply measure to deliver an additional 9,600 acre-feet of water to the Chief Joseph Dam Project for irrigation (O14, O16, and O21, respectively). It is outside the scope of this EIS to determine the exact method and timing of delivery of this water.

The modeling intended to show how diverting this water would impact downstream flows. However, at most, this diversion would result in 50 cfs less flow in the river, which is within the noise of the model. The impacts on other resources are discussed in their respective sections of this EIS.

5.2 WASHINGTON INTERRUPTIBLE WATER RIGHTS

The State of Washington defines "interruptible water rights" that are curtailed when the March 1, April to September Dalles forecast drops below 60 million acre-feet. The models use the same set of modified inflows for all the alternatives, including the same forecasts. Because The Dalles forecast does not change from alternative to alternative, the frequency of triggering the "interruptible water rights" occurring does not change from alternative to alternative. From the ResSim No Action model, there is a 2.4 percent probability of the 5,000-year simulations where the Dalles forecast would drop below 60 million acre-feet.

5.3 COLUMBIA BASIN PROJECT DELIVERIES

Water for the Columbia Basin Project is pumped from Lake Roosevelt to Banks Lake via six pumps and six pump-generators who's pump capacities vary with the elevations in both lakes. The pump-generators cannot operate when Lake Roosevelt is below elevation 1,240 feet (NGVD29), which reduces the overall pumping plant capacity.

Project water is delivered from Banks Lake, which can draw down if project deliveries exceed the amount pumped from Lake Roosevelt. Generally, Banks Lake is allowed to fluctuate within the top five feet of space, although it has NEPA compliance to draw down as low as 11 feet in order to ensure deliveries to the Columbia Basin Project (Odessa 2013).

For this NEPA study, Banks Lake was outside the scope of evaluation. However, an analysis was conducted to ensure that current water supply obligations could be met without drawing Banks below existing NEPA compliance. The analysis found that even in the most extreme years when Lake Roosevelt was drawn down for spring flood control operations, the necessary water could be delivered without drawing Banks Lake more than 11 feet down as long as all six pumps were operational in April, May, and June. Grand Coulee maintenance plan activities will not be conducted during April through June so that all six pumps are operational in wet years to meet this criteria.

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Draft Columbia River System Operations Environmental Impact Statement

Annex A
Pacific Northwest Regional Office Design Group Analysis Memorandums

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36 **ACRONYMS AND ABBREVIATIONS**

cfs	cubic feet per second
CRSO	Columbia River System Operations
EIS	environmental impact statement
ft	feet/foot
GE	General Electric
gpm	gallons per minute
hp	horsepower
kWh	kilowatt-hour
MIP	minimum irrigation pool
MOP	minimum operational pool
PNRO	Pacific Northwest Regional Office (Reclamation)
RPM	revolutions per minute
Corps	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

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CHAPTER 1 - SURFACE WATER DIVERSIONS

Prepared by: PNRO Design Group, Bureau of Reclamation
Prepared for: PNRO Water Management Group, Bureau of Reclamation
Subject: CSRO EIS Appendices
Date Completed: 5/23/19

1.1 GENERAL

The current minimum pool elevation or the MIP or "minimum irrigation pool" that exists behind the John Day Dam is 262.5 feet (ft). The original proposal for this study was to reduce the pool elevation to the "minimum operational pool" or MOP, of 257 ft (a drawdown of 5.5 ft.). The magnitude of the drawdown was later modified to meet the "minimum navigational pool" at an elevation of 261 ft. (a drawdown of 1.5 ft.).

The goal of this study is to determine the effects that drawdown of the John Day pool will have on surface-water points of diversion in the study area and to provide cost estimates for the modifications that will be needed to keep the systems operating at their current capacity. These diversions exist on both banks of the Columbia River and rely on surface-water sources in and around the John Day pool. These diversions and their associated water rights are used for a variety of purposes, from irrigation to municipal uses.

Due to limited data availability, the analysis was performed on the points of diversion on the Oregon side of the Columbia River. The results were then scaled to include the Washington side of the Columbia River for the final cost estimate.

1.2 METHODS/ANALYSIS

1.2.1 Study Area

The study area was limited to the area between the John Day Dam and the McNary Dam within 1-mile of the shores of the Columbia River. These constraints are similar to those defined in a previous study (U.S. Army Corps of Engineers [Corps] 2002). While the effects of drawdown will not be limited to this area, it was assumed that the impact outside of this area would be minimal and no analysis was performed.

A simplified understanding of surface water dynamics was applied and it was assumed that the drawdown would result in a uniform water surface elevation drop of 1.5 ft. across the entire study area.

1.2.2 Defining Sample Set

Within the study area, 91 permits were identified that authorized the use of surface water sources. A sample set of points that had critical data for analysis available was selected from these points. This yielded a total sample size of 14 points, or 15 percent of the total points. This

sample set is assumed to be a reasonable representation of all the surface water diversions in the study area that would be affected by the drawdown of the John Day pool.

1.2.3 Assessing Impacts of Loss of Net Positive Suction Head from Drawdown

The drawdown will result in a loss of net positive section head at each pumping system. As a result, each system will require more power to continue delivering water in the same capacity post-drawdown. Calculations were performed to estimate the additional power each system will need to remain operable. This data is presented in Table A-1-1.

Available pump information and use rate from the water rights data was used to estimate the static head capacity of the existing systems. Some systems have multiple pumps, but the configuration of these systems is not specified, and it is uncertain if the systems have pumps set up to run in parallel or in series. To simplify the calculation, the total horsepower capacity of the pumps was used to estimate the dynamic head capacity of the existing system. The additional power that will be needed in the system post-drawdown was estimated by adding the drawdown of 1.5 ft. to the static head capacity of each system to estimate the new head capacity requirements. This new head requirement, max use rate, and pump efficiency of 80 percent (Corps 2002), were used to calculate a new power requirement for each system.

The new power requirement minus the existing power of the system gave the additional power that each system will need to maintain operability post-drawdown.

1.2.4 Cost Estimating

The maximum potential cost that the additional required horsepower could incur annually was estimated by assuming the irrigation systems would operate 24 hours a day from March 15 to October 15 (214 total days) and the non-irrigation systems would operate 24 hours a day year-round (365 total days). An average commercial electricity cost rate for Moro, Oregon of 9.66 cents/kilowatt-hour (kWh) [1] was used. The cost was calculated for the sample dataset and used to determine an average cost per surface water diversion. This was then multiplied by the total number of surface water diversions within the study area to get the total annual operating cost increase that will result from the drawdown. This data is presented in Table A-1-2.

1.2.5 Assessing Impacts of Drawdown on Intake Function

Aside from the loss of net positive suction head over the pumps, the primary concern was that lowering the reservoir level could drop the water surface below the pump intakes, thus rendering the current systems inoperable.

It was assumed that the surface water pumping systems were designed to operate through the average range of water surface elevations that result from seasonal fluctuations in the pool level during a typical irrigation season. Data from the U.S. Geological Survey (USGS) was analyzed to determine the mean annual maximum and minimum pool elevations based on daily

values gathered from 2003 to 2010 (the pool elevations are given as a distance from the submerged USGS senor to the water surface level), this data is presented in Table A-1-3. The maximum mean pool surface elevation occurs in early April, the minimum mean pool surface elevation occurs in late September. It was concluded that the surface water pumping stations in the sample set were designed to be functional through this range of water surface elevations.

The post-drawdown pool elevations were compared to historical pool elevation data to determine if the pump systems would remain functional throughout the year after the water surface was lowered. It was determined that during the typical irrigation season of March to October, the post-drawdown water surface level only dropped below the functional range of the surface water pumping systems for September 28 to October 3. This data is presented in Table A-1-4.

1.3 RESULTS

The drawdown of 1.5 ft will result in a loss of net positive suction head. This impacts the systems and requires additional horsepower at the pump stations in the sample set ranging from 0 to 72 horsepower. This additional power requirement will incur additional estimated annual energy costs of $429,390 for the entire study area.

Post drawdown, it was anticipated that the intakes of the systems will remain operable for the vast majority of the typical irrigation season. It is anticipated that the pool will only drop low enough to prevent proper water intake at the lowest pool elevations, specifically from September 28 to October 3.

1.4 CONCLUSIONS

The loss in net positive suction head over the pump may not have a significant impact on the larger systems if pumps are sized for the system curve and ignore the net positive suction head at the pump intake. In the case where the pumps account for the head at the intakes, the pumping system would experience a shift in system efficiency which would result in higher power costs to maintain irrigation needs.

Individual systems may require further analysis and modification to keep them functional post-drawdown. These should be addressed on a system by system basis.

1.5 SOURCES

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141 **Table A-1-1. Surface Water Pump Station Data**

Current Diversion Information					Current Pump Information					Post Drawdown Pump Requirements			
No.	Permit No.	Use type	Feature	Max Use Rate (cfs)	Pump Type	Motor Info	Total Horse-power (hp)	Lift Capacity (ft)	Pump Efficiency (assumed)	Required Lift Capacity (ft)	Calculated Horse-power	Additional Horse-power Needed	Additional Power Cost per Irrigation Season
1	33937	Irrigation of 507.55 acres	Pump station	13.67	Turbine	2 x 200 hp	400	206.23	0.8	207.7	403	3	$1,110
2	10550	Irrigation of 514.25 acres	Pump station	6.525	Unknown pump type	1 x 20 hp 1 x 30 hp 1 x 350 hp 1 x 200 hp	600	648.08	0.8	649.6	601	1	$370
3	45468	Supplemental irrigation of 544.2 acres	Pump station	16	Turbine	Site 1: 2 x 200 hp Site 2: 1 x 350 hp	750	330.37	0.8	331.9	754	4	$1,480
4	36940	Irrigation	Low lift river station	322.3	Turbine	1200 hp 9200 hp, Booster 1: 7800 hp Booster 2: 4400 hp Booster 3: 450 hp	23,050	504.05	0.8	505.5	23122	72	$26,638
5	37150	Irrigation of 594.5 acres	High lift river station	14.86	Turbine	14,000 hp	14,000	6,640.00	0.8	6641.5	14005	5	$1,850

Current Diversion Information					Current Pump Information					Post Drawdown Pump Requirements			
No.	Permit No.	Use type	Feature	Max Use Rate (cfs)	Pump Type	Motor Info	Total Horse-power (hp)	Lift Capacity (ft)	Pump Efficiency (assumed)	Required Lift Capacity (ft)	Calculated Horse-power	Additional Horse-power Needed	Additional Power Cost per Irrigation Season
6	45563	Irrigation of 12 acres, supplemental irrigation of 45.4 acres	Bank of pumps	0.5	Turbine	75 hp	75	1,057.18	0.8	1058.7	75	0	$0
7	37150	Irrigation of 4410.3 acres	Pump station in an 8'x20'x 8' steel tank	68.97	Turbine	1,400 hp	1,400	143.06	0.8	144.6	1415	15	$5,550
8	32487	Irrigation of 923.1 acres	Bank of pumps	23.08	Turbine	3 x 400 hp 2 x 250 hp	1,700	519.12	0.8	520.6	1705	5	$1,850
9	37275	Irrigation of 458.9 acres	Pump station	11.47	Turbine	1 x 600 hp	600	368.68	0.8	370.2	603	3	$1,110
10	31346	Irrigation of 427.2 acres	Pump station	7.39	Turbine	4 x 125 hp	500	476.85	0.8	478.4	502	2	$740
11	31346	Supplemental irrigation of 42 acres	Pump station	0.72	Turbine	4 x 125 hp	500	4,894.36	0.8	4895.9	500	0	$0
12	37108	Irrigation of 2971.3 acres	Pump station	62.8	Turbine	10,000 hp	10,000	1,122.27	0.8	1123.8	10015	15	$5,550
13	24125	Irrigation of 93.48 acres	Pump station	1.56	6" centrifugal	26 hp	26	117.46	0.8	119.0	26	0	$0

Current Diversion Information					Current Pump Information					Post Drawdown Pump Requirements			
No.	Permit No.	Use type	Feature	Max Use Rate (cfs)	Pump Type	Motor Info	Total Horse-power (hp)	Lift Capacity (ft)	Pump Efficiency (assumed)	Required Lift Capacity (ft)	Calculated Horse-power	Additional Horse-power Needed	Additional Power Cost per Irrigation Season
14	33883	Irrigation of 50.02 acres	Pump station	1.25	3 x two stage turbine pump, 30" bowls 20"	600 hp	600	3,382.98	0.8	3384.5	600	0	$0

142 cfs = cubic feet per second; ft = feet/foot; hp = horsepower

143 **Table A-1-2. Cost Estimate**

Sample Set Total Annual Cost Increase	Number of Surface Water Diversions in Sample Set	Average Cost per Pumping Plant	Total Number of Surface Water Diversions (Washington & Oregon)	Total Annual Cost Increase
$46,248	14	$3,303	130	$429,390

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Table A-1-3. Daily Mean Distance of Water Surface Elevation Above the USGS Sensor in the John Day Pool

Day of month	Mean of Daily Distance of Water Surface Elevation above USGS Sensor Values for the Available Years of Record (10/01/2003–09/30/2018)							
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1	–	32.42	32.19	32.14	32.23	32.21	32.09	28.67
2	–	32.44	32.15	32.11	32.27	32.22	32.06	28.61
3	–	32.43	32.12	32.06	32.29	32.23	32.06	28.45
4	–	32.46	32.09	32.07	32.28	32.17	32.1	–
5	–	32.54	32.06	32.04	32.3	32.16	32.14	–
6	–	32.55	32.18	31.96	32.12	32.16	32.17	–
7	31.73	32.38	32.26	32.03	32	32.19	32.12	–
8	31.63	32.42	32.19	32.05	32.13	32.26	32.08	–
9	31.6	32.5	32.23	32.05	32.1	32.3	32.09	–
10	31.6	32.42	32.19	32.04	32.12	32.32	32.15	–
11	31.79	32.34	32.07	32.14	32.14	32.34	32.14	–
12	32.06	32.36	32.12	32.15	32.14	32.33	32.07	–
13	31.86	32.38	32.11	31.96	32.21	32.31	31.98	–
14	31.84	32.38	32.18	31.95	32.18	32.3	31.93	–
15	32.2	32.37	32.16	31.89	32.17	32.3	31.84	–
16	31.89	32.32	32.14	31.96	32.19	32.32	31.77	–
17	31.97	32.38	32.09	32.09	32.18	32.33	31.79	–
18	32.24	32.46	31.98	32.12	32.16	32.31	31.53	–
19	32.28	32.35	32.17	32.24	32.17	32.26	31.39	–
20	32.18	32.32	32.24	32.21	32.16	32.28	31.47	–
21	32.27	32.32	32.2	32.18	32.13	32.32	31.53	–
22	32.37	32.3	32.18	32.2	32.14	32.36	31.48	–
23	32.45	32.26	32.21	32.2	32.16	32.37	31.59	–
24	32.43	32.16	32.26	32.17	32.16	32.35	31.71	–
25	32.38	32.16	32.15	32.15	32.14	32.33	31.67	–
26	32.41	32.26	32.28	32.19	32.11	32.3	31.48	–
27	32.38	32.23	32.18	32.19	32.08	32.24	30.66	–
28	32.37	32.24	32.16	32.27	32.09	32.16	28.32	–
29	32.29	32.27	32.19	32.26	32.15	32.01	28.61	–
30	32.39	32.31	32.18	32.19	32.23	32.04	28.47	–
31	32.4	–	32.17	–	32.2	32.07	–	–

147 **Table A-1-4. Daily Mean Distance of Water Surface Elevation Above the USGS sensor in the**
148 **John Day Pool Post-Drawdown with 1.5-ft pool drop**

Day of Month	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1	–	30.92	30.69	30.64	30.73	30.71	30.59	**27.17**
2	–	30.94	30.65	30.61	30.77	30.72	30.56	**27.11**
3	–	30.93	30.62	30.56	30.79	30.73	30.56	**26.95**
4	–	30.96	30.59	30.57	30.78	30.67	30.6	–
5	–	31.04	30.56	30.54	30.8	30.66	30.64	–
6	–	31.05	30.68	30.46	30.62	30.66	30.67	–
7	30.23	30.88	30.76	30.53	30.5	30.69	30.62	–
8	30.13	30.92	30.69	30.55	30.63	30.76	30.58	–
9	30.1	31	30.73	30.55	30.6	30.8	30.59	–
10	30.1	30.92	30.69	30.54	30.62	30.82	30.65	–
11	30.29	30.84	30.57	30.64	30.64	30.84	30.64	–
12	30.56	30.86	30.62	30.65	30.64	30.83	30.57	–
13	30.36	30.88	30.61	30.46	30.71	30.81	30.48	–
14	30.34	30.88	30.68	30.45	30.68	30.8	30.43	–
15	30.7	30.87	30.66	30.39	30.67	30.8	30.34	–
16	30.39	30.82	30.64	30.46	30.69	30.82	30.27	–
17	30.47	30.88	30.59	30.59	30.68	30.83	30.29	–
18	30.74	30.96	30.48	30.62	30.66	30.81	30.03	–
19	30.78	30.85	30.67	30.74	30.67	30.76	29.89	–
20	30.68	30.82	30.74	30.71	30.66	30.78	29.97	–
21	30.77	30.82	30.7	30.68	30.63	30.82	30.03	–
22	30.87	30.8	30.68	30.7	30.64	30.86	29.98	–
23	30.95	30.76	30.71	30.7	30.66	30.87	30.09	–
24	30.93	30.66	30.76	30.67	30.66	30.85	30.21	–
25	30.88	30.66	30.65	30.65	30.64	30.83	30.17	–
26	30.91	30.76	30.78	30.69	30.61	30.8	29.98	–
27	30.88	30.73	30.68	30.69	30.58	30.74	29.16	–
28	30.87	30.74	30.66	30.77	30.59	30.66	**26.82**	–
29	30.79	30.77	30.69	30.76	30.65	30.51	**27.11**	–
30	30.89	30.81	30.68	30.69	30.73	30.54	**26.97**	–
31	30.9	–	30.67	–	30.7	30.57	–	–

149 *Highlighted values indicate days when pool surface dips below the annual minimum and pump intakes may no
150 longer be operable

CHAPTER 2 - GROUNDWATER WELL DIVERSIONS

Prepared by: PNRO Design Group, Bureau of Reclamation
Prepared for: PNRO Water Management Group, Bureau of Reclamation
Subject: CSRO EIS Appendices
Date Completed: 5/23/19

2.1 GENERAL

The current minimum pool elevation or the MIP or "minimum irrigation pool" that exists behind the John Day Dam, is at an elevation of 262.5 ft. The original proposal for this study was to reduce the pool elevation to the "minimum operational pool" or MOP, of 257 ft (a drawdown of 5.5 ft.). The magnitude of the drawdown was later modified to meet the "minimum navigational pool" at an elevation of 261 ft. (a drawdown of 1.5 ft.).

The goal of this study is to determine the effects that drawdown of the John Day pool will have on groundwater fed points of diversion in this area and to provide cost estimates for the modifications that will be needed to keep the systems operating at their current capacity. These points exist along both banks of the Columbia River above the John Day Dam. They rely on groundwater sources around the John Day Pool and are used for a variety of purposes from irrigation to municipal uses.

Due to limited data availability, the analysis was performed on the points of diversion on the Oregon side of the Columbia River. The results were then scaled to include the Washington side of the Columbia River for our final cost estimate.

2.2 METHODS/ANALYSIS

2.2.1 Study Area:

The study area was limited to the area between the John Day Dam and the McNary Dam within 1-mile of the shores of the Columbia River. These constraints are similar to those defined in a previous study (Corps 2002). While the effects of drawdown will not be limited to this area, it was assumed that the impact outside of this area would be minimal and no analysis was performed.

A simplified analysis of the complex dynamics of groundwater aquifers was applied for this study. It was assumed that the 1.5 ft drawdown of the John Day Pool will have a universal effect of lowering the groundwater table in our area of interest by 1.5 ft.

2.2.2 Defining Sample Set

Within the study area, 89 permits were identified that authorized the use of groundwater sources. A sample set of points that had critical data for analysis available was selected from these points. This yielded a total sample size of 24 points, or 27 percent of the total 89 points.

This sample set is assumed to be a reasonable representation of all the groundwater diversions in the study area that would be affected by the drawdown of the John Day pool.

2.2.3 Assessing Impacts of Loss of Net Positive Suction Head from Drawdown

The drawdown will result in a lower water surface elevation in each well and thus a loss of net positive section head. As a result, the pumping system in each well will require more power to continue delivering water in the same capacity post-drawdown. Calculations were performed to estimate the additional power each system will need to remain operable. This data is presented in Table A-2-1.

Available pump information and use rate from the water rights data was used to estimate the static head capacity of the existing systems. Some systems have multiple pumps, but the configuration of these systems is not specified, and it is uncertain if the systems have pumps set up to run in parallel or in series. To simplify the calculation, the total horsepower capacity of the pumps was used to estimate the dynamic head capacity of the existing system. The additional power that will be needed in the system post-drawdown was estimated by adding the drawdown of 1.5 ft. to the static head capacity of each system to estimate the new head capacity requirements. This new head requirement, max use rate, and pump efficiency of 80 percent (Corps 2002), were used to calculate a new power requirement for each system.

The new power requirement minus the existing power of the system gave the additional power that each system will need to maintain operability post-drawdown.

2.2.4 Cost Estimating

The maximum potential cost that the additional required horsepower could incur annually was estimated by assuming the irrigation systems would operate 24 hours a day from March 15 to October 15 (214 total days) and the non-irrigation systems would operate 24 hours a day year-round (365 total days). An average commercial electricity cost rate for Moro, Oregon of 9.66 cents/kWh [1] was used. The cost was calculated for the sample dataset and used to determine an average cost per groundwater diversion. This was then multiplied by the total number of groundwater diversions within the study area to get the total annual operating cost increase that will result from the drawdown. This data is presented in Table A-2-2.

2.2.5 Assessing Impacts of Drawdown on Well Operability

Aside from the loss of net positive suction head, the primary concern was that lowering the reservoir level could cause the wells to “dry up”, thus rendering the current systems inoperable.

To determine whether this would occur, the depth of water in the well post-drawdown was estimated. If this calculation yielded a negative number, it was assumed that the water surface would drop below the bottom of the well and additional drilling will be needed to keep the well from drying up.

2.3 RESULTS

The results of the analysis can be found in Table A-2-2.

All of the wells are predicted to remain operable post drawdown. The most prominent effect will be an increased power cost due to a loss of net positive suction head in each well. This impacts the systems and requires additional horsepower at the pump stations in the sample set ranging from 0 to 1 horsepower. This additional power requirement will incur additional estimated annual energy costs of $10,036 for the entire study area.

2.4 CONCLUSIONS

The magnitude of drawdown considered by this study would not cause any of the sample wells to dry up by dropping the groundwater table below the bottom of the well. The drawdown will result in an increased power requirement and subsequent power costs, however the increased power requirement and subsequent costs are relatively minimal due to the small magnitude of the drawdown.

The results of this report are based on assumptions and generalizations. Individual systems may require further analysis and modification to keep them functional post-drawdown. These should be addressed on a system by system basis.

2.5 SOURCES

Electricity Local. 2020. Moro, OR Electricity Statistics. Available at: https://www.electricitylocal.com/states/oregon/moro/. Accessed February 2020.

U.S. Army Corps of Engineers (Corps). 2002. *Lower Snake River Juvenile Salmon Migration Feasibility Report and Environmental Impact Statement (Final FR/EIS).*

Table A-2-1. Groundwater Well Data

Current Well Information						Current Pump Information			Post Drawdown Well Information			Post Drawdown Pump Requirements		
No.	Permit ID No.	Use Type	Depth (ft)	Depth to Water Table (ft)	Max Use Rate (cfs)	Pump type	Total Horse-power (hp)	Lift Capacity (ft)	Depth of Water in Well (ft)	Additional Drilling Required?	Required Lift Capacity (ft)	Calculated Horse-power	Additional Horse-power Needed	Additional Annual Power Cost
1	5271	Supplemental irrigation of 6 acres	40	30	0.075	4" centrifugal	15	1409.6	8.5	No	1411.1	15	0	$0
2	4474	Irrigation of 11.98, supplemental irrigation of 1.3 acres	34	24	0.164	3 stage turbine, 20 hp electric	20	859.5	8.5	No	861.0	20	0	$0
3	6640	Irrigation of 99.6 acres	71	54	1.25	100 hp electric	100	563.8	15.5	No	565.3	100	0	$0
4	8263	Municipal	48	30	1.11	100 hp turbine	100	634.9	16.5	No	636.4	100	0	$0
5	6876	Irrigation of 1156.6 acres	25	4	5.5	~1000 hp of electric turbines at pumping site and approximately the same of centrifugals on the land	2000	2562.9	19.5	No	2564.4	2001	1	$370
6	7241	Municipal uses (for the city of Irrigon)	72	50	0.89	400 gpm vertical turbine pump and motor 15 hp 1750 RPM	15	118.8	20.5	No	120.3	15	0	$0
7	7563	Municipal Uses	72	50	1.33	900 gpm vertical turbine, 10 hp 1800 rpm	10	53	20.5	No	54.5	10	0	$0
8	4257	Supplemental irrigation of 4.4 acres	65	38	0.057	2.5" submersible 1 5 hp single phase electric	5	618.2	25.5	No	619.7	5	0	$0

Current Well Information						Current Pump Information			Post Drawdown Well Information			Post Drawdown Pump Requirements		
No.	Permit ID No.	Use Type	Depth (ft)	Depth to Water Table (ft)	Max Use Rate (cfs)	Pump type	Total Horse-power (hp)	Lift Capacity (ft)	Depth of Water in Well (ft)	Additional Drilling Required?	Required Lift Capacity (ft)	Calculated Horse-power	Additional Horse-power Needed	Additional Annual Power Cost
9	6789	Irrigation of 48 acres	60	28	0.6	6" centrifugal, 30 hp electric	30	352.4	30.5	No	353.9	30	0	$0
10	5602	Irrigation of 15 acres	45	10	0.19	Deep well turbines 6" bowls, Electric motor- 2 hp	2	74.2	33.5	No	75.7	2	0	$0
11	6031	Irrigation of 132 acres	55	14	1.65	10" shallow well electric turbine, 75 hp vertical hollow shaft	75	320.4	39.5	No	321.9	75	0	$0
12	6032	Irrigation of 188.4 acres	60	16	2.36	10" shallow well electric turbine pump, 125 hp vertical hollow shaft motor	125	373.3	42.5	No	374.8	126	1	$370
13	5159	Irrigation of 351.9 acres	90	14	4.4	10" shallow well electric turbine pump, 150 hp vertical hollow shaft motor	150	240.3	74.5	No	241.8	151	1	$370
14	6661	Irrigation of 53.3 acres	123	18	0.67	6-" ingersall Rand, 50 hp General electric (GE)	50	526	103.5	No	527.5	50	0	$0
15	7065	Irrigation of 22.6 acres	200	81	0.28	6" turbine, Motor 30 hp electric	30	755.1	117.5	No	756.6	30	0	$0
16	8111	Irrigation/ park use	150	10	1.5	15 hp	15	70.5	138.5	No	72.0	15	0	$0
17	4269	Municipal uses	350	50	0.27	6" vertical turbine 20 hp electric motor	20	522.1	298.5	No	523.6	20	0	$0

Current Well Information						Current Pump Information			Post Drawdown Well Information			Post Drawdown Pump Requirements		
No.	Permit ID No.	Use Type	Depth (ft)	Depth to Water Table (ft)	Max Use Rate (cfs)	Pump type	Total Horse-power (hp)	Lift Capacity (ft)	Depth of Water in Well (ft)	Additional Drilling Required?	Required Lift Capacity (ft)	Calculated Horse-power	Additional Horse-power Needed	Additional Annual Power Cost
18	7828	Irrigation of 12.7 acres	460	90	0.16	25 hp sub turbine Berkley pump	25	1101.2	368.5	No	1102.7	25	0	$0
19	6386	Irrigation of 47.6 acres	502	120	0.6	Line shaft turbine 6" suction, 6" discharge, Motor 100 hp electric	100	1174.6	380.5	No	1176.1	100	0	$0
20	2560	Municipal uses (for City of Umatilla)	785	400	1.25	Peerless No. 46273-10" 100 hp GE motor	100	563.8	383.5	No	565.3	100	0	$0
21	2664	Municipal uses (for the city of Boardman)	500	30	1.5	8" multi stage submersible turbine pump, 40 hp electric submersible motor	40	187.9	468.5	No	189.4	40	0	$0
22	8763	Irrigation of 92.5 acres	540	62	1.16	75 hp pump	75	455.7	476.5	No	457.2	75	0	$0
23	1201	Municipal use	619	93	1.1	Deep well turbine pumps in well 1, Worthington 6" type 10QE 6 stage 400 gpm, 40 hp 440 volt 3 phase 60 cycle 1750 RPM engine	40	256.3	524.5	No	257.8	40	0	$0

Current Well Information						Current Pump Information			Post Drawdown Well Information			Post Drawdown Pump Requirements		
No.	Permit ID No.	Use Type	Depth (ft)	Depth to Water Table (ft)	Max Use Rate (cfs)	Pump type	Total Horse-power (hp)	Lift Capacity (ft)	Depth of Water in Well (ft)	Additional Drilling Required?	Required Lift Capacity (ft)	Calculated Horse-power	Additional Horse-power Needed	Additional Annual Power Cost
24	2560	Commercial uses	785	255	0.75	Peerless No. 46273-10" estimated 100 hp GE motor	100	939.7	528.5	No	941.2	100	0	$0

cfs = cubic feet per second; ft = feet/foot; GE = General Electric; gpm = gallons per minute; hp = horsepower; RPM = revolutions per minute

Table A-2-2. Cost Estimate

Sample Set Total Annual Cost Increase	Number of Surface Water Diversions in Sample Set	Average Cost per Pumping Plant	Total Number of Surface Water Diversions (Washington & Oregon)	Total Annual Cost Increase
$1,110	24	$46.25	217	$10,036

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Draft Columbia River System Operations Environmental Impact Statement

Appendix O
Environmental Justice

CHAPTER 1 - ENVIRONMENTAL JUSTICE

The tables in this appendix supplement the Environmental Justice Affected Environment section of this EIS (Section 3.15.2). According to the Council on Environmental Quality (CEQ) guidance for implementing Executive Order 12898 under the National Environmental Policy Act (NEPA), "[a]gencies should consider the composition of the affected area, to determine whether minority populations, low-income populations, or Indian tribes are present in the area affected by the proposed action, and if so whether there may be disproportionately high and adverse human health or environmental effects on minority populations, low-income populations, or Indian tribes" (CEQ 1997). This supplemental material is intended to show the details of how the populations for environmental justice analysis were identified using demographic data. It also illuminates the socioeconomic and cultural vulnerabilities that necessitate these populations be studied to address the potential for disproportionately adverse effects. Specifically, this appendix includes the following tables to provide additional detailed breakdown:

- Table 1-1 provides a breakdown of low-income population, illustrating the number of census block groups and associated population that are considered low-income in each county in the study area.
- Table 1-2 provides a breakdown of minority population, illustrating the number of census block groups and associated population that are considered minority in each county in the study area.
- Table 1-3 provides additional information on minority populations and race and ethnicity for each county in the study area.
- Table 1-4 provides other socioeconomic indicators that evaluate income and employment, age distribution, and education for counties in the study area.
- Table 1-5 provides socioeconomic indicators for Indian tribes in the study area that evaluate income and employment, age distribution, and education.

Demographic information for Indian tribes in the study area has been collected from the U.S. Census Bureau (U.S. Census). These data include metrics typically used by researchers and in EPA's EJ screening tools to represent the "social vulnerability" characteristics of a disadvantaged population (EPA 2017). However, these data do not capture a complete picture of the current economic, social, and health conditions in these communities. For example, U.S. Census may not fully capture tribal members that are transient during the year as it relies on those with permanent addresses.

Note, the demographic data included in Table 5 represent statistics for the population residing within the geographic boundaries of the reservation, and includes off-reservation trust lands as well, where data was included in the U.S. Census data.

37 **Table 1-1. Low-Income Populations in the Study Area, by County**

State	County	Number of Block Groups			Population of Block Groups		
		Total	Meet Low-Income Criteria[1/]	Percent Low-Income	Total	Meet Low-Income Criteria[1/]	Percent Low-Income
California	Modoc County, CA	12	4	33%	9,033	2,629	29%
	California Total	**12**	**4**	**33%**	**9,033**	**2,629**	**29%**
Idaho	Ada County, ID	169	39	23%	425,798	63,935	15%
	Adams County, ID	3	1	33%	3,865	1,573	41%
	Bannock County, ID	60	28	47%	83,815	36,593	44%
	Bear Lake County, ID	7	2	29%	5,928	1,359	23%
	Benewah County, ID	9	3	33%	9,068	2,925	32%
	Bingham County, ID	30	6	20%	45,261	9,048	20%
	Blaine County, ID	13	2	15%	21,427	2,804	13%
	Boise County, ID	4	2	50%	6,891	3,008	44%
	Bonner County, ID	35	8	23%	41,389	10,459	25%
	Bonneville County, ID	68	22	32%	108,989	25,687	24%
	Boundary County, ID	9	2	22%	11,141	2,451	22%
	Butte County, ID	3	1	33%	2,592	1,013	39%
	Camas County, ID	1	0	0%	968	0	0%
	Canyon County, ID	84	36	43%	202,782	60,788	30%
	Caribou County, ID	7	0	0%	6,813	0	0%
	Cassia County, ID	19	5	26%	23,441	4,927	21%
	Clark County, ID	1	1	100%	960	960	100%
	Clearwater County, ID	13	0	0%	8,528	0	0%
	Custer County, ID	4	2	50%	4,185	2,318	55%
	Elmore County, ID	16	9	56%	26,103	12,559	48%
	Franklin County, ID	10	0	0%	13,013	0	0%
	Fremont County, ID	12	2	17%	12,896	1,544	12%
	Gem County, ID	12	6	50%	16,853	9,402	56%
	Gooding County, ID	13	3	23%	15,157	3,579	24%
	Idaho County, ID	15	5	33%	16,251	3,532	22%

State	County	Number of Block Groups			Population of Block Groups		
		Total	Meet Low-Income Criteria[1/]	Percent Low-Income	Total	Meet Low-Income Criteria[1/]	Percent Low-Income
	Jefferson County, ID	14	2	14%	27,096	1,876	7%
	Jerome County, ID	15	6	40%	22,694	5,664	25%
	Kootenai County, ID	66	12	18%	147,716	20,039	14%
	Latah County, ID	31	11	35%	38,593	18,007	47%
	Lemhi County, ID	8	3	38%	7,743	3,312	43%
	Lewis County, ID	6	1	17%	3,826	878	23%
	Lincoln County, ID	4	0	0%	5,292	0	0%
	Madison County, ID	22	12	55%	38,114	23,870	63%
	Minidoka County, ID	16	5	31%	20,331	7,190	35%
	Nez Perce County, ID	36	8	22%	39,995	10,494	26%
	Oneida County, ID	3	0	0%	4,269	0	0%
	Owyhee County, ID	10	5	50%	11,356	5,195	46%
	Payette County, ID	15	5	33%	22,773	5,346	23%
	Power County, ID	7	1	14%	7,696	1,252	16%
	Shoshone County, ID	18	7	39%	12,551	5,715	46%
	Teton County, ID	4	1	25%	10,437	2,477	24%
	Twin Falls County, ID	53	18	34%	80,955	22,437	28%
	Valley County, ID	7	2	29%	9,897	2,636	27%
	Washington County, ID	10	2	20%	10,035	1,668	17%
	Idaho Total	**962**	**286**	**30%**	**1,635,483**	**398,520**	**24%**
Montana	Beaverhead County, MT	8	3	38%	9,317	3,477	37%
	Broadwater County, MT	4	0	0%	5,692	0	0%
	Deer Lodge County, MT	11	5	45%	9,176	4,377	48%
	Flathead County, MT	70	16	23%	94,696	22,447	24%
	Glacier County, MT	15	11	73%	13,695	11,012	80%
	Granite County, MT	3	1	33%	3,212	1,189	37%
	Jefferson County, MT	10	2	20%	11,601	1,454	13%
	Lake County, MT	25	10	40%	29,311	12,405	42%

State	County	Number of Block Groups			Population of Block Groups		
		Total	Meet Low-Income Criteria[1/]	Percent Low-Income	Total	Meet Low-Income Criteria[1/]	Percent Low-Income
	Lincoln County, MT	17	7	41%	19,268	6,685	35%
	Madison County, MT	7	1	14%	7,810	1,398	18%
	Mineral County, MT	4	1	25%	4,223	899	21%
	Missoula County, MT	76	25	33%	113,101	32,496	29%
	Powell County, MT	8	0	0%	6,928	0	0%
	Ravalli County, MT	31	13	42%	41,130	17,585	43%
	Sanders County, MT	10	6	60%	11,375	7,047	62%
	Silver Bow County, MT	37	16	43%	34,560	15,354	44%
	Montana Total	**336**	**117**	**35%**	**415,095**	**137,825**	**33%**
Nevada	Elko County, NV	37	7	19%	52,029	8,991	17%
	Humboldt County, NV	14	3	21%	17,091	4,458	26%
	Nevada Total	**51**	**10**	**20%**	**69,120**	**13,449**	**19%**
Oregon	Baker County, OR	17	5	29%	16,030	4,253	27%
	Benton County, OR	61	30	49%	87,455	40,084	46%
	Clackamas County, OR	217	26	12%	394,967	42,653	11%
	Clatsop County, OR	37	10	27%	37,660	9,025	24%
	Columbia County, OR	36	5	14%	49,645	6,354	13%
	Coos County, OR	63	21	33%	62,944	18,779	30%
	Crook County, OR	16	6	38%	21,334	5,786	27%
	Curry County, OR	16	5	31%	22,364	6,080	27%
	Deschutes County, OR	85	21	25%	170,813	35,293	21%
	Douglas County, OR	84	36	43%	107,375	46,771	44%
	Gilliam County, OR	3	0	0%	1,913	0	0%
	Grant County, OR	8	3	38%	7,227	2,745	38%
	Harney County, OR	7	2	29%	7,214	1,372	19%
	Hood River County, OR	19	2	11%	22,842	3,236	14%
	Jackson County, OR	127	44	35%	210,916	78,884	37%
	Jefferson County, OR	16	5	31%	22,305	8,865	40%

State	County	Number of Block Groups			Population of Block Groups		
		Total	Meet Low-Income Criteria[1/]	Percent Low-Income	Total	Meet Low-Income Criteria[1/]	Percent Low-Income
	Josephine County, OR	54	21	39%	84,063	32,979	39%
	Klamath County, OR	67	28	42%	65,946	24,372	37%
	Lake County, OR	9	3	33%	7,799	2,097	27%
	Lane County, OR	257	96	37%	360,273	131,839	37%
	Lincoln County, OR	39	15	38%	46,685	18,368	39%
	Linn County, OR	85	28	33%	119,862	40,092	33%
	Malheur County, OR	30	17	57%	30,474	19,032	62%
	Marion County, OR	192	64	33%	326,527	111,381	34%
	Morrow County, OR	11	3	27%	11,207	3,230	29%
	Multnomah County, OR	520	158	30%	778,193	273,499	35%
	Polk County, OR	41	12	29%	78,470	20,562	26%
	Sherman County, OR	2	1	50%	1,705	764	45%
	Tillamook County, OR	28	9	32%	25,552	8,046	31%
	Umatilla County, OR	64	21	33%	76,582	28,661	37%
	Union County, OR	26	10	38%	25,758	10,023	39%
	Wallowa County, OR	7	1	14%	6,836	1,507	22%
	Wasco County, OR	22	2	9%	25,657	2,034	8%
	Washington County, OR	303	52	17%	564,088	93,206	17%
	Wheeler County, OR	2	1	50%	1,369	760	56%
	Yamhill County, OR	54	15	28%	102,217	29,041	28%
	Oregon Total	**2,625**	**778**	**30%**	**3,982,267**	**1,161,673**	**29%**
Washington	Adams County, WA	15	6	40%	19,100	10,209	53%
	Asotin County, WA	21	7	33%	22,113	6,808	31%
	Benton County, WA	134	35	26%	187,519	48,815	26%
	Chelan County, WA	55	10	18%	74,761	13,232	18%
	Clallam County, WA	54	14	26%	72,969	17,136	23%
	Clark County, WA	280	34	12%	450,893	53,567	12%
	Columbia County, WA	5	1	20%	3,971	1,196	30%

State	County	Number of Block Groups			Population of Block Groups		
		Total	Meet Low-Income Criteria[1/]	Percent Low-Income	Total	Meet Low-Income Criteria[1/]	Percent Low-Income
	Cowlitz County, WA	89	26	29%	102,854	24,366	24%
	Douglas County, WA	29	8	28%	40,101	11,318	28%
	Ferry County, WA	7	5	71%	7,639	5,172	68%
	Franklin County, WA	48	14	29%	87,810	30,329	35%
	Garfield County, WA	3	1	33%	2,231	606	27%
	Grant County, WA	46	16	35%	92,530	35,039	38%
	Grays Harbor County, WA	61	21	34%	71,233	20,520	29%
	Island County, WA	56	4	7%	80,113	4,770	6%
	Jefferson County, WA	26	6	23%	30,333	5,798	19%
	King County, WA	1,420	218	15%	2,079,550	342,063	16%
	Kitsap County, WA	162	14	9%	257,488	20,640	8%
	Kittitas County, WA	25	7	28%	42,785	12,197	29%
	Klickitat County, WA	19	4	21%	20,930	4,088	20%
	Lewis County, WA	62	18	29%	75,724	22,037	29%
	Lincoln County, WA	11	2	18%	10,326	2,056	20%
	Mason County, WA	49	17	35%	61,060	22,695	37%
	Okanogan County, WA	44	23	52%	41,299	19,734	48%
	Pacific County, WA	19	11	58%	20,743	9,903	48%
	Pend Oreille County, WA	14	3	21%	13,001	3,157	24%
	Pierce County, WA	558	132	24%	832,896	172,644	21%
	San Juan County, WA	13	0	0%	16,056	0	0%
	Skagit County, WA	81	23	28%	120,475	34,943	29%
	Skamania County, WA	10	3	30%	11,316	3,459	31%
	Snohomish County, WA	499	59	12%	758,649	85,359	11%
	Spokane County, WA	322	110	34%	485,859	147,823	30%
	Stevens County, WA	34	13	38%	43,744	13,611	31%
	Thurston County, WA	160	32	20%	266,311	49,594	19%
	Wahkiakum County, WA	5	1	20%	4,051	888	22%

State	County	Number of Block Groups			Population of Block Groups		
		Total	Meet Low-Income Criteria[1/]	Percent Low-Income	Total	Meet Low-Income Criteria[1/]	Percent Low-Income
	Walla Walla County, WA	43	19	44%	59,809	24,627	41%
	Whatcom County, WA	102	29	28%	209,729	63,651	30%
	Whitman County, WA	33	12	36%	47,494	22,520	47%
	Yakima County, WA	149	71	48%	247,681	123,507	50%
	Washington Total	**4,763**	**1,029**	**22%**	**7,073,146**	**1,490,077**	**21%**
Wyoming	Teton County, WY	14	2	14%	22,623	2,521	11%
	Wyoming Total	**14**	**2**	**14%**	**22,623**	**2,521**	**11%**

Source: U.S. Census Bureau 2017

Notes:

1/ For this analysis, census block groups for which the U.S. Census reports that 20 percent or more of the population is living below the poverty level are categorized as low-income populations.

Table 1-2. Minority Populations in the Study Area, by County

State	County	Number of Block Groups			Population of Block Groups		
		Total	Meet Minority Criteria[1/]	Percent Minority	Total	Meet Minority Criteria[1/]	Percent Minority
California	Modoc County, CA	12	0	0%	9,033	0	0%
	California Total	**12**	**0**	**0%**	**9,033**	**0**	**0%**
Idaho	Ada County, ID	169	59	35%	425,798	136,851	32%
	Adams County, ID	3	0	0%	3,865	0	0%
	Bannock County, ID	60	21	35%	83,815	26,584	32%
	Bear Lake County, ID	7	0	0%	5,928	0	0%
	Benewah County, ID	9	3	33%	9,068	2,925	32%
	Bingham County, ID	30	14	47%	45,261	19,307	43%
	Blaine County, ID	13	6	46%	21,427	11,399	53%
	Boise County, ID	4	0	0%	6,891	0	0%
	Bonner County, ID	35	0	0%	41,389	0	0%
	Bonneville County, ID	68	26	38%	108,989	32,632	30%
	Boundary County, ID	9	0	0%	11,141	0	0%

State	County	Number of Block Groups			Population of Block Groups		
		Total	Meet Minority Criteria[1/]	Percent Minority	Total	Meet Minority Criteria[1/]	Percent Minority
	Butte County, ID	3	0	0%	2,592	0	0%
	Camas County, ID	1	0	0%	968	0	0%
	Canyon County, ID	84	66	79%	202,782	162,380	80%
	Caribou County, ID	7	0	0%	6,813	0	0%
	Cassia County, ID	19	14	74%	23,441	16,710	71%
	Clark County, ID	1	1	100%	960	960	100%
	Clearwater County, ID	13	2	15%	8,528	2,149	25%
	Custer County, ID	4	0	0%	4,185	0	0%
	Elmore County, ID	16	10	63%	26,103	18,073	69%
	Franklin County, ID	10	1	10%	13,013	1,326	10%
	Fremont County, ID	12	4	33%	12,896	4,755	37%
	Gem County, ID	12	2	17%	16,853	3,213	19%
	Gooding County, ID	13	12	92%	15,157	13,850	91%
	Idaho County, ID	15	1	7%	16,251	867	5%
	Jefferson County, ID	14	4	29%	27,096	8,376	31%
	Jerome County, ID	15	13	87%	22,694	20,561	91%
	Kootenai County, ID	66	2	3%	147,716	2,061	1%
	Latah County, ID	31	4	13%	38,593	6,793	18%
	Lemhi County, ID	8	0	0%	7,743	0	0%
	Lewis County, ID	6	2	33%	3,826	1,801	47%
	Lincoln County, ID	4	4	100%	5,292	5,292	100%
	Madison County, ID	22	6	27%	38,114	5,655	15%
	Minidoka County, ID	16	15	94%	20,331	19,535	96%
	Nez Perce County, ID	36	6	17%	39,995	5,661	14%
	Oneida County, ID	3	0	0%	4,269	0	0%
	Owyhee County, ID	10	8	80%	11,356	9,004	79%
	Payette County, ID	15	9	60%	22,773	14,423	63%
	Power County, ID	7	5	71%	7,696	6,144	80%

State	County	Number of Block Groups			Population of Block Groups		
		Total	Meet Minority Criteria[1/]	Percent Minority	Total	Meet Minority Criteria[1/]	Percent Minority
	Shoshone County, ID	18	1	6%	12,551	625	5%
	Teton County, ID	4	2	50%	10,437	4,586	44%
	Twin Falls County, ID	53	25	47%	80,955	39,971	49%
	Valley County, ID	7	0	0%	9,897	0	0%
	Washington County, ID	10	3	30%	10,035	3,539	35%
	Idaho Total	**962**	**351**	**36%**	**1,635,483**	**608,008**	**37%**
Montana	Beaverhead County, MT	8	2	25%	9,317	3,114	33%
	Broadwater County, MT	4	0	0%	5,692	0	0%
	Deer Lodge County, MT	11	3	27%	9,176	3,032	33%
	Flathead County, MT	70	11	16%	94,696	11,082	12%
	Glacier County, MT	15	14	93%	13,695	13,112	96%
	Granite County, MT	3	0	0%	3,212	0	0%
	Jefferson County, MT	10	0	0%	11,601	0	0%
	Lake County, MT	25	19	76%	29,311	23,901	82%
	Lincoln County, MT	17	1	6%	19,268	507	3%
	Madison County, MT	7	0	0%	7,810	0	0%
	Mineral County, MT	4	0	0%	4,223	0	0%
	Missoula County, MT	76	19	25%	113,101	31,023	27%
	Powell County, MT	8	1	13%	6,928	1,453	21%
	Ravalli County, MT	31	5	16%	41,130	6,326	15%
	Sanders County, MT	10	2	20%	11,375	1,867	16%
	Silver Bow County, MT	37	10	27%	34,560	12,314	36%
	Montana Total	**336**	**87**	**26%**	**415,095**	**107,731**	**26%**
Nevada	Elko County, NV	37	10	27%	52,029	12,879	25%
	Humboldt County, NV	14	2	14%	17,091	2,787	16%
	Nevada Total	**51**	**12**	**24%**	**69,120**	**15,666**	**23%**
Oregon	Baker County, OR	17	0	0%	16,030	0	0%
	Benton County, OR	61	15	25%	87,455	22,346	26%

State	County	Number of Block Groups			Population of Block Groups		
		Total	Meet Minority Criteria[1/]	Percent Minority	Total	Meet Minority Criteria[1/]	Percent Minority
	Clackamas County, OR	217	57	26%	394,967	115,424	29%
	Clatsop County, OR	37	6	16%	37,660	5,636	15%
	Columbia County, OR	36	1	3%	49,645	1,102	2%
	Coos County, OR	63	12	19%	62,944	12,332	20%
	Crook County, OR	16	1	6%	21,334	677	3%
	Curry County, OR	16	1	6%	22,364	2,534	11%
	Deschutes County, OR	85	10	12%	170,813	18,047	11%
	Douglas County, OR	84	5	6%	107,375	6,156	6%
	Gilliam County, OR	3	1	33%	1,913	470	25%
	Grant County, OR	8	0	0%	7,227	0	0%
	Harney County, OR	7	0	0%	7,214	0	0%
	Hood River County, OR	19	11	58%	22,842	15,039	66%
	Jackson County, OR	127	34	27%	210,916	64,887	31%
	Jefferson County, OR	16	8	50%	22,305	13,854	62%
	Josephine County, OR	54	6	11%	84,063	7,179	9%
	Klamath County, OR	67	23	34%	65,946	22,706	34%
	Lake County, OR	9	2	22%	7,799	1,925	25%
	Lane County, OR	257	50	19%	360,273	80,954	22%
	Lincoln County, OR	39	10	26%	46,685	11,994	26%
	Linn County, OR	85	14	16%	119,862	21,479	18%
	Malheur County, OR	30	21	70%	30,474	23,012	76%
	Marion County, OR	192	106	55%	326,527	190,456	58%
	Morrow County, OR	11	5	45%	11,207	8,262	74%
	Multnomah County, OR	520	267	51%	778,193	450,750	58%
	Polk County, OR	41	10	24%	78,470	21,143	27%
	Sherman County, OR	2	0	0%	1,705	0	0%
	Tillamook County, OR	28	4	14%	25,552	2,951	12%
	Umatilla County, OR	64	35	55%	76,582	50,431	66%

State	County	Number of Block Groups			Population of Block Groups		
		Total	Meet Minority Criteria[1/]	Percent Minority	Total	Meet Minority Criteria[1/]	Percent Minority
	Union County, OR	26	1	4%	25,758	1,021	4%
	Wallowa County, OR	7	0	0%	6,836	0	0%
	Wasco County, OR	22	9	41%	25,657	10,107	39%
	Washington County, OR	303	176	58%	564,088	363,459	64%
	Wheeler County, OR	2	0	0%	1,369	0	0%
	Yamhill County, OR	54	20	37%	102,217	41,553	41%
	Oregon Total	**2,625**	**921**	**35%**	**3,982,267**	**1,587,886**	**40%**
Washington	Adams County, WA	15	9	60%	19,100	15,019	79%
	Asotin County, WA	21	0	0%	22,113	0	0%
	Benton County, WA	134	46	34%	187,519	64,576	34%
	Chelan County, WA	55	23	42%	74,761	32,180	43%
	Clallam County, WA	54	8	15%	72,969	9,583	13%
	Clark County, WA	280	62	22%	450,893	102,784	23%
	Columbia County, WA	5	0	0%	3,971	0	0%
	Cowlitz County, WA	89	13	15%	102,854	14,652	14%
	Douglas County, WA	29	17	59%	40,101	21,624	54%
	Ferry County, WA	7	1	14%	7,639	1,700	22%
	Franklin County, WA	48	40	83%	87,810	79,260	90%
	Garfield County, WA	3	0	0%	2,231	0	0%
	Grant County, WA	46	28	61%	92,530	61,263	66%
	Grays Harbor County, WA	61	12	20%	71,233	14,601	20%
	Island County, WA	56	13	23%	80,113	19,850	25%
	Jefferson County, WA	26	1	4%	30,333	1,025	3%
	King County, WA	1,420	780	55%	2,079,550	1,225,129	59%
	Kitsap County, WA	162	29	18%	257,488	48,043	19%
	Kittitas County, WA	25	2	8%	42,785	6,048	14%
	Klickitat County, WA	19	2	11%	20,930	3,067	15%
	Lewis County, WA	62	6	10%	75,724	9,499	13%

State	County	Number of Block Groups			Population of Block Groups		
		Total	Meet Minority Criteria[1/]	Percent Minority	Total	Meet Minority Criteria[1/]	Percent Minority
	Lincoln County, WA	11	0	0%	10,326	0	0%
	Mason County, WA	49	7	14%	61,060	10,621	17%
	Okanogan County, WA	44	20	45%	41,299	20,788	50%
	Pacific County, WA	19	3	16%	20,743	2,959	14%
	Pend Oreille County, WA	14	1	7%	13,001	708	5%
	Pierce County, WA	558	262	47%	832,896	415,806	50%
	San Juan County, WA	13	0	0%	16,056	0	0%
	Skagit County, WA	81	21	26%	120,475	32,795	27%
	Skamania County, WA	10	0	0%	11,316	0	0%
	Snohomish County, WA	499	183	37%	758,649	313,589	41%
	Spokane County, WA	322	24	7%	485,859	32,989	7%
	Stevens County, WA	34	2	6%	43,744	2,064	5%
	Thurston County, WA	160	43	27%	266,311	87,200	33%
	Wahkiakum County, WA	5	0	0%	4,051	0	0%
	Walla Walla County, WA	43	16	37%	59,809	20,510	34%
	Whatcom County, WA	102	12	12%	209,729	27,363	13%
	Whitman County, WA	33	5	15%	47,494	12,271	26%
	Yakima County, WA	149	106	71%	247,681	178,814	72%
	Washington Total	**4,763**	**1,797**	**38%**	**7,073,146**	**2,888,380**	**41%**
Wyoming	Teton County, WY	14	6	43%	22,623	8,096	36%
	Wyoming Total	**14**	**6**	**43%**	**22,623**	**8,096**	**36%**

Source: U.S. Census Bureau 2017

Note:

1/ For purposes of this analysis, minority populations are identified by comparing the minority population percentage in an affected area (i.e., census block group) to the minority population percentage in the associated state population (i.e., general population). Minority population reflects all populations not identified as "Not Hispanic or Latino: White alone" in the U.S. Census Bureau's American Community Survey.

48 **Table 1-3. Breakdown of Race and Ethnicity in the Study Area, by County**

State	County	Total Population	White Alone	Minority Population[2/]	Breakdown of Minority Populations[1/]					
					American Indian or Alaskan Native	Asian or Pacific Islander	Black or African American	Hispanic or Latino	Some Other Race	Two or More Races
California	Modoc County, CA	9,033	7,014	2,019	367	118	82	1,335	5	112
	California Total	**9,033**	**7,014**	**2,019**	**367**	**118**	**82**	**1,335**	**5**	**112**
	California Percent of Total Population	**100%**	**78%**	**22%**	**4%**	**1%**	**1%**	**15%**	**0%**	**1%**
Idaho	Ada County, ID	425,798	364,242	61,556	1,913	10,912	4,999	32,905	370	10,457
	Adams County, ID	3,865	3,597	268	73	8	8	122	11	46
	Bannock County, ID	83,815	71,181	12,634	2,194	1,104	506	6,678	135	2,017
	Bear Lake County, ID	5,928	5,559	369	17	35	46	243	0	28
	Benewah County, ID	9,068	7,682	1,386	750	127	20	300	0	189
	Bingham County, ID	45,261	33,606	11,655	2,239	488	132	8,037	40	719
	Blaine County, ID	21,427	16,481	4,946	9	260	25	4,444	0	208
	Boise County, ID	6,891	6,340	551	101	35	30	260	0	125
	Bonner County, ID	41,389	38,799	2,590	225	282	43	1,143	0	897
	Bonneville County, ID	108,989	91,505	17,484	331	967	466	13,517	50	2,153
	Boundary County, ID	11,141	10,138	1,003	174	16	17	493	0	303
	Butte County, ID	2,592	2,450	142	4	0	31	101	0	6
	Camas County, ID	968	881	87	3	0	0	82	0	2
	Canyon County, ID	202,782	144,636	58,146	1,288	1,958	743	49,941	65	4,151
	Caribou County, ID	6,813	6,283	530	13	0	13	363	4	137
	Cassia County, ID	23,441	16,585	6,856	118	109	44	6,248	27	310
	Clark County, ID	960	496	464	0	0	1	454	0	9
	Clearwater County, ID	8,528	7,778	750	166	87	18	329	0	150
	Custer County, ID	4,185	4,007	178	17	1	0	132	0	28
	Elmore County, ID	26,103	19,326	6,777	354	852	658	4,204	12	697

State	County	Total Population	White Alone	Minority Population[2/]	Breakdown of Minority Populations[1/]					
					American Indian or Alaskan Native	Asian or Pacific Islander	Black or African American	Hispanic or Latino	Some Other Race	Two or More Races
	Franklin County, ID	13,013	11,889	1,124	24	20	37	871	0	172
	Fremont County, ID	12,896	10,995	1,901	46	56	41	1,589	13	156
	Gem County, ID	16,853	14,864	1,989	165	131	0	1,362	0	331
	Gooding County, ID	15,157	10,328	4,829	202	105	12	4,388	23	99
	Idaho County, ID	16,251	14,877	1,374	401	58	20	507	0	388
	Jefferson County, ID	27,096	23,622	3,474	120	92	18	2,810	0	434
	Jerome County, ID	22,694	14,525	8,169	137	117	20	7,622	6	267
	Kootenai County, ID	147,716	134,752	12,964	1,867	1,074	470	6,219	3	3,331
	Latah County, ID	38,593	34,617	3,976	248	914	274	1,559	52	929
	Lemhi County, ID	7,743	7,241	502	59	34	16	231	9	153
	Lewis County, ID	3,826	3,309	517	187	29	3	160	0	138
	Lincoln County, ID	5,292	3,572	1,720	97	9	0	1,577	0	37
	Madison County, ID	38,114	34,110	4,004	2	459	225	2,639	9	670
	Minidoka County, ID	20,331	12,937	7,394	140	89	45	6,869	0	251
	Nez Perce County, ID	39,995	34,963	5,032	2,203	359	146	1,429	0	895
	Oneida County, ID	4,269	4,017	252	20	0	0	162	0	70
	Owyhee County, ID	11,356	7,739	3,617	340	14	14	3,001	0	248
	Payette County, ID	22,773	18,030	4,743	197	286	87	3,796	46	331
	Power County, ID	7,696	4,856	2,840	286	2	17	2,487	19	29
	Shoshone County, ID	12,551	11,572	979	223	54	43	412	2	245
	Teton County, ID	10,437	8,439	1,998	22	11	18	1,814	0	133
	Twin Falls County, ID	80,955	65,504	15,451	589	1,149	511	12,235	12	955
	Valley County, ID	9,897	9,670	227	11	11	1	111	0	93
	Washington County, ID	10,035	7,896	2,139	60	61	0	1,743	40	235
	Idaho Total	**1,635,483**	**1,355,896**	**279,587**	**17,635**	**22,375**	**9,818**	**195,589**	**948**	**33,222**

State	County	Total Population	White Alone	Minority Population[2/]	Breakdown of Minority Populations[1/]					
					American Indian or Alaskan Native	Asian or Pacific Islander	Black or African American	Hispanic or Latino	Some Other Race	Two or More Races
	Idaho Percent of Total Population	**100%**	**83%**	**17%**	**1%**	**1%**	**1%**	**12%**	**0%**	**2%**
Montana	Beaverhead County, MT	9,317	8,534	783	209	154	8	358	0	54
	Broadwater County, MT	5,692	5,336	356	86	80	10	70	0	110
	Deer Lodge County, MT	9,176	8,327	849	128	218	32	282	0	189
	Flathead County, MT	94,696	88,370	6,326	1,295	536	234	2,417	41	1,803
	Glacier County, MT	13,695	4,290	9,405	8,716	68	36	386	0	199
	Granite County, MT	3,212	3,042	170	19	2	2	64	0	83
	Jefferson County, MT	11,601	10,813	788	190	31	8	254	1	304
	Lake County, MT	29,311	19,304	10,007	7,164	131	72	1,197	0	1,443
	Lincoln County, MT	19,268	17,987	1,281	197	114	11	516	0	443
	Madison County, MT	7,810	7,361	449	39	14	13	235	0	148
	Mineral County, MT	4,223	4,108	115	14	32	2	56	4	7
	Missoula County, MT	113,101	101,865	11,236	2,646	1,557	470	3,413	0	3,150
	Powell County, MT	6,928	6,260	668	274	68	29	170	0	127
	Ravalli County, MT	41,130	38,374	2,756	219	231	32	1,322	24	928
	Sanders County, MT	11,375	10,266	1,109	421	55	18	299	0	316
	Silver Bow County, MT	34,560	31,512	3,048	711	305	202	1,411	0	419
	Montana Total	**415,095**	**365,749**	**49,346**	**22,328**	**3,596**	**1,179**	**12,450**	**70**	**9,723**
	Montana Percent of Total Population	**100%**	**88%**	**12%**	**5%**	**1%**	**0%**	**3%**	**0%**	**2%**
Nevada	Elko County, NV	52,029	35,044	16,985	2,689	683	552	12,522	6	533
	Humboldt County, NV	17,091	11,192	5,899	778	84	82	4,419	198	338

State	County	Total Population	White Alone	Minority Population[2/]	Breakdown of Minority Populations[1/]					
					American Indian or Alaskan Native	Asian or Pacific Islander	Black or African American	Hispanic or Latino	Some Other Race	Two or More Races
	Nevada Total	**69,120**	**46,236**	**22,884**	**3,467**	**767**	**634**	**16,941**	**204**	**871**
	Nevada Percent of Total Population	**100%**	**67%**	**33%**	**5%**	**1%**	**1%**	**25%**	**0%**	**1%**
Oregon	Baker County, OR	16,030	14,657	1,373	213	167	65	615	14	299
	Benton County, OR	87,455	71,510	15,945	483	5,789	851	6,100	119	2,603
	Clackamas County, OR	394,967	328,760	66,207	2,031	16,764	3,163	32,503	169	11,577
	Clatsop County, OR	37,660	32,445	5,215	139	497	267	3,074	0	1,238
	Columbia County, OR	49,645	44,362	5,283	573	672	303	2,301	0	1,434
	Coos County, OR	62,944	53,888	9,056	1,320	815	403	3,910	72	2,536
	Crook County, OR	21,334	18,903	2,431	217	48	39	1,588	0	539
	Curry County, OR	22,364	19,513	2,851	402	133	87	1,457	25	747
	Deschutes County, OR	170,813	150,077	20,736	769	1,848	797	13,029	80	4,213
	Douglas County, OR	107,375	95,301	12,074	1,042	1,063	380	5,649	16	3,924
	Gilliam County, OR	1,913	1,657	256	54	10	6	186	0	0
	Grant County, OR	7,227	6,650	577	46	17	30	253	1	230
	Harney County, OR	7,214	6,294	920	241	42	46	356	42	193
	Hood River County, OR	22,842	14,741	8,101	202	398	111	7,046	0	344
	Jackson County, OR	210,916	173,329	37,587	1,280	2,862	1,321	25,058	285	6,781
	Jefferson County, OR	22,305	13,410	8,895	3,614	242	226	4,421	0	392
	Josephine County, OR	84,063	73,736	10,327	1,022	651	297	5,850	30	2,477
	Klamath County, OR	65,946	52,273	13,673	2,118	718	394	7,823	65	2,555
	Lake County, OR	7,799	6,679	1,120	90	70	44	592	10	314
	Lane County, OR	360,273	299,530	60,743	3,155	9,911	3,442	29,403	574	14,258
	Lincoln County, OR	46,685	38,725	7,960	1,334	648	205	4,028	80	1,665
	Linn County, OR	119,862	103,248	16,614	1,623	1,479	591	10,054	69	2,798

State	County	Total Population	White Alone	Minority Population[2/]	Breakdown of Minority Populations[1/]					
					American Indian or Alaskan Native	Asian or Pacific Islander	Black or African American	Hispanic or Latino	Some Other Race	Two or More Races
	Malheur County, OR	30,474	18,902	11,572	167	492	306	10,015	39	553
	Marion County, OR	326,527	218,448	108,079	1,952	8,798	3,547	83,659	249	9,874
	Morrow County, OR	11,207	6,857	4,350	44	54	15	3,886	0	351
	Multnomah County, OR	778,193	553,241	224,952	4,389	57,730	41,100	86,579	1,899	33,255
	Polk County, OR	78,470	62,253	16,217	849	1,733	621	10,232	54	2,728
	Sherman County, OR	1,705	1,506	199	42	2	8	87	0	60
	Tillamook County, OR	25,552	21,733	3,819	199	289	79	2,573	4	675
	Umatilla County, OR	76,582	51,612	24,970	1,641	624	519	19,596	41	2,549
	Union County, OR	25,758	23,106	2,652	202	567	170	1,131	13	569
	Wallowa County, OR	6,836	6,407	429	29	16	27	174	7	176
	Wasco County, OR	25,657	19,499	6,158	921	389	109	4,289	0	450
	Washington County, OR	564,088	382,165	181,923	1,865	55,148	10,013	91,495	894	22,508
	Wheeler County, OR	1,369	1,291	78	15	9	0	26	0	28
	Yamhill County, OR	102,217	79,759	22,458	791	1,759	777	15,768	54	3,309
	Oregon Total	**3,982,267**	**3,066,467**	**915,800**	**35,074**	**172,454**	**70,359**	**494,806**	**4,905**	**138,202**
	Oregon Percent of Total Population	**100%**	**77%**	**23%**	**1%**	**4%**	**2%**	**12%**	**0%**	**3%**
Washington	Adams County, WA	19,100	6,813	12,287	34	185	59	11,820	0	189
	Asotin County, WA	22,113	20,230	1,883	228	205	56	791	0	603
	Benton County, WA	187,519	135,362	52,157	1,104	4,530	2,589	38,146	459	5,329
	Chelan County, WA	74,761	51,466	23,295	738	700	303	20,307	10	1,237
	Clallam County, WA	72,969	61,008	11,961	3,281	1,174	687	4,274	223	2,322
	Clark County, WA	450,893	360,807	90,086	2,407	22,278	8,084	39,042	695	17,580
	Columbia County, WA	3,971	3,491	480	18	76	15	270	15	86

State	County	Total Population	White Alone	Minority Population[2/]	Breakdown of Minority Populations[1/]					
					American Indian or Alaskan Native	Asian or Pacific Islander	Black or African American	Hispanic or Latino	Some Other Race	Two or More Races
	Cowlitz County, WA	102,854	87,013	15,841	1,002	1,557	600	8,640	73	3,969
	Douglas County, WA	40,101	26,177	13,924	282	345	90	12,247	26	934
	Ferry County, WA	7,639	5,636	2,003	1,150	111	13	316	0	413
	Franklin County, WA	87,810	36,534	51,276	337	1,835	1,752	45,685	54	1,613
	Garfield County, WA	2,231	2,058	173	7	19	0	74	0	73
	Grant County, WA	92,530	51,364	41,166	744	947	604	37,124	38	1,709
	Grays Harbor County, WA	71,233	56,988	14,245	2,918	1,379	744	6,864	18	2,322
	Island County, WA	80,113	64,659	15,454	844	3,968	2,385	5,402	142	2,713
	Jefferson County, WA	30,333	26,912	3,421	574	526	267	1,045	2	1,007
	King County, WA	2,079,550	1,294,359	785,191	11,354	346,392	124,303	194,189	3,929	105,024
	Kitsap County, WA	257,488	200,165	57,323	2,557	13,600	6,159	18,375	354	16,278
	Kittitas County, WA	42,785	36,177	6,608	324	881	474	3,653	8	1,268
	Klickitat County, WA	20,930	17,217	3,713	560	186	138	2,520	0	309
	Lewis County, WA	75,724	63,979	11,745	491	910	502	7,292	42	2,508
	Lincoln County, WA	10,326	9,506	820	121	72	32	308	0	287
	Mason County, WA	61,060	49,879	11,181	1,639	1,027	578	5,465	24	2,448
	Okanogan County, WA	41,299	27,387	13,912	3,873	425	246	7,869	22	1,477
	Pacific County, WA	20,743	17,167	3,576	368	415	59	1,855	11	868
	Pend Oreille County, WA	13,001	11,566	1,435	455	121	30	455	11	363
	Pierce County, WA	832,896	571,006	261,890	8,466	60,203	53,881	84,021	1,093	54,226
	San Juan County, WA	16,056	14,308	1,748	128	262	97	937	47	277
	Skagit County, WA	120,475	90,922	29,553	1,774	2,431	839	21,310	71	3,128
	Skamania County, WA	11,316	9,989	1,327	261	111	104	668	13	170

State	County	Total Population	White Alone	Minority Population[2/]	Breakdown of Minority Populations[1/]					
					American Indian or Alaskan Native	Asian or Pacific Islander	Black or African American	Hispanic or Latino	Some Other Race	Two or More Races
	Snohomish County, WA	758,649	546,155	212,494	6,061	76,313	19,427	72,859	952	36,882
	Spokane County, WA	485,859	415,979	69,880	5,823	13,328	8,346	25,143	212	17,028
	Stevens County, WA	43,744	38,114	5,630	1,903	326	200	1,468	8	1,725
	Thurston County, WA	266,311	203,511	62,800	3,573	17,390	7,611	21,856	404	11,966
	Wahkiakum County, WA	4,051	3,633	418	85	79	5	188	0	61
	Walla Walla County, WA	59,809	43,428	16,381	269	997	887	12,508	104	1,616
	Whatcom County, WA	209,729	168,060	41,669	5,754	8,944	1,958	18,517	170	6,326
	Whitman County, WA	47,494	37,902	9,592	164	3,774	950	2,681	54	1,969
	Yakima County, WA	247,681	111,448	136,233	9,026	2,519	1,835	118,091	120	4,642
	Washington Total	**7,073,146**	**4,978,375**	**2,094,771**	**80,697**	**590,541**	**246,909**	**854,275**	**9,404**	**312,945**
	Washington Percent of Total Population	**100%**	**70%**	**30%**	**1%**	**8%**	**3%**	**12%**	**0%**	**4%**
Wyoming	Teton County, WY	22,623	18,370	4,253	66	410	139	3,433	8	197
	Wyoming Total	**22,623**	**18,370**	**4,253**	**66**	**410**	**139**	**3,433**	**8**	**197**
	Wyoming Percent of Total Population	**100%**	**81%**	**19%**	**0%**	**2%**	**1%**	**15%**	**0%**	**1%**

Source: U.S. Census Bureau 2017

Notes:

1/ The U.S. Census distinguishes between two ethnic groups: Not Hispanic or Latino and Hispanic or Latino. Within these two groups, the Census reports racial identification. For the purpose of this analysis, all peoples in the Hispanic or Latino ethnic group are counted as Hispanic or Latino, regardless of their race. For example, a person that is of Hispanic or Latino ethnicity that identifies as black or African American would not appear in the Black or African American category but rather in the Hispanic or Latino category.

2/ For purposes of this analysis, minority population reflects all populations not identified as "Not Hispanic or Latino: White alone" in the U.S. Census Bureau's American Community Survey.

57 **Table 1-4. Other Socioeconomic Indicators in the Study Area, by County**

State	Geographic Region	Median Household Income[1/]	Per Capita Income[1/]	Unemployment Rate	Percent Over Age 64	Percent Under Age 5	Percent Population with less than High School Education[2/]	Percent Households in Linguistic Isolation[3/]
N/A	**United States**	**$55,322**	**$29,829**	**7%**	**14%**	**6%**	**13%**	**4%**
California	Modoc County, CA	$44,567	$22,755	7%	23%	4%	14%	2%
	California	**$63,783**	**$31,458**	**9%**	**13%**	**6%**	**18%**	**9%**
Idaho	Ada County, ID	$58,264	$30,589	5%	13%	6%	5%	2%
	Adams County, ID	$42,468	$22,707	11%	25%	4%	10%	1%
	Bannock County, ID	$48,197	$21,938	7%	13%	8%	8%	1%
	Bear Lake County, ID	$46,063	$22,297	3%	20%	7%	6%	1%
	Benewah County, ID	$42,880	$22,347	10%	21%	6%	13%	0%
	Bingham County, ID	$49,015	$20,028	7%	13%	8%	14%	3%
	Blaine County, ID	$58,556	$36,780	4%	16%	6%	10%	3%
	Boise County, ID	$46,901	$26,844	8%	22%	3%	6%	0%
	Bonner County, ID	$43,063	$24,601	6%	21%	5%	10%	0%
	Bonneville County, ID	$53,481	$23,874	5%	12%	9%	9%	2%
	Boundary County, ID	$38,676	$22,688	4%	20%	6%	11%	0%
	Butte County, ID	$40,762	$25,313	7%	20%	4%	10%	1%
	Camas County, ID	$42,708	$26,544	4%	17%	7%	12%	2%
	Canyon County, ID	$41,799	$18,211	8%	13%	8%	16%	3%
	Caribou County, ID	$58,653	$24,614	2%	17%	7%	8%	1%
	Cassia County, ID	$45,647	$18,537	5%	13%	9%	18%	8%
	Clark County, ID	$32,422	$14,622	5%	11%	11%	30%	20%
	Clearwater County, ID	$40,603	$22,546	7%	25%	3%	12%	0%
	Custer County, ID	$40,498	$24,225	4%	25%	4%	7%	2%
	Elmore County, ID	$45,950	$22,380	6%	12%	8%	14%	4%
	Franklin County, ID	$51,828	$19,982	4%	14%	8%	10%	2%
	Fremont County, ID	$49,707	$21,014	5%	16%	7%	13%	3%
	Gem County, ID	$41,848	$19,004	9%	21%	5%	13%	1%
	Gooding County, ID	$45,068	$20,082	4%	17%	7%	24%	6%

State	Geographic Region	Median Household Income[1/]	Per Capita Income[1/]	Unemployment Rate	Percent Over Age 64	Percent Under Age 5	Percent Population with less than High School Education[2/]	Percent Households in Linguistic Isolation[3/]
	Idaho County, ID	$39,386	$19,250	6%	24%	5%	12%	0%
	Jefferson County, ID	$51,825	$20,396	5%	10%	9%	13%	2%
	Jerome County, ID	$43,461	$17,776	5%	12%	9%	25%	11%
	Kootenai County, ID	$52,151	$27,166	7%	17%	6%	8%	0%
	Latah County, ID	$49,669	$24,779	8%	12%	6%	4%	1%
	Lemhi County, ID	$34,980	$22,791	6%	27%	4%	8%	1%
	Lewis County, ID	$35,963	$23,287	6%	24%	5%	11%	0%
	Lincoln County, ID	$45,924	$18,600	5%	13%	7%	22%	7%
	Madison County, ID	$40,892	$14,785	9%	6%	10%	4%	1%
	Minidoka County, ID	$48,021	$22,468	5%	15%	8%	22%	9%
	Nez Perce County, ID	$51,206	$25,193	6%	19%	6%	8%	0%
	Oneida County, ID	$40,796	$18,990	7%	19%	6%	6%	1%
	Owyhee County, ID	$33,248	$17,439	9%	16%	7%	25%	7%
	Payette County, ID	$43,686	$22,451	8%	17%	7%	13%	1%
	Power County, ID	$53,079	$22,080	7%	15%	10%	21%	6%
	Shoshone County, ID	$39,083	$22,490	11%	21%	5%	14%	0%
	Teton County, ID	$57,864	$31,476	6%	8%	8%	9%	6%
	Twin Falls County, ID	$46,810	$21,450	4%	15%	8%	13%	3%
	Valley County, ID	$52,502	$28,514	5%	21%	5%	4%	1%
	Washington County, ID	$36,809	$20,235	9%	23%	5%	16%	3%
	Idaho	**$49,174**	**$24,280**	**6%**	**14%**	**7%**	**10%**	**2%**
Montana	Beaverhead County, MT	$44,028	$26,173	7%	20%	5%	6%	1%
	Broadwater County, MT	$47,801	$28,056	6%	21%	4%	6%	0%
	Deer Lodge County, MT	$42,005	$23,822	4%	21%	3%	11%	0%
	Flathead County, MT	$50,464	$27,306	7%	17%	6%	5%	0%
	Glacier County, MT	$35,028	$17,464	11%	11%	9%	10%	0%
	Granite County, MT	$47,324	$25,914	7%	28%	4%	11%	0%
	Jefferson County, MT	$60,114	$28,654	6%	19%	4%	5%	0%

State	Geographic Region	Median Household Income[1/]	Per Capita Income[1/]	Unemployment Rate	Percent Over Age 64	Percent Under Age 5	Percent Population with less than High School Education[2/]	Percent Households in Linguistic Isolation[3/]
	Lake County, MT	$42,723	$24,741	9%	20%	6%	9%	0%
	Lincoln County, MT	$36,370	$22,512	12%	25%	4%	12%	0%
	Madison County, MT	$46,684	$29,505	4%	26%	4%	5%	0%
	Mineral County, MT	$35,305	$21,600	7%	27%	5%	13%	0%
	Missoula County, MT	$50,723	$28,339	7%	14%	5%	5%	1%
	Powell County, MT	$45,188	$25,850	1%	19%	4%	11%	0%
	Ravalli County, MT	$43,557	$23,651	8%	23%	5%	9%	0%
	Sanders County, MT	$33,663	$19,985	9%	26%	5%	12%	0%
	Silver Bow County, MT	$44,198	$25,645	7%	17%	5%	9%	0%
	Montana	**$48,380**	**$27,309**	**6%**	**17%**	**6%**	**7%**	**0%**
Nevada	Elko County, NV	$69,725	$29,998	5%	9%	7%	17%	2%
	Humboldt County, NV	$66,138	$28,729	8%	11%	8%	18%	4%
	Nevada	**$53,094**	**$27,253**	**9%**	**14%**	**6%**	**15%**	**6%**
Oregon	Baker County, OR	$42,174	$25,183	9%	25%	5%	10%	1%
	Benton County, OR	$56,271	$28,175	8%	14%	4%	5%	2%
	Clackamas County, OR	$73,266	$35,759	7%	16%	5%	7%	2%
	Clatsop County, OR	$49,015	$26,526	7%	19%	5%	8%	2%
	Columbia County, OR	$54,804	$26,795	9%	17%	5%	10%	0%
	Coos County, OR	$41,573	$25,089	11%	24%	5%	11%	1%
	Crook County, OR	$40,478	$21,276	11%	24%	5%	12%	0%
	Curry County, OR	$40,078	$25,015	11%	32%	4%	10%	1%
	Deschutes County, OR	$55,499	$29,918	7%	18%	5%	7%	1%
	Douglas County, OR	$44,780	$23,621	11%	24%	5%	11%	0%
	Gilliam County, OR	$42,727	$22,711	11%	24%	6%	10%	1%
	Grant County, OR	$40,370	$23,516	7%	27%	4%	10%	1%
	Harney County, OR	$40,761	$22,519	14%	22%	5%	10%	2%
	Hood River County, OR	$57,084	$28,518	5%	15%	7%	20%	4%
	Jackson County, OR	$48,724	$26,445	9%	20%	6%	11%	2%

State	Geographic Region	Median Household Income[1/]	Per Capita Income[1/]	Unemployment Rate	Percent Over Age 64	Percent Under Age 5	Percent Population with less than High School Education[2/]	Percent Households in Linguistic Isolation[3/]
	Jefferson County, OR	$50,785	$23,346	13%	18%	7%	16%	1%
	Josephine County, OR	$40,034	$22,908	11%	25%	5%	11%	0%
	Klamath County, OR	$42,503	$21,885	11%	19%	6%	12%	1%
	Lake County, OR	$36,274	$20,613	9%	23%	5%	16%	0%
	Lane County, OR	$49,390	$25,915	9%	17%	5%	9%	2%
	Lincoln County, OR	$43,528	$25,254	7%	25%	5%	11%	1%
	Linn County, OR	$48,768	$23,213	10%	17%	6%	10%	1%
	Malheur County, OR	$38,230	$18,441	10%	16%	7%	20%	5%
	Marion County, OR	$52,487	$23,806	9%	14%	7%	15%	5%
	Morrow County, OR	$52,167	$22,514	6%	14%	7%	25%	9%
	Multnomah County, OR	$65,493	$35,097	8%	12%	6%	9%	4%
	Polk County, OR	$54,313	$24,530	10%	17%	6%	9%	2%
	Sherman County, OR	$42,471	$32,170	7%	24%	5%	7%	0%
	Tillamook County, OR	$46,692	$24,351	7%	23%	5%	10%	0%
	Umatilla County, OR	$49,820	$22,742	9%	14%	7%	17%	4%
	Union County, OR	$47,897	$25,352	7%	18%	6%	7%	0%
	Wallowa County, OR	$44,521	$25,965	8%	27%	5%	7%	0%
	Wasco County, OR	$49,049	$23,005	7%	20%	6%	14%	2%
	Washington County, OR	$72,019	$33,275	7%	12%	7%	9%	4%
	Wheeler County, OR	$33,304	$22,849	10%	36%	2%	8%	0%
	Yamhill County, OR	$58,760	$26,259	8%	16%	6%	12%	3%
	Oregon	**$53,270**	**$28,822**	**8%**	**16%**	**6%**	**10%**	**3%**
Washington	Adams County, WA	$48,443	$20,074	6%	10%	11%	34%	19%
	Asotin County, WA	$46,803	$24,517	8%	21%	6%	10%	0%
	Benton County, WA	$66,628	$29,563	7%	13%	7%	10%	4%
	Chelan County, WA	$53,850	$26,286	7%	17%	7%	17%	4%
	Clallam County, WA	$47,274	$26,508	9%	27%	5%	8%	2%
	Clark County, WA	$67,468	$30,511	7%	14%	6%	8%	3%

State	Geographic Region	Median Household Income[1/]	Per Capita Income[1/]	Unemployment Rate	Percent Over Age 64	Percent Under Age 5	Percent Population with less than High School Education[2/]	Percent Households in Linguistic Isolation[3/]
	Columbia County, WA	$43,098	$28,282	9%	27%	5%	10%	1%
	Cowlitz County, WA	$48,928	$24,317	10%	18%	6%	12%	1%
	Douglas County, WA	$53,421	$23,911	5%	16%	7%	19%	7%
	Ferry County, WA	$38,829	$21,595	10%	22%	4%	13%	0%
	Franklin County, WA	$59,422	$22,621	7%	8%	10%	26%	13%
	Garfield County, WA	$49,938	$23,022	4%	22%	7%	4%	0%
	Grant County, WA	$50,353	$21,070	9%	13%	8%	25%	9%
	Grays Harbor County, WA	$46,595	$24,561	12%	19%	6%	12%	2%
	Island County, WA	$62,599	$32,832	7%	22%	6%	5%	1%
	Jefferson County, WA	$49,896	$30,621	7%	32%	4%	5%	0%
	King County, WA	$88,238	$44,165	6%	12%	6%	8%	6%
	Kitsap County, WA	$69,142	$32,857	6%	16%	6%	6%	1%
	Kittitas County, WA	$50,415	$26,332	7%	15%	5%	9%	1%
	Klickitat County, WA	$48,222	$22,786	5%	21%	5%	13%	1%
	Lewis County, WA	$45,991	$22,984	10%	20%	6%	13%	2%
	Lincoln County, WA	$49,632	$25,381	4%	24%	5%	9%	1%
	Mason County, WA	$53,866	$27,516	11%	21%	5%	13%	2%
	Okanogan County, WA	$43,161	$23,086	8%	20%	7%	18%	3%
	Pacific County, WA	$38,388	$21,342	8%	28%	4%	12%	2%
	Pend Oreille County, WA	$44,553	$24,597	9%	24%	5%	11%	0%
	Pierce County, WA	$64,655	$29,862	8%	13%	7%	9%	3%
	San Juan County, WA	$58,233	$40,716	5%	30%	3%	5%	1%
	Skagit County, WA	$55,952	$28,330	7%	19%	6%	11%	3%
	Skamania County, WA	$50,862	$28,326	8%	17%	5%	10%	0%
	Snohomish County, WA	$78,327	$34,503	6%	12%	6%	8%	4%
	Spokane County, WA	$52,422	$26,253	7%	15%	6%	7%	2%
	Stevens County, WA	$43,469	$22,049	9%	21%	5%	10%	0%
	Thurston County, WA	$65,131	$30,975	8%	15%	6%	6%	2%

State	Geographic Region	Median Household Income[1/]	Per Capita Income[1/]	Unemployment Rate	Percent Over Age 64	Percent Under Age 5	Percent Population with less than High School Education[2/]	Percent Households in Linguistic Isolation[3/]
	Wahkiakum County, WA	$49,898	$27,336	7%	31%	3%	7%	0%
	Walla Walla County, WA	$50,243	$25,965	6%	16%	6%	11%	4%
	Whatcom County, WA	$57,279	$29,195	8%	15%	6%	9%	2%
	Whitman County, WA	$45,149	$23,694	9%	10%	4%	4%	4%
	Yakima County, WA	$48,033	$21,528	8%	13%	8%	28%	9%
	Washington	**$62,848**	**$32,999**	**7%**	**14%**	**6%**	**9%**	**4%**
Wyoming	Teton County, WY	$77,343	$45,186	2%	12%	5%	5%	3%
	Wyoming	**$59,143**	**$30,139**	**5%**	**14%**	**7%**	**8%**	**1%**

Source: U.S. Census Bureau 2017

Notes:

1/ In the past 12 months using 2016 inflation-adjusted dollars.

2/ Percent of population 25 years and older.

3/ A linguistically isolated household is one in which no member 14 years old and over (1) speaks only English or (2) speaks a non-English language and speaks English "very well."

Table 1-5. Demographic Information for Indian Reservations in the Study Area[1/]

Tribe[2/]	Total Population	Percent Below Poverty Level[3/]	Median Household Income[4/]	Per Capita Income[4/]	Unemployment Rate	Percent Over Age 64	Percent Under Age 5	Percent Population with less than High School Education
Alturas Indian Rancheria, California[5/]	No data	No data	No data	No data	No data	No data	No data	No data
Blackfeet Tribe of the Blackfeet Indian Reservation of Montana	10,842	38%	$25,641	$14,249	14%	9%	8%	10%
Burns Paiute Tribe	138	26%	$30,625	$13,799	29%	18%	9%	13%
Cedarville Rancheria, California	21	30%	No data	$24,552	0%	5%	5%	0%
Coeur D'Alene Tribe[5/]	7,064	19%	$45,375	$24,666	9%	22%	5%	11%

Tribe[2/]	Total Population	Percent Below Poverty Level[3/]	Median Household Income[4/]	Per Capita Income[4/]	Unemployment Rate	Percent Over Age 64	Percent Under Age 5	Percent Population with less than High School Education
Confederated Salish and Kootenai Tribes of the Flathead Reservation[5/]	28,938	23%	$37,540	$21,685	10%	18%	7%	10%
Confederated Tribes and Bands of the Yakama Nation	31,283	30%	$40,958	$14,916	10%	10%	10%	38%
Confederated Tribes of Siletz Indians of Oregon	412	33%	$31,250	$13,164	18%	9%	9%	18%
Confederated Tribes of the Chehalis Reservation	828	30%	$40,729	$16,533	22%	8%	13%	17%
Confederated Tribes of the Colville Reservation	7,460	29%	$34,457	$18,047	17%	15%	8%	17%
Confederated Tribes of the Coos, Lower Umpqua and Siuslaw Indians[6/]	95	No data	No data	No data	No data	9%	16%	No data
Confederated Tribes of the Grand Ronde Community of Oregon	130	15%	$33,125	$21,155	11%	55%	2%	18%
Confederated Tribes of the Umatilla Indian Reservation	2,782	21%	$47,679	$21,444	10%	18%	7%	10%
Confederated Tribes of the Warm Springs Reservation of Oregon	4,548	30%	$42,390	$13,020	25%	8%	7%	20%
Coquille Indian Tribe[5/]	388	23%	$25,000	$20,456	13%	35%	10%	24%
Cow Creek Band of Umpqua Tribe of Indians	152	35%	$41,667	$12,729	14%	14%	8%	12%
Cowlitz Indian Tribe[5/]	No data	No data	No data	No data	No data	No data	No data	No data
Elko Band (Constituent band of the Te-Moak Tribe of Western Shoshone Indians of Nevada) [5/]	932	27%	$35,250	$20,532	12%	10%	4%	17%
Fort Bidwell Indian Community of the Fort	190	51%	$21,875	$9,590	28%	4%	8%	40%

Tribe[2/]	Total Population	Percent Below Poverty Level[3/]	Median Household Income[4/]	Per Capita Income[4/]	Unemployment Rate	Percent Over Age 64	Percent Under Age 5	Percent Population with less than High School Education
Bidwell Reservation of California								
Fort McDermitt Paiute and Shoshone Tribes of the Fort McDermitt Indian Reservation, Nevada and Oregon[5/]	482	44%	$16,250	$7,579	46%	14%	11%	28%
Hoh Indian Tribe	153	55%	$34,583	$9,084	14%	4%	8%	35%
Jamestown S'Klallam Tribe[6/]	27	No data	No data	No data	No data	0%	0%	No data
Kalispel Indian Community of the Kalispel Reservation	280	27%	$39,500	$17,209	3%	9%	3%	19%
Klamath Tribes[5/]	43	72%	$9,722	$7,660	77%	28%	0%	34%
Kootenai Tribe of Idaho	41	15%	$61,250	$28,871	0%	0%	0%	17%
Likely (Pit River Tribe, California) [5/]	No data	No data	No data	No data	No data	No data	No data	No data
Lookout (Pit River Tribe, California) [5/]	16	25%	$34,375	$14,363	0%	13%	0%	18%
Lower Elwha Tribal Community	379	36%	$30,938	$14,453	24%	8%	7%	23%
Lummi Tribe of the Lummi Reservation[5/]	5,428	25%	$50,397	$20,977	11%	14%	8%	13%
Makah Indian Tribe of the Makah Indian Reservation[5/]	1,590	21%	$35,114	$15,667	19%	8%	10%	17%
Muckleshoot Indian Tribe	3,991	22%	$47,039	$20,607	15%	14%	8%	19%
Nez Perce Tribe[5/, 7/]	3,554	30%	$40,278	$13,735	27%	No data	No data	29%
Nisqually Indian Tribe[5/]	735	23%	$51,250	$17,769	16%	10%	7%	23%
Nooksack Indian Tribe[6/]	1,132	No data	No data	No data	No data	11%	11%	No data
Port Gamble S'Klallam Tribe	560	31%	$37,500	$14,749	12%	7%	5%	18%
Puyallup Tribe of the Puyallup Reservation	49,416	14%	$66,668	$30,629	7%	12%	7%	10%

Tribe[2/]	Total Population	Percent Below Poverty Level[3/]	Median Household Income[4/]	Per Capita Income[4/]	Unemployment Rate	Percent Over Age 64	Percent Under Age 5	Percent Population with less than High School Education
Quileute Tribe of the Quileute Reservation[5/]	433	33%	$36,750	$16,984	22%	3%	12%	18%
Quinault Indian Nation[5/]	1,159	33%	$33,906	$14,447	23%	15%	7%	19%
Samish Indian Nation[5/]	37,397	10%	$61,160	$38,538	5%	28%	4%	5%
Sauk-Suiattle Indian Tribe[5/]	69	13%	$62,500	$25,632	16%	9%	7%	3%
Shoalwater Bay Indian Tribe of the Shoalwater Bay Indian Reservation	88	22%	$47,813	$20,526	21%	17%	7%	12%
Shoshone-Bannock Tribes of the Fort Hall Reservation	6,061	22%	$42,365	$16,558	21%	13%	7%	20%
Shoshone-Paiute Tribes of the Duck Valley Reservation, Nevada[5/ 6/]	1,450	27%	$34,792	$17,526	21%	12%	8%	13%
Skokomish Indian Tribe[5/]	934	33%	$37,917	$14,376	15%	13%	4%	18%
Snoqualmie Indian Tribe[5/]	No data	No data	No data	No data	No data	No data	No data	No data
South Fork Band (Constituent band of Te-Moak Tribe of Western Shoshone Indians of Nevada)	70	13%		$28,317	6%	24%	0%	13%
Spokane Tribe of the Spokane Reservation[8/]	2,085	33%	$34,150	$15,733	26%	13%	10%	15%
Squaxin Island Tribe of the Squaxin Island Reservation	352	22%	$40,938	$17,059	20%	7%	5%	26%
Stillaguamish Tribe of Indians of Washington[6/]	11	No data	No data	No data	No data	18%	0%	No data
Summit Lake Paiute Tribe of Nevada	No data	No data	No data	No data	No data	No data	No data	No data
Suquamish Indian Tribe of the Port Madison Reservation[5/]	7,832	11%	$62,012	$33,207	6%	16%	5%	5%

Tribe[2/]	Total Population	Percent Below Poverty Level[3/]	Median Household Income[4/]	Per Capita Income[4/]	Unemployment Rate	Percent Over Age 64	Percent Under Age 5	Percent Population with less than High School Education
Swinomish Indian Tribal Community	2,843	11%	$58,167	$33,384	5%	35%	3%	7%
Tulalip Tribes of Washington	10,064	13%	$68,498	$31,004	11%	15%	5%	13%
Upper Skagit Indian Tribe[5/]	259	44%	$31,250	$10,651	35%	7%	12%	37%
Wells Band (Constituent band of Te-Moak Tribe of Western Shoshone Indians of Nevada) [5/]	106	21%	$46,875	$14,252	6%	6%	8%	10%
Winnemucca Indian Colony of Nevada[5/]	35	54%	$11,458	$16,254	17%	40%	6%	50%
XL Ranch (Pit River Tribe, California)[5/]	97	8%	$39,125	$12,839	7%	7%	8%	4%

Sources: Manson et al. 2018; U.S. Census Bureau 2018; Nez Perce Tribe 2019; USDA 2016

Notes:

1/ The demographic indicators presented in this table include metrics typically used by researchers and in EPA's EJ screening tools to represent the "social vulnerability" characteristics of a disadvantaged population (EPA 2017).

2/ Unless otherwise noted, these data represent statistics for the population residing within the geographic boundaries of the reservation (including tribal member and non-tribal member households) as well as off-reservation trust lands.

3/ Defined as percentage of all people whose income in the past 12 months is below poverty level.

4/ In the past 12 months using 2016 inflation-adjusted dollars.

5/ Includes reservation only; off-reservation trust land not included.

6/ 2013-2017 estimates from U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates (U.S. Census Bureau 2018).

7/ These data are from the Nez Perce Tribe Demographics Database (Nez Perce Tribe 2019).

8/ Data on population, poverty rate, and unemployment rate are from the HUD Promise Zone factsheet on the Spokane Indian Reservation (USDA 2016).

CHAPTER 2 - REFERENCES

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