Kootenai River Native Fish Conservation Aquaculture Program

Step 2 Document

Volume 2 – Appendices

Prepared by the Kootenai Tribe of Idaho

August 2012

Appendices

A. **Technical Basis for the Kootenai Sturgeon Conservation Aquaculture Program**

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Appendix A

Technical Basis for the Kootenai Sturgeon Conservation Aquaculture Program

Technical Basis for the Kootenai Sturgeon Conservation Aquaculture Program

Prepared by the Kootenai Tribe of Idaho for the Northwest Power and Conservation Council and Bonneville Power Administration

August 2012

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1 SUMMARY

This document provides a detailed explanation of current objectives, strategies, production targets, critical uncertainties and an adaptive monitoring and management framework for the Kootenai sturgeon conservation aquaculture program. This information provides the basis for proposed construction of additional hatchery facilities identified in the Kootenai River Native Fish Conservation Aquaculture Master Plan (Master Plan) (KTOI 2010).[1] This information also addresses related questions identified by the Independent Scientific Review Panel (ISRP) during their Step 1 review of the program.

Almost 20 years into a dedicated conservation and recovery effort for Kootenai sturgeon, we have reached a critical juncture where we must decide whether to continue down the same path or plot a new course. Decisions made now regarding implementation of habitat and hatchery actions can either lay a sound foundation for recovery or doom this population to a continued long slow slide into extinction. Maintaining current hatchery production levels and practices might be adequate to conserve a segment of the sturgeon population for another generation but will likely only perpetuate the undesirable status quo or extend the extinction trajectory. The failure of other more limited and incremental flow and habitat measures implemented to date have led us to conclude that: 1) the status quo is inadequate and 2) more substantive habitat and hatchery actions are needed. Population viability, resilience, and persistence are now the primary long-term aquaculture program objectives and are requirements to avoid extinction of endangered Kootenai River white sturgeon.

The Kootenai Tribe of Idaho (Tribe or KTOI) believes that an additional hatchery facility is essential for meeting these long -term sturgeon conservation and recovery objectives. Although co-managers and agency partners may weigh the relative importance of specific benefits of an additional facility differently, co-managers including the U.S. Fish and Wildlife Service (USFWS) and the Idaho Department of Fish and Game (IDFG) are in agreement regarding the need for a new facility.

The Tribe's goal extends beyond merely avoiding extinction to include recovery of Kootenai sturgeon as a viable component of a functional ecosystem. Sturgeon recovery is also essential to the provision and maintenance of federal trust responsibility and mitigation obligations for the negative effects of federal hydropower development in the Kootenai River system. An effective aquaculture program is part of the Tribe's comprehensive ecosystem restoration effort that also includes: 1) nutrient addition to increase biological productivity and food availability; 2) aquatic, riparian, and adjacent terrestrial habitat restoration; and 3) rebuilding of other depleted native species such as kokanee and burbot.

The Kootenai Tribe is committed to restoration of natural production of Kootenai sturgeon; nothing in this conservation aquaculture proposal should be construed as a lack of endorsement or commitment by the Tribe to restoration of natural production. While the conservation aquaculture program is designed to provide a contingency for continuing natural recruitment failure, long-term recovery will clearly depend on the effective restoration of habitat conditions suitable for natural recruitment. Significant habitat restoration activities, nutrient enhancement, and flow modifications are being

[1] *Prepared by the Kootenai Tribe of Idaho and submitted to the Northwest Power and Conservation Council (NPCC) for review under their "three-step" review process for all artificial production initiatives proposed for funding by the Bonneville Power Administration under the NPCC's Fish and Wildlife Program.*

implemented for this purpose. While no one is sure when (or if) these collective efforts will succeed, the potential for success within the next 20-30 years should not be discounted. Natural production remains a fundamental priority for Kootenai sturgeon conservation and recovery. The conservation aquaculture program will be modified to complement natural production when it occurs.

1.1 Between a Rock and a Hard Place

Kootenai River white sturgeon are in a very tough spot. Their physical and biological ecosystem has been severely altered by decades of human activity. Natural recruitment has failed for over 50 years (Paragamian et al. 2005). The wild population now consists entirely of an ever-dwindling cohort of large, old fish. If not for their longevity, sturgeon would have followed Kootenai burbot and kokanee into extinction years ago. Twenty years of research and experimentation has determined that recruitment is failing in the incubation stage because spawning currently occurs in an area dominated by clay, clay rubble, and sand substrates, where sand smothers the embryos. However, it is unknown why fish choose to spawn in such unfavorable habitat. Whether spawning sites were historically suitable or fish previously spawned somewhere more favorable is unclear. More importantly, we don't know what actions or magnitude of actions will restore natural recruitment. All attempts to date to restore natural recruitment using flow measures have failed.

The Kootenai Tribe's sturgeon aquaculture program is the only conservation measure that has produced any measurable benefits for Kootenai sturgeon to date. The program began in 1988 as a temporary research facility designed to assess gamete viability and explore the feasibility of sturgeon aquaculture which was then in its infancy in North America. Program objectives and facilites have evolved over time in response to demonstrated successes, lessons learned through the implementation of the program, and the growing awareness of the Program's significance to sturgeon conservation. Experimental releases of small numbers of fish began in 1990 and production increased over the next decade. Through 2011, a total of 200,274 juvenile sturgeon have been released by the Tribe's conservation aquaculture program (including the Kootenai Tribal Hatchery in Idaho and the fail-safe Kootenay Hatchery in British Columbia). Approximately 19,800 of these are estimated to have survived as of 2012.

The program has achieved, at least for the time being, the immediate objectives of producing multiple juvenile age classes and forestalling demographic extinction. Post-release monitoring has demonstrated that substantial numbers of hatchery-reared fish have successfully adapted to current river conditions. If sufficient numbers of these hatchery-produced fish continue to survive, grow, and mature, the hatchery program will have bought time to implement the large-scale ecosystem improvements necessary to restore natural production and long -term population sustainability.

1.2 Limitations of Existing Facilities

It is now apparent that the next sturgeon generation may well depend almost entirely on hatchery production. At a minimum, the conservation aquaculture program must be designed to provide a contingency for uncertain prospects in the timing and scale of any natural production that might be restored. The existing Tribal hatchery facilities were developed to meet near-term objectives of avoiding demographic extinction with an assumption that natural recruitment would be restored by flow measures in the interim. However, numbers of broodstock, families and total releases provided by current production facilities are inadequate to address longer-term conservation risks in the absence of substantial natural recruitment. Additionally, the existing facility is operating at its physical and functional capacity, thus restraining any program operational flexibility in the future. Expansion of the current facilities is not a viable alternative because the available space and water sources are fully utilized.

Hatchery broodstock capacity is limited by existing facilities. Current annual broodstock capacity of approximately 24 adults is determined by the lack of space and tanks for holding broodstock, segregating sexes, and isolating ready females, and a limited ability to regulate water temperature to control maturation of individual fish. These limitations preclude near-term increases in broodstock numbers. The program has not yet encountered substantial difficulty in obtaining target broodstock numbers and additional broodstock could be collected if suitable facilities were available.

Juvenile rearing capacity of the current facility also limits the number of families that can be produced. A family is defined as the offspring from one pair of parents. Families are reared separately to provide genetic and demographic accountability, and to limit the potential for inadvertent hatchery selection for some families at the expense of others. The current facilities can produce approximately 12 to 18 full- or half-sibling families per year in separate tanks where juveniles are reared to sizes (30 g) and ages (1+) necessary to avoid apparent natural habitat limitations for Age-0 fish identified by Justice et al. (2009). The Tribal Sturgeon Hatchery can effectively rear up to about 5 to 10 thousand juveniles under current family number and family size protocols, with additional production of up to 5 half-sibling families in the fail-safe Kootenay Sturgeon Hatchery in British Columbia.

Space and water limitations of the Tribal Sturgeon Hatchery also limit flexibility to grade and manage portions of families as needed to effectively manage survival, growth, health, and condition, and minimize the potential for inadvertent selection in the hatchery. Family and juvenile production numbers cannot be increased without increasing risks of potentially-detrimental hatchery selection effects that the conservation program is actively managing to avoid (differential growth, condition, pre- and post-release mortality due to stress-mediated disease and competition). Warm summer water temperatures in some years also result in significant stress and mortality of juveniles.

1.3 Long -term Production Requirements

The Tribe's Aquaculture Master Plan identifies a combination of upgrades to the Tribal Sturgeon Hatchery and construction of the new Twin Rivers Hatchery designed to increase numbers of broodstock, families, and total annual releases necessary to sustain a demographically and genetically viable Kootenai sturgeon population through the next generation in the event that significant natural production does not occur in the near term (Increased numbers of broodstock provided by the new facility will help preserve native genetic and life history diversity by capturing and spawning adequate numbers of representative broodstock before the dwindling wild population reaches extinction or senescence. While genetic analysis of broodstock conducted to date has demonstrated that a high percentage of the common lineages are represented, we cannot conclude that a full complement of the population's functional genome has been captured (particularly rare alleles). Increasing the number of broodstock collected now will also provide contingencies for uncertain future availability of wild broodstock and prospects for restoring natural recruitment.

Table 1). Planned production levels are designed to balance often-competing short-term and long-term risks.

Increased numbers of broodstock provided by the new facility will help preserve native genetic and life history diversity by capturing and spawning adequate numbers of representative broodstock before the dwindling wild population reaches extinction or senescence. While genetic analysis of broodstock conducted to date has demonstrated that a high percentage of the common lineages are represented, we cannot conclude that a full complement of the population's functional genome has been captured (particularly rare alleles). Increasing the number of broodstock collected now will also provide contingencies for uncertain future availability of wild broodstock and prospects for restoring natural recruitment.

Table 1. Annual production in current and planned facilities relative to program objectives.

	Current facilities [a]	Proposed Facility Capacity		
		Total	Tribal Sturgeon Hatchery	Twin Rivers Hatchery
Broodstock number	24	Up to 45	Up to 18	Up to 27
Families produced [b]	12-18	Up to 30	Up to 12	Up to 18
Fish/family	1,000-1,500	500-1,000	500-1,000	500-1,000
Total releases per year	10,000-15,000	15,000-30,000	6,000-12,000	9,000-18,000

[a] *Includes Kootenai Tribal Sturgeon Hatchery in Bonners Ferry and fail-safe Kootenay Sturgeon Hatchery in B. C. All broodstock holding and spawning occurs at the Kootenai Tribal Sturgeon Hatchery. A portion of the fertilized eggs are transported to the Kootenay Sturgeon Hatchery for rearing in the fail-safe program.*

[b] *Family is defined as offspring of one pair of parents.*

Increased numbers of families will recombine and express genetically-based (inherited) life history trait diversity and adaptive plasticity through a wider range of unique phenotypes. Diverse phenotypic expression will allow the population to take full advantage of current and future habitat and environmental conditions and increase the likelihood of future natural recruitment, a prerequisite for population down-listing and delisting. This strategy employs increased broodstock numbers and factorial mating matrices to maximize expression of the available diversity. Conserving and optimizing genetic diversity through maximum phenotypic expression might ultimately prove to be the single most effect long-term recovery strategy for Kootenai sturgeon.

Increased juvenile production will help bridge the "death valley" period between the disappearance of the remaining wild fish and the maturation of the hatchery-produced generation. During this interval, too few fish are expected to be available to capitalize on favorable natural spawning conditions in any year or to provide hatchery broodstock. Failure to maintain an adequate effective spawning population size in the wild will also exacerbate risks of genetic bottlenecks that reduce diversity or cause inbreeding depression in the next and subsequent generations. The Tribe is pursuing a rigorously precautionary, inclusive production approach that optimizes the probability of species persistence rather than extinction. At the same time, very large release numbers could exceed the uncertain capacity of the system and trigger potentially detrimental reductions in survival, growth and maturation of fish released into the wild. To address this risk, family size targets have been reduced to 500-1,000 from current levels (Table 1) and the initial Step 1 Master Plan proposal of 1,000-1,500.

Increased operational flexibility at the new Twin Rivers Hatchery facilities will address current limitations at the Tribal Sturgeon Hatchery by reducing the risks of inadvertent and potentially detrimental hatchery selection or domestication. More space, water, volume, containers and temperature regulation capabilities will allow fish to be reared at lower densities to reduce stress, disease, and mortality. The availability of three water sources at the new Twin Rivers facility will provide cost-effective temperature management that will improve management of broodstock maturation and juvenile growth, conversion and health.

Finally, spawning and rearing of sturgeon at the new Twin Rivers facility will provide the opportunity to experimentally determine if fish can be induced to migrate into more favorable spawning habitats upstream from Bonners Ferry where they do not currently go. Upstream migration might be enhanced either by imprinting juveniles to water sources higher in the system or attracting adults to chemical cues in the hatchery discharge during ovulation and spawning of broodstock in the hatchery.

1.4 Critical Uncertainties & Adaptive Management

Kootenai sturgeon conservation and recovery efforts continue to face daunting challenges and uncertainties. We do not know if and when natural recruitment will be restored, how long the aging wild population will remain reproductive, and whether hatchery-reared fish will ultimately spawn and recruit successfully in the wild. We also don't know if returning to a yearling release strategy will improve hatchery sturgeon survival from recent low rates; where future density-related limitations may reduce survival of older sturgeon; or to what extent habitat productivity may be improved by nutrient enrichment and habitat restoration actions.

Rather than pursing a speculative reductionist approach to key uncertainties, the program supports a "true" adaptive management strategy involving systematic, rigorous learning by designing management actions as experiments. True adaptive management is an appropriate strategy when uncertainty is high, risks are acceptable or reversible, and answers can be obtained in a reasonable time frame.[2] Implementation of a truly adaptive management approach for Kootenai sturgeon involves: 1) aggressive use of hatchery production to inform recovery strategies by experimentally evaluating system dynamics and limitations, and 2) implementation of a comprehensive monitoring and evaluation program involving explicit test hypotheses, quantitative benchmarks, and a decision pathway for program adjustments. This effort will continue to be implemented through the cooperative efforts of the Kootenai Tribe, IDFG, and other co-managers, and will involve regular annual operational reviews and consultations regarding the need for decisions based on progress and new information.

Current plans reflect our best attempt to implement an effective precautionary sturgeon conservation aquaculture program; however, experience has demonstrated that surprises and course adjustments will be inevitable. Research and monitoring efforts over the last 10 to 20 years have produced a number of surprises, each with significant implications for recovery. For instance, age validation studies showed that the wild fish are substantially older than previously thought, which led to reassessing the importance of non-flow-related (pre-dam) habitat requirements and the nature, timing and causes of

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[2] *"True" adaptive management is contrasted with "pretend" adaptive management which involves implementation of a project, monitoring, and adaptation if problems are evident. The latter strategy is generally effective only when you know where you stand, where you want to go, how to get there, and uncertainty is low.*

natural recruitment failure. Monitoring post-release survival of hatchery-reared fish identified a second critical life history bottleneck at the young-of-the-year (YOY) stage that may constrain our ability to restore natural recruitment (Justice et al. 2009). More recently, expanded sampling efforts in Kootenay Lake demonstrated that the wild population is larger than previously estimated but that many of these fish rarely appear to participate in spawning (Beamesderfer et al. 2012a). Finally, the failure of flow measures implemented to date must be regarded as a surprise relative to the assumptions guiding development of the 1999 Kootenai Sturgeon Recovery Plan.

The hallmark of the Kootenai sturgeon recovery effort has been its experimental adaptive approach to address substantial uncertainties. Over its brief history, the program has evolved in response to new data, information, and changing demands. New information and evaluations have characterized the sturgeon conservation and recovery effort in the face of very large uncertainty regarding limiting factors and effective remedies. Hatchery facility requirements also change over the course of the recovery effort in response to risks encountered at various stages. We have every reason to expect this pattern to continue for the duration of the recovery effort. The additional facility at Twin Rivers along with upgrades of the Kootenai Tribal Sturgeon Hatchery will provide the flexibility in space, systems and water necessary to continue to implement this program in an adaptive and effective manner.

2 Recovery Goals and Planning Objectives

Past and planned sturgeon culture activities address long-term recovery goals and interim objectives that chart a pathway to recovery. Recovery goals and hatchery objectives have evolved over the last 10 to 20 years based on new information and experience. The proposed hatchery facilities identified in the Master Plan and this Step 2 document are an adaptive response to developments and new information collected since the Kootenai River White Sturgeon Recovery Plan was adopted in 1999 (USFWS 1999), and are designed to maximize future operational flexibility.

2.1 1999 Recovery Plan

The Kootenai River White Sturgeon Recovery Plan (USFWS 1999) identified objectives and criteria reflecting the best available information at that time. The Recovery Plan identified a long-term goal of down-listing and delisting Kootenai white sturgeon when the population becomes self-sustaining. The plan noted that recovery will not be complete until there is survival to sexual maturity, which may take upwards of 25 years for females and until the late teens for males. However, specific long-term goals or delisting criteria were not identified due to substantial uncertainties in population status, life history, biological productivity, and effects of flow augmentation.

The Recover Plan also described intial steps for preventing extinction and initiating recovery, focusing on the first 5 to 10 years of recovery efforts. Short-term objectives included reestablishing natural recruitment and preventing extinction through conservation aquaculture. The Recovery Plan suggested that down-listing would be appropriate when short-term criteria are achieved. Three criteria for reclassification or down-listing were identified:

1. Natural production occurring in at least 3 different years of a 10-year period. A naturally-produced year class was defined as when at least 20 juveniles were sampled at more than 1 year of age.
2. Stable or increasing population. This includes juveniles released from the conservation aquaculture program each year for a 10-year period in numbers large enough to produce 24 to 120 sturgeon surviving to sexual maturity.
3. A long-term flow strategy adequate to produce natural recruits.

The conservation aquaculture program was initially designed as a temporary “bridge” to fill in a gap of missing year classes until effective flow measures could restore natural recruitment. The 1999 Recovery Plan acknowledged there was uncertainty about limiting factors and action effectiveness, and emphasized research, monitoring, and evaluation to address and reduce these critical uncertanties. Subsequent work and findings have demonstrated the wisdom of this precautionary, adaptive approach in preventing extinction of the endanged Kootenai sturgeon population.

2.2 Developments Subsequent to the 1999 Recovery Plan

At the time of listing, it was believed that flow regulation associated with Libby Dam operations (post-1974) was the primary factor responsible for natural recruitment failure at the spawning and early life history life stage. However, initial hopes for a relatively simple water management solution to the recruitment problem have not been realized. Although a variety of measures have been implemented since completion of the Recovery Plan, all efforts to date have failed to increase or restore natural

natural recruitment or to identify an effective remedy for restoring natural recruitment (Paragamian and Beamesderfer 2004). We now know that recruitment failure results from much more pervasive changes in the Kootenai River ecosystem related to upstream hydro operations, watershed-scale land use impacts, Kootenai Valley floodplain development, river channel confinement, Kootenay Lake level management, and the additive, altered productivity and ecological effects of all these factors (Anders et al. 2002).

Refinements in aging methods also indicated that recruitment failure pre-dates Libby Dam completion by at least 10 to 15 years (Paragamian and Beamesderfer 2003). Decades of post-release flow monitoring also found that recruitment bottlenecks occur during incubation in the wild (Anders et al. 2002; Kock et al. 2006) and during the YOY life stage for hatchery released fish (Justice et al. 2009). Given that current regulated flows do not provide suitable conditions for effective reproduction, it is clear that other ecological limitations must also be addressed. It seems clear now that ongoing recruitment failure cannot be expected to be resolved by slight increases of nutrient-deficient water from Libby Dam that remain a fraction of average annual historical freshet volumes. This is not to say that flow measures are unnecessary, but rather that without other improvements, sturgeon have been unable benefit from flow modifications. This is why the Tribe is also implementing the complementary Kootenai River Habitat Restoration Project Master Plan (KTOI 2009), the Kootenai River Ecosystem Restoration Project (nutrient additions and biomonitoring), and other complementary habitat restoration projects (e.g., tributary reconnection).

Recent information suggests that recovery will be more difficult, more expensive, and take longer than initially anticipated. Although the hatchery program was intially designed as a short-term, stop-gap measure, Paragamian et al. (2005) concluded that "most likely, the next generation will be produced primarily or entirely by the conservation aquaculture program." Effective flow remedies have not been achieved and habitat restoration is underway but will take many years. At this point, even if some measure of restoration is achieved, natural production alone may not be adequate to produce enough fish or capture enough of the dwindling population to avoid future genetic founder effects (population bottlenecks) and ensure long-term population viability and persistence.

The need to revise and update the 1999 Recovery Plan has been widely recognized (Paragamian et al. 2005). The USFWS plans to revise the Recovery Plan in coordination with the Kootenai River White Sturgeon Recovery Team, but as of the writing of this document this effort has not been formally initiated. In recognition of the long-term role the conservation aquaculture program must play in recovery of Kootenai sturgeon, the availability of new information, and the absence of an updated Recovery Plan, the Tribe has coordinated with agency partners and co-managers to identify a series of working goals, objectives, and criteria[3] for recovery. These goals and criteria are based on a review of essential elements common to other sturgeon and salmon recovery plans (Dryer and Sandoval 1993; UCWSRI 2002; LCFRB 2004; NMFS 2007; CDFO 2009; NMFS 2009). The upgraded and new facilities identified in the Master Plan (and refined in the Step 2 document) are designed to work together to meet the essential role and long-term requirements reflected in the following working goal, objectives, and criteria.

[3] *Criteria identified in the 1999 Recovery Plan have not been formally revised to address current status and information.*

2.3 Working Goal

An informal "working" recovery goal for Kootenai sturgeon has been identified by the Kootenai Tribe to guide the development of the conservation aquaculture program. The goal is:

> ***To ensure the persistence and viability of a naturally-reproducing population as an essential element of an adequately functional ecosystem and a resource supporting traditional beneficial uses.***

Because the conservation aquaculture program is also designed to address Tribal trust responsibilities, the working goal also incorporates traditional beneficial uses.

2.4 Working Population Objectives

Working population objectives established to guide the development of the conservation aquaculture program include specific population objectives related to long-term viability of Kootenai sturgeon.[4] Population viability objectives are based on four population attributes: abundance, productivity, distribution/spatial structure, and diversity. The technical basis relating viability to these four attributes is adapted from salmon conservation, as reflected in the Viable Salmonid Population concept (McElhany et al. 2000). The Canadian Recovery Strategy for white sturgeon, listed under the Species at Risk Act, also identified recovery targets based on a population viability framework that considered abundance, productivity, spatial structure and diversity (NRTWS 2009). Abundance targets in the Canadian plan are based in part on results of Population Viability Analyses (PVAs) reported in the conservation biology literature for other species; no PVAs specific to sturgeon were included because information was insufficient on Canadian white sturgeon populations. Working population objectives for Kootenai sturgeon are identified in Box 1, and discussed in the following paragraphs.

Abundance. Long-term abundance objectives for conservation are generally based on minimum viable population (MVP) sizes that are naturally self-sustaining. A viable population is large enough to: 1) survive normal environmental variation, 2) allow compensatory processes to provide resilience to perturbation, 3) maintain genetic diversity, and 4) provide important ecological functions (McElhany et al. 2000). Critical low abundance levels occur due to: 1) the breakdown in normal population processes as low numbers (e.g., depensation), 2) genetic effects of inbreeding depression or fixation of deleterious mutations, 3) demographic stochasticity, and 4) uncertainty in status evaluations (Lande and Barrowclough 1987; Nelson and Soulé 1987; Lynch 1990; Hilborn and Walters 1992; Lande 1993; Lawson 1993; Lynch 1996; Courchamp et al. 1999; McElhany et al. 2000; Lynch and O'Hely 2001).

A wide range of viable abundance values has been established for different species. The conservation science literature typically identifies a minimum viable genetic effective population size of at least 50 to 1,000 adults (Thompson 1991; NRTWS 2009). Because census numbers are typically several times greater than effective population size due to non-random mating, sampling error (not all fish spawning in every year), population abundance targets ranging from 1,000 to 20,000 have been recommended for various species (IUCN 2001, NRTWS 2009).

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[4] *Working objectives were identified by the Kootenai Tribe for hatchery planning purposes in the absence of established recovery goals. Recovery and down-listing goals are the responsibility of the listing authority.*

Box 1. Working population objectives established to guide the development of the conservation aquaculture program for Kootenai white sturgeon.

Abundance

- A minimum adult population size of 2,500.

Productivity

- Naturally-produced recruitment and juvenile population sizes sufficient to support the desired adult population size.
- Stable or increasing trends in adult and juvenile numbers.
- Representative and stable size and age structure.

Distribution

- Distribution and use of habitats throughout the majority of the historical range.
- Breadth of distribution such that population is not vulnerable to any single human-caused catastrophic event (chemical spill for instance).

Diversity

- Stable genetic diversity (including frequencies of common and rare alleles).
- Effective population sizes adequate to allow for normal genetic and evolutionary processes.

Use

- Numbers (consistent with above) adequate to support significant subsistence harvests and recreational fishery uses.

Other white sturgeon recovery plans have identified abundance objectives ranging from 1,000 per population with multiple populations (NRTWS 2009) to a single population value of 2,500 (UCWSRI 2002). Historical numbers also provide a useful reference point for establishing goals, and are presumed to be consistent with historical levels of ecological function. Paragamian and Hansen (2008) identified a goal of 7,000 subadults and adults for what was thought to be a relatively viable population size before 1980. For planning purposes, we used 2,500 adults (IUCN 2001; UCWSRI 2002) as a minimum viability objective.[5] This number is consistent with the 7,000 adults and subadults assumed to be viable by Paragamian and Hansen (2008).

The question of effective genetic population size and MVP size has only recently begun to be widely considered for sturgeon and no clear consensus has emerged. Most attempts to derive these numbers have proven to be rather speculative exercises based on simplistic genetic models and untested assumptions. An MVP of 80 to 150 post-YOY male and female individuals was estimated for lake sturgeon populations in the Great Lakes basin using a stochastic population viability model with a 5% extinction risk over 250 years (Schueller and Hayes 2011). This population size is much smaller than the 1,188 spawning females estimated to be necessary for persistence of lake sturgeon in the stage structured assessment by Velez-Espino and Koops (2009). However, all these numbers are up to two orders of magnitude lower than empirical abundance estimates for white sturgeon populations with significant natural recruitment. Abundance of the smallest recruiting and largest non-recruiting white sturgeon populations was estimated at between 3,000 and 4,000 individuals, based on empirical information provided by regional sturgeon managers and reports from the Columbia, Fraser, and

[5] *These numbers are not intended to replace the USFWS down-listing or delisting objectives – they are solely for the purposes of planning the KTOI program. The Tribe assumes that the formal down-listing and delisting numbers will be updated as part of development of the revised Recovery Plan.*

Sacramento river systems (Anders et al. 2004). Jager et al. (2010) similarly recognized difficulties in estimating abundance-based viability thresholds and recommended recruitment rather than abundance-based thresholds. Based on the large discrepancy between these recently published MVP estimates, we propose higher target demographic and genetic targets as well as a suite of complementary productivity, distribution and diversity objectives.

Productivity. Productivity refers to a population's ability to replace itself and rebound from a low level to a viable equilibrium population level. Productivity of viable populations is such that: 1) abundance can be maintained above the viable level, 2) viability is independent of hatchery subsidy, 3) numbers are maintained even during extended sequences of poor environmental conditions, 4) declines in abundance are not sustained, 5) life history traits are not in flux, and 6) conclusions are independent of uncertainty in parameter estimates (McElhany et al. 2000).

Productivity objectives for sturgeon obviously include natural recruitment in numbers sufficient to support adult abundance objectives. Net recruitment is a function of annual spawner numbers or population fecundity, frequency of suitable conditions, and the magnitude of annual or individual recruitment success. No specific annual recruitment objective is identified for sturgeon because adult objectives can be achieved by a variety of combinations of these factors. However, diversity objectives discussed below will require significant recruitment contributions from multiple parents during multiple years to maintain inherent or desirable population characteristics. Stable or increasing trends in juvenile and adult numbers are clearly related to long-term population viability. For long-lived species such as sturgeon, size, age, and sex ratios are particularly powerful indicators of long-term productivity patterns. Viable sturgeon populations are characterized by a broad distribution of sizes and ages. Size and age distributions are stable over the long-term in a population at equilibrium.

Distribution/Spatial Structure. Spatial structure refers to the amount of habitat available, the organization and connectivity of habitat patches, and the relatedness and exchange rates of adjacent populations. Large habitat patches or a connected series of smaller patches are generally associated with wider species distribution and increased population viability. In a highly viable species: 1) the number of habitat patches is stable or increasing; 2) exchange rates among metapopulations are stable; 3) marginally suitable habitat patches are preserved; 4) refuge source populations are preserved, and 5) uncertainty is taken into account (McElhany et al. 2000).

In Kootenai sturgeon, there is only one extant population and limited opportunity to establish an additional population within the historical range.[6] Spatial structure objectives for this population would be met by the broad distribution of sturgeon among river, delta, and lake habitats, the diversity of habitat types accessible within the historical range, and the relative stability and resilience of the Kootenay Lake habitat where a large portion of the adult population spends a majority of its time.

Diversity. Diversity refers to individual and population variability in genetic-based life history, behavioral, and physiological traits. Genetic diversity is related to population viability because it allows a species to use a wider array of environments, protects species against short-term spatial and temporal changes in the environment, and provides the raw material for surviving long-term environmental

[6] *A guidance document for evaluating an experimental, non-essential (ESA 10(j)) Kootenai River white sturgeon population was provided to the USFWS (Anders 2007).*

changes (McElhany et al. 2000). Loss of diversity is thought to reduce productivity by reducing physiological and life history variability that is adaptive in a diverse and variable environment (NRC 1996). Reduced diversity is typically first manifested by the loss of rare alleles. Low diversity can also result in inbreeding depression, which is the loss in fitness due to breeding between closely related individuals (for instance, through increased expression of deleterious recessive traits).

Diversity objectives for Kootenai sturgeon are based on genetic criteria. These include maintaining adequate abundance to protect existing diversity and to allow for normal genetic and evolutionary processes. Genetic risks are related to effective population size (N_e), which is based on an idealized population where every individual has an equal chance of mating with every other. Small N_es increase the likelihood of genetic drift, founder effects from managed populations, and inbreeding depression. Numbers associated with genetic risk are theoretical and are generally derived from simple population genetics models and conservation biology literature. Genetic considerations are a primary driver for abundance objectives and conservation aquaculture objectives identified for Kootenai sturgeon.

Use. Specific use-related objectives are not identified for Kootenai sturgeon but working objectives recognize a long-term interest in considering the need and feasibility for broad sense use objectives when conservation objectives are met. Natural production rates sufficient to provide harvest or withstand other fishery impacts recognize a desire to restore historical Tribal trust fishing opportunities as well as other cultural uses. Reproductive rates that provide a harvestable surplus within the limitations of current system capacity also provide an additional safety factor from long-term risks to population viability.

3 Conservation Aquaculture Strategy

3.1 Conservation Aquaculture vs. Supplementation

The goal of conservation aquaculture is to conserve and recover imperiled fish populations, without harvest or production quotas driving hatchery operations. Conservation hatcheries are focused on producing sustainable age class structures in populations with limited or no natural recruitment, while optimizing remaining native genetic diversity. Conservation aquaculture involves incorporating local gene pools and allowing sufficient migration of genes into hatchery broodstock and progeny groups to allow adequate allelic representation for population viability and persistence. It requires careful selective breeding programs to provide sufficient diversity within a fish population of interest. It necessitates eliminating as much artificial conditioning as possible. When successful, it provides the increased population base on which natural selection can operate. Because of its design, conservation aquaculture can reduce the commonly considered risks associated with high-density salmonid supplementation hatchery production, such as competitive feeding behaviors, reduced growth rates, domestication selection, and increased incidence of disease.

Traditional hatchery supplementation programs often measure success largely by the total number of fish released. Supplementation hatcheries often produce fish destined for release in other areas, compared to the within-basin focus of conservation programs, consistent with co-evolved plasticity, life history expression, and pathogen resistance attributes. Some supplementation programs treat the symptom of declining fish populations in lieu of addressing serious issues of degraded and lost fish habitat, or other causal factors. A comparison between the Tribe’s proposed conservation aquaculture programs for burbot and sturgeon, and a salmon supplementation program is presented to enhance this discussion, which was requested by the ISRP (Table 2).

Table 2. Comparison of conservation aquaculture and supplementation programs.

Program Component	Conservation Aquaculture	Supplementation Programs
Goal	Conservation, recovery of threatened, endangered, or imperiled populations.	Harvestable excess, enhance population size
Production	Relatively few fish	Large number of fish
Rearing density	Lower	Higher
Disease risk	Reduced	Increased
Domestication risk	Lower	Higher
Post-stocking survival	Higher	Lower
Genetic criteria	High priority	Lower Priority

The failure to account for the natural range of species-specific life history trait expressions and behaviors in the hatchery can jeopardize the success of any hatchery program (Brannon 1993). Brannon (1993) further suggested that if hatchery programs neglect the requirements of natural populations, and therefore the traits they possess that allow them to synchronize their life history with specific environmental constraints, failure is all but certain. Thus, well designed conservation aquaculture programs should focus on hatchery protocols and facility designs and operations that best mimic and complement natural reproductive and life history attributes of the target species (Table 3) and the adaptive and evolutionary benefits of those attributes (Table 4).

Table 3. Comparison of white sturgeon and Pacific salmon reproductive and life history strategies.

Reproductive and Life History Attributes	White Sturgeon *(Acipenser transmontanus)*	Burbot (*Lota lota*)	Pacific Salmonids (*Oncorhynchus spp.*)
Spawning type	Iteroparity Communal spawners Broadcast spawning	Iteroparous, inter-mittent, communal spawning	Semelparity Paired spawners Redd-building
Individual fecundity (number of eggs per female)	100,000 ->1 million eggs	< ~ 3 million eggs 300,000-400,000 eggs per 2.0 kg Moyie Lake Fish UI-ARI	1,500 – 12,000 eggs
Generation length	20-30 years	~ 5 years	3-6 years
Longevity	≥ 100 years	Up to 20 years	< 10 years
Age at first maturity	15-25 years	2-3years (males) 4-5 years (females)	2-7 years
Number of year-classes spawning together	Several - dozens	Several	1-3

Source: Modified from Anders 2004 to include burbot

Table 4. Beneficial aspects of white sturgeon reproductive and life history attributes to incorporate into conservation aquaculture programs.

Reproductive and Life History Attributes	Benefits
Iteroparity	Multiple opportunities to pass gametes on to subsequent generations within a single lifespan
Overlapping generations	Increases between and among generation gene flow
Differential sex-specific age at first maturity	Reduces reproductive synchrony of male female siblings
Differential sex-specific spawning periodicity, communal, broadcast spawning	Reduces reproductive synchrony of male and female siblings

Source: Anders 2004

For example, because sturgeon are iteroparous, females should be allowed to serve as broodstock in the hatchery upon subsequent availability, as long as they are mated with numerous different males, as would occur during natural spawning of larger populations in the wild due to sex-specific differences in spawning periodicity. As another example, communal broadcast spawning naturally contributes to complex gene flow patterns in sturgeons. This trait should also be reflected in the design of their breeding matrices. This feature can be addressed to some degree in the hatchery by fertilizing each female with gametes from multiple, different males, either directly or by volitional (in-tank) spawning by a unique array of male and female spawners in each tank.

Natural reproduction in viable sturgeon populations is also characterized by interbreeding individuals from many cohorts, year-classes, generations, and families. Spawning matrix design can partially incorporate this natural reproductive strategy by ensuring that fish of considerably different ages (sizes) and cohorts are interbred. Although it is not assumed that every ripe male and female spawn successfully within a cohort, intentionally mating fish of considerably different sizes (ages) from larger populations increases inter-generational gene flow, based on assumptions of the natural sturgeon reproductive model, while acknowledging that the number of different family lineages decreases non-linearly with reduced population abundance or remnant population status.

Finally, whether in the wild or in the hatchery, reproductive and life history traits retained by natural selection and evolution as evolutionarily stable strategies affect cohort performance and survival before and after release from the hatchery. Therefore, it is critical that fish managers, hatchery managers, fish geneticists, and fish culturists to work together to collectively understand the natural reproductive and life history strategies of fishes they manage and culture because these natural models provide successful, time-tested examples to guide design and operation of species-specific conservation aquaculture facilities and programs.

3.2 Risk Identification

The objectives of the Kootenai sturgeon program require fundamentally different hatchery strategies than in many salmonid production or conservation programs. While the lessons learned from the uses and misuses of hatcheries for salmon provides cautionary instruction (e.g. Meffe 1992), sturgeon hatchery considerations can also be hampered by the application of “salmo-centric” thinking due to the fundamental differences in life history and reproductive strategies between sturgeon and salmon (Anders 1998, 2004).

Because of their very long life span and late age of maturation, sturgeon strategies demand a very measured consideration of time. “Long-term” takes on a special meaning for species like sturgeon for which planning horizons must be expressed in decades or even centuries. The successful sturgeon life history strategy is characterized by accrued, additive impacts of small incremental effects in patterns that are manifested over a long period. Kootenai River white sturgeon are going extinct in slow motion and recovery will occur in the same fashion. Current trends are the result of impacts that occurred 50 years ago. Actions we take now will fix the path for the next 50 years and beyond.

Therefore, hatchery production strategies must take both a near-term and long-term point of view. It is not simply a case of establishing annual production targets and protocols. It is not as easy as identifying the future population goals and then back-calculating annual release numbers required to produce that number of fish. Developing an effective conservation aquaculture strategy is, in effect, an optimization exercise in balancing a number of time-sensitive risks (Table 5). Hatchery priorities, strategies, and production targets will change over time based on temporal risk patterns, actions needed to address immediate risks, and actions designed to anticipate future risks.

Questions regarding sturgeon conservation aquaculture objectives often focus on long-term outcomes; e.g., how many juveniles need to be released in order to meet adult abundance objectives (or to seed the available habitat to capacity). However, both near-term and long-term risks warrant careful consideration in the design of an effective conservation program.

Table 5. Conservation risks for Kootenai white sturgeon including wild population risks that the aquaculture program is designed to address and hatchery-related risks that the aquaculture program is designed to avoid.

Risk	***Summary***
Demographic	
Depletion	Population declines in response to reduced annual reproduction or recruitment
Depensation	Collapse of normal population processes at low numbers resulting in a spiraling slide toward extinction (the "extinction vortex")
Functional extinction	Too few fish for effective reproduction or to provide hatchery broodstock
Genetic	
Loss of diversity	Founder effect in next generation that results from failure to include adequate numbers of fish in the spawning broodstock
Inbreeding depression	Unbalanced contribution of only a few fish to the next generation that accrues deleterious recessive traits and reduces fitness
Selection	Directional change in genetic composition due to domestication or inadvertent selection over time in the hatchery
Ecological	
Intraspecific competition or predation	Depression of wild recruit survival, growth, maturation, etc.
Disease magnification	Increased incidence of disease and associated effects resulting from transmission in the hatchery
Uncertainty	
Measurement	Many activities are scaled to uncertain estimates of survival, etc. Hatchery fish may also confound detection of natural recruitment
Process	Fundamental lack of understanding of limiting factors and population dynamics

3.3 Objectives

Near- and long-term objectives are identified for the aquaculture program in order to address conservation-related risks over time (Box 2). Near-term objectives focus primarily on the current generation that includes the declining remnant wild population. Near-term objectives help plot a course forward from a population's current demographic and genetic condition to future desired conditions. Long-term objectives involve future generations, including fish produced primarily in the hatchery from the remnant wild generation, and any natural recruits in the interval until the last wild fish dies or becomes scenescent. Long-term objectives provide a vision of the ultimate destination. Near-term objectives establish a sound foundation for meeting the long-term objectives. Each of the ten conservation aquaculture objectives listed in Box 2 are described below.

Box 2. Period-specific objectives of the conservation aquaculture program to protect and restore Kootenai white sturgeon (periods describe the interval during which related risks are manifested).

Near-Term Objectives

1. Prevent demographic extinction by replacing failed natural recruitment.
2. Establish an increasing trend and broad distribution of ages and sizes in the wild population in order to ensure future sustainability.
3. Preserve and express native genetic, phenotypic, and life history diversity by capturing and spawning significant numbers of representative broodstock.
4. Provide contingencies for uncertain future availability of wild broodstock and prospects for restoring natural recruitment.
5. Inform recovery strategies by using hatchery fish to identify limiting life stages and habitat capacity.

Long-Term Objectives

6. Avoid annual spawning stock limitation where too few fish might be available to capitalize on favorable natural spawning conditions in any year (or to continue to provide hatchery broodstock).
7. Minimize, to the extent possible, the time interval between the functional extinction of remaining wild adults and maturation of the first hatchery generation.
8. Maintain an effective population size in the wild adequate to avoid genetic bottlenecks that risk loss of diversity or inbreeding depression in the next generation.
9. Avoid significant detrimental impacts of hatchery fish on natural production due to competition, predation, or disease magnification.
10. Avoid hatchery selection or domestication that might reduce future fitness or viability.

1. Prevent demographic extinction by replacing failed natural recruitment.

Forestalling demographic extinction is an essential near-term objective of the program. Simple demographic objectives are both a function of fish quantity and quality, as reflected by the amount of genetic diversity they represent. They are also met by producing fish in numbers adequate to reverse the declining population trend. Given ongoing, long-term natural recruitment failure, long-term commitment to propagation is necessary to sustain population growth in a long-lived species like sturgeon. Avoiding demographic extinction was a primary focus of the 1999 Recovery Plan and previous program activities when the immediate objective was replacement of a 20-year period of missing year classes (Kincaid 1993; Duke et al. 1999; USFWS 1999).

2. Establish an increasing trend and broad distribution of ages and sizes in the wild population in order to ensure future sustainability.

Current production levels have successfully established an increasing trend and broad distribution of ages and sizes of hatchery-produced fish in the wild. Consistent regular production rebuilds the broad size and age structure that is reuired for a healthy sturgeon population.

3. Preserve and express native genetic, phenotypic, and life history diversity by capturing and spawning significant numbers of representative broodstock.

Capture and effective propagation of as much of the remaining genetic diversity as is reasonably possible is an essential element of the conservation and recovery strategy driving the need for the additional hatchery. The future of this population depends on the total amount of genetic material represented by the collective founders, which are produced solely by this program. Failure to preserve this diversity will reduce the associated genotypes, phenotypes, behaviors, and adaptive plasticity in some proportion to the amount of lost genetic material.

Since the Recovery Plan was completed, aquaculture objectives have evolved from replacement of a few year classes to the replacement an entire sturgeon generation, which must now serve as the basis for all subsequent generations. This fundamental shift in aquaculture program purpose and scope requires preserving the native genetic and life history diversity of the current population and propagating this material for the next sturgeon generation. At best, the hatchery can only perpetuate the native genetic material currently represented by the broodstock. Failure to collect adequate and representative numbers of broodstock will reduce genetic diversity in the next generation even if no artificial selection or domestication occurs within the rearing facility. This objective generally requires increasing the number of different wild adult spawners and the corresponding number of families produced, both within and among years by increasing the distribution of collections across the spatial and temporal extents of annual spawning seasons.

Genetic risks of sturgeon aquaculture have been clearly documented (Jager 2005; Crossman et al. 2011; Welsh et al. 2010). Genetic modeling of a hypothetical sturgeon population by Jager (2005) demonstrated the risks of genetic introgression over multiple generations when future broodstock derive from hatchery-produced fish and the diversity of the founding population was limited. This work highlighted the need to continue to introduce wild broodstock into the hatchery-origin population where wild fish continue to be available. Similar assessments of genetic risks led Welsh et al. (2010) to adopt genetic guidelines recommending that effective population size (Ne) be increased by increasing the number of parents used for each generation for lake sturgeon stocking.

Salmon hatchery programs throughout the basin have been roundly criticized for failures to adequately protect wild population diversity. These failures have translated into substantial declines in the breadth of adaptive potential and productivity of natural salmon populations. In light of this experience and critical unknowns regarding genetically effective population sizes and processes in sturgeon, the Tribe has elected to pursue a precautionary strategy for sturgeon conservation aquaculture.

There are two critical elements of genetic diversity in the Kootenai population. One involves the native diversity of alleles and allelic frequencies contained in the parent population. The second is the synergy of allele combinations expressed through recombination. Since any single offspring includes only half of the genetic diversity of each parent, it requires multiple offspring to carry the full complement forward. While the same genetic material may be contained in multiple parents, different combinations are expressed among individual siblings, collectively producing the mosaic of diversity for natural selection to act upon. The net results include variable individual and collective (population level) fitness and resilience levels. Thus, multiple offspring from each parent are needed to represent the broadest range of phenotypic characteristics for natural selection to subsequently act on. And it is not enough to just produce them. It is also critical to avoid potentially selective hatchery practices that reduce this diversity. In addition, it is necessary to produce enough fish for adequate numbers to survive to adulthood to successfully found the next generation(s). This requires adequate demographic representation from reproductive ages from 30 to over 80 years of age.

The precautionary genetic aquaculture strategy involves: 1) propagating a representative complement of the already-limited genetic diversity of this population; 2) optimizing non-selective expression of this diversity with many different combinations of traits; and 3) providing the opportunity for contribution of this diversity to subsequent spawning generations. The addition of the Twin Rivers facility to the existing Tribal Sturgeon Hatchery will help achieve this strategy by: 1) increasing number of wild broodstock spawned while they are still available in order to provide a large effective founder population; 2) employing factorial mating strategies to optimize expression of the existing diversity; 3) reducing rearing densities to avoid artificial selection and mortality in the hatchery; 4) increasing the ability to separately rear individual families to avoid artificial size-related mortality in the hatchery or following release; and 5) producing enough fish to ensure that a representative number survive to pass this diversity into the next generation of adults.

Conserving and optimizing genetic diversity might ultimately prove to be the single most effective recovery strategy for Kootenai sturgeon over the long-term. A wide range of physiological requirements and life history expressions should maximize the probability that some individuals in the next generation(s) will capitalize on existing and future habitat features and characteristics that are not currently conducive to natural production. For instance, it has been hypothesized that suitable spawning and incubation habitat exists upstream from the braided reach and that this habitat could support natural reproduction if only sturgeon would use it. There might be unique combinations of uncommon genetic characteristics in the current population that favor expression of a riverine migration and spawning life history. Thus, optimizing the potential for expression of genetic diversity through wise use of the hatchery program will put the population in the best position to test this hypothesis.

The current facility cannot spawn sufficient numbers of broodstock or independently raise enough families to provide an appropriately precautionary genetic safety factor. Opportunities for additional expansion of the current facility are limited by the available space and water supply. The Twin Rivers Hatchery is necessary to increase broodstock numbers, broodstock handling, and holding. The Twin Rivers Hatchery includes additional adult spawning and holding areas, and temperature control systems for broodstock purposes. Heating and chilling controls will allow better management of maturation and spawning of wild sturgeon broodstock. Maturation cycles, gamete viability, and fertilization success has been hampered by unfavorable river temperatures or temperature fluctuations at the existing facility. Temperature regulation in the adult holding facility would also provide the opportunity to hold males at the hatchery and to bring them into spawning condition as females are ready.

4. *Provide contingencies for uncertain future availability of wild broodstock and prospects for restoring natural recruitment.*

Hatchery objectives include contingencies for future uncertainties such as front-loading production while broodstock remain available. We still have significant ground to make up following 50 years of failed natural recruitment. Failure to capitalize on this opportunity based on a highly uncertain assumption that these fish will continue to be available indefinitely is an unacceptably risky strategy. Additional hatchery facilities and operational flexibility will allow broodstock and family numbers to be increased while adequate numbers of broodstock still exist.

Considerable uncertainty remains regarding the status of the remnant wild population and how long significant numbers of adults will remain available for hatchery broodstock or to take advantage of proposed habitat improvements. Recent analyses suggest that the population may be somewhat larger than previously estimated. We previously feared that broodstock limitations were imminent based on population estimates of fewer than 500 adults in 2005 and an annual mortality rate of 9% reported in Paragamian et al. (2008). However, more recent empirical data analyses indicated the current population is around 1,000 fish with an annual mortality rate estimated at between 2% and 8% based on various models (Beamesderfer et al. 2012b).[7]

However, the wild population is composed entirely of adults that continue to decline in numbers each year. Many adult-sized fish do not appear to be spawning as frequently as was previously estimated, and we have no way of knowing if or when reproductive senescence might occur. The reproductive lifespan of white sturgeon is unknown but substantial age-related differences in reproduction have been documented for other Acipenseriform species (Scarnecchia et al. 2011). By 2030, we project that the youngest of the remaining wild fish will be 70-80 years of age. There is little information in the sturgeon literature regarding reproductive senescence and no one has had experience using exclusive very old broodstock as will occur in this program during the next decade. We do not know whether mortality

[7] *The difference results from a failure to account for incomplete mixing of tagged and untagged fish in the river and lake. Tagging occurs primarily during spawning migrations into the river and all adult-sized fish do not appear to spawn with similar frequency.*

rates of very old fish will begin to increase or whether the viability of their gametes or progeny will decrease. Old fish are also very difficult to handle as captive broodstock due to their large size.

Rather than relaxing hatchery efforts in light of revised population estimates, we have instead taken a rigorous precautionary approach of increasing hatchery production to take advantage of these "additional" fish before they die. If the wild population was in its last stage of decline, it would be too late to increase broodstock numbers. However, the recognition that there are still good numbers of fish available allows us to bolster the effective population size of the founder population for the next, and all subsequent, sturgeon generations.

Recent population estimates suggest that significant numbers of wild adults will continue to be available for the near-term to provide the spawners needed to meet the increased production targets. The sturgeon aquaculture program has not yet encountered difficulty in obtaining sufficient broodstock, and while numbers vary from year to year, the program has been able to capture as many as the current facility can support at one time. We are confident based on recent experience that increased broodstock needs can be met from Idaho waters. All fish in this population appear to spawn exclusively in Idaho. More than 20 years of telemetry data from this population indicate that maturing adults generally migrate into Idaho over an extended period from late fall until spring; some overwinter in the river and migrate upstream during the following spring to reproduce. Sampling in proximity to current spawning areas consistently provides high catch per unit effort and a high percentage of ripening adults suitable for broodstock.

We can speculate at length on future broodstock availability and program sustainability but there are no guarantees. However, as time passes, potential risks associated with or resulting from speculation increasingly weigh against future population resilience. Meanwhile, the fish that have been released provide a contingency against future uncertainties in natural production and broodstock availability. Fish in the water now are fish in the future sturgeon population bank.

Having operated the Tribal Sturgeon Hatchery for years on very modest budgets, the Tribe recognizes that costs versus benefits must always be considered. Expanding hatchery capacity clearly involves a significant cost, but because the existing Tribal Sturgeon Hatchery does not provide adequate contingency for the uncertain future availability of wild broodstock, the additional facilities now proposed ultimately represent an investment in achieving program goals and reducing risk. Given the irrreversible consequences of failure, the Tribe concludes that the benefits of the proposed precautionary investments warrant the costs. It is possible that in 30 years, we could look back and conclude that this precautionary measure was not necessary; however, we would not want to look back in 30 years to find that failure to take aggressive action when we had the opportunity had resulted in the loss of this population altogether.

5. *Inform recovery strategies by using hatchery fish to help identify limiting life stages and habitat capacity.*

The new hatchery will also help support empirical testing of hypotheses regarding critical uncertainties currently limiting our ability to identify and implement effective recovery strategies involving natural recruitment. The facility will allow testing of imprinting and attraction hypotheses. The imprinting hypothesis is based on the idea that juvenile sturgeon, like salmon, might imprint to local water chemistry signatures during incubation and early rearing, then return to the same area to spawn. The new hatchery will provide an opportunity to imprint sturgeon to areas higher in the system where habitats appear to be more conducive to successful recruitment. When fish reared in the hatchery mature in 20 or more years, it is possible that they will migrate farther upstream to spawn. The attraction hypothesis is based on the idea that pheromones produced by spawning adults might attract other adults into the same area. If true, holding and spawning adults in this upstream hatchery might attract other adults to migrate and spawn in presumably more-favorable habitats. Production from the new facility will also provide the necessary sampling power and experimental framework for testing the performance and limitations of the system, particularly those related to life stage-specific carrying capacity.

Given the continuing lack of an obvious recipe for sturgeon recovery, we cannot underestimate the potential significance of new revelations and unforeseen dynamics that can be gained by testing the Kootenai sturgeon population and ecosystem with an aggressive experimental recovery program. This strategy has already paid substantial dividends in identifying system constraints and opportunities. In the short history of this program, we have already seen at least three significant "surprises." One involved the identification of a second recruitment bottleneck in the Age-0 rearing stage due to spawning in substrates unsuitable for egg incubation. The second was the recognition that there is a significant adult population component in the lake that might be spawning relatively infrequently. The third was the recent observation of juvenile distribution upriver into Montana. All of these critical findings or developments resulted from an adaptive experimental approach involving the release and monitoring of significant numbers of hatchery fish. All have important implications for development of effective recovery measures. None would have occurred if a more conservative hatchery approach had been pursued over the last 20 years. The continuing program is planned to identify and capitalize on similar developments by design.

Adaptive management is an essential element in the conservation and recovery strategy for Kootenai sturgeon and of all of the Tribe's fish and wildlife projects. The ability to implement successful natural restoration measures has been challenged by critical uncertainties regarding limiting life stages and factors responsible for those limitations. There are simply too many unknowns to project future status and trends with any reasonable degree of confidence. The sturgeon aquaculture program can play a critical role in supporting a robust effort to identify critical uncertainties and effective measures. Rather than speculating on critical uncertainties such as hatchery fish performance in the wild, habitat capacity, ecosystem interactions, negative or positive density-dependent responses, and the potential for imprinting of juveniles or attraction of adults to specific spawning locations, this program will help support systematical and adaptive testing of these uncertainties. This information can then be incorporated into future conservation aquaculture, habitat, and other measures to enhance prospects for recovery.

Clearly, there are risks associated with the hatchery strategy that must be carefully considered. A primary concern identified by the ISRP and some of the Tribe's co-managers involves density-dependent system limitations that might affect future sturgeon productivity and ecosystem effects from introducing large numbers of sturgeon into a relatively unproductive system. While these risks may be qualified, and in some cases, theoretically quantified, we simply lack the necessary scientific information to accurately estimate their probability of occurrence and the magnitude of effects at any given level of hatchery production. Analysis of density dependent and ecosystem effects is also confounded by positive and negative effects, many of which will be very difficult or impossible to predict. Thus, the hatchery monitoring and evaluation plan has been designed and implemented to help quantify the significance of these risks with an experimental, adaptive framework.

6. *Avoid annual spawning stock limitation where too few fish might be available to capitalize on favorable natural spawning conditions in any year (or to continue to provide hatchery broodstock).*

Future natural production of strong year classes in the wild will depend on the availability of adequate numbers of ripe adult male and female sturgeon to spawn in any given year and the occurrence of migration, spawning, incubation, and early-rearing conditions conducive to success. Adequate numbers of mature males and females must be available to spawn in each year to capitalize on future natural spawning and recruitment conditions that may only periodically be favorable. Future spawner availability is a function of release numbers, years of release, and time required for significant numbers of released fish to reach sexual maturity and reproduce. If too few fish are produced to provide a sufficiently large future adult spawner population, then periodically-favorable spawning conditions might be missed. This is the sturgeon version of the "Allee effect" where normal demographic processes begin to fail in populations with low abundances exacerbated by protacted spawning periodicities.

A related issue concerns the removal of adult fish from the wild for use as hatchery broodstock which eliminates the potential of successful natural spawning. Under natural conditions, a viable sturgeon population might theoretically be sustained by periodic large year classes sufficient to bridge extended periods of poor recruitment. The life history strategy involving episodic recruitment is consistent with the longevity, delayed maturation, large fecundity, inter-generational spawning, and iteroparous characteristics of all sturgeons. However, no strong year class of Kootenai sturgeon has been naturally produced since at least 1974 and possibly not since prior to 1960 (Paragamian et al. 2005; Rust and Wakkinen 2011). Natural flood events and subsequent post-dam artificial flow measures have categorically failed to produce significant natural production. After 50 years of failed recruitment, we are no longer dealing with a viable population or natural conditions capable of sustaining a viable population through natural production. It is no longer feasible to rely on the hope of an occasional large year class to preserve this population. The highest priority for mature adults in any year is currently for use as hatchery broodstock. At the same time, this use must be balanced with the availability of wild spawners to take advantage of favorable conditions for natural recruitment if they occur.

7. *Minimize, to the extent possible, the time interval between the functional extinction of remaining wild adults and maturation of the first hatchery generation.*

Front-loading hatchery production now to compensate for decades of failed natural production is expected to shorten the interval between the demise of the wild population and the maturation of adults from hatchery-reared juveniles, as the leading edge of faster-growing, earlier-maturing individuals from successive hatchery cohorts reach adulthood first, followed by slower-growing, later-maturing individuals. Larger annual releases can reduce the interval until hatchery fish begin to mature because individual variation in growth rate is large and greater release numbers will include more fast-growing individuals.

Beamesderfer et al. (2009, 2012b) have recently estimated that the wild sturgeon population is larger and declining at a slower rate than previously estimated (Paragamian et al. 2005). However, these revised estimates do not eliminate the risk of an extended duration when mature spawners will not be available to support hatchery or wild recruitment. First, a significant fraction of the new population estimate appears to be composed of fish that either do not migrate into the river to spawn or do so at a reduced frequency, relative to the balance of the population. Second, the longevity and reproductive vigor of individual sturgeon cannot be predicted when the remaining fish reach very old ages. Third, even if significant numbers of reproducing adults are still present, the pool of suitable spawners will still diminish, and many individuals were previously utilized in the conservation aquaculture program.

8. *Maintain an effective population size in the wild adequate to avoid genetic bottlenecks that risk loss of diversity or inbreeding depression in the next generation.*

Long-term recovery objectives address the viability of the next sturgeon generation in the wild. Long-term population abundance objectives are established in part to avoid genetic bottlenecks that risk loss of diversity or inbreeding depression in the next generation. Even if bottlenecks are avoided in the current generation, failure to release enough families or enough fish per family could simply postpone the problem until the hatchery-produced cohort matures and spawns. This objective requires propagation of a diverse population consisting of large numbers of unrelated individuals.[8] The ideal strategy is to produce many families with sufficent releases from each family to ensure that representative numbers survive to adulthood, without swamping the contributions from other families.

Existing facilities limit the number of wild broodstock and unique families that can be handled, brought into captivity, spawned, and reared to optimize preservation and propagation of genetic diversity. As stated previously, we have one chance to propagate a full complement of genetic material as the basis for all future generations. Even if the current facility were successful in staving off demographic extinction for a generation, long-term prospects for recovery could be limited by failure to incorporate adequate genetically-based adaptive potential of expressed life history traits.

9. *Avoid significant detrimental impacts of hatchery fish on natural production due to competition, predation, or disease magnification.*

Hatchery objectives include avoiding significant detrimental impacts of hatchery fish on natural production due to factors such as competition, predation, or disease magnification. Increased competition is of particular concern due to the potential for large numbers of hatchery fish to reduce growth or survival of natural-origin fish. This was a significant concern in the initial years of hatchery operation when it was hoped that restoration of natural recruitment was imminent. However, given the continued lack of natural recruitment, the choice at this time is clear: this program must produce enough fish to ensure that the next generation of endangered Kootenai sturgeon is demographically and genetically fit, because the program must provide all the genetic diversity required for the long-term viability of the population in all future generations.

Current habitat capacity for sturgeon in the Kootenai River is unknown and cannot be reasonably inferred from existing information. Recent analysis of post-release hatchery fish survival suggests there

[8] In a remnant, post-glacially re-founded, isolated population (one that receives no incoming gene flow), outbreeding depression is not expected to be a concern.

may be size-related density-dependent limitations during the first year of age although these results must be interpreted with caution. No negative density dependent response has yet been observed among older fish (see Section 5.5 for futher discussion of habitat capacity).

Monitoring hatchery fish will continue to provide useful information regarding recovery prospects and alternatives (e.g., Ireland et al. 2002a; Beamesderfer et al. 2009; Justice et al. 2009). Hatchery releases provide an experimental basis for evaluating habitat capacity and potential limiting factors. Hatchery fish will are also provide a basis for evaluating habitat suitability for early life history in areas upstream from Bonners Ferry and the feasibility of imprinting fish to upstream areas with more suitable spawning habitat.

10. Avoid hatchery selection or domestication that might reduce future fitness or viability.

Hatchery objectives include avoiding selection or domestication that might reduce future individual and population level fitness or viability. Failure to adopt non-selective spawning and rearing practices would likely have long-term irreversible consequences which would not be manifest until the next (hatchery-produced) population begans to spawn in the wild.

This objective is generally met by increasing family sizes, decreasing rearing density, minimizing rearing mortality and selective culling, and avoiding fish quality effects that might contribute to differential post-release mortality. Facility and spatial requirements for conservation aquaculture programs are more extensive than for simple production programs. Conservation aquaculture is fundamentally about production quality rather than production numbers. Thus, facilities must be adequate to increase broodstock holding capacity, rear each family separately, avoid hatchery selection, and provide adequate fish health and facility infrastructure safety factors. Strategies to address each of the biological objectives for the Tribe's Kootenai white sturgeon program are described below.

***Separate Family Rearing*.** Separate family rearing is needed to ensure that offspring from each parent are adequately represented in short- and long-term arrays of release groups. If families are pooled, there currently is no way of knowing which fish comes from which parents. Different families often perform differently in the hatchery during spawning, incubation, and/or rearing stages. Survival and growth may vary substantially among different families, even when every effort is made to rear all families under similar or identical conditions. Growth, survival, and biological condition differences within and among families are likely due to inherent genetic and environmental variability. Separate rearing avoids inadvertent selection that can occur if the stronger-performing family is favored by rearing conditions or culling practices. Separate rearing of families requires many containers for each life stage (incubation jars, troughs, and circular tanks), which requires adequate hatchery floor space and systems to support each container.

***Avoiding Hatchery Selection*.** Considerable variation in feeding and growth is apparent among hatchery sturgeon, even within a family group. While some individuals do better in a hatchery environment than others, these same traits did not categorically prove adapative when fish were released into the wild (Ireland et al. 2002b). It is imperative that hatchery practices do not artificially select for fish that do well in the hatchery environment, for instance by grading fish to separate fast and slow growing individuals. Experience has shown that individual variation is compounded by high rearing densities.

The larger individuals in a cohort appear to outcompete or otherwise inhibit feeding of the smaller individuals, further exacerbating size dimorphism or polymorphism in ungraded rearing groups.

To avoid hatchery-selective rearing, additional tank space and supporting systems are required. Low rearing densities, growth management, and adequate containers are key program components to avoid size-related hatchery selection or survival. Effective growth management also requires size grading (the ability to separate large and small members of each family for rearing). When smaller individuals are moved to a separate rearing container containing similar-sized fish, they can be caught up to size by a combination of reduced competition, increased feeding, and water temperature regulation.

Fish Health**.** Reducing rearing densities and using multiple facilities also reduces risks of catastrophic losses due to disease outbreaks or systems failures. Disease outbreaks are an ever-present risk in hatchery systems because fish densities and stress are elevated over natural conditions. Uncontrolled outbreaks can cause the loss of an entire brood year production or more likely selected families, both of which impairs our ability to effectively propagate the wild population's remaining genetic diversity. An increased incidence of disease among hatchery fish also poses a risk of pathogen transfer to fish in the river. Upgrades to the existing hatchery that improve handling of adult females brought into the hatchery will also reduce stress to those females. Multiple water sources at the Twin Rivers facility will also provide for more favorable rearing conditions than are currently available in the Kootenai Tribal Sturgeon Hatchery, where warm temperature conditions during summer in some years are higher then optimum and result in increased stress and mortality.

4 PRODUCTION TARGETS

The definition of production targets is complicated by the need to balance competing risks and objectives over time. Targets to address specific objectives often provide competing direction. For example, the risk of genetic bottlenecks or founder effects in the current generation is addressed by the increasing the number of broodstock incorporated into the program. The need to reduce the pending period of broodstock limitation ("death valley") and risks of having too few broodstock to support production during that interval argues for a front-loaded production strategy of large releases. However, large numbers of broodstock produce large numbers of offspring that potentially exceed the habitat rearing capacity and increase risks of competition with any wild fish that are produced. Numbers might be reduced by culling to a smaller family release target, but any kind of reduction risks inadvertent selection or loss of some of the diversity we are trying to propagate and perpetuate. Consistent releases of small family sizes also increase the likelihood that too few progeny might survive to spawn in the next generation, which would fail to meet long-term program objectives and simply delay the bottleneck issue.

Kootenai sturgeon conservation aquaculture program production targets identified in the Master Plan have been updated, as shown in Table 6, to ensure that immediate preservation objectives are met while balancing considerations of longer-term risks. Targets for total broodstock, family size, fish size at release, and total releases shown in Table 6 are derived from a series of quantitative analyses tailored to address specific competing risks. The basis for these targets is described in the following sections.

Table 6. Kootenai sturgeon conservation aquaculture program production targets.

	Target	Focus
Broodstock (total)	>500 (minimum) >1000 (optimum) Up to 45/year	Preserve existing diversity, Maximize phenotypic diversity
Families produced	Up to 30/year	Near-term precaution for future uncertainty
Fish / family	500 - 1,000	Perpetuate diversity through the next generation
Size at release	30 grams (avg.)	Optimize survival/selection balance
Total releases / year	15,000 – 30,000	Balance demographic objectives & risks

4.1

Broodstock/Family Number

<u>Background</u>

Female broodstock collection in the Kootenai typically occurs from February into June, depending on annual water temperature patterns. Current broodstock collection efforts are focused on females that are in later stages of vitellogenesis (egg development) for spawning in the spring and early summer. Female readiness for spawning is subsequently monitored in the hatchery until fish are ready for ovulation, which is stimulated by hormone injection (Conte et al 1988). Spawning typically occurs during May and June. Female broodstock may be held in the hatchery from late winter/early spring until July, although each individual fish is typically held for only a portion of that time. This approach has consistently provided adequate numbers of broodstock to fill the current hatchery, and is expected to continue to provide sufficient numbers to meet increased broodstock targets of the new facilities, at least in the near-term.

Currently, male broodstock are not held in the hatchery. Since the mid-1990s, sperm has been successfully collected in the field from flowing males. Sperm collection from males typically begins when a female has been injected with a priming dose of hormone, which generally stimulates ovulation within one or two days. Sperm is expressed from running males in the field and can be chilled for preservation for up to several days. Throughout the spring broodstock sampling season, field crews keep track of the timing of male ripeness in the river to gauge male gamete availability for use in the hatchery.

Given the current availability of ripe females, there has been no need to collect early vitellogenic females and hold them in captivity until they ripen. Female white sturgeon typically require about 18-24 months from the onset of vitellogenesis until spawning. In any given year, the female population will include some ripening fish that spawn within that year, some developing fish that will spawn in the following year, and some resting fish that are two or more years from spawning. Stage of female maturity can be readily identified by biopsy at capture. Past experience with this and other white sturgeon hatchery programs has found that collection of ripe females is a much more effective alternative than extended holding of pre-vitellogenic fish. Extended holding requires additional tanks and water, and the fish must also be fed and monitored. Holding may also disrupt the normal maturation cycle, resulting in dedication of resources to fish which cannot ultimately be spawned. Although the ability to hold sturgeon for extended periods before spawning might reduce the cost and difficulty of broodstock collection under certain circumstances, this benefit is currently offset by the cost and difficulty of holding these fish for extended periods of time, and the uncertainty of reproductive success following longer periods in captivity.

The Kootenai program typically divides the eggs from individual females into separate lots which are fertilized with milt from two different males in order to maximize fertilization, survival and genetic contribution. A family is defined as the offspring from one pair of parents. Families from one female and one male are referred to as full-sibling families. Families from the same female and different males are referred to as half-sibling families.

From 1990 through 2011, 291 wild broodstock were spawned (195 males and 96 females), producing 156 full or half-sibling families (Table 3). Annual broodstock numbers averaged 6.5 per year from 1995-

1998, 14.8 per year from 1999 to 2004 (following the 1999 upgrade of the Tribal Sturgeon Hatchery and the involvement of facilities in British Columbia), and 24.2 per year since 2005 when targets increased up to the facility capacity in response to continuing recruitment failure. Current production capacity of the combined Tribal Sturgeon Hatchery and the fail-safe Kootenay Sturgeon Hatchery in British Columbia is 12-18 familes per year (with up to 5 families currently produced annually at the Kootenay Sturgeon Hatchery).

Adult capacity is currently constrained by facilities – to date there has not been any difficulty obtaining natural-origin broodstock. Actual numbers of sturgeon spawned varies from year to year depending on variation in timing and maturation success of the potential broodstock brought into the hatchery (particularly females). Broodstock numbers are lower than the theoretical capacity in some years when maturing females brought into the facility fail to ovulate successfully.

Target

The future program objective reflected in the Master Plan is to increase the production targets from the current level of 12-18 familes per year to up to 30 familes per year. Ideally, two or more males would be spawned with each female to maximize phenotypic expression. Up to 45 broodstock (15 females) would be utilized per year with a long-term goal of using a founder population of at least 1,000 broodstock.

The 30 family/year goal will not be met every year due to variable success of fish capture and spawning. The average number of families is expected to be less, particularly beginning 10-20 years hence. However, a front-loaded strategy requires maximum hatchery production rather than average production. This is one of the reasons the new hatchery facility is needed at Twin Rivers.

Figure 4 contrasts wild broodstock numbers at the current hatchery capacity and the expanded capacity. Projections assume that Twin River operations will begin in 2014, target broodstock numbers will be available for at least 10 years, and that broodstock availability will decline thereafter. The new facility would increase total broodstock numbers from 700 to over 900 under this scenario (a 30% increase).

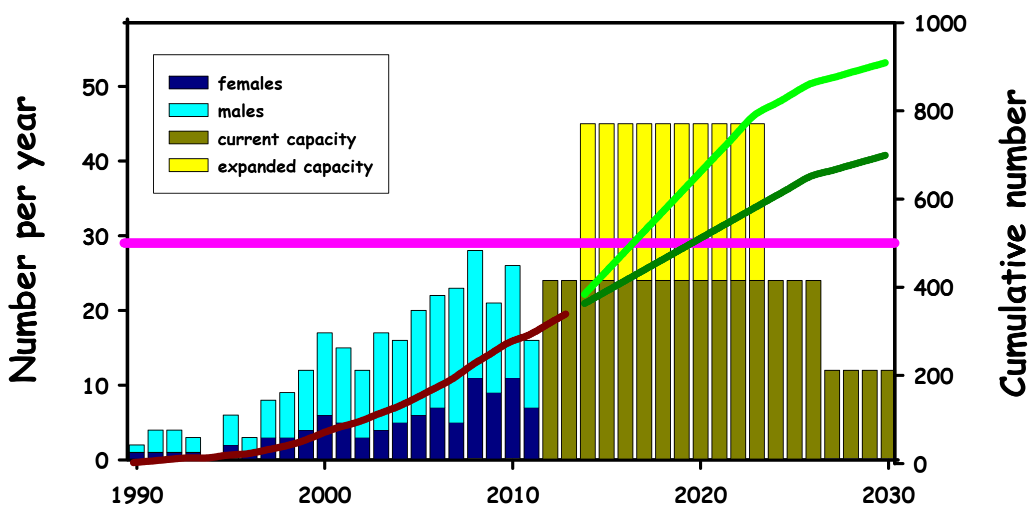

Figure 1. Broodstock numbers and projections with and without new facilities.

Table 7 Summary of broodstock, egg take, and spawning success.

	Males	Females			Egg take (thousands)			Egg-larval Survival	
Year	**Brood**	**Held**	**Brood**	**Families**	**Total**	**Mean**	**Range**	**Mean**	**Range**
1990	1	1	1	1	60 [a]	60	--	2%	--
1991	3 [e]	2	1	1	69 [a]	69	--	20%	--
1992	3 [f]	2	1	3	142 [a]	142	--	16%	Na
1993	2	2	1	2	86 [ab]	86	--	21%	Na
1994	0 [g]	0 [g]	0 [g]	0 [g]	0	--	--	--	--
1995	4	2	2	4	143 [b]	71	71–72	28%	--
1996	2	2	1	2	62 [b]	62	--	<1% [h]	--
1997 [i]	5	4	3	6	201 [b]	67	40–97	30%	Na
1998	6	3	3	6	217 [b]	72	60–92	28%	Na
1999	8	5	4	8	277 [bcd]	69	38–105	63%	40–80%
2000	11	6	6	11	306 [bcd]	51	17–112	73%	25–92%
2001	10	8	5	10	294 [bcd]	59	51–69	70%	35–86%
2002	9	6	3	9	151 [bcd]	50	34–62	86%	50–97%
2003	13	8	4	13	246 [bcd]	61	56–74	93%	85–99%
2004	11	13	5 [j]	17	369 [bcd]	74	60–98	81%	15–95%
2005	14	13	6 [k]	16	1,163 [bcd]	108	17–255	78%	15–97%
2006	15	11	7	11 [l]	790 [bcd]	113	54-164	88%	66-100%
2007	18	8	5	18	289	58	38-85	94%	72-98%
2008	19	12	11	17	1,070	97	53-162	89%	60-99%
2009	17	11	9	12	1,025	114	70-179	95%	60-99%
2010	15		11	17					
2011	9		7	16					
Total	195			200	6,960	**78**	**17-255**	**61%**	**15-100%**

[a] *Eggs collected by c-section*
[b] *Eggs collected by hand stripping*
[c] *Portion of egg take incubated at Tribal Sturgeon Hatchery*
[d] *Portion of egg take used for research purpose*
[e] *Sperm from 3 males pooled*
[f] *Eggs fertilized separately from each male*
[g] *No fish handled due to ESA listing*
[h] *Low success due to low gamete quality*
[i] *No survivors to release due to facility failure*
[j] *3 females transported upriver, 5 females released unspawned*
[k] *5 of 11 females spawned successfully were used only for egg outplants. 5 additional families were produced for experimental river releases*
[l] *5 additional families were produced for experimental river releases*

As the wild population continues to decline, males may need to be held temporarily in the hatchery to meet production objectives. The new facility will provide the space and systems required, including the ability to manipulate water temperature to control the availability and timing of ripe males as needed. The Canadian sturgeon hatchery program successfully uses water temperature regulation to ensure a ready supply of ripe males from broodstock held in the hatchery. Male ripeness can be turned on and off several times over the course of a spawning season by increasing and decreasing holding temperatures. New facilities are designed to enable a similar practice to be employed as necessary in Idaho culture facilities.

Extended holding of females might become necessary at some point to reliably provide adequate annual hatchery broodstock numbers and production targets. However, implementation of the proposed front-loaded production strategy allowed by the additional hatchery facility may successfully mitigate this need. The Tribe is pursuing the hatchery expansion now while broodstock are available and the benefits of additional production capacity can be realized in the most cost-effective and timely manner. If extended broodstock holding is required at some future point to meet hatchery conservation objectives, the new facility also is designed to provide the necessary space, water, and optimal grow-out facilities and densities.

Rationale

Broodstock and family number targets were established to address the near-term objective of preserving native genetic and life history diversity by capturing and spawning significant numbers of representative broodstock. Increasing demands of the aquaculture program due to the continuing natural recruitment failure account for the large increases in broodstock and family targets relative to those initially identified by Kincaid (1993). Kincaid developed initial program targets of 3 to 9 females spawned with an equal number of males to produce 4 to 12 families annually for 20 years, targeting an effective population size of 200 fish (10 per year), and an assumption that natural recruitment would be restored during those 20 years (1994-2013). These targets were designed to approximate a normal expanding natural population and to avoid exaggerated genetic contributions of a small fraction of the parent population from the hatchery to the natural population (Kincaid 1993). However, since the conservation aquaculture program was initiated the 1990s, natural recruitment has not increased and annual recruitment failure continues into its sixth decade.

Minimum and optimum targets for founder population size were identified because the scientific literature does not provide clear guidance on what effective population sizes are necessary to represent normal population diversity. Most literature values are based on relatively simple genetic population models with unclear transferability to natural populations. A minimum 500-fish target was based on recommendations by Thompson (1991), corresponding to an effective population size adequate to preserve genetic diversity including rare alleles. An optimum broodstock target of >1,000 reflects the need for a census population size substantially greater than the theoretical effective population size because mating is obviously non-random and not all spawners contribute equally to the next generation.[9] For context, these targets are only 20 to 40% of the working recovery goal of 2,500, about

[9] *The effective breeding number (N_e) for a population is the number of individuals in a random breeding population with an equal sex ratio, which would yield the same rate of inbreeding or genetic drift as the population being*

5 to 10% of the historical population size, but only 50 to 100% of the current population estimate. It is not possible to capture and spawn every remaining wild fish in the hatchery. However, a precautionary approach will involve propagating as many of these wild fish as possible during the next decade or more.

The program places a very high priority on preserving diversity over the near-term in order to preserve the long-term viability and adaptive plasticity, and resilience of the population. This involves both capturing representative diversity from the remaining population and ensuring that enough diversity is propagated to prevent a bottleneck in the next generation.

In simplistic terms, the effective population size is rapidly reduced in successive generations when only a portion of the adult population is able to spawn effectively (Figure 1). Chances of a second generation founder effect would be substantially increased by low initial hatchery numbers, low future broodstock sample rates, or low natural spawning frequencies. The dynamics of actual population genetics are likely much more complicated than this simple example illustrates. On the one hand, many individuals in the population share common alleles. On the other hand, expression of individual variation through recombination and intergenerational, communal spawning provides the spectrum of traits that helps sustain population viability/resilience in the face of normal variation in habitat and environmental conditions. However, the magnitude, severity, and duration of anthropogenic disturbance and the declining size of the remnant wild population in the Kootenai River continues to jeopardize population restoration by natural production.

Furthermore, because sturgeon genetic population dynamics are still not that well understood, the conservation aquaculture program has elected to take the precaution of targeting a relatively large number of broodstock. Any locally adapted genetic material not incorporated by wild broodstock would be permanently lost because all future populations will be founded by the current and subsequent generations. There will be no do-overs in this population if we fail to take advantage of opportunity afforded by incorporating the remaining wild spawners into the program.

Another way to look at the multi-generation aspects of the limitations imposed by the hatchery production capacity is to consider the effective population size in relation to sturgeon generation time and annual broodstock numbers. At a sturgeon generation time of 25 years, annual production of 20 adults will result in an effective broodstock population size of just 500 fish during that period (Figure 2). Thus, forty spawners would be needed per year to meet a 1,000-fish target within a 25-year period.

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studied (Falconer 1981; Ryman and Lairke 1991; Kincaid 1993): $N_e = 4 X (Nm\sim x Nf/)/ (Nm +NF)$. *This formula calculates the* N_e *(effective population size) for populations produced from random mating of Nm male parents and Nf female parents. Ideally,* N_e *is calculated from counts of the actual number of parents that contribute progeny to the next broodstock generation. Because the actual number of individuals contributing progeny to the next generation and the number of progeny each contributes is unknown in most populations, the number of individuals that spawn and produce progeny is used in the calculation, i.e., the total number of fish spawned of each sex. For animal species with multi-year generation intervals,* N_e *is calculated using the sum of all males (Nm) and females (Nf) spawning each year for the number of years in the generation interval adjusted by any difference in sex ratio and the number of individuals that spawn more than once per generation. The generation interval is defined as the average age of females at first maturity, or about 20 years for the Kootenai River white sturgeon. The Ne will be the total of all spawners (different fish spawned) over the 20-year generation interval.*

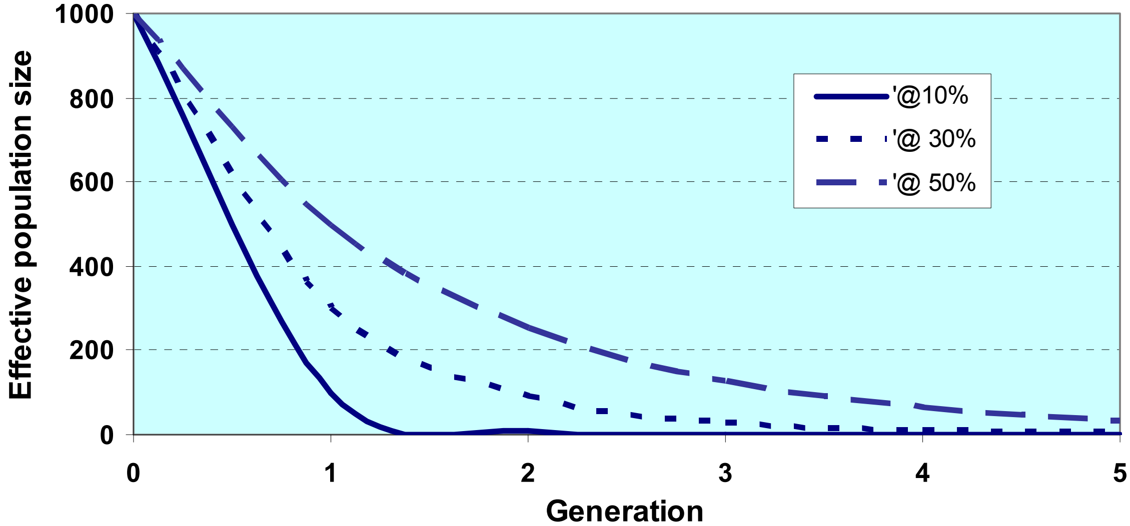


Figure 2. Theoretical reduction in effective population size over generations based on the proportion of the available adults that reproduce effectively.

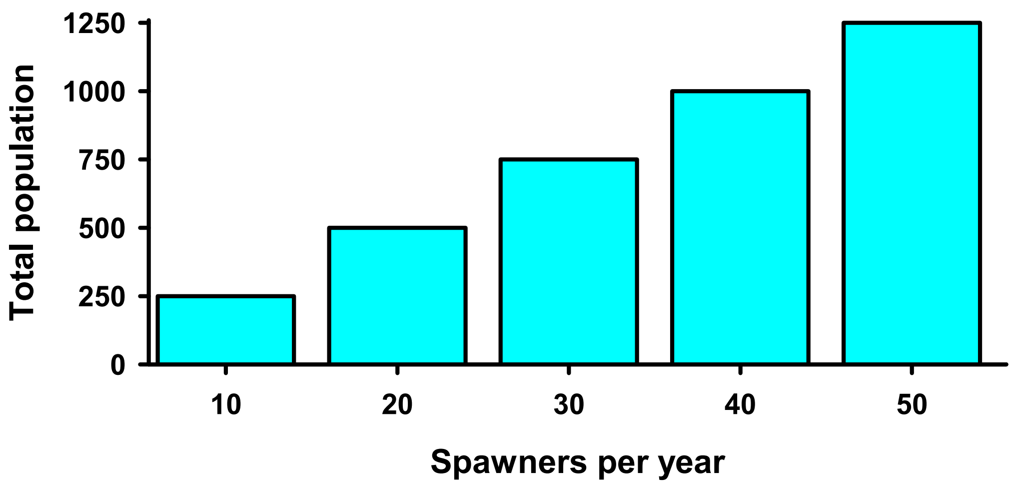
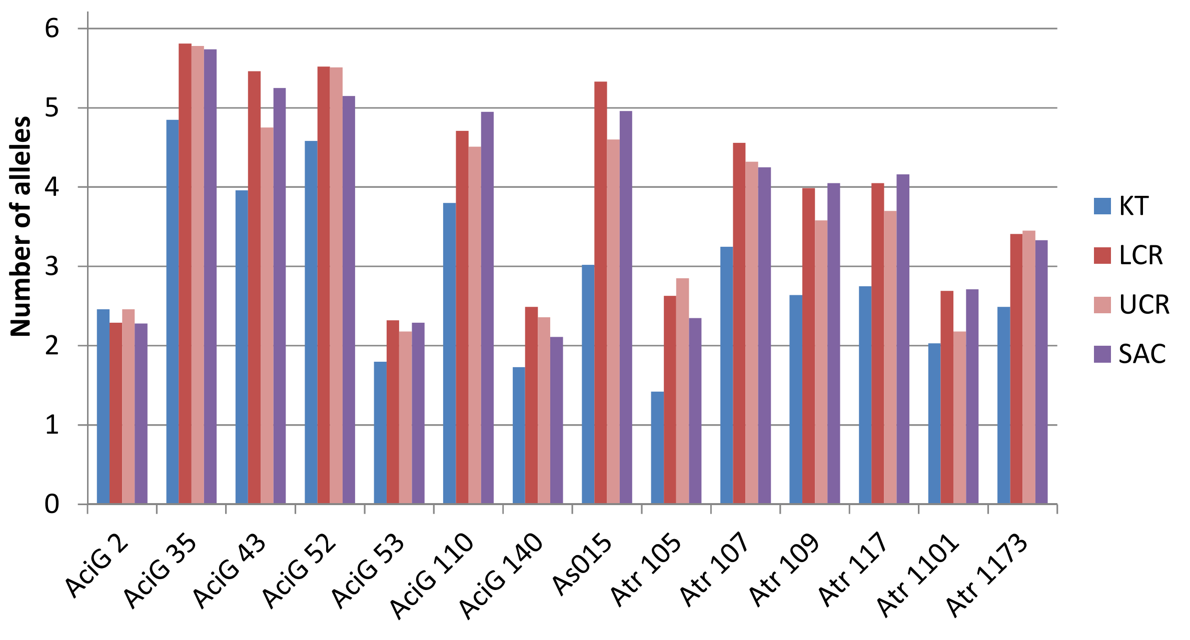


Figure 3. Estimated founder broodstock population size in a 25-year sturgeon generation in relation to annual numbers.

Actual genetic effective population sizes (N_e) of broodstock used to date were estimated to range from 2.0 to 25.7 fish from 1990 through 2011. Annual N_e values increased as the program and facilties were refined and have ranged from 15.7 to 25.7 per year from 2007 through 2009 (Drauch-Schreier et al. 2012). It is not possible to calculate an effective population size for the total program due to overlapping generations. Estimates of the effective population size in the next generation assume that at least some offspring of all broodstock are effectively propagated and survive to adulthood. We already know that some families have fared poorly in the hatchery and that some groups of fish released at small sizes have fared poorly in the wild. Conversely, other families fare well in the hatchery; it is assumed that both genetics and hatchery conditions may be responsible for observed differences. Hence, estimates of effective population size based on broodstock numbers and mating matrices tend to overestimate the actual effective population of hatchery-origin adult spawners in the next generation.

Genetic analysis of wild Kootenai River white sturgeon broodstock and juveniles provides a population-level indicator of how well the program is incorporating wild population genetic attributes into the next generation. Genetic variability (frequency distribution of alleles) and genetic diversity (total number of alleles) is monitored annually. All broodstock spawned and all progeny groups produced in the hatchery are analyzed using microsatellite DNA methods that have become widely used for many conservation and management applications due to their high resolution and highly variable nature (McQuown et al. 2000; Rodzen and May 2002; Rodzen et al. 2004; Drauch and May 2007, 2008, 2009).

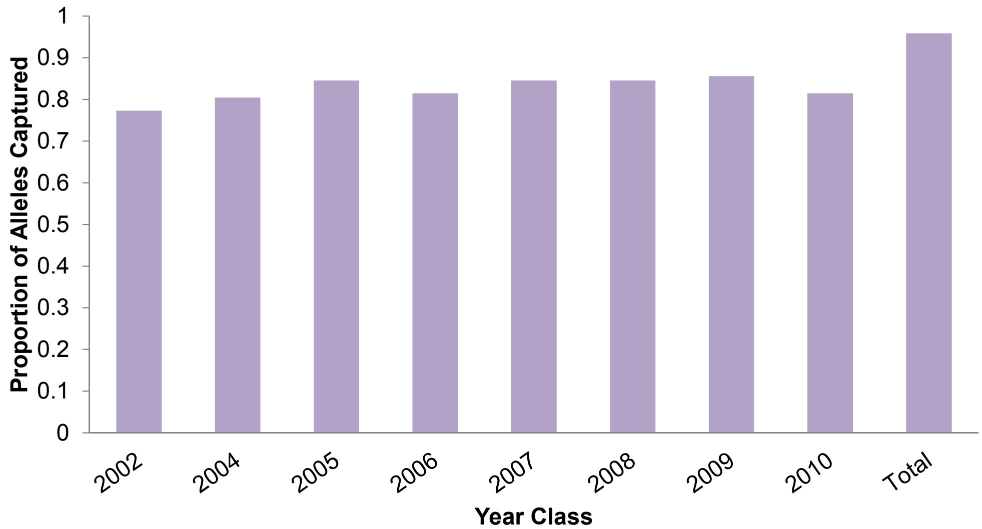
Recent microsatellite analysis by Rodzen et al. (2004) found that the wild Kootenai River sturgeon population is approximately 25% to 50% less diverse than eight other North American white sturgeon populations. Similar results are reported by Drauch-Schreier et al. (2011), as shown in Figure 4. This is not surprising, given that the Kootenai population is a headwater population at the edge of the species' geographic range that has likely experienced a natural loss of rare alleles since post-Pleistocene re-founding due to genetic drift. Further artificial loss of native diversity has also occurred due to recent anthropogenic demographic and associated genetic bottlenecks.



Source: Drauch Schreier et al. 2011

Figure 4. Number of alleles identified for 14 loci in Kootenai, Lower Columbia, Upper Columbia, and Sacramento River white sturgeon populations.

To date, nearly 400 Kootenai sturgeon adults have been genotyped by the University of California (UC) Davis laboratory. From 75% to 85% of the sampled alleles have been incorporated into the hatchery broodstock groups annually from 2002 through 2010, with 96% incorporated into the broodstock during the 20 years of program operation between 1991 and 2010 (Drauch-Schreier et al. 2012), as shown in Figure 5.



Source: Drauch Schreier et al. 2012

Figure 5. Example of the representation of population genetic diversity among Kootenai sturgeon broodstock.

Schreier (2012) advises that the genetic monitoring is intended to determine whether the number of broodstock currently used by the program is enough to minimize the founder effect and maximize the Ne. The fact that a majority of alleles in the population have been detected in broodstock suggests that the program has been successful at reducing the founder effect and minimizing genetic drift. One can easily imagine a scenario (perhaps in a small salmonid hatchery) where only 50% of a population's genetic diversity was being captured by artificial propagation, which would be a major concern. Continued discussion about optimizing genetic diversity by continuing to use the same or larger numbers of broodstock is not about increasing the amount of neutral genetic diversity. The impetus for increasing the number of broodstock spawned annually is to increase the number of parental combinations that are made and increase the numbers of different combinations of alleles at adaptive loci that may lead to unique phenotypes and behaviors. Remember, the neutral genetic markers are a proxy for adaptive genetic markers – if population processes are such that neutral genetic diversity is preserved, these processes will also support the preservation of adaptive alleles. However, the genetic monitoring results don't at all speak to the process of recombination and the potential of the hatchery program to capture the greatest possible number of allele combinations which may produce different phenotypes and behaviors important for the long-term adaptability and resilience of the population.

The alleles monitored are neutral genetic markers. These provide a gross index of the amount of diversity incorporated into the broodstock. If an incomplete sample of these neutral markers has not been incorporated, then it is likely that an incomplete sample of the adaptive genetic markers have been incorporated as well. However, the converse may not be true. There are at least 10,000 protein-coding genes in the sturgeon genome and a sample of just a handful of the non-coding markers cannot be assumed to be representative of the full spectrum of available potentially-adaptive diversity. The loss of potentially-adaptive rare alleles due to small sample founder effects is of particular concern.

4.2 Family Size

<u>*Background*</u>

Family size targets of 1,000 yearlings or 5,000 Age-0 fingerlings were originally identified by Kincaid (1993). Numbers were established to avoid an exaggerated contribution of a small fraction of the parent population. Kincaid based the original calculation on an objective of 8 progeny per family at the assumed breeding age of 20. This estimate was based on the best available information at that time and a goal of supplementing natural production to create a “normal expansion” of the population.

Based on guidance from Kincaid, the conservation aquaculture program established family size targets of 1,000 to 1,500 yearlings from 1994 through 2003 (KTOI 2004), and then again from 2009 to present (2012). This range accomodates differences in hatchery survival of family groups. Because of variation in egg fertilization and survival to release, family groups can range in size from a few hundred to several thousand fish. Rather than equalizing release groups down to the size of the smallest family group, a target range was established in order to balance the need to release sufficient numbers from each family group to ensure a next generation with the need to limit excessive contributions from any single family. Population modeling by Jager (2005) found no long-term genetic risk of modest variation in family numbers and hence little benefit of family equalization. While very large differences in family size (e.g., 100,000 vs. 10,000) might be grounds for concern, smaller differences on the order of a few hundred to a thousand are not a concern (e.g., less than an order of magnitude difference in release size may be acceptable).

Around 2002, assessments of hatchery fish survival after release estimated rates substantially greater than Kincaid initially assumed (net survival of 3% vs. 0.8% to age 20) and age of maturity is older (25 vs. 20 years). However, at the same time, Kincaid’s original adult targets were determined to be much too low to sustain the population in the absence of natural production (KTOI 2004).

In 2004, the program initiated age 0 fingerling releases in order to increase net production (see Section 4.3 below). Family size targets of 3,000 to 4,000 were used because fish were released at a smaller size. However, survival of the smaller fish was very poor relative to previous release groups. It was unclear whether reduced survival was due to environmental limitations within the first year of life or size-specific density dependent effects (Justice et al. 2009). Regardless, targets were changed back in 2009 to the original family size (1,000 to 1,500 fish averaging 30 g) to avoid the survival bottleneck at the YOY stage (Justice et al. 2009).

<u>*Target*</u>

With the construction of the Twin Rivers facility, family size release targets will be reduced from the current 1,000 to 1,500 to 500 to 1,000 yearings. This reduction is intended to balance the need for increased broodstock numbers to optimize phenotypic expression while also controling total release numbers which might trigger at negative compensatory response at higher densities. It is anticipated that average family size will be intermediate within the target range due to normal variation in fertilization and survival rates of different family groups.

Rationale

Family size targets are established to: 1) ensure survival of a representative number of offspring from each family to an age where they can spawn and contribute to the next generation, 2) avoid excessive contributions from any one family that might swamp the population genetics, and 3) limit total population size in order to limit intra-species competition and density-dependent growth and survival limitations.

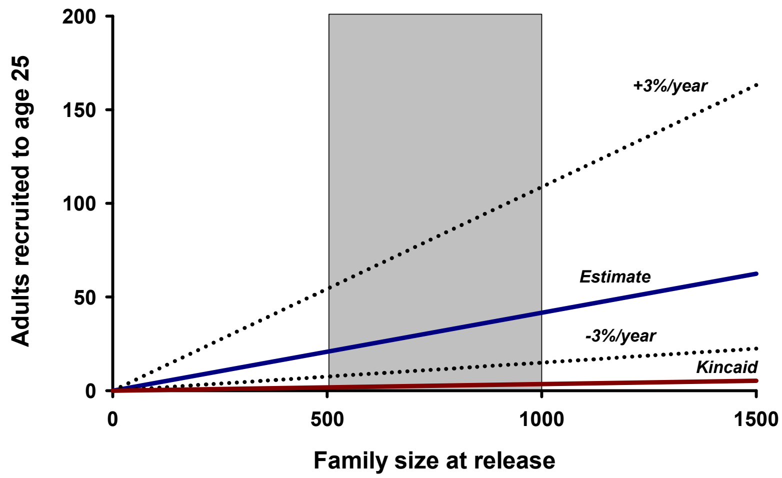
Use of recombination to produce genetically-based trait diversity is an essential part of the recovery strategy which will depend in part on the occurrence of individuals in the population that can succeed under the available habitat and environmental conditions. Large family sizes are clearly better from a diversity expression and maintenance point of view. The benefits of propagating existing genetic diversity will be eroded if too few offspring from each family survive to reproduce in the next generation. For instance, if parents only replaced themselves with two offspring that survived to spawn 20 to 30 years later, important genetic material would likely be lost because each offspring only contains a portion of their parent's genetics. Large family sizes also reduce the potential for artificial selection due to limited numbers of contributing progeny, and allow natural selection to regulate abundance and condition on a wider array of genotypes. However, we are cognizant of habitat capacity limitations and the potential negative demographic responses to releasing too many fish.

Family sizes of 500 to 1,000 yearlings are projected to provide multiple siblings per family well into reproductive age at current estimates of survival (Figure 6). We estimate recruitment to age 25 of 22 to 42 fish per family. Projections are extremely sensitive to even small differences in estimated annual survival. For instance, increases of 3% per year triples the projected number of recruits. Decreases of 3% per year reduce the estimate by two thirds. Survival rates are of course uncertain and even very small differences in initial annual survival have a big effect on long-term survival and the resulting age class structure due to the compounding effects over many years.

4.3 Size/Age at Release

Background

Until 2005, fish were released primarily at age 1 or older in order to PIT-tag every hatchery fish so they could be distinguished from wild juveniles. Fish need to be at least 30 g for successful PIT-tagging. Substantial numbers of these fish were estimated to survive in the wild (Ireland et al. 2002b; KTOI 2004, 2008).



Best current estimates are based on first year hatchery survival of 15% (recent average), 88% per year for ages 1-3, and 96% thereafter. The shaded box represents planned family size production targets.

Figure 6. Effect of release group size on number of adult recruits from that cohort.

Beginning in 2005, fish were released at younger ages and smaller sizes in an attempt to increase production numbers while working within the current limitations of the Tribal Sturgeon Hatchery. Concerns about ongoing natural recruitment failure led the Tribe to increase release numbers and family sizes within the constraints of the existing hatchery facilities as a precaution for the coming interval when too few wild fish will remain to provide broodstock. The Tribal Sturgeon Hatchery and the Kootenay Sturgeon Hatchery had the capacity to raise greater numbers of each family if fish were released at a smaller size. Numbers were increased by releasing fish at 10 to 15 g as Age-0+ in fall rather than 30 g at Age-1+ or Age-2. This avoided the space limitation in the existing hatchery caused by simultaneously rearing multiple overlapping brood years. Minimizing time in the hatchery was also expected to minimize opportunities for hatchery selection effects and unforeseen rearing catastrophes (disease, equipment failure, etc.).

Previous production levels were constrained by the need to raise all fish to sizes suitable for PIT-tag placement and retention, and to rear families separately so that family sizes could be equalized within an order of magnitude upon release. Subsequent evaluations concluded that low population size in the next generation is a much more acute demographic and genetic risk than unequal family contributions in the following generation. Batch marking of fish with scute removal patterns allowed a smaller size at release while preserving a means of distinguishing hatchery-reared fish in the wild. Eliminating the PIT-tag requirement provided the flexibility to release fish at smaller sizes and ages which opened up space for more family groups in the hatchery. Upon release, smaller fish were expected to survive at similar annual rates as those observed in previous groups, although an extra year of natural mortality means that slightly fewer fish from any release group would be expected to survive to a given age. Increased release numbers allowed by this change in use of hatchery space was expected to more than offset this effect.

However, subsequent monitoring found that survival of the more recent release groups has declined substantially from the early estimates (Justice et al. 2009). Where very high recapture rates were observed for the initial release groups, recaptures of later releases occurred at a much lower rate (Justice et al. 2009). The decline was most pronounced among the small hatchery fish (<25 cm) while survival of the larger hatchery fish was similar to previous estimates. This negative relationship between release numbers and survival suggested that density-related competition or predation may be influencing mortality of juvenile sturgeon during their first year at large. However, this effect appeared limited to the first year at large, as indicated by the relatively stable survival rates for fish recaptured two or more years following release.

Although larger releases were intended to increase the number of hatchery juveniles in the wild, the release of fish at smaller sizes beginning in 2005 actually produced the opposite effect. The benefit of this adaptive experiment was the identification of a second life history bottleneck during the first year of life that may affect both hatchery and wild fish. The effect of the Tribe's habitat restoration measures on this first year bottleneck will be one of the outcomes that are monitored. To date, large release numbers have not translated into a large juvenile population size. As a result, the program has now returned to releasing fewer, smaller, older fish (yearling and Age-1) that continue to demonstrate high survival rates (Beamesderfer et al. 2009).

From 2008-2012, Age-0 free embryos were released upstream from Bonners Ferry based on the recommendation of the Recovery Team members. These releases are also identified as a Reasonable and Prudent Alternative (RPA) in the 2006 Biological Opinion and 2008 BiOp clarification for Libby Dam operations (USFWS 2006, 2008). This 5-year experiment was intended to evaluate: 1) post-release survival of free embryos produced at the Tribal Sturgeon Hatchery, and 2) suitability of receiving habitat for completion of Age-0 life stages. Experimental in situ rearing documented 14-day survival of free embryos over gravel/cobble, which supports the program objectives of encouraging upstream sturgeon migration to these habitats. However, monitoring post-release survival has determined that the survival rate of Kootenai sturgeon embryos, free embryos and larvae has been essentially zero (Rust et al. 2003; Rust and Wakkinen 2004). To date there is no evidence of survival from these free embryo releases, with the exception of a single 14-day post-hatch larva captured as part of a side-channel incubation and early rearing experiment [10] (pers. comm., Pete Rust, IDFG, December 2009).

Target

Stocking Age-1 and older fish is the preferred (and currently the only successful) method for rebuilding the population.

Rationale

There are obvious production trade-offs at the existing facility between releasing younger fish with reduced survival rates and releasing fewer larger fish that exhibit higher post-release survival rates. Net contributions to the natural population can still be greater with reduced survival as long as the larger release compensates for the decrease in survival (Figure 7). Unfortunately, that was not the case for the Kootenai sturgeon and the program now has reverted to releasing larger fish. It remains to be seen

[10] *The Tribe's habitat restoration program includes measures to reconnect Kootenai River side channels and may create additional side channel habitat by redirecting flow into the primary channel.*

whether the larger fish will survive at similar rates to the like-sized fish groups released before 2004, given increasing density of hatchery-reared juvenile sturgeon in the river. In addition, as the habitat restoration program is implemented, the magnitude of the habitat carrying capacity limitation may be reduced.

It might be argued that release of younger, smaller fish would reduce opportunities for selection in the hatchery or the development of domesticated behavior that is not adaptive in the wild. However, the Tribe's studies have concluded that the demographic risks of releasing fewer larger fish outweigh any presumed natural selectivity or behavioral benefits (Justice et al. 2009). We have observed that releases at a smaller average size actually compound hatchery selectivity risks by favoring survival of the larger fish in the release group. Instead, we are managing hatchery culling practices (currently required to limit total release numbers) irrespective of size.

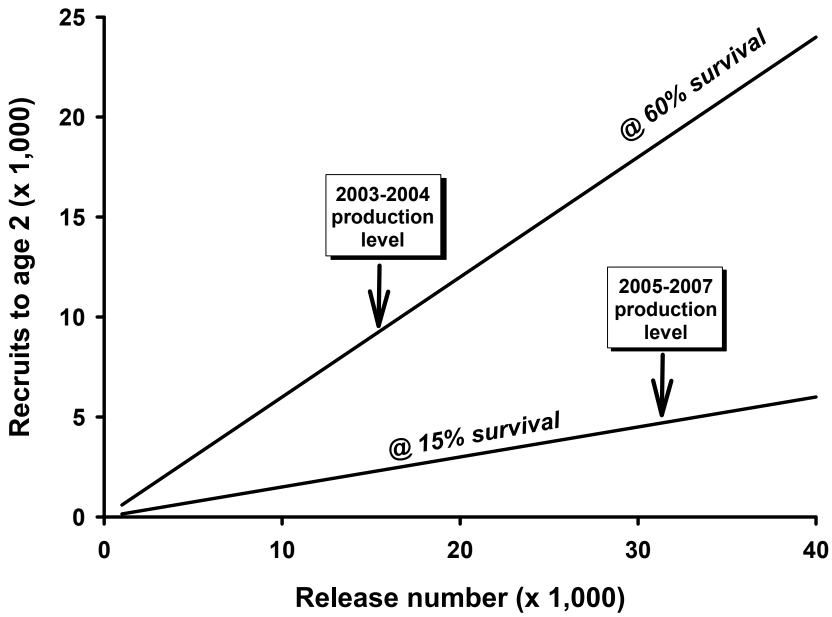


Figure 7. Tradeoff in recruitment between release number and survival.

Unfortunately, there is little or no published information addressing the degree of "in-hatchery evolution" for any sturgeon species. Most of what we know about this comes from the salmon world and much of that is either hypothetical or based on production programs that were not designed with conservation in mind. In practice, it is extremely difficult to operate any hatchery program without some degree of inadvertent artificial selection. That is why minimizing the length of time in the hatchery is desirable. Unfortunately, sturgeon released as post larvae or Age-0 juveniles survive either very poorly or not at all in the Kootenai. Thus, the Kootenai program must rely on releases of Age-1 or older fish to be effective. The hatchery strategy has been designed to recognize and minimize genetic risks to the greatest extent possible in both the existing and proposed facilities. The proposed Twin Rivers hatchery is an essential element of this strategy.

As previously noted, Age-0 larval releases in the Kootenai were implemented as a 5-year experiment to evaluate the benefits of this alternative, but have provided no measureable recruitment to date. It was hypothesized that sufficient numbers might survive, thereby reducing the need, with associated costs and risks, of hatchery rearing from the post-larval to the YOY stage. We were also hopeful that release of embryos, free embryos, or larvae might prove to be an effective alternative to extended hatchery rearing because pallid sturgeon recovery efforts in the Missouri River system have documented some survival from larval releases. However, no survival has been documented following the release of millions of embryos, free embryos, larvae and YOY over many years. By contrast, releases of Age-1 or older fish are documented to result in reasonable post-release survival (Ireland et al. 2002b; Justice et al. 2009; Beamesderfer et al. 2009, 2012a), consistent with genetic and demographic objectives. Therefore, Age-1 releases are expected to continue (at most annually) and are considered the highest priority until repeatable, adequate natural production is restored. Experimental Age-0 (free embryo) releases are scheduled to end after 2012.

4.4 Total Releases

Background

A total of 200,274 Kootenai white sturgeon have been released from 1992 through 2011 (Figure 8, Table 8). Juvenile sturgeon are typically released at 1 to 1.5 years of age. Fish are released from the Kootenay Trout Hatchery in British Columbia in the spring after reaching suitable tagging size (30 g). Fish are released from the Tribal Sturgeon Hatchery in the fall at Age-1+ and include the faster growing individuals from a brood year cohort. Smaller fish from the same brood year are typically retained in the hatchery and released in the following spring as 2-year-old fish.

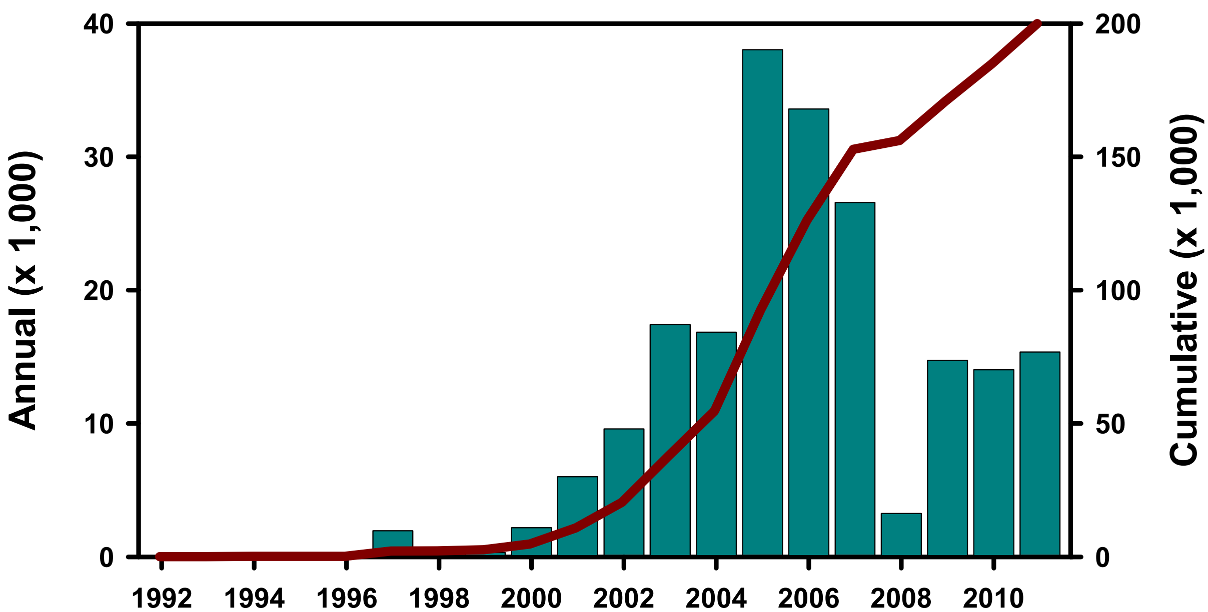


Figure 8. Annual (bars) and cumulative (line) numbers of juvenile white sturgeon released into the Kootenai River and Kootenay Lake.

Table 8. Numbers of hatchery produced white sturgeon juveniles released into the Kootenai River and Kootenay Lake in Idaho and British Columbia, 1992-2011.

Year Class	Rearing Facility [a]	Release Number		Mean Total Length (mm) (SD[b])	Mean Weight (g) (SD[b])	Release Season & Year
		Tagged	Untagged			
1990	KTOI	14	--	457 (53)	321 (112)	Summer 1992
1991	KTOI	104	--	255 (17)	66 (13)	Summer 1992
1992	KTOI	123	--	483 (113)	549 (483)	Fall 1994
1995	KTOI	1,075	--	228 (27)	47 (17)	Spring 1997
1995	KTOI	884	--	344 (44)	148 (64)	Fall 1997
1995	KTOI	97	--	411 (68)	288 (138)	Summer 1998
1995	KTOI	25	--	582 (40)	863 (198)	Summer 1999
1998	KTOI	309	--	260 (42)	79 (44)	Fall 1999
1999	KTOI	828	--	256 (22)	71 (18)	Fall 2000
1999	KH	1,358	--	248 (33)	67 (28)	Fall 2000
1999	KTOI	491	--	284 (54)	108 (60)	Spring 2001
1999	KH	1,583	--	306 (40)	56 (39)	Spring 2001
2000	KTOI	2,286	--	244 (39)	64 (31)	Fall 2001
2000	KH	1,654	--	240 (23)	58 (16)	Fall 2001
2000	KH	2,209	--	283 (29)	99 (30)	Spring 2002
2000	KH	30	--	365 (14)	195 (20)	Summer 2002
2000	KTOI	214	--	409 (54)	294 (110)	Fall 2002
2000	KTOI	907[c]	--	333 (36)	193 (63)	Jan. 2003
2000	KT	10[d]	--	558 (28)	88 (18)	Feb. 2004
2000	KT	3[e]	--	662 (61)	425 (66)	Summer 2006
2001	KT	2,672	--	200 (38)	33 (16)	Fall 2002
2001	KH	4,469	--	227 (24)	52 (17)	Fall 2002
2001	KH	1,715	--	257 (26)	72 (24)	April 2003
2001	KT	1[e]	--	570	750	Summer 2006
2001	KH	1[e]	--	560[j]	1152	Spring 2009
2002	KH	5,864	--	217 (25)	41 (14)	May 2003
2002	KT	856	--	214 (44)	42 (23)	Oct. 2003
2002	KT	~550[f]	--			Nov. 2003
2002	KT	3,852	--	215 (37)	43 (20)	Winter 2003
2002	KT	3,663	--	214 (55)	43 (27)	Winter 2003-2004
2002	KT	1[e]	--	550	740	Summer 2006
2003	KH	9,020	--	223 (26)	49 (24)	Spring 2004
2003	KH	19[g]	--	230 (27)	52 (19)	Sept. 2004
2003	KT	3,519	--	227(47)	55 (32)	Late winter 2004
2003	KT	3[e]	--	437 (27)	347 (49)	Summer 2006
2004	KT	--	3,000[h]			Fall 2004
2004	KT	--	1,275[h]			Winter 2004-2005
2004	KT	--	17, 723[h]			Spring 2005
2004	KH	1,238	800[i]	196 (28)[j]	57 (33)	Spring 2005
2004	KH	--	3,440[h]			Spring 2005
2004	KT	--	8,637[h]			Summer 2005
2004	KT	1	--	510	490	Winter 2007
2004	KH	5[e]	--	452(23)[j]	563(116.5)	Spring 2009
2005	KT	--	6,200[h]			Fall 2005
2005	KH	14[k]	--	299 (14)[j]	174 (28)	Spring 2006
2005	KH	1,765	--	198 (25)[j]	54 (22)	Spring 2006
2005	KH	--	13,665[h]			Spring 2006

Year Class	Rearing Facility [a]	Release Number Tagged	Release Number Untagged	Mean Total Length (mm) (SD[b])	Mean Weight (g) (SD[b])	Release Season & Year
2005	KT	--	3,947[h]			Spring 2006
2005	KT	510[l]	--	171(47)	27 (20)	Fall 2006
2005	KH	1[e]	--	330[j]	225	Spring 2009
2006	KH	--	6,900[h]			Fall 2006
2006	KH	--	600[i]	149 (11)[j]	23 (5)	Fall 2006
2006	KT	--	6,175[h]			Fall 2006
2006	KH	--	5,800[h]			Spring 2007
2006	KH	1,877	1,000[i]	182 (15)[j]	44 (12)	Spring 2007
2006	KT	--	12,973[h]			Spring 2007
2006	KT	4,922	--	171 (30)	22 (11)	Winter 2007
2007	KH	2,167	--	241(24)[j]	92(27)	Spring 2008
2007	KT	884	203[i]	151(36)	20(10)	Fall 2008
2008	KH	9,982	--	198(35)[j]	56(19)	Spring 2009
2008	KT	3,875	882	194(52)	32(19)	Fall 2009
2009	KH	7,884	0			Spring 2010
2009	KT	5,343	808			Fall 2010
2010	KH	5,759	0			Spring 2011
2010	KT	7,785	1,825			Fall 2011
Total		**200,274**				

[a] *Kootenai Tribal Hatchery in Idaho (KT) or Kootenay Hatchery in British Columbia (KH)*
[b] *Standard deviation*
[c] *Ten fish from this group held over for later upriver release with transmitters*
[d] *These 10 fish were released upriver (rkm 306.5) with sonic and radio tags.*
[e] *These fish were held over for later release (2006-released with Vemco tags).*
[f] *No measurements available for these fish; exact number not known*
[g] *These fish were first taken to Kokanee Creek Provincial Park, then released in Sept.'04.*
[h] *These fish were not given a PIT-tag or measured.*
[i] *These fish did not have a PIT-tag added and were all given fish #999.*
[j] *Value given is for mean fork length (mm)*
[k] *These fish were released upriver (299.0 and 258.7), 6 of them with Vemco sonic tags.*
[l] *There were 200 fish held over at the Tribal Sturgeon Hatchery for Biopar study.*

Significant releases began in 1997 after the hatchery was identified as a critical component of the Recovery Plan. Hatchery releases prior to 1997 were largely experimental. Production was increased in 2003 after hatchery upgrades. Annual releases have ranged from about 3,000 to 37,000 fish per year from 2003 to 2009 (average 21,000). Past production averaged about 16,000 yearlings or 33,000 subyearlings. The 2008 release of only 3,254 fish was a transition year from a subyearing to yearling release protocol (fish that would have been released in 2008 as yearlings had already been released in 2007 as subyearlings). Current production is approximately 15,000 per year from the combined U.S. and Canadian facilities. Initial monitoring of hatchery-reared fish after release revealed excellent initial survival in the wild (Figure 9). These fish were primarily Age-1+ when released in spring or fall with average weights of 30 g or greater at release. Survival was estimated at 60% during the first year as hatchery fish adapt to the wild environment and 90% per year thereafter based on analysis of mark-recapture data (Ireland et al. 2002b). Juvenile sturgeon mortality is significant in the first year following release from the hatchery as individual success in adapting to natural conditions is variable. Similar patterns are observed in many other species, including salmon and steelhead. It is simply a difficult transition to go from the benign hatchery environment where food is readily available to a natural environment where food must be foraged and predators avoided.

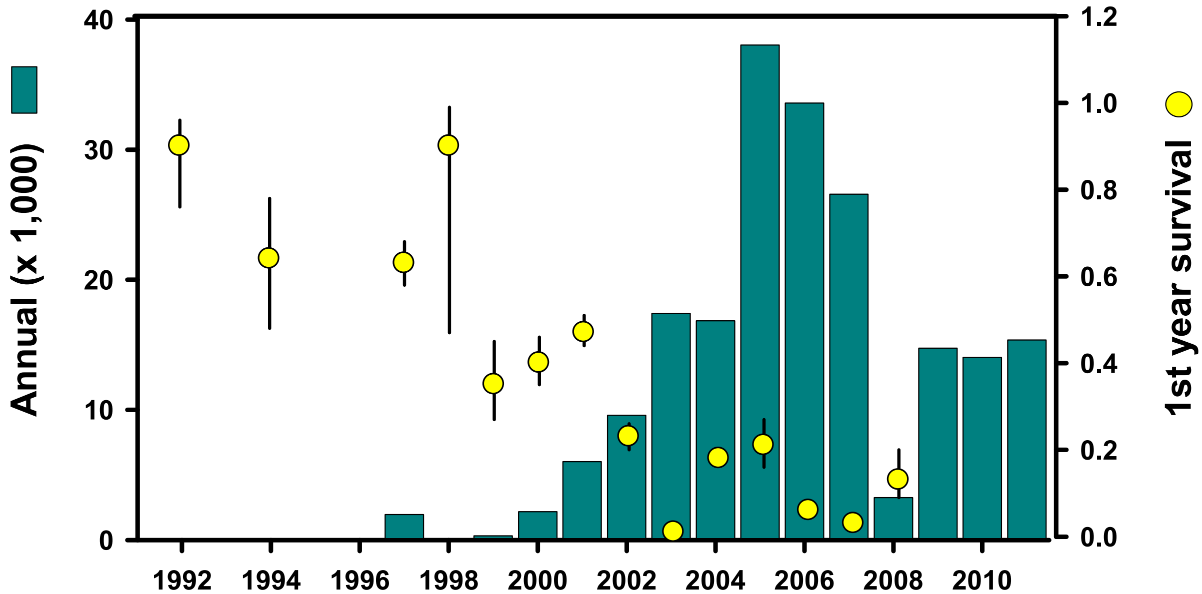


Figure 9. Estimates of year 1 survival and release numbers for 1992-2011 hatchery release groups (Beamesderfer et al. 2012a).

Growth and condition of many sturgeon has also been found to be poor in the first year following release (Ireland et al. 2002b). Many fish recaptured within a year or two of release weighed less than when released from the hatchery. However, after several years at large, most recaptured fish exhibited significant growth in length and/or weight. Fish that initially struggled may have adapted or died, leaving only the successful survivors. Size and condition in the wild were not related to size and condition at release. Thus, how well fish performed in the hatchery did not appear strongly related to how well they survived in the wild. This dynamic illustrates the importance of producing a diversity of individuals across the genetic spectrum on which natural selection can operate (Brannon 1993; Anders 1998). It also highlights the importance of avoiding selective rearing practices that favor fish that do well in the hatchery.

Substantially lower survival rates were documented among more recent release groups (Justice et al. 2009). First year survival rates fell to about 15% or less. The reduction in survival was correlated with increasing abundance of hatchery-reared juveniles in the wild. However, the comparison was at least partially confounded by changes in size, season, and location at release. Earlier releases generally consisted of larger fish that were more likely to be released in the spring. More recent releases included smaller fish released at Age-0 in the fall and Age-1 in the spring. It is unclear how much of the observed decrease was due to increased density (including the release groups and other juveniles from previous releases) and how much was due to reduced size, timing, or location of release. Unfortunately, release and recapture sample sizes are not adequate to conduct a more stratified analysis needed to tease apart the respective effects of size at release, location, number in release group, release season, and subsequent density. Because of observed low survival rates among the small-sized fish, size at release has now been increased similar to those in the early years of the hatchery program.

The actual population size of hatchery-reared juveniles in the wild is much smaller than the total hatchery release numbers due to significant mortality during the first year post-release adjustment period (Figure 10). Only about 10% (19,800) of the 200,274 hatchery sturgeon released into the system from 1992 through 2011 were estimated to have survived through 2011 (based on mark-recapture survival estimates).

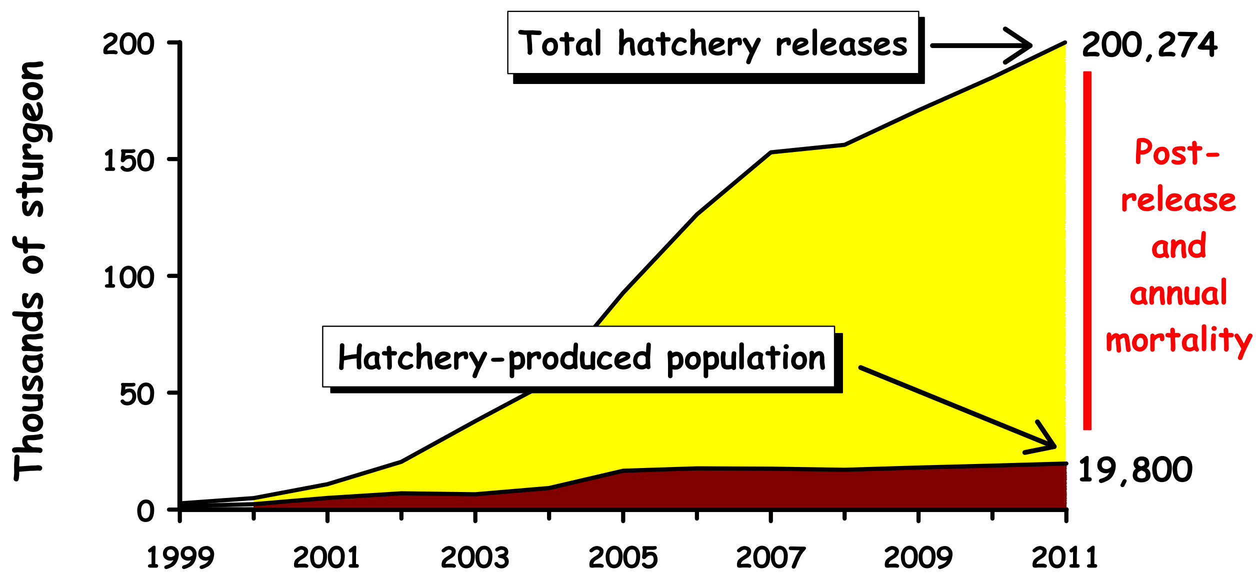


Figure 10. **Estimated population of hatchery-reared sturgeon one year following release into the Kootenai River from 1999-2011.**

Target

Release numbers consistent with family number and family size number targets developed to meet genetic objectives would be 15,000 to 30,000 sturgeon per year. This represents an increase from existing production targets of 15,000 to 20,000 per year. While current production targets are expressed as a range, recent release levels have typically been around the low end of this range (15,000).

While family number is being increased from about 15 per year to 30 per year, family size has been reduced from 1,000-1,500 to 500-1,000. This change has been made to ameliorate potential risks of a strong negative density-dependent response due to large release numbers. The reduction in family size (and corresponding total releases) is a change from the target numbers identified in the Step I Master Plan and addresses concerns raised by the ISRP in their review of the Master Plan and by the Tribe's co-manager and agency partners during the Tribe's hatchery workshop in February 2012.

Figure 11 depicts annual and cumulative release numbers to date and projections through the year 2030 with and without the new facilities. Projections assume current annual production levels of 15,000 could be maintained for at least the next 12 years after which it is anticipated that family numbers will begin to be limited by declining broodstock availability. The new facilities are projected to increase total annual production for at least a 10-year period following completion of the new hatchery. Although family number is planned to double during this period, reductions in family size result would result in an annual increase in releases of only 7,500 yearlings per year (assuming an average family size of 750). With the increased production, cumulative releases through 2030 increase by about 17% from 450,000 to 520,000.

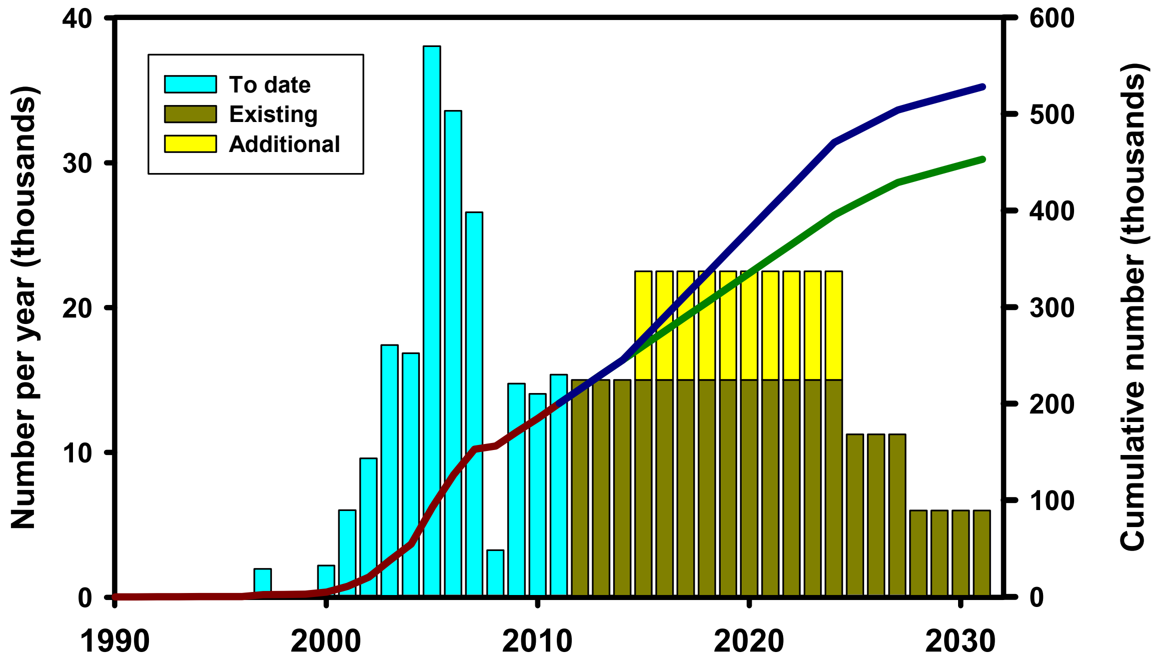


Figure 11. Release numbers of first generation hatchery fish and projections with and without new facilities.

Rationale

Juvenile production capacity is regulated by the need to rear family groups separately and to size-grade fish to age 1+ prior to release. Families are reared separately to enable genetic and demographic accountability, and to guard against inadvertent hatchery selection for some families at the expense of others. Fish are again being reared to a larger size (>30 g) to avoid empirically confirmed size-related post-release mortality (Justice et al. 2009). Not every circular tank is ultimately filled to its theoretical capacity with juveniles every year due to differential fertilization success and survival among families. However, it is not appropriate to fill underutilized tank space by moving unmarked (too small to be marked) fish from different families into the same tanks. A significantly greater number of juveniles cannot be reared in the existing facility without increasing risks of potentially-detrimental hatchery selection effects that the conservation program is actively managing to avoid (differential growth, condition, disease, pre- and post-release survival, etc.).

Annual and total release numbers are largely a function of broodstock number and family size guidelines adopted to balance near-term and long-term genetic and demographic risks. In practice, genetic and density-related risks argue for contrary strategies. Genetic risks are mediated by releasing large numbers of fish from many families. Density-related demographic risks are mediated by releasing fewer fish.

Of course, the hatchery-origin population size will be much less than the cumulative number due to post-release mortality. This large difference between total numbers stocked and total numbers surviving reflects the normal reproductive strategy of sturgeons in the wild rather than a failure of the hatchery program. Although individual female sturgeon have high fecundity (produce and spawn large numbers of eggs), very few survive to maturity given no parental care following broadcast communal spawning (i.e., sturgeons are “r-selected” vs. “k-selected” reproductive strategists [MacArthur and Wilson 1967]). Natural selection among individuals is a normal process Hence, all other things being equal, it may be more desirable from a long-term population viability standpoint to release a larger number (within reason) and let natural selection prevail rather to artificially select fewer hatchery fish in order to avoid natural mortality.

The current program acknowledges concerns regarding potential negative density-related effects of very large hatchery releases into the wild (see Section 5.5 for additional discussion of density dependence). Potential negative density-related population responses are longer-term risk that must be anticipated by the program. However, the program is focused on the near-term need to capture remaining genetic diversity and propagate this diversity into the next generation. While the pursuit of short-term and long-term goals need not be mutually exclusive, the failure to meet short-term genetic and demographic goals will all but guarantee population failure in future generations.

Current habitat capacity for sturgeon is unknown and cannot be defensibly estimated from existing information (see Section 5.5). However, even if capacity could be estimated, process uncertainty, natural variability and measurement errors in survival rates confound the accurate back-calculation of appropriate release numbers. Even very small differences in annual survival result in vastly different calculations of release numbers needed to establish any given population level. Figure 12 highlights the sensitivity of abundance projections to estimated survival rates due to the compounding effects over the long sturgeon lifespan. Just a ±1% change in annual survival amortized throughout the sturgeon life span can shift projected adult abundance by thousands of fish in either direction. These values are well within the range of error of current empirical estimates of stage-specific survival rates. The sensitivity of abundance to very small variation in survival rates results in low confidence in using release number target back-calculations to accurately predict (and meet) future abundance goals.

Large, diverse, near-term hatchery releases provide the best prospects for the experimental detection of density-dependent effects. Habitat capacity will be experimentally estimated by intensive annual monitoring of post-release survival, condition, and growth in relation to juvenile abundance and size distribution. Results will provide a quantitative, empirical basis for subsequent adaptive adjustments in hatchery production which will be managed adaptively based on feedback from the monitoring program.[11]

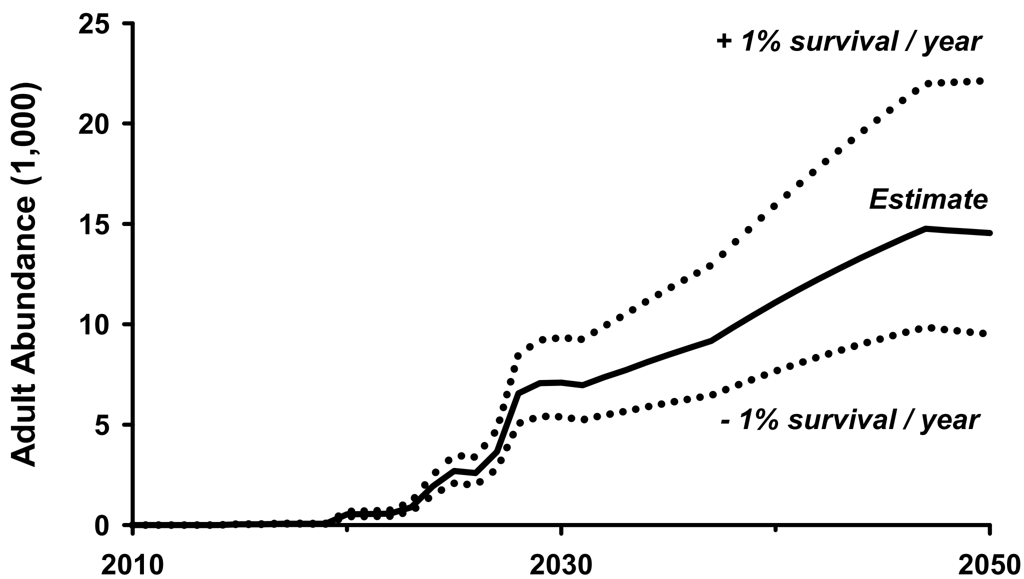


Figure 12. Sensitivity of projected adult abundance to small changes in annual survival rates (based on an actual releases and survival through 2011, annual releases planned for 2012-2030, and recent average survival estimates of 0.12 in the first year following release, 0.95 annually through age 3, and 0.96 thereafter).

4.5 Population Projections

Population projections suggest that planned production targets at current estimates of survival will produce a sizable juvenile, subadult and adult sturgeon population (Figure 13). Increased release numbers associated with the new hatchery produce a relatively modest increase in life stage-specific abundance relative to current production levels because of reductions in family size. Effects of large release numbers (up to 22,500 per year) are also limited by relatively high first year mortality which has averaged 88% for the most recent 7 years of mark-recapture data (2002-2008 release years). Note that these years include all releases following the last significant program expansion, include both Age-0 and Age-1 releases, and that survival has varied from <1% to 23% for different release groups over this period.

Population projections include only first generation hatchery-origin fish and make no assumptions regarding the amount of hatchery or natural production contributing to a second sturgeon generation following extinction of the remaining wild fish. At this point, it is unknown whether natural production

[11] In the longer term, the Tribe is developing a comprehensive adaptive management plan that will incorporate monitoring information from the conservation aquaculture program, habitat restoration efforts, nutrient supplementation program and other efforts, in order to better understand the interrelated effects of these efforts and adaptively manage each program.

can be restored or if substantial numbers of sexually mature hatchery fish will be available to produce a second hatchery generation if natural recruitment continues to fail.

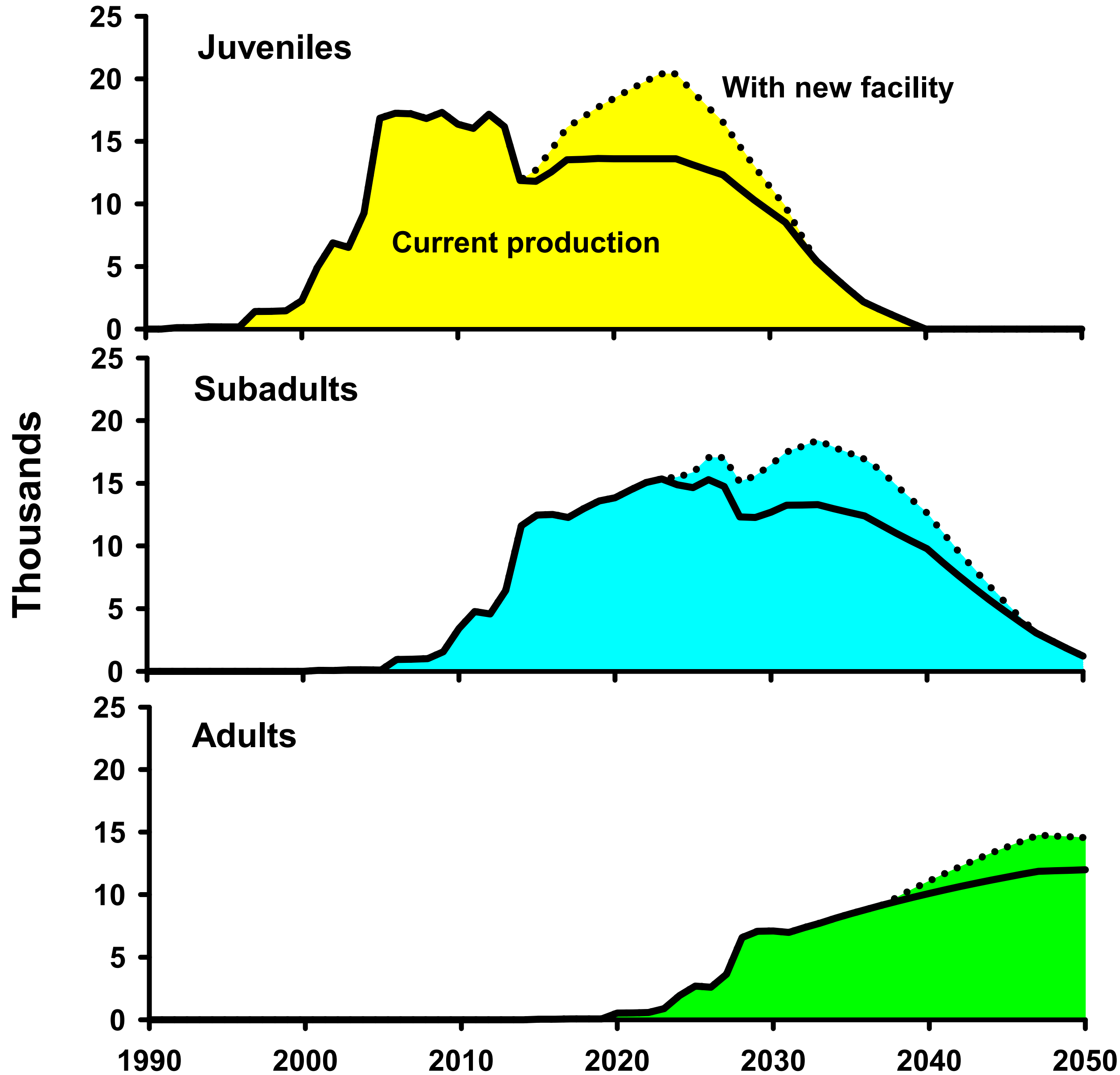


Figure 13. Projected numbers of first-generation hatchery-origin juveniles (ages 1-10), subadults (ages 11-24) and adults (ages 25+) based on expected release levels from the Kootenai Tribal and Twin Rivers facilities and current estimates of survival.

Projections are based on an actual releases and survival through 2011, annual releases of corresponding to the proposed facility expansion 2012-2030 at recent average survival estimates of 0.12 in the first year following release, 0.95 annually through age 3, and 0.96 thereafter.

Juvenile (age 1-10) abundance is projected to stabilize at around 15,000-20,000 over the next 20 years. Numbers are similar to current levels as the age 1-10 span has been filled in by annual releases that began in 2002. Although some of the earlier releases in this period were limited, survival was generally greater than in later releases. Survival was relatively poor in release groups of smaller fish from 2005-2007, but this disadvantage was offset by the large release number. Juvenile numbers would begin to fall off after 2030 if natural recruitment is not restored and broodstock are no longer available for hatchery production.

Subadult (age 11-24) abundance is projected to slowly build to around 15,000 fish between 2020 and 2040 as age classes will be filled out by contining hatchery releases.

Adult abundance is projected to gradually increase beginning around 2020 as fish from the first release groups reach age 25. White sturgeon in other Columbia River populations typically begin to reach sexual maturity around 25 years of age but it is unclear whether the same pattern will occur in the Kootenai where we have no historical reference. Virtually all of the wild population is currently 50 years of age or older. Maturation appear to be a function of both size and age – effects of slower growth rates in the cold Kootenai River system remain to be determined. Adult numbers are projected to peak at around 15,000 by year 2050.

5 Critical Uncertainties

5.1 *Future Survival of Hatchery Fish*

Population projections displayed in Figure 13 represent the most likely patterns of future survival based on the best information currently available. Actual numbers will depend on survival rates of future release groups, which remain highly uncertain. Since the program began releasing substantial numbers of fish each year, first year survival rates have averaged an estimated 12% but ranged from less than 1% to 23% (Figure 9). This range includes years of predominately Age-0 (2005-2007) and Age-1 releases (2002-2004, 2008). High and low values were seen for both types of releases. It remains to be seen what rates will be consistently associated with a return to Age-1 releases. It is reasonable to assume that survival will rebound to intermediate values (~12%) between recent extremes but nowhere near the high rates (40 to 90%) seen in the early years of the program.

Projections of future sturgeon abundance are extremely sensitive to differences in survival within the range observed in recent years (Figure 14). For instance, a 3% to 20% difference in first year survival results in abundance projections over the next 20 years ranging between 5,000 and 35,000 for juveniles, 7,000 and 30,000 for subadults, and 6,000 and 22,000 for adults.

Given the very high level of sensitivity of projections to uncertain survival rates, population projections of this type need to be considered with extreme caution. Depending on what we assume, projections can indicate anything from releases that are too few to avoid damaging genetic bottlenecks, to releases that are too great to avoid damaging density dependence. We expect that large process variation and uncertainty related to future broodstock availability, post-release survival trends, habitat capacity limitations, and the potential for density-dependent feedback could produce very substantial departures between current projections and actual future trends. While projections of this nature are useful for illustration purposes, they should not be the primary driver for identifying sturgeon program production targets. In practice, ongoing monitoring and evaluation efforts will be used to continually refine future estimates of population parameters and trends. This information will be used to implement adaptive management responses like those that have characterized this program since it's inception.

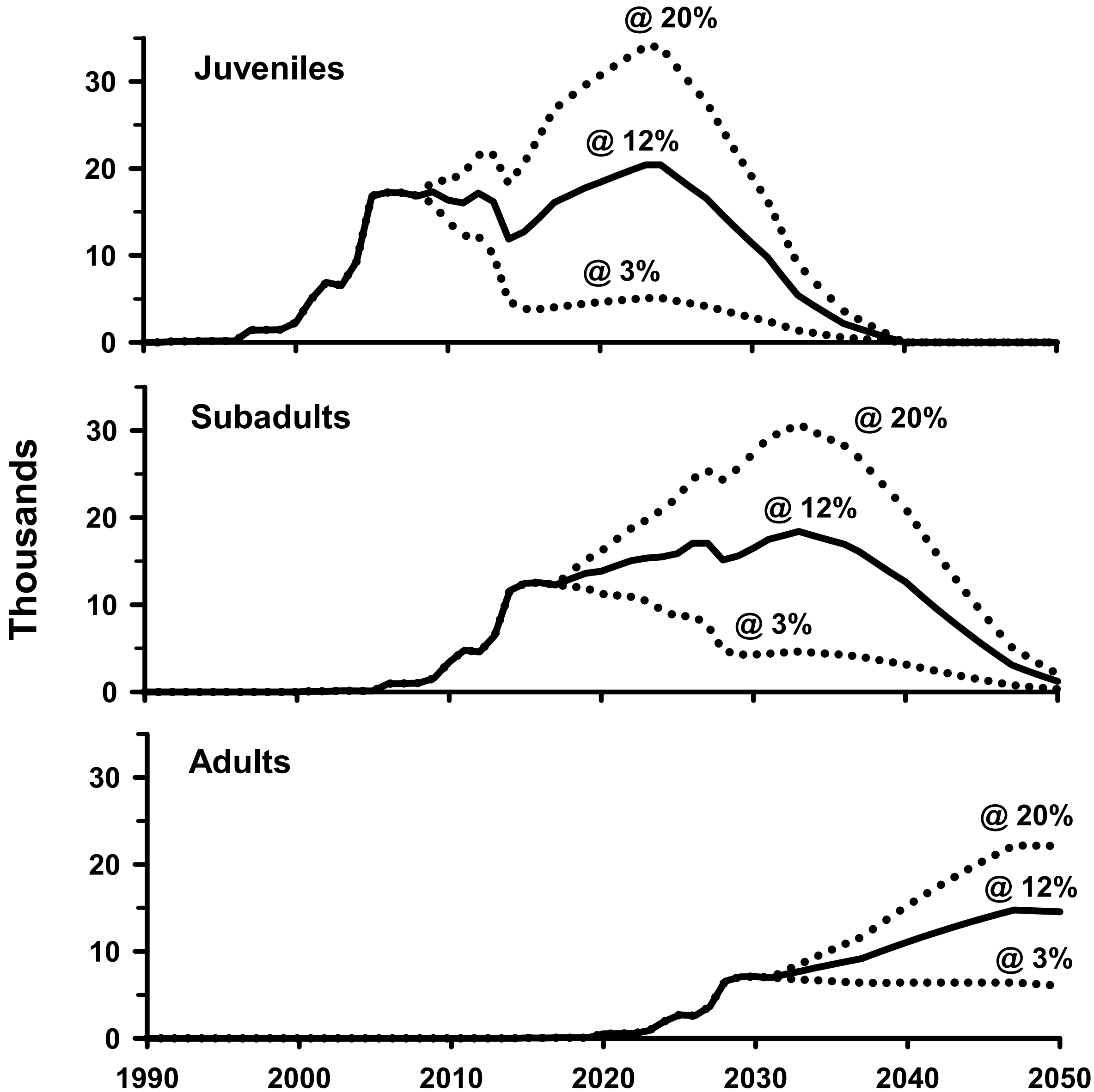


Figure 14. Projected numbers of first-generation hatchery-origin juveniles (ages 1-10), subadults (ages 11-24) and adults (ages 25+) based on expected release levels from the Kootenai and Twin Rivers facilities and alternative estimates of survival representing low, average and high annual values estimated from 2002-2008.

5.2 Future Broodstock Availability

How long wild broodstock will continue to be available to support either natural or hatchery production remains a critical unknown. Although recent status assessments indicated that current population numbers are greater than previously estimated (Beamesderfer et al. 2012a), the endangered population condition remains essentially unchanged: meaningful natural recruitment has not occurred for 40 or 50 years. Remnant numbers of wild adults continue to decline every year. Beamesderfer et al. (2012a) estimated abundance of wild Kootenai sturgeon to be approximately 910 in 2009 based on long-term mark recapture data (Figure 15). Projections of future broodstock numbers are extremely sensitive to uncertain annual survival rates. Analysis of mark-recapture data from floy tags, PIT tags and acoustic transmitters yields annual mortality estimates ranging from 2% to over 8% depending on various model assumptions (Figure 15). At a 2% annual mortality rate, abundance would not fall below 500 wild adults until after 2050. At an 8% annual mortality rate, numbers could be expected to fall below 500 wild adults within the next 10 years.

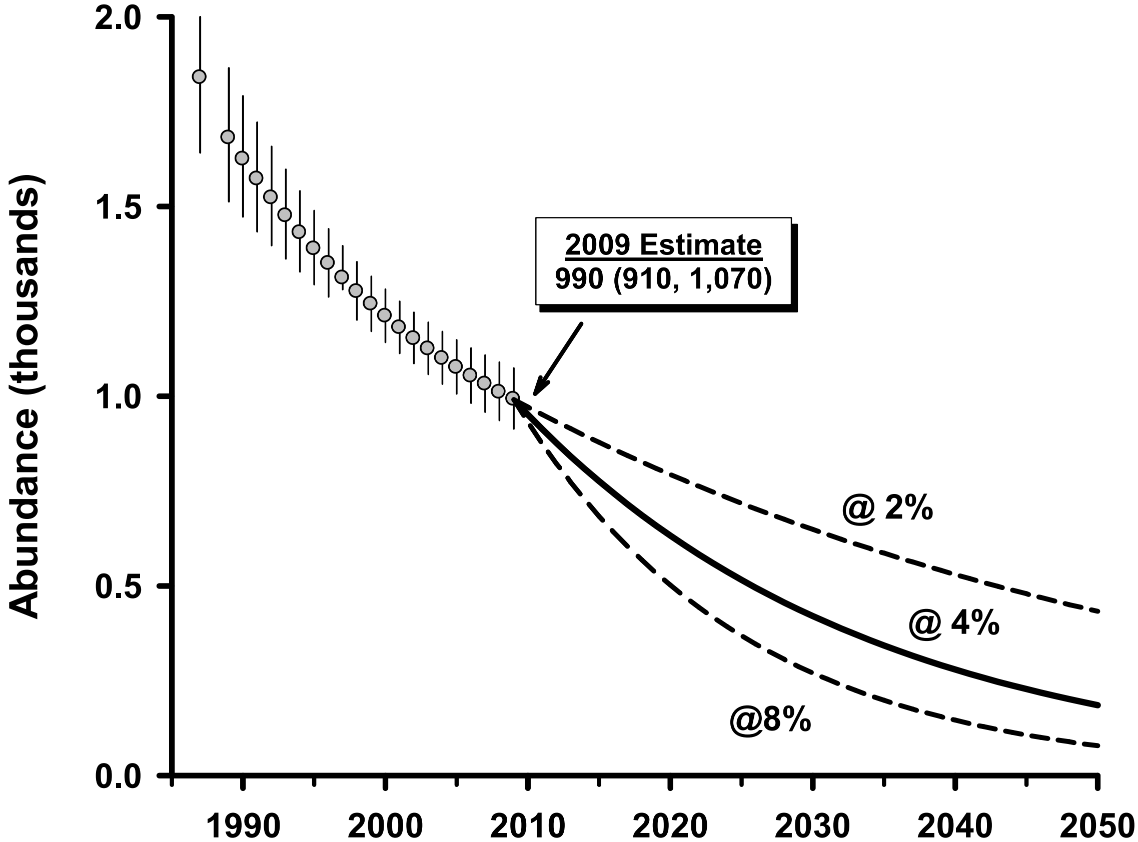


Figure 15. Estimated abundance (and 95% confidence intervals) of Kootenai white sturgeon, 1978-2009, and projected abundance at various annual survival rates.

These projections do not include adjustments for any increased mortality or reduced spawning periodicity that might accompany any increase in senility of the aging wild population. The remaining fish are very old and we do not know how long they will remain reproductive. At some point, too few wild fish will be available to sustain the hatchery program or to take advantage of improved natural conditions if they occur. Without an effective conservation aquaculture program, the population will go extinct.

The good news is that there are more fish than previously estimated and the rate of decline is less than previously estimated (Paragamian et al. 2005; Beamesderfer et al. 2012a). This could explain why the program has not yet encountered difficulty in collecting broodstock. The finding also suggests that prospects for broodstock availability are good for the foreseeable future. If hatchery-reared fish from past releases mature in a timely fashion, we might avoid an extended gap in adult numbers between the demise of the wild fish and the availability of hatchery-origin adults.

At the same time, observations suggest a significant population segment in Kootenay Lake appear to enter the river spawning population at a lower frequency than fish that occupy the river upstream. These fish appear to be of reproductive sizes and ages, but we don't know if they represent late maturing fish that will be available in future years, fish with greater spawning periodicity (more years between successive spawning events), or a post-reproductive component of the aging population. The most likely explanation is that different individuals spend different amounts of time in the river, where they are vulnerable to capture and tagging. Those that enter the river more frequently are more likely to be tagged than those that spend more time in the lake. There is surely a continuum of behavior, some related to spawning periodicity and some related to preferred foraging habitats. This does not mean there is a different, unique population of fish in the lake. Variability in spawning periodicity and movement patterns is common to virtually all sturgeon populations where information on these attributes has been reported. Reproductive senescence would be of particular concern for future broodstock availability.

5.3 Homing and Attraction

Homing fidelity in sturgeon is implied but not proven by 1) consistent use of common spawning reaches every year by different sturgeon in the Kootenai and other populations, 2) tagging of fish in spawning areas, and 3) genetic metapopulation structure of species with access to multiple spawning areas. This work collectively and consistently supports a hypothesis of homing site fidelity in shortnose sturgeon (*Acipenser brevirostrum*), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), Gulf of Mexico sturgeon (*Acipenser oxyrinchus desotoi*) and lake sturgeon (*Acipenser fulvescens*) (Dadswell 1984; MacNeill and Busch 1994; Stabile et al. 1996; Lucas and Baras 2001; Wirgin et al. 2002, 2008, 2007; Grunwald et al. 2007; Kynard et al. 2007; Welsh et al 2010). For instance, shortnose sturgeon in the Connecticut River spawn in the same general reach each year, and may change their specific spawning locations among years within that reach as dictated by annual variation in discharge. Tagging of shortnose sturgeon in the Connecticut River identified males and females repeatedly returning to the same spawning site (Kieffer and Kynard 1996). Tagged male and female Chinese sturgeon (*Acipenser sinensis*) have also been reported to return repeatedly to the same site in the Yangtze River (Wang et al. 2012). The starry or stellate sturgeon (*Acipenser stellatus*) in the Danube River shows genetic differences that could only be present if the adults consistently home to several areas (Kynard and Suciu 2002).

One of the biggest unknowns is how the hatchery fish will behave upon maturity, in terms of migration, spawning site selection, and success of natural production. The new hatchery will enable the Tribe to spawn and rear fish farther upstream in the Kootenai system in an effort to induce fish to spawn where habitat conditions are more suitable. Because significant numbers of hatchery-reared sturgeon are not expected to mature for at least 10 to 20 years, the answers to these questions will not be known for some time.

5.4 *Food and Feeding*

Feeding ecology of juvenile sturgeon in the Kootenai River has not been investigated extensively, and would be a valuable subject for future study. Sturgeon are opportunistic, omnivorous predators that as adults, occupy an upper trophic niche that likely plays an important regulatory role in shaping prey taxa assemblages, affecting food web dynamics. The magnitude of this effect is expected to increase with population size.

The diet of white sturgeon varies with fish size. Juveniles typically rely on benthic invertebrates. Sub-adults consume a variety of benthic organisms. Larger white sturgeon are increasingly picivorous. Because of very large differences in size over their lifespan, different size classes of sturgeon exploit, affect, and are limited by very different components of the aquatic community. We expect that carrying capacity will be specific to different size classes of sturgeon over the course of their lifespan. So while juveniles might be limited for a time by the productivity and availability of benthic invertebrates, these limitations might be relaxed as fish grow to larger sizes where they may take advantage of more diverse food sources.

Some information is available on general food habits of white sturgeon in other areas. Juvenile white sturgeon (> than 80 cm total length) in the lower Columbia River have been reported to feed mainly on invertebrates, with amphipods (*Corophium sp*.) being the most-often selected prey items (McCabe et al. 1993; Romano et al. 2002). McCabe et al. (1993) also noted that a substantial portion of the diet for white sturgeon in this size class consists of eulachon eggs, isopods, mysids, Asian clams, snails, and small fish (such as sculpins and assorted fry). As white sturgeon grow, their diets typically become more diverse. Larger sturgeon in the lower Columbia River feed increasingly on fish including euchalon, northern anchovy, American shad, lamprey, Pacific herring and various salmonids (McCabe et al. 1993). Large adult sturgeon are capable of consuming large prey, including adult salmon. Fish dominate the adult sturgeon diet through most of the year (50%); in winter, benthic invertebrates become dominant with clams being the most important item (12 to 41%) (Semakula and Larkin 1968; McKechnie and Fenner 1971; Scott and Crossman 1973).

Diet information is particularly limited for Kootenai white sturgeon, where sacrifice to identify stomach contents is precluded by their low numbers and ESA-listed status. Partridge (1980) collected information on 22 stomachs of sturgeon turned in by anglers in 1979. Plant material was found in 19 of these. *Chironomid* larvae occurred in virtually all stomachs where plant material was found. Fish parts were found in three stomachs. Small clams were found in three stomachs. One fish contained numerous mayfly and stonefly larvae. Examination of 24 stomachs in 1981 commonly found plant material and *chironomid* larvae, followed by fish, clams, snails, and leeches (Partridge 1982). Similar findings were reported in 1982 (Partridge 1983).

Stomach contents were collected from 41 juvenile Kootenai River white sturgeon in Idaho and B.C. during 2002. *Chironomid* spp. were the most common diet item by weight and number (Rust et al. 2003). During 2003, 15 additional juveniles were found to contain primarily *Chironomid* larvae (Rust et al. 2004). Diets of juvenile white sturgeon from other areas of the Columbia Basin also included significant numbers of *Chironomids*, along with large numbers of other benthic organisms such as mollusks and amphipods (Sprague et al. 1993).

Survival data indicate that there is a period of acclimation following release that might be related to success in transitioning to a natural diet (Ireland et al. 2002b; KTOI 2008). Food limitations could well account for possible density-related differences in survival of Age-0 and Age-1 fish. A narrower array of prey items may be available for Age-0 than Age-1 fish due to differences in fish size, gape limitation, and foraging strategies. Other factors, including increased vulnerability to predation and effects of food reserves on first overwinter survival, may also contribute to the differences. Current production goals are for release of Age-1 fish to avoid the apparent Age-0 survival bottleneck that was identified through monitoring the post-release survival of hatchery-reared fish.

In the future, hatchery produced fish are expected to provide a means of collecting much better information on Kootenai sturgeon diet. One of the benefits of hatchery-origin fish is that they have been released in sufficient numbers to conduct food habitat studies.

5.5 Habitat Capacity and Density Dependence

Carrying capacity of the Kootenai system is a critical issue for this program, and could ultimately prove to be a significant factor that could limit the extent of recovery. Carrying capacity is currently unknown and density dependence in sturgeon is poorly understood. Large numbers and densities might elicit a strongly-negative density-dependent response that could reduce survival, slow growth, and delay maturation.

A significant density dependent response to increasing sturgeon abundance has not yet been observed, except possibly among Age-0 sturgeon. It remains unclear if low survival rates of the smaller hatchery fish released in recent years are due to smaller size of release or increased competition with increasing numbers of hatchery fish (Justice et al. 2009). However, the effect appears to be limited to the smaller Age-0 or Age-1 fish in the release groups. Survival of larger fish appears to have remained consistent. To date, no obvious reduction in growth or condition factor of surviving fish is apparent as might be expected under conditions of limiting competition.[12] It is also possible that observed low rates of some groups of fish might be an artifact of changing release strategies (e.g., smaller size at release) or density-independent factors.

Production in every system is ultimately limited by carrying capacity. Increasing numbers of sturgeon must theoretically stimulate a density dependent response at some point. Therefore, the key distinction is whether carrying capacity for white sturgeon in the current and future Kootenai River ecosystem exceeds demographic and genetic threshold for viability and persistence.

In an ideal world, we could accurately estimate sturgeon carrying capacity of the system and scale hatchery production accordingly. However, little information currently exists regarding habitat carrying capacity for sturgeon in general, and in the Kootenai River specifically. We have generated hind-casted projections of historical sturgeon abundance, but the Kootenai ecosystem has been altered and we

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[12] *It should be noted that recent sample data on fish collected in the Montana portion of the river upstream has documented apparent high growth rates and condition factors for hatchery fish that have migrated upstream. Densities of sturgeon in these areas are very low. Hence, individuals are unlikely to be limited by intra-specific competition. However, habitat conditions and productivity are much different from the meander reach of the river in Idaho where most hatchery sturgeon occur. At this point, it is uncertain how much of the growth and condition difference is related to habitat or density.*

cannot accurately infer current capacity from historical numbers. It is also likely that capacity varies for different sturgeon life stages, which utilize different resources and habitats, and we do not know which life stages will ultimately be limiting.

The ISRP recommended the Tribe use trophodynamic modeling to develop at least ballpark estimates of carrying capacity. The ISRP also inquired about bioenergetics modeling and feeding ecology as part of this program. Based on these comments, we conducted additional exploration of these methods (see Attachment 1 of this document). This exercise highlighted the challenges of attempting to infer capacity based on limited information and inherently variable parameters. Capacity estimates might be derived using various models, but these inferences would be speculative at best given the broad assumptions required to parameterize the models.

Given these uncertainties, the Tribe has elected to experimentally identify habitat capacity based on monitoring the population response to increasing sturgeon numbers or densities. After extensive consideration of various alternatives for inferring capacity, we concluded that an experimental approach is the only effective approach. Rather than speculating on where capacity lies and artificially limiting production based on questionable assumptions, the proposed experimental approach will provide a real answer with no significant downside risk. Consequently, the recovery program incorporates an intensive hatchery marking and annual monitoring program (see Appendix B of the Step 2 document, Monitoring and Evaluation Plan for the Kootenai Sturgeon). Post-release fish growth, condition, and survival are being monitored in the wild in relation to population size and density. Habitat capacity will be identified by a detectable response. Future juvenile, subadult, and adult population levels will be managed adaptively based on continuing monitoring and evaluation.

Not all density-dependent responses are detrimental. Much of the concern over potential density-dependence appears founded on an unstated presumption that this effect will be entirely negative. While there are certainly potentially negative aspects (e.g., reduced survival, delayed maturation), significant positive responses can also be anticipated which could balance or surpass the negative effects. For instance, the upstream expansion of juvenile distribution into Montana might represent a behavioral response to high densities in the meander reach. It would be a huge benefit if increased competition stimulates a wider dispersal of fish into upper river reaches where they subsequently may spawn in more favorable habitats. It is also unclear whether current recruitment failure is simply related to spawner stock abundance and might be at least partially ameliorated by rebuilding the adult population to higher levels.

The role of density dependence in a normally functioning natural sturgeon population is unclear. Density-related processes are a normal dynamic in many healthy wild fish populations. Natural selection will act to regulate year class abundance and density dependence might serve some functional role in sustaining long-term viability. Natural selection acting upon natural or enhanced production might act to favor more successful traits.

Habitat capacity and density dependence are just two of many unknowns and risks that must be considered by this program (Table 5). Many risks pose competing challenges. For instance, stocking very large numbers to optimize diversity risks could trigger a potentially counterproductive density-dependent response. Conversely, limiting stocking rates to avoid the risk of a negative density-dependent response will exacerbate the risk of reducing genetic diversity. Program objectives and targets have been designed in an attempt to balance a wide spectrum of very uncertain demographic, genetic, and ecological risks and benefits over multiple generations of sturgeon recovery.

The near-term hatchery strategy is focused on addressing the immediate genetic risks while collecting information needed to weigh future density-related risks. The central issue here is one of balancing the risk of losing genetic diversity versus the risk of negative density-dependent responses in the population and the ecological community. Loss of genetic and phenotypic diversity is an acute, immediate, and terminal risk associated with the continuing decline of wild fish in the current generation. We have an opportunity to capture and express representative genetic diversity before the wild population disappears. Failure to conserve remnant locally-adapted genetic material from this endangered population would likely be irreversible. If we fail to capture critical elements that might allow the next generation to effectively utilize the available habitat, we may be dooming the population regardless of what happens with density dependence.

Habitat capacity limitations and negative density dependence are intermediate to long-term risks that we will confront as the age and size structure population gradually rebuild over the next ten to twenty years. The carrying capacity of the Kootenai River remains unknown and we are unsure when a significant negative density-dependent response will be triggered. These risks will be addressed by empirically evaluating system carrying capacity at each sturgeon life stage by releasing significant numbers of hatchery-reared sturgeon and monitoring the system response in terms of survival, growth and condition. This information will provide a sound technical basis for appropriate management of density dependence.

In weighing tradeoffs among risks and benefits, it is useful to consider the down-side consequences if we are wrong:

- The greatest risks associated with large stocking rates probably revolve around density-related decreases in survival or growth. Reduced survival would offset the large initial stocking rates. However, depressed survival could be a problem if it affects different brood years so as to reduce representation of family groups in the next generation.[13]
- In the extreme case, reduced growth might also delay maturation of adults in the next generation and extend the interval between the demise of the wild fish and the maturation of the hatchery-reared generation.
- Another concern might be the limitation or swamping of natural production by large numbers of hatchery fish. Prospects for natural production remain uncertain. Small levels of sporadic natural recruitment seen in the data will not be adequate to sustain a population after nearly 50 years of recruitment failure. By marking hatchery fish and continuing the monitoring program, we will be able to detect significant natural recruitment if it occurs and the necessary accomodations can be made.

[13] *Equal representation among families at maturity should not be assumed relative to genetic and environmental variability, even in wild populations.*

Ultimately, density-dependent circumstances are reversible and would eventually be self-regulating, albeit at some level of ecological cost. Hatchery-related measures will be adjusted accordingly to achieve an optimum balance between competing risks and demographic and genetic objectives. For instance, total releases and family sizes might be reduced, fish might be reared to a larger size to avoid size-related post-release survival bottlenecks, biomass might be reduced by removing fish from the population, or the program might be adjusted to simply allow demographic selection to occur in the current environment.

5.6 Effects of Ecosystem Improvement

Current ecosystem improvement plans include a combination of flow, physical habitat restoration, and nutrient enrichment actions. These actions could have significant effects on habitat conditions and capacity for sturgeon, as well as the entire ecosystem. Actions are experimental and effects are uncertain. The net effects of all these changes on system trophic dynamics and habitat capacity are difficult to predict. These limitations are why an empirical monitoring and evaluation approach to identifying sturgeon capacity is being implemented using releases of hatchery-reared sturgeon. Improvements may or may not be significant but will be monitored. Future recovery efforts, including the conservation aquaculture program, will be adapted accordingly. Following is a summary of major ecosystem restoration actions that are underway and planned:

Kootenai River Habitat Restoration Project (BPA Project No. 200200200)

The goal of the Kootenai River Habitat Restoration Program is to restore and maintain Kootenai River habitat conditions that support (1) all life stages of endangered Kootenai sturgeon and (2) all life stages of native focal species (i.e., burbot, bull trout, kokanee, westslope cutthroat trout, redband trout) through design and implementation of a suite of habitat restoration projects in the Braided, Straight and Meander reaches of the Kootenai River.

The Kootenai River Habitat Restoration Program is a large-scale, collaborative, adaptively implemented and managed, ecosystem-based habitat restoration program to restore and maintain Kootenai River habitat conditions that support all life stages of endangered Kootenai sturgeon and other aquatic focal species within a 55-mile reach of the Kootenai River. In 2009, the Kootenai Tribe finished the *Kootenai River Habitat Restoration Master Plan*. This plan identified a toolbox of different restoration treatments designed to help restore or enhance different habitat conditions for Kootenai sturgeon, burbot, bull trout, kokanee, and other native fish.

Building on nearly two decades of data collection and modeling related to physical habitat conditions in the Kootenai River, and on monitoring and evaluation data collected through IDFG's project 198806500, and the Tribe's Nutrient, Operational Loss Assessment, Reconnect, and Conservation Aquaculture projects, the expertise of regional and local experts, the Tribe in collaboration with regional partners developed the Kootenai River Habitat Restoration Master Plan. The Habitat Restoration Master Plan identifies limiting factors associated with river morphology, riparian habitat, aquatic habitat (including limiting factors associated with the six focal fish species), and other constraints, treatments to address those limiting factors, and restoration strategies for each river reach.

Restoration treatments implemented through this project are designed to address: bank erosion and fine sediment inputs to downstream reaches, lack of cover for juvenile fish, lack of off channel habitat for rearing, insufficient depth for Kootenai sturgeon migration, lack of mainstem hydraulic complexity in the form of variable depth and velocity, insufficient pool frequency, simplified food web, lack of surfaces that support riparian recruitment, loss of floodplain connection, lack of coarse substrate for Kootenai sturgeon egg attachment and larval hiding, lack of bank vegetation, lack of off-channel habitat, lack of fish passage into tributaries, and grazing and floodplain land use. Project actions are based on ecosystem restoration principles and will help to provide habitat attributes for Kootenai sturgeon that are identified in the Libby Dam Biological Opinion (implementation of the project is included in the Libby Dam settlement agreement), in addition to habitat needs for a range of life stages of burbot, bull trout, kokanee, westslope cutthroat trout, and redband trout.

The Tribe is coordinating with IDFG, Montana Department of Fish, Wildlife & Parks and other partners, including the B.C. Ministry of Fish, Forests, Land, and Natural Resource Operations (BC Ministry), U.S. Army Corps of Engineers (USACE), USFWS, and Bonneville Power Administration (BPA) to incorporate the most recent data and analysis in each stage of the project design process and in development and implementaton of the monitoring and evaluation and adaptive management program.

Reconnect Kootenai River with the Historical Floodplain Project (BPA Project No. 200200800)

The primary goal of the Reconnect Project is to investigate and implement actions that enhance terrestrial and lentic habitats by reconnecting the Kootenai River with its historical floodplain in the Kootenai River. This project was originally categorized as a wildlife habitat restoration project and the project was closely linked to work conducted under the Albeni Falls Wildlife Mitigation Project (199206105) and the Ecosystem Operational Loss Assessment, Protection, Mitigation and Rehabilitation (Oploss) Project (Project No. 200201100). The Oploss Project is developing the framework to assess and monitor reconnection opportunities. Each reconnect or mitigation project can be folded back into the ecological framework developed by the Oploss Project to assess cumulative impacts of multiple projects over time. Floodplain reconnection activities under this project are purposely associated with the Tribe's wildlife mitigation program to ensure long-term protection and designed to address both lentic and terrestrial objectives. Under this project the Tribe has examined the feasibility of reconnecting floodplain habitats with the mainstem in the Meander Reaches of the Kootenai River. Since 2002, this included identification and initial assessment of the feasibility of reconnecting six tributary/wetland complexes to the mainstem Kootenai River.

In addition to supporting feasibility assessment work for Ball Creek and completing initial feasibility analysis for reconnecting six other tributary/wetland complexes in the Meander Reaches, LiDAR data collected as part of this project has helped develop a 2D hydrodynamic model that is used to assess Libby Dam hydraulic impacts, model vegetation succession, and simulate restoration effects to the floodplain under the Oploss Project along with supporting development of the Kootenai River Habitat Restoration Project Master Plan and conceptual design of projects to be implemented under Project No. 200200200.

This project will complement and augment habitat restoration work planned in the Meander Reaches under Phase 3 of Project No. 200200200 by creating conditions that help support an enhanced food web, and contribute to a more complex and diverse terrestrial habitat communities for a variety of wildlife focal species and aquatic species. An important aspect of the Reconnect Project is that it purposefully focuses on wildlife mitigation in the Kootenai River floodplain to ensure long-term protection and enhancement opportunities. Moreover, the Reconnect Project targets floodplain biotic communities identified by Oploss Project assessments with an emphasis on the intersection between aquatic and terrestrial connectivity. The complementary work conducted under Project No. 200200200 will be addressing sturgeon and other focal species (e.g., burbot, kokanee, etc.) mitigation restoration opportunities in the Meander Reaches and focusing primarily on aquatic/riparian restoration objectives.

Biomonitoring data conducted under the Nutrient Project (Project No. 199404900) are used to help inform project design and will help measure the biological benefits of this project.

Kootenai River Ecosystem Restoration (Nutrient Enhancement) (BPA Project No. 199404900)

The Tribe, in coordination with IDFG, is also implementing an experimental river fertilization program to improve productivity of the system (Kootenai River Ecosystem Restoration [Nutrient Project] Project No. 199404900)**.** The primary goal of this project is to recover a productive, healthy and biologically diverse Kootenai River aquatic ecosystem across multiple trophic layers. This work is important to help mitigate the effects of Libby Dam impoundment on aquatic processes in downstream river reaches. Currently the project is implementing several nutrient restoration efforts to help mitigate 30 years of lost productivity due to Libby Dam hydro operations.

The primary objective of the project has been to address factors limiting key fish species within an ecosystem perspective. Major project components completed include: establishment of a comprehensive and thorough biomonitoring program, investigation of ecosystem-level productivity, testing the feasibility of a large-scale Kootenai River nutrient addition experiment, the rehabilitation of key Kootenai River spawning and rearing tributaries, the provision of funding for the Canadian government for nutrient enrichment and monitoring in Kootenay Lake, providing written summaries of all research activities, and, holding an annual workshop with other agencies to discuss management, research, and monitoring strategies related to Kootenai River basin activities.

A portion of this project is jointly implemented by the Kootenai Tribe and IDFG (the nutrient addition component for the river is a shared responsibility between the agencies). The Tribe is responsible for the monitoring of lower trophic levels (water quality, algae and invertebrates) while IDFG is responsible for fish community data collections and analyses associated with nutrient addition in the Kootenai River. Additionally, the Tribe purchases the nutrient supply on an annual basis and IDFG is responsible for nutrient site day-to-day management activities. IDFG, the BC Ministry, and the Tribe coordinate to hold an annual 2-day workshop centering largely around the nutrient restoration efforts on the Kootenai River and Kootenay Lake, referred to as the IKERT meeting.

Addition of nutrients in the Canyon Reach of the Kootenai River and in the south arm of Kootenay Lake (where Kootenai River discharges into the Lake) in Canada are being used as a mitigative approach to addressing nutrient losses. Nutrient addition of this type are not possible in the Meander Reaches of the Kootenai River because critical environmental conditions that allow for significant primary productivity (i.e., clear, shallow water, rocky substrates) are not present in this reach. However, nutrient effects, such as organic matter spiraling from the upriver nutrient addition zone, and fish migrations, such as kokanee spawner returns from Kootenay Lake, will likely augment trophic productivity in the Meander Reach over time. Nutrient additions in the Canyon reach have helped reestablish the food web in the Canyon and further downstream into the Braided Reach (to a somewhat lesser degree, but still significant) since inception in 2005. The Tribe anticipates that Canyon Reach nutrient addition will compliment habitat restoration work implemented through Project No. 200200200 in the Braided and Straight Reaches.

The large-scale biomonitoring program associated with this project covers approximately 235 kilometers (km) of the Kootenai River and key tributaries. This biomonitoring program is designed to be sensitive to water borne nutrients, species and community level responses within the water chemistry, algal, macroinvertebrate, and fish communities. In addition, the project developed a fine-scale biomonitoring program in 2005, specifically to monitor the effectiveness of the nutrient addition experiment in the Kootenai River. This targeted monitoring project is collecting data on algae species dynamics and key water chemistry parameters in the heart of the nutrient addition zone to provide managers with fine-scale information for adaptive management of the nutrient project on a timely basis.

The biomonitoring program provides critical monitoring data to help measure and evaluate the biological response of habitat restoration actions conducted under BPA project nos. 200200200 and 200200800 as well as supporting the Tribe's conservation aquaculture program. Data gathered through this biomonitoring program will also be critical to implementation of the Kootenai River Habitat Restoration Program adaptive management plan and the Tribe's subbasin-scale adaptive management plan.

The Tribe began a multi-year stream habitat/biota survey of lower Kootenai River tributaries (between Bonners Ferry and Porthill, Idaho) in 2000. Similar to efforts in the Kootenai River, an ecosystem-based perspective has been used in development of monitoring plans and restoration work in tributaries. Streams where historical kokanee salmon spawning has occurred were given top priority in the selection of tributaries segments to be restored. The critical stream segments this project has and will continue to focus on are the area near the confluence of several key tributaries with the Kootenai River on its historical floodplain. This tributary restoration work and the kokanee response is an important component of larger-scale efforts to enhance the Kootenai River food web. This project addresses in river conditions only i.e., work is targeted to the aquatic ecosystem within the confines of the river banks, for the most part (some tributary riparian work has occurred and is planned).

Analysis is ongoing to assess effects of nutrient addition on condition, growth, and survival of post-release juvenile sturgeon before and after the onset nutrient addition. The Kootenai River has now undergone 5 years of experimental nutrient addition in a reach at the Idaho-Montana border. A significant response has been confirmed by analysis of pre- and post-fertilization nutrient availability, algae abundance, chlorophyll accrual rates, invertebrate biomass, diversity, and richness, and recruitment and size of juvenile mountain whitefish (Holderman et al 2009a, Holderman et al. 2009b; Ericksen et al. 2009; Shafii et al. 2010).

Statistically significant ($p<0.05$) increases in biological productivity have also been documented in portions of the Kootenai River where nutrients have been added since 2005. Kootenay Lake fertilization has also stimulated a biological response that has been successfully managed since the early 1990s. Significant positive trophic level responses have also been documented in Kootenay Lake following annual fertilization which began in the North Arm in 1991 and in the South Arm during 2004 (Ashley and Thompson 1993; Schindler et al. 2010).

Kokanee Restoration

Kokanee restoration efforts have significantly increased annual returns to the Kootenai River and tributaries. Kokanee will be an important part of the food web for the sturgeon population and in addition, will provide a general indicator of improving ecosystem health.

A population of kokanee which historically migrated from the South Arm of Kootenay Lake into Kootenai River tributaries to spawn was largely extirpated due to the loss of spawning habitat and declines in productivity and food availability in Kootenay Lake (Ashley and Thompson 1993). This kokanee population has begun to rebuild due to restocking and nutrient supplementation efforts (Anders et al. 2007; Ericksen et al. 2009).

Kokanee abundance and escapement has increased from a low in the hundreds of thousands to recent escapment estimates of millions and abundance estimates in the tens of millions. Substantial increases in kokanee escapement to seven lower Kootenai River tributaries were documented in 2007 and 2008. Substantial kokanee escapement was also reported in 2009 and 2010. In 2011, counts of over 1,000 kokanee were recorded for just one stream (pers. comm., Chris Lewandowski, KTOI Hatchery Manager, Sept. 27, 2011).

5.7 Stochastic Processes

The ISRP noted that studies on sturgeons in natural settings suggest that there may be big differences in year class strength, and that for a variety of reasons, it may not be optimal to have every year class be “strong” and of the same approximate size. In fact, the reproductive and life history strategies of sturgeons can provide long-term population sustainability in the face of missing year classes or even periods of missing year classes. However, the protracted recruitment failure in the Kootenai River has created a very large hole in the current population structure. Failing to incorporate as much of the remaining genetic and life history diversity would be inconsistent with the stated goals and inherent approach of the Tribe’s program. The current production strategy is to support significant annual production to compensate for this unnatural, extended period of recruitment failure.

Stochastic analysis suggested by the ISRP is a commonly used approach in conservation biology to evaluate the chances that a population might “bottom out” due to combined effects of reduced productivity and normal environmental variation. These Population Viability Analyses, or PVAs, have been widely applied to salmon (Beamesderfer 2010) but are used less frequently for sturgeon. These models very effectively consider the status of listed salmon populations in a risk-based framework based on the interaction of low numbers and productivity with environmentally-mediated variability in recruitment and survival. Stochasticity is an essential element in the salmon life cycle and population viability cannot be effectively evaluated without models that incorporate stochastic processes.

Stochastic models have been employed for population viability analysis of a variety of sturgeon populations (Jager 2001, 2005, 2006a, 2006b; Jager et al. 2001, 2010; Paragamian and Hansen 2008; Schueller and Hayes 2011; ODFW 2011). Jager (2001, 2005, 2006a, 2006b) used an individual-based stochastic population model to explore the effects of river fragmentation and individual variation on risks for sturgeon. Paragamian and Hansen (2008) also used a PVA approach to evaluate the effects of episodic natural recruitment on sturgeon demographics. However, this approach offers limited utility when applied to Kootenai River sturgeon, for which annual natural recruitment at the population level (to maturity) has been zero since the late 1950s to early 1960s (Paragamian et al. 2005).

These analyses have been most useful for evaluating the relative influence of different parameters, assumptions and actions on risk, but have also demonstrated that absolute estimates of risk depend strongly on speculative underlying assumptions regarding depensatory thresholds. Flather et al. (2011) highlighted the difficulties inherent in applying generic threshold values to the development of MVP sizes. Morris and Doak (2002) further emphasized the limitations of stochastic population viability analysis when too few data are available upon which to base quantitative assessments and when models omit many ecological, economic, and political factors that can affect population viability. Absolute estimates of risk hinge on arbitrary decisions regarding what risk level is acceptable, what population thresholds pose risk, and over what length of time risks should be considered. These models are most robust in relative comparisons of the effects of different conditions or parameters on risk.

Conventional PVAs of the effects of environmental variability on population cycles are not particularly informative for Kootenai sturgeon where the problem is not variable recruitment, but no recruitment. Long-term trends in sturgeon populations with large overlap in the age structure of successive generations are essentially driven by long-term trends and averages in recruitment and mortality rather than annual patterns of variability. Where annual patterns cause large and risky fluctuations in abundance of impaired salmon populations, sturgeon populations are very well-buffered from the effects of short-term variability. This is the cornerstone of the successful sturgeon life history strategy; however, the cost of this life history strategy is that populations that take a long time to go extinct also take a long time to recover.

Because of their longevity and delayed mortality, the viability of sturgeon populations over the long-term is relatively insensitive to normal annual variation in demographic parameters. Variation tends to average out over the long-term, producing population trajectories and risk estimates that are essentially the same in stochastic and deterministic models. While there may be hypothetical circumstances where stochastic models and deterministic models produce different results – for instance, where recruitment consists of periodic large year classes – that is not the situation in the Kootenai. We expect that a stochastic population analysis would highlight the point that it is not necessary to produce fish every year in order to forestall extinction if demographic extinction is the primary metric. The particulars of what risk level is associated with what level of production and variability would depend on parameterization of the simulation. Since we currently have no significant natural recruitment and variability is essentially zero, the purpose of this analysis would be largely to illustrate the concept rather than to provide any specific guidance.

Extinction probabilities in stochastic risk models are typically a function of variability (stochasticity) and generation times. High extinction probabilities are associated with high variability, shorter generation times, and low overlap in cohorts. Meaningful calculations of risk typically require simulations over multiple generations. In salmon for instance, many PVAs are currently based on 100-year simulations that include 20 or more salmon generations. A particular problem with application and interpretation of these models to sturgeon is the need to calculate risks over multiple generations. Multiple sturgeon generations might typically span several hundred years. A comparable time calculation for sturgeon would be 500 years at a 25-year generation time. However, simulations must also represent conditions throughout the period of interest and it would be difficult to argue that we can realistically parameterize conditions for the next five centuries, as this approach would suggest. Simulations for this duration would entail critical assumptions regarding future conditions far beyond our ability to reasonably represent corresponding uncertainties.

Rather than employing a stochastic PVA approach like that suggested by the ISRP, we identified production targets for this program based on a series of deterministic model projections focused on time-specific risks. Risks are compartmentalized into specific periods, which is an effective alternative to the problem of unstable population patterns addressed by the PVA. This approach includes sensitivity analyses of the effects of alternative assumptions that reflect the uncertainty in population parameter estimates.

In the course of reviewing the literature on stochastic and deterministic modeling, we evaluated an intriguing and potentially useful alternative to conventional PVA type modeling for sturgeon, using an individual-based approach like that of Jager (2001, 2005) and Schueller and Hayes (2011). This approach considers the effects of individual variability on genetic and demographic questions related to sturgeon aquaculture. We are currently exploring development and application of this approach to Kootenai sturgeon and expect to implement this approach in the future. We are in the process of adapting a stochastic individual-based model for Kootenai sturgeon. However, model analyses will be focused on the effects of individual variability on population dynamics and risk. In particular, we anticipate using this approach to evaluate effects of various hatchery production and mating alternatives on genetic and demographic population structure.

5.8 Long-term Viability of Hatchery Strategy

The conservation aquaculture program is intended to be an interim strategy until natural recruitment can be restored. The period of hatchery need has proven to be a lot longer than was originally hoped and the program has been adapted in response to the continuing need. However, significant questions remain regarding the potential for inadvertent hatchery selection over the long term. The practical limitations of hatchery production mean that no program can completely mirror natural processes and the corresponding risks to continuing natural population viability can be expected to increase the longer the hatchery must be employed.

The present hatchery protocols relax natural selection on many important behavioral traits allowing many individuals to survive that would not in the wild (B. Kynard, personal communication). This can lead to a general decrease in diversity of traits and a lowering of population "fitness" and a long-term failure of the enhancement program. Brannon (1993) noted that "The failure to account for the natural range of species-specific life history trait expressions and behaviors in the hatchery can jeopardize the success of any hatchery program." Brannon (1993) further suggested that if hatchery programs neglect the requirements of natural populations, and therefore the traits they possess that allow them to synchronize their life history with specific environmental constraints, failure is all but certain. Thus, well-designed conservation aquaculture programs should focus on hatchery protocols and facility designs and operations that best mimic and complement natural reproductive and life history attributes of the target species and the adaptive and evolutionary benefits of those attributes.

Hatchery protocols that start with mate selection and spawning (particularly, the egg fertilization environment) is where natural selection begins to operate on the next generation to produce "fit", genetically-diverse individuals. The current program employs protocols during this period and the early rearing environment for free embryos, larvae, early juveniles that are essentially the same as those used in commercial production of young sturgeon that will not be released to any river. Kynard (personal communication) suggests that if the program wants to produce fit, diverse individuals for conservation stocking, the early rearing procedures in the hatchery should be different from commercial protocols and reflect, as much as possible, the natural environment, so selection can operate to produce young sturgeon with the genetic and behavioral diversity most similar to wild fish. Kynard hypothesizes that changes to the hatchery protocols may reduce the number of individuals produced, but the few individuals produced will be more fit than the previous thousands released and better reflect the genetic and behavioral diversity needed for supplementation or restoration of a wild population.

Kynard et al. (2010) have demonstrated the use of a semi-natural stream for spawning, incubation and rearing of shortnose sturgeon at a limited scale. Initial plans for the new Kootenai sturgeon hatchery contemplated the feasibility of developing similar systems for application to white sturgeon. At this time, these systems have been assigned a lower priority for development given the experimental nature of the associated protocols. Of particular concern is the potential for elevated mortality in an unproven semi-natural system. At this time, the most precautionary strategy would appear to be avoiding potentially selective survival through the hatchery system. The Tribe will continue to work with interested parties to explore and develop more natural spawning, incubation and rearing conditions.

6 MONITORING AND EVALUATION

6.1 True Adaptive Management

Kootenai sturgeon conservation and recovery efforts continue to face daunting challenges and uncertainties. We do not know if and when natural recruitment will be restored, how long the aging wild population will remain reproductive, and whether hatchery-reared fish will ultimately spawn and recruit successfully in the wild. We also don't know if returning to a yearling release strategy will improve hatchery sturgeon survival from recent low rates, where future density-related limitations may reduce survival of older sturgeon, or to what extent future habitat productivity may be improved by nutrient enrichment and habitat restoration actions.

The Tribe has attempted to use the best available science to identify and qualify potential risks and benefits associated with these important demographic issues. However, the best available science and our understanding of the system is currently limited. In many cases, the relative magnitudes of risks and benefits, and associated response curves and thresholds can be modeled, but are impossible to accurately predict. While the Kootenai sturgeon conservation and recovery effort has made strides in avoiding near-term extinction, the history has also been confounded with unresolvable arguments involving value judgments of relative risks and responses based on opinion.

Rather than pursing a speculative reductionist approach to key uncertainties, the Program supports a "true" or active adaptive management strategy involving a systematic, rigorous approach for learning through designing management actions as experiments.[14] True adaptive management is an appropriate strategy when uncertainty is high, risks are acceptable or reversible, and answers can be obtained in a reasonable time frame (Marmorek 2011). Far from "trial and error", this involves a structured, iterative process designed to support optimal decision making in the face of uncertainty, with an aim to reducing uncertainty over time by learning via experimental management and system monitoring as originally conceived by Holling (1978) and Walters (1986) and reiterated by Ludwig and Walters (2002).

With Kootenai sturgeon, we are presented with the rare opportunity to manage fish recovery in a truly adaptive fashion involving large scale implementation, monitoring and evaluation of actions to test the limits of the system and to monitor the response(s). This approach has already proven successful in identifying critical new information during the initial 20 years of the program. Research and monitoring efforts have produced a number of surprises, each with significant implications for recovery. For instance, age validation studies showed that the wild fish are substantially older than previously thought, which led to reassessing the importance of non-flow-related (pre-dam) habitat requirements and the nature, timing and causes of natural recruitment failure. Monitoring post-release survival of hatchery-reared fish identified a second critical life history bottleneck at the YOY stage that may constrain our ability to restore natural recruitment (Justice et al. 2009). Expanded sampling efforts in Kootenay Lake demonstrated that the wild population is larger than previously estimated but that many of these fish rarely appear to participate in spawning (Beamesderfer et al. 2012a). And finally, recent sampling in Montana has found large juvenile hatchery fish dispersing into upstream riverine habitats

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[14] *"True" adaptive management is contrasted with "pretend" or passive adaptive management which involves implementation of a project, monitoring, and adaptation if problems are evident. The latter strategy is generally effective only when you know where you stand, where you want to go, how to get there, and uncertainty is low.*

(Stephens et al. 2010; Stephens and Sylvester 2011) which might be much more conducive to successful reproduction when those fish reach sexual maturity.

Current plans reflect our best attempt to implement an effective precautionary sturgeon aquaculture program. However, experience has demonstrated that surprises and course adjustments will be inevitable. The hallmark of the Kootenai sturgeon recovery effort has been its effective experimental adaptive approach. Over its brief history, the program has evolved in response to new data, information, and changing demands. New information and evaluations have characterized the sturgeon conservation and recovery effort in the face of very large uncertainty regarding limiting factors and effective remedies. Program needs will also change over the course of the recovery effort in response to risks encountered at various stages. We have every reason to expect this pattern to continue for the duration of the recovery effort. The additional facility, along with upgrades of the Kootenai Tribal Sturgeon Hatchery, will provide the flexibility in space, systems and water necessary to continue to implement this program in an effective adaptive manner.

Implementation of a truly adaptive management approach for Kootenai sturgeon will continue to involve: 1) aggressive, informed use of hatchery production to inform recovery strategies by experimentally evaluating system dynamics and limitations, and 2) implementation of a comprehensive monitoring and evaluation program involving explicit test hypotheses, quantitative benchmarks, and a decision pathway for program adjustments. This effort will continue to be implemented through the cooperative efforts of the Kootenai Tribe, IDFG, and other co-managers and will be formalized through the In-season Management Procedure (ISMP) and Annual Production Review (APR) structured decision framework described in the Step 2 document and in the Kootenai sturgeon monitoring and evaluation plan (Appendix B of the Step 2 document).

6.2 Decision Framework

The Kootenai sturgeon conservation aquaculture program will include checkpoints and evaluations at periodic, scheduled intervals as part of the ISMP and APR that are overseen by the Kootenai Tribe, as well as coordination with the USFWS led Kootenai River White Sturgeon Recovery Team. Figure 16 and Box 2 detail a decision pathway for adaptively managing the conservation aquaculture program based on monitoring and evaluation of wild and hatchery-origin sturgeon.

Key decision points for the sturgeon program might be triggered by the restoration, frequency, and magnitude of natural recruitment, changes in spawning distribution following habitat restoration activities, identification of effective alternatives such as larval releases, unavailable or senescent (non-reproducting) broodstock, strong density-dependent habitat limitations, or delayed maturation of hatchery-origin fish

Program termination or large substantive changes in program objectives and activities will be driven by monitoring and evaluation of the system responses. Termination can be triggered by either success or failure. Programs will be terminated when and if:

- Productive naturally self-sustaining populations of white sturgeon are restored in the Kootenai system (e.g., recovery criteria identified in Box 1 are met).

- Conservation aquaculture activities significantly interfere with or otherwise preclude restoration of productive naturally self-sustaining populations of white sturgeon in the Kootenai system.
- Conservation and restoration objectives (as in Box 2) cannot be substantively achieved and programs cannot be reasonably adapted to achieve objectives.
- Benefits prove to be marginal and adaptations prove cost-prohibitive relative to program objectives.

It is currently difficult to foresee which specific factors, conditions or metrics might trigger a fundamental reconsideration of the conservation aquaculture program for sturgeon. It is expected that program objectives and activities will continue to be refined throughout their duration based on evolving conditions and new information.

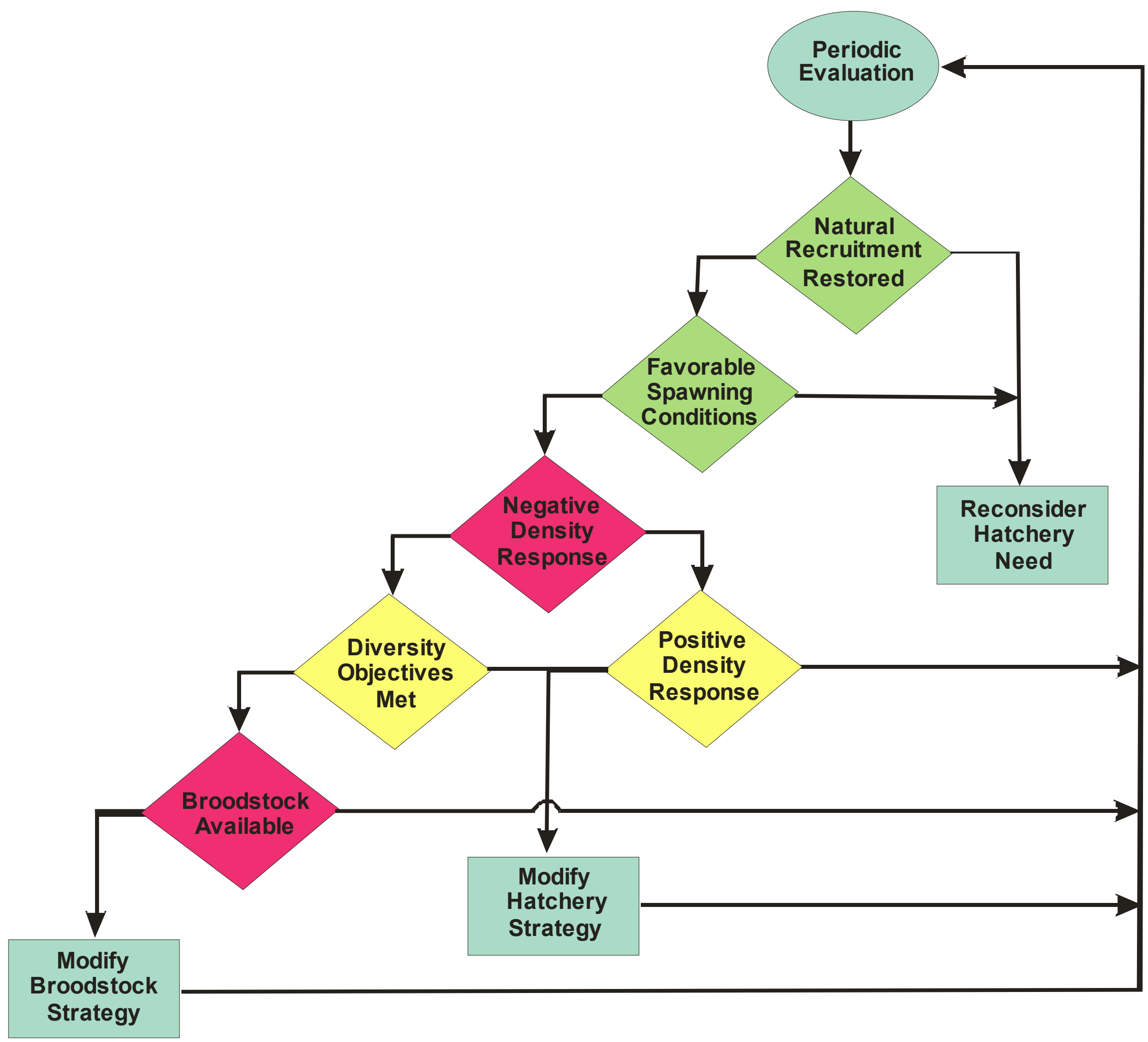

Figure 16. Monitoring and evaluation decision tree for the Kootenai sturgeon conservation aquaculture program.

Box 2. Decision pathway guiding future monitoring and implementation of the Kootenai sturgeon aquaculture program.

Question 1: Has substantial natural recruitment occurred?

Metrics: *Number/percentage of unmarked fish in juvenile sampling program.*

Response: *Re-evaluate appropriate level of hatchery supplementation based on frequency and magnitude of natural recruitment.*

Question 2: Has the wild spawning distribution shifted to upstream areas of potentially more suitable spawning habitat?

Metrics: *Telemetry data on movements of mature fish during spawning periods.*

Response: *Re-evaluate whether wild broodstock, if limited, are best employed in the wild or the hatchery.*

Question 3: Are wild spawner numbers adequate to continue to provide hatchery broodstock?

Metrics: *Catch per unit effort, annual number of broodstock collected, percentage of previously-unspawned individuals in annual adult sampling program*

Response: *Consider modification of broodstock collection program numbers, need for extended broodstock holding, or reduction in program based on cost/benefit analysis and progress toward objectives.*

Question 4: Are broodstock numbers and mating strategies adequate to optimize genetic diversity?

Metrics: *Effective population size based on broodstock numbers, representation of genetic types in broodstock*

Response: *Consider increasing or decreasing annual broodstock numbers as appropriate.*

Question 5: Has survival, growth or condition of age 1 or older juveniles declined substantially in response to increasing density?

Metrics: *Annual survival and growth rates estimated with mark-recapture data from juvenile monitoring program. Condition estimated from length-weight relationship. Size and age at maturation and reproductive periodicity of hatchery-origin fish.*

Response: *Consider reductions in annual releases, changes in release distribution, changes in family sizes, rearing fish to a larger size to avoid size-specific limitations, and fish removal to reduce biomass as appropriate based on risk/benefit calculation and progress toward objectives.*

Question 6: Has juvenile sturgeon distribution or behavior changed substantially in response to increasing density?

Metrics: *Catch per unit effort by area, movement data from tagged fish.*

Response: *Weigh relative benefits of expanded distribution versus detriments of increased competition in considering program modifications.*

Question 7: Are there other new data, information or developments that warrant consideration?

Metrics: *Associated with habitat, nutrient and other species monitoring efforts.*

Response: *Program refinements as appropriate.*

6.3 Quantitative Benchmarks

Three levels of quantitative benchmarks are identified for the sturgeon conservation aquaculture program:

Working population objectives identified in Box 1 (page 11) serve as interim recovery objectives. Criteria have been identified consistent with characteristics of a viable sturgeon population, including abundance, productivity, distribution, diversity, and other purposes including harvest. Quantitative objectives are identified for abundance (minimum of 2,500 adults). Qualitative objectives are identified for other attributes where data and information are not yet sufficient to determine specific quantitative values. The Kootenai Sturgeon Recovery Team is expected to develop more explicit quantitative objectives as part of a planned revision of the Recovery Plan.

Production targets presented in Table 6 (page 28) identify numbers of broodstock, families, family size, size at release, and annual releases developed consistent with working criteria to guide hatchery planning and operations. These numbers are based on working recovery criteria and provide the basis for facility designs for the Kootenai sturgeon conservation aquaculture program.

Population Benchmarks provide reference values for monitoring and evaluating progress toward recovery criteria achieved by current production targets. Benchmarks identify quantitative values for key population attributes (Table 9). Targets for wild fish identify desired values based on recovery objectives. Targets for hatchery fish identify baseline values from current information. Triggers identify values that warrant reconsideration and possible adjustment of hatchery production targets under the adaptive management framework for the conservation aquaculture program.

Table 9. Benchmarks for monitoring the Kootenai sturgeon population response to recovery measures.

Attribute	Target	Trigger
Adult abundance	>2,500-10,000	2,500
Trend in adult abundance (annual rate of increase)	Increasing or stable slope	Decreasing slope
Wild age structure (% of population age 25 and greater)	30% < N < 50%[a]	<30% or > 50%
Wild recruitment @ age 1 (annual avg.)	To be determined [b]	
Hatchery broodstock number (adults per generation)	≥ 1,000	< 900
First year survival (age 1 hatchery fish)	≥ 25% [c]	< 25%
Survival ages 2-5 (hatchery fish post release)	≥ 95% [d]	< 95%[d]
Growth rate (age 1-5 hatchery fish)	≥ 6 cm/yr [d]	< 6 cm/yr
Condition factor (Wr, relative weight)	≥ 95% [e]	< 95%
Juvenile sample rate (annual capture probability)	≥ 5% [d]	<5%
Spawner distribution (% of tagged spawners upstream from Hwy 95 bridge)	≥ 40% [e]	<40%

[a] *Based on stable equilibrium levels in Paragamian et al. (2005) model simulations.*
[b] *To be determined based on realized survival rates that produce adult targets.*
[c] *Minimum of 1999-2003 annual estimates for age 1 and 1+ releases of comparable size to current practice (Beamesderfer et al. 2012a)*
[d] *Based on baseline values reported in Beamesderfer et al. (2012a)*
[e] *Criteria defined in the amended 2006 Libby Dam Biological Opinion (USFWS 2006)*

6.4 Implementation

Kootenai sturgeon recovery efforts are subject to a comprehensive monitoring program (Appendix B of the Step 2 document) designed to evaluate population status in the wild and the effectiveness of recovery actions including aquaculture, flow and habitat measures. Field monitoring components of this program are cooperatively implemented by the Kootenai Tribe, IDFG, and the BC Ministry.

The Kootenai Tribe will be responsible for general administration, hatchery production, and the execution of a four-step ISMP that will guide the conservation aquaculture program. IDFG and the BC Ministry will conduct field sampling within the respective countries. Implementation of the monitoring and evaluation plan will create a self-correcting in-season management process that invites input and participation from all cooperating agencies to ensure that hatchery production, management, and habitat goals are compatible with established conservation goals. Each year before decisions about broodstock management, gamete collection, production goals, release strategy, harvest, and monitoring and evaluation activities for the coming year are made, an APR will be conducted through a workshop sponsored by the Tribe. All cooperating agencies and stakeholders will be urged to participate.

The Step 1 Master Plan describes monitoring and evaluation elements specific to implementation of the conservation aquaculture program. The Step 2 document provides more detailed monitoring and evaluation plans for the conservation aquaculture program. Monitoring and evaluation of the broader program context is addressed by elements described in the USFWS Recovery Plan, the current recovery implementation plan and schedule (KTOI 2005), and other project-specific plans including the Kootenai River Habitat Resoration Master Plan (KTOI 2009). The Tribe is also currently in the process of developing a subbasin-scale adaptive management plan that will link all of the Tribe's programs. Additionally, the ISRP requested the that Tribe work with IDFG to develop a synthesis of the sturgeon related projects that have been implemented in the Kootenai subbasin by the Tribe and IDFG. Additional details on the monitoring and evaluation (M&E) tasks and methods may be found in separate M&E plan documents[15] for Kootenai sturgeon (Anders et al. 2012) and burbot (Young 2012).

[15] *The M&E plans for sturgeon and burbot are presented as Appendix A and Appendix B, respectively, of the Step 2 document.*

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Attachment 1 – Carrying Capacity Estimation

Definition of Capacity

For the purposes of this analysis, capacity is defined as the maximum biomass of sturgeon that can be supported on average by the Kootenai system. Trophodynamics typically refers to the transfer and effects of bottom-up energy production and transfer through higher levels of the food chain. For Kootenai sturgeon, we might ask how much primary production is available and how many sturgeon can this level of production support?

Production can be described interms of biomass/area/time (e.g. $kg/m^2/yr$). Capacity can be described in terms of biomass (kg). Thus, capacity is a function of productivity of the system and energetic demand, where:

Capacity = Available Production / Demand

Available production is a product of net production and the portion available in a form that is consumable by sturgeon. Therefore:

Capacity = [(System Productivity) (% available)] / Demand

So in theory, sturgeon carrying capacity could be estimated, at least on a coarse scale, based on: 1) the productivity of the Kootenai system at the sturgeon prey level (e.g., secondary productivity by heterotrophs); 2) the portion of this trophic level available to sturgeon as prey; and 3) demand, which can be described simply as biomass of sturgeon per biomass of prey.

Kg sturgeon = [(kg 2° production/year) (% sturgeon prey)] / (kg sturgeon per kg prey)

Below we present and discuss the methods and data available to estimate each of these parameters.

Demand

There are essentially two approaches to determine the amount of food necessary to support a unit of sturgeon demand (kg sturgeon / kg prey). The first is a bioenergetics model to infer food consumption from growth, while the second relies on calculating a simple food conversion rate based on empirical data (X amount of food to produce X amount of biomass).

Bioenergetics modeling

Bevelhimer (2002) presented the first known sturgeon bioenergetics model to investigate whether differences in thermal regimes among Snake River reaches could result in substantial differences in growth and reproductive output. Using the Bevelhimer (2002) model, we can generally assess energetic requirements of Kootenai River white sturgeon among various temperature regimes and across life history stages.

The basic bioenergetics model equates the amount of consumed food with the ultimate fate of that food (Kitchell et al. 1977):

$$C = G + R + F + U$$

where C is energy consumed as food, G is growth, R is the total metabolic rate, F is enery lost through egestion, and U is the cost of excretion. R can be calculated as:

$$R(cal\ day^{-1}) = 7.13W^{0.78}e^{(T\,0.0693)}ACT + SDA$$

where ACT is an activity multiplier that increases the total metabolic rate above the resting rate to account for routine activity. Specific dynamic action (SDA) is the cost of digesting and processing food.

Based on Bevelhimer's (2002) laboratory experiments, he calculated SDA as a constant proportion (0.12) of calories consumed. Likewise, for excretion (U) and egestion (F), he calculated constant proportions of calories consumed: 0.5 and 0.15, respectively. Bevelhimer (2002) used modelled values for ACT based on swim speed adapted from a model designed by Geist for northern pike (Bevelhimer pers. comm.). Using observed and modeled values of initial body weight (g), body weight change (g), water temperature (°C) in conjunction with values for ACT, F, and U identical to those reported by Bevelhimer (2002), we were able to calculate food consumption (g).

Sensitivity analyses suggest that small changes in the parameters used, for example in ACT (Figure A1), result in large changes in the model output. Using this example, the food demand can range from 100-800 g/day based on the activity level of that fish, and when applied to the entire population, the model can yield vastly different results. Since there is insufficient data specific to the Kootenai River to calibrate these components of the model, outputs are subjective; thus, food demand cannot currently be determined with any certainty using this approach.

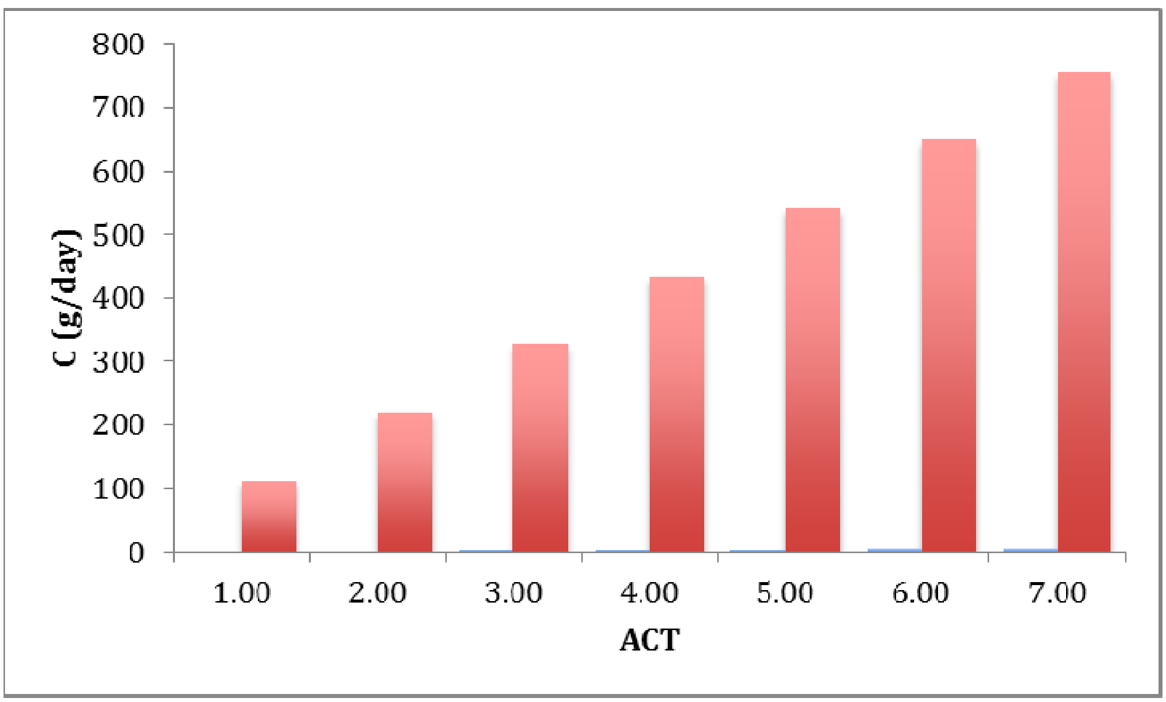


Figure A1 An example of the range of values calculated for consumption (C in cal/g) of a 15 kg white sturgeon using a bioenergetics model adapted from Bevelhimer (2002) over a range of activity multipliers (ACT) which is a parameter that increases metabolic rate.

Food conversion rates

Experimental data are available on food conversion rates for white sturgeon. Results from experiments conducted by Hung et al. (1989 and 1993) suggested an optimal feeding rate between 1.5 and 2.0% body weight (BW) per day for white sturgeon between 0.25 and 0.5 kg at 18°C. A similar study by Hung and Lutes (1987) found that growth rates were highest for 30 g white sturgeon with a feeding rate of 2.0% BW/day at 20°C.

Age-specific daily rations can be estimated using food conversion rates and empirical Kootenai sturgeon length and weight data reported by Paragamian et al. (2005). Individual rations estimated by this method are much greater among adult-sized fish 25 years of age and greater than for smaller fish.

Population requirements and demands for food can also be estimated based on projected sturgeon abundance. Abundance was projected using the population model described in Paragamian et al. (2005) to simulate two scenarios: the first assumes high first year survival, no density dependence, no senility and continued broodstock availability. The second scenario assumes low first year survival, density dependence, senility, and reduced broodstock availability. Applying a 2.0% BW/day consumption rate across all age classes to projected age-specific abundances under the 2 scenarios and modeled weight-at-age data, approximate daily maximum food requirements can be calculated. Using this methodology, the maximum food requirements for white sturgeon juveniles (age 1-10), sub adults (11-24), and adults (25+) by year are presented in Figure A2.

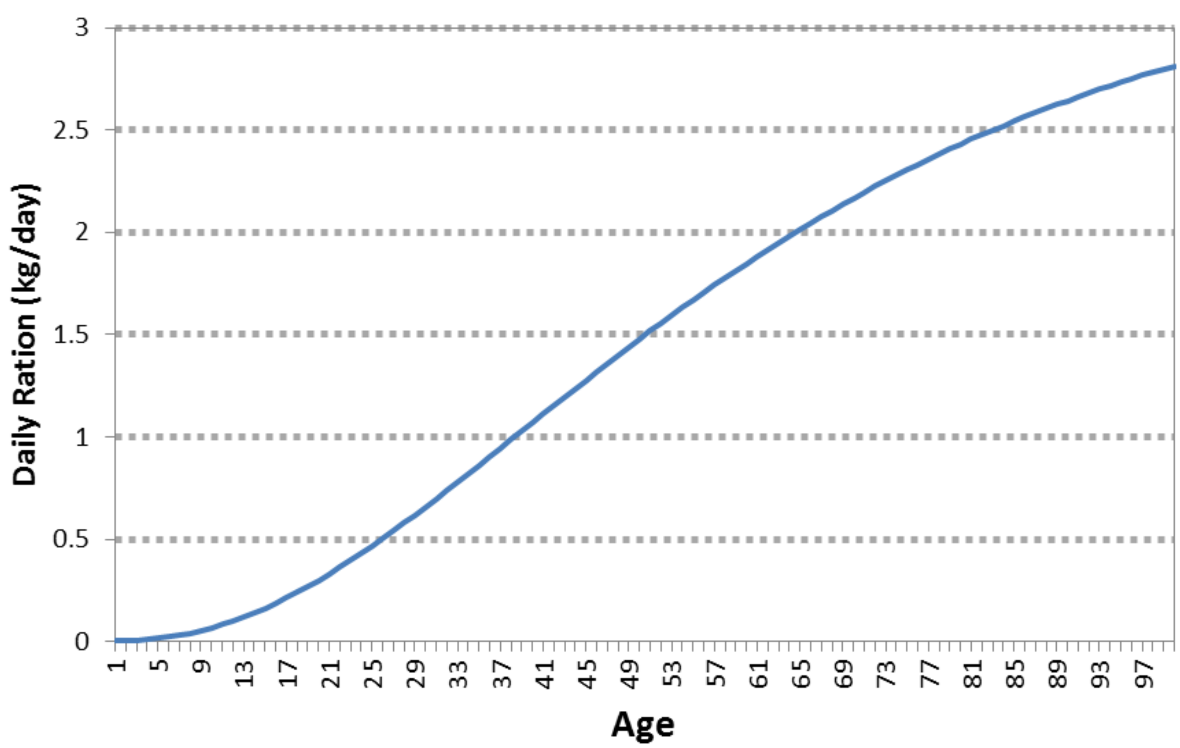
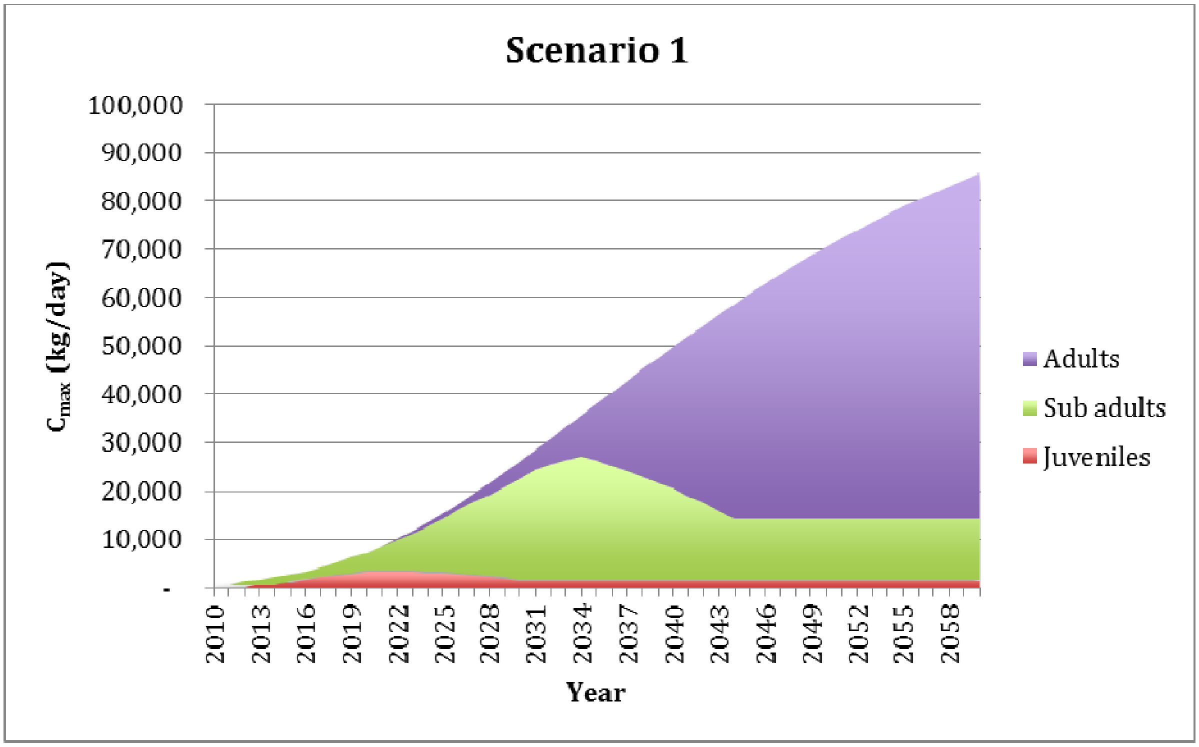


Figure A2. Estimated daily ration by age for Kootenai sturgeon based on length-at-age and length-weight relationships and a 2% daily ration.



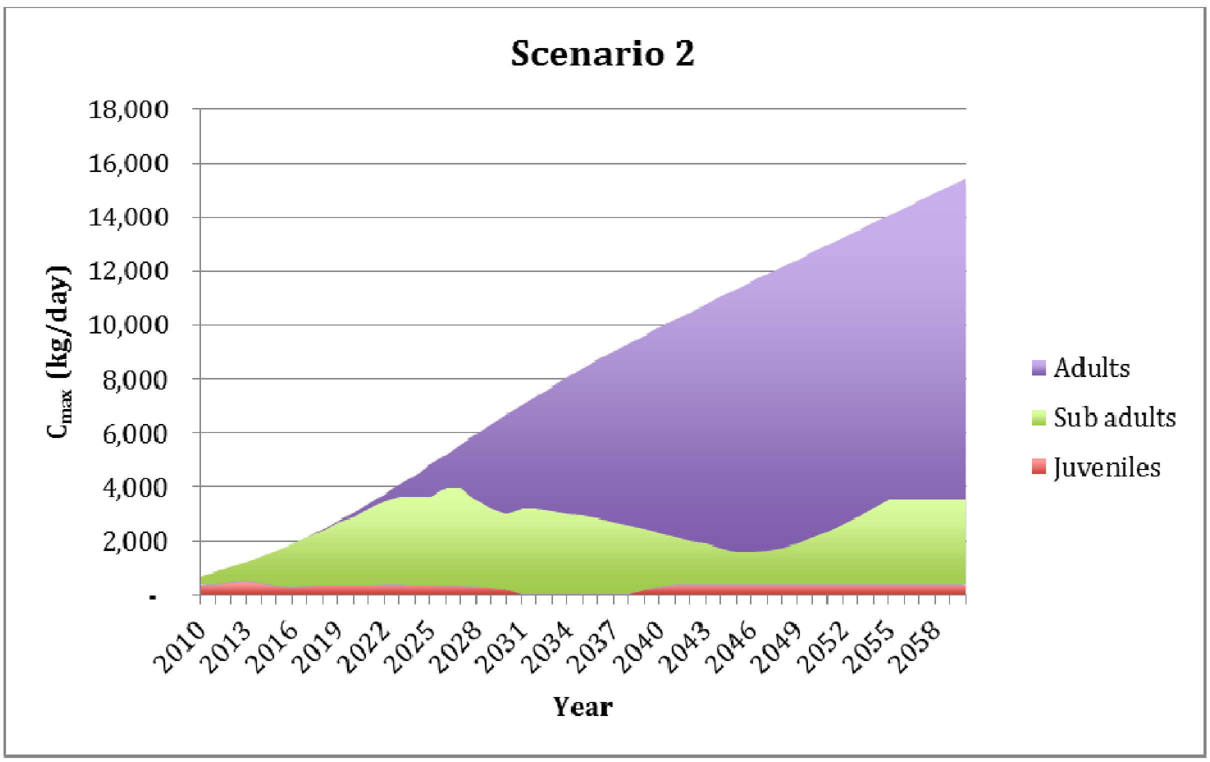


Figure A3. Estimated daily white sturgeon maximum food consumption (Cmax) under two scenarios for projected abundances based on planned hatchery release levels with the new facility. Scenario 1 assumes high first year survival (0.60), no density dependence, no senility, and continued broodstock availability. Scenario 2 assumes low first year survival (0.15), density dependence, senility, and reduced broodstock availability.

These examples demonstrate that, under certain assumptions, the food requirements of a hatchery-produced sturgeon population can be very large, particularly for adult sturgeon. Requirements of the juvenile population are quite modest in comparison. However, estimating feeding demands based on extrapolation of laboratory or hatchery daily rations to a population in the wild is highly speculative.

Estimates of white sturgeon food consumption were made using several assumptions. First, it is important to note that using a food conversion rate approach is more applicable to juvenile white sturgeon than to adults, because the relationships between feeding and growth rate are well described in the literature for hatchery-released fish, but much less so for adults. Additional confounding factors involving food conversion rates for adult sturgeon include energy investment directed towards gonadal development and associated variability, both of which could be significant.

Furthermore, the white sturgeon diet varies, depending on seasonal prey availability (McCabe et al. 1993). The caloric content and energetic value among prey species (i.e., macroinvertebrates vs. various fish species) also varies. Food consumption is also temperature-related. It tends to decrease when temperatures are above and below optimum ranges, which will artificially inflate estimates derived at optimum temperatures (Lebreton and Beamish 2004). Lastly, it is noteworthy that the studies by Hung et al. (1989 and 1993) and Hung and Lutes (1987) were conducted in a controlled hatchery-type environment such that the juvenile white sturgeon had access to an abundant food source and were able to consume their daily maximums (C_{max}); in their natural environment, sturgeon will likely consume only a fraction of C_{max}. Thus, estimates of C generated using this approach will likely be overestimated.

Availability – Food & Feeding

Estimates of food demands would need to be applied to size, nutritional value, and abundance of specific prey species for each life stage. In order to assess whether the habitat can support high abundances of white sturgeon, estimates of C_{max} would need to be expressed in terms of equivalency in numbers of prey species consumed per day. Further information would also be needed regarding age-specific food preferences (white sturgeon diets transition towards piscivory with maturity); prey diversity and availability; prey size and weight; maximum size of prey species consumable per age/weight class; and the caloric density of prey species.

Unfortunately, detailed empirical data regarding food and feeding of white sturgeon are sparse. Food habits are typically very dynamic in fish, particularly for opportunistic feeders like sturgeon. Diets change seasonally and by area, depending on physiological requirements and prey availability.

Total Production

Estimates of ecosystem productivity of the Kootenai system are not currently available for any trophic level. Some information on productivity is being collected for evaluation of the local effects of nutrient addition. However, this information is limited to specific areas.

Therefore, we attempted to derive a ballpark range of sturgeon production potential for the area available to Kootenai sturgeon by evaluating fish production data from other areas. Chapman (1978) reported that fish production values in temperate lakes and streams typically range from 1 to 20 g/m2/yr. These values translate into potential fish production of 410,000 to 8,208,000 kg/year for the combined areas of the Kootenai River and Kootenay Lake (Table A1). The lake area accounts for over 95% of this production potential.

Table A1. Example estimates of potential fish production in the Kootenai system based on habitat area and representative production values reported by Chapman (1978).

Location		Area (ha)	Productivity (g/m2/yr)			Net production (kg/year)		
Lake	N arm	16,523	1	-	20	165,230	-	3,304,600
	Duncan River delta	298	1	-	20	2,980	-	59,600
	S arm	21,475	1	-	20	214,750	-	4,295,000
	Kootenai River delta	870	1	-	20	8,700	-	174,000
River	Canada	849	1	-	20	8,490	-	169,800
	Canada – Bonners	750	1	-	20	7,500	-	150,000
	Bonners – Falls	275	1	-	20	2,750	-	55,000
		41,040				410,400		8,208,000

Sturgeon population projections translate to values of food requirements ranging from about 5 to 30 million kg/year around the year 2050. Top-end projections of net population demand would clearly exceed optimistic estimates of potential, even assuming all of the potential production was comprised of sturgeon. On the other hand, these numbers demonstrate that the Kootenai system has the potential, by virtue of its large size, to produce significant numbers of sturgeon. For instance, daily rations translate to an annual ration of about 0.5 kg for a 1-year-old sturgeon. Annual fish production estimates from **Error! Reference source not found.** for the Kootenai River and delta alone would be 27,000 and 550,000 kg/year. This would be the equivalent of 54,000 to 1,100,000 Age-1 sturgeon if all the potential fish production were comprised of sturgeon. Both these numbers are greater than the 22,000 hatchery-produced sturgeon estimated to have survived to 2012. These overly simplistic examples highlight the uncertainties associated with estimating carrying capacity based on limited production and demand information.

Another way to address carrying capacity is by comparing current Kootenai sturgeon densities with those observed in other areas. Unfortunately, the utility of this exercise is limited by the lack of appropriate reference populations and the unknown transferability of estimated values among different rivers. Estimates of biomass per habitat area are available from the unimpounded lower Columbia River and several lower Columbia River reservoirs (Table A2). Sturgeon densities in the Lower Columbia are generally much greater than those currently estimated for the Kootenai. However, lower Columbia numbers do not provide comparable information for juveniles, may not represent capacity, are clearly from a much more productive system than the Kootenai River, and are also affected by fishery exploitation.

Density estimates might be calculated from sturgeon population abundance estimates in other portions of the basin. However, virtually all nonanadromous populations are impaired by limited recruitment and likely to be considerably under the theoretical capacity of the habitat. We also get quite different density values for Kootenai sturgeon depending on how much of the available habitat is assumed to be utilized. For instance, juvenile densities drop from 11 kg/ha based on the river and delta area to <1 kg/ha if the north and south arms of the lake. The reality lies somewhere between these extremes because at least some juvenile sturgeon are likely to utilize other portions of the lake but use is also likely to be less than in the meander reach of the river and the delta portion of the lake.

Table A2. Example estimates of sturgeon standing crop on a biomass per unit area basis.

Location	Life stage	Year	Abundance (n)	Biomass (kg)	Area (ha)	Density (kg/ha)
L. Columbia River[1]	≥ subadults	1986-90	895,000	5,300, 00	0,000	90
Bonneville Reservoir[2]	≥ subadults	1989	35,400	252,000	8,400	30
The Dalles Reservoir[2]	≥ subadults	1987-88	19,500	270,000	4,500	60
John Day Reservoir[2]	≥ subadults	1990	6,300	84,000	21,000	4
Kootenai River & la ke	adult	2011	1,000	40,000	41,000	1
K ootenai River & lake	juveniles	2012	22,000	30,000	41,000	<1
Kootenai River & delta	juveniles	2012	22,000	30,000	2,700	11

[1] *Devore et al. 1995*
[2] *Beamesderfer et al. 1995*

Conclusions

Estimates of carrying capacity presented above are examples, and do not represent an exhaustive treatment of the subject. It is clear from this exercise that the food requirements of a large sturgeon population could easily surpass the food available in a relatively unproductive system like the Kootenai. We can also infer that planned production levels could reasonably be expected to elicit some type of density-dependent response at some point in time. Perhaps the most valuable lesson from this exercise is that it highlights the need for considering the ecosystem context of the sturgeon recovery effort and the complexity of ecological interactions that must be considered. Even where these models have little real-world predictive value, they are still useful in helping us understand how the system works.

However, this exercise also illustrates the challenges of attempting to infer capacity based on limited information and inherently variable parameters. Capacity estimates might be derived using various models, but these inferences would be speculative at best given the broad assumptions required to parameterize the models. Modeling requires detailed information, which is currently not available, about the following factors: 1) age-specifc white sturgeon abundances, 2) age-specific white sturgeon weights, 3) feeding ecology of juvenile and adult white sturgeon, 4) estimates of primary productivity, 5) biomass estimates of prey species, 6) temperature specific growth rates for white sturgeon across age classes, and 7) nutritional information on prey species. Where, when, and how density-related effects will be manifested remains to be determined.

Due to considerable variability and uncertainty associated with the sturgeon population and the altered Kootenai River ecosystem, the Tribe chose to adopt an adaptive, experimental management approach to estimate carrying capacity. Current and proposed hatchery release practices are designed to reduce detrimental effects of short term local inter- and intra-specific competition. Releases are distributed throughout the Kootenai River from Montana downstream to Kootenay Lake. Tagging data indicates that juveniles rapidly disperse throughout the suitable habitats following release. Empirical estimation will involve continued monitoring of population parameters relative to increasing fish density as hatchery releases lead to greater sturgeon abundance. This approach is consistent with conclusions in the ISAB's recent Food Web report which found that experimental manipulation of the number and timing of hatchery releases is a logical method to evaluate density dependence (ISAB 2011). The ISAB, while highlighting the importance of understanding food webs and trophic dynamics, also emphasized the value of large scale experiments to address critical uncertainties.

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Appendix B

Monitoring and Evaluation Plan for Kootenai River White Sturgeon

(Acipenser transmontanus)

Monitoring and Evaluation Plan for Kootenai River White Sturgeon

(Acipenser transmontanus)

Prepared by the Kootenai Tribe of Idaho for the Northwest Power and Conservation Council and Bonneville Power Administration

August 2012

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The Tribe would like to acknowledge that we produced this document based on the monitoring and evaluation (M&E) plans created for the Chief Joseph Dam Hatchery Program by the Confederated Tribes of the Colville Reservation and their consultant, D.J. Warren & Associates, Inc. (Colville Tribes 2009a, 2009b). We believe their approach, which provided a framework for implementing and evaluating hatchery and field monitoring and a process for multi-agency cooperation and management, with some modification, is well-suited to characterize monitoring and evaluation activities associated with the Kootenai River Native Fish Conservation Aquaculture Program, and will help to ensure the program's success.

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1 INTRODUCTION

This Monitoring and Evaluation Plan for Kootenai River White Sturgeon (Sturgeon M&E Plan) is a critical component of the Kootenai River Native Fish Conservation Aquaculture Program (KTOI 2010). Key elements to be monitored are broodstock, aquaculture production, juveniles, adults, spawning, natural recruitment, and future harvest opportunities. The monitoring and evaluation (M&E) objectives and activities presented in this plan are designed to ensure that hatchery operations produce high quality, disease-free fish that can survive in the receiving environment, can forestall extinction, and can effectively meet demographic and genetic population rebuilding goals.

This plan involves the participation of multiple agencies and entities that will be responsible for program design, implementation, and conducting M&E activities. The Kootenai Tribe of Idaho (Tribe or KTOI) will be responsible for general program administration, hatchery production, and the execution of a four-step In-Season Management Procedure (ISMP) structured decision-making framework that will guide hatchery-based population restoration efforts. Personnel from the Idaho Department of Fish and Game (IDFG) and British Columbia Ministry of Forests, Lands, and Natural Resource Operations (BC Ministry) will conduct field sampling within their respective countries, and Cramer Fish Sciences (CFS) will assist by lending expertise regarding various sturgeon M&E design, implementation, and critical uncertainty research and analytical issues upon request.

Program actions will be managed using data and information provided by M&E activities described in this plan. As mentioned above, the ISMP will provide a framework to support adaptive management, and will be coordinated through an Annual Project Review (APR). The APR will facilitate input and participation from all cooperating agencies to ensure that hatchery production, management, and habitat goals are compatible with conservation goals for recovering the Kootenai River white sturgeon population. Through the ISMP and APR, the M&E results will be used to determine whether program conservation goals are being achieved within the anticipated time frames.

Section 2 of this M&E Plan summarizes program objectives for Kootenai River sturgeon. Section 3 outlines specific ISMP and APR actions. Section 4 identifies variables that will be monitored to estimate and update key metric values. Section 5 addresses how the program's key metrics and annual population and hatchery production status updates will be used to guide hatchery operations and inform conservation targets and potential future harvest goals (considered long-term goals, since harvest is not anticipated in the near-term). Section 6 describes the adaptive management platform, including discussions of quantitative benchmarks and the relationship between precision and sampling intensity. References are provided in Section 7.

2 PROGRAM OVERVIEW – WHITE STURGEON

2.1 PROGRAM HISTORY

The Tribe began the Kootenai sturgeon hatchery program in 1988 in response to decades of cumulative ecosystem impacts and the associated precipitous decline of Kootenai sturgeon. The program has evolved in several phases over time as efforts were expanded and adapted in response to demonstrated successes, several hard lessons, and the increasing realization of the program's significance to sturgeon conservation.

Developmental Phase - This phase spanned the first two decades of the program from its inception in 1988 until about 2008. The program started as a very basic experimental facility designed to address critical uncertainties and limiting factors, to assess gamete viability, and to explore the feasibility of sturgeon aquaculture. Program objectives and facilities evolved following the initial success of sturgeon propagation and stocking during the early to mid-1990s, as recognition grew of the need to artificially supplement ongoing natural recruitment failure.

Preservation Phase - This phase began in 2008 when it became clear that the next sturgeon generation would be produced primarily in the hatchery. The preservation phase is expected to extend for the next 10 to 20 years while the remnant wild population gradually dwindles and disappears through natural mortality and before significant numbers of hatchery produced fish reach sexual maturity. Wild broodstock are expected to be available for at least the immediate future to support aquaculture. During this period, program objectives are designed to capture the majority of the native genetic diversity and propagate it in such a manner that can effectively sustain the next generation of adults, whether they spawn in the wild or in the hatchery. These objectives justify the need for the new facilities identified in the Master Plan (KTOI 2010). The preservation phase will coincide with implementation of extensive habitat restoration actions in the Kootenai River during the next 10 to 15 or more years to perpetuate the population, prevent extinction, and restore habitat conditions needed to restore future natural recruitment, and to down-list and delist the population.

Adaptive Management Phase - The future of the program beyond the next 10 to 20 years will be determined by events as they unfold and will be managed in an adaptive fashion. We know that after the next 20 years, most of the wild fish will have died, wild hatchery broodstock will become increasingly scarce, and the oldest hatchery fish will begin to reach maturity. We don't know how quickly these specific events will occur or what other surprises we will encounter along the way. Thus, precautionary actions taken during the current preservation phase are key to providing the demographic and genetic foundation needed for the adaptive management phase. This phase will coincide and be coordinated with complementary adaptive management aspects of Kootenai River habitat restoration actions.

2.2 PROGRAM OBJECTIVES

Conservation and management of a naturally producing, self-sustaining Kootenai River white sturgeon population is the primary long-term goal of this program. This goal initially requires the combined implementation of hatchery production and habitat restoration measures, both currently implemented by the Tribe and other collaborating agencies and entities. Along with upgrading the existing Tribal hatchery facilities, the proposed Twin Rivers Hatchery will be an integral program component contributing to a population that can once again support harvest at levels consistent with conservation of Kootenai River sturgeon.

The program for white sturgeon includes a series of short- and long-term population restoration objectives:

Short-term objectives:

1) Prevent demographic extinction;
2) Maintain an increasing trend of age and size distribution;
3) Preserve native genetic and life history diversity;
4) Provide contingencies for future uncertainties; and
5) Identify limiting life stages and habitat capacity.

Long-term objectives:

1) Avoid annual spawning stock limitation by contributing to future broodstock availability;
2) Minimize the amount of time when the population contains only naturally produced fish that are too old to reproduce and hatchery-produced fish that are too young to reproduce, by increasing families and release numbers;
3) Avoid genetic bottlenecks in the next generation(s) by maximizing the numbers of families produced annually and by releasing adequate numbers of fish per family to provide sufficient future broodstock;
4) Avoid detrimental impacts on natural production and community composition by adaptively revising the program as needed based on annual M&E outcomes;
5) Avoid and minimize hatchery selection or domestication by employing hatchery best management practices; and
6) Provide future harvest opportunities for tribal and non-tribal fishers consistent with population persistence, viability, and conservation goals.

Expected program outcomes for annual sturgeon production (Table 1) are based on periodically updated empirical modeling (Beamesderfer et al. 2011).

Table 1. Current and expected future white sturgeon production values with and without the Twin Rivers Hatchery. Estimates are based upon Age-1 juvenile releases and no contribution from natural recruitment.

	Current Facilities [a]	Program Objective	Facility	
			Kootenai Tribal Hatchery	Twin Rivers Hatchery
Broodstock number	24	Up to 45	Up to 18	Up to 27
Families produced	12-18	Up to 30	Up to 12	Up to 18
Fish/family	1,000-1,500	500-1,000	500-1,000	500-1,000
Size at release	30 grams	30 grams	30 grams	30 grams
Total releases per year	15,000-20,000	15,000-30,000	6,000-12,000	9,000-18,000

[a] Males and females.

3 In-Season Management Procedure and Annual Review

3.1 Annual Project Review

Each year, before making decisions about broodstock management, gamete collection, production goals release strategies, and M&E activities for the coming year, the Kootenai Tribe will convene and host an APR workshop. The purpose of the APR is to implement the four-step ISMP and document the outcomes of that process. The four steps of the ISMP include: (1) updating key assumptions, (2) updating population status information, (3) reviewing Decision Guidelines (discussed in Section 3.3.3, below, and summarized in Table 11), and (4) setting biological targets for the coming year.

The APR is a science-driven process that allows workshop participants to collectively plan and implement annual M&E procedures for the program. The APR findings will be summarized in an annual action plan for the coming season. The action plan will be completed during the workshop. The workshop and resulting action plan constitute the coordinated planning and implementation components of the program. Participants in the APR workshop will include appointed representatives of agencies with specific M&E and management responsibilities as well as sturgeon experts; this group will include some members of the Kootenai River White Sturgeon Recovery Team. Information generated through the APR will be reviewed with the Kootenai River White Sturgeon Recovery Team at the time that that group meets.

The Kootenai sturgeon APR workshop will be conducted each spring to allow time to complete the previous year's M&E results for use in planning the upcoming year, while arriving at goals for broodstock and gamete collection before the spawning period (which occurs between mid-

May and mid-July for Kootenai sturgeon). A facilitator selected by the Tribe will guide the workshop in order to address four fundamental questions:

1) Given the information provided, what are the best estimates for the key assumptions (see ISMP Step 1, Section 3.3.1)?

2) Do the assumptions need to be changed (see ISMP Step 3, Section 3.3.3)?

3) What are the biological targets for the coming year (see ISMP Step 4, Section 3.3.4)?

4) How can the M&E program be improved in the coming year?

The first part of the workshop will feature presentations of M&E results related to the key assumptions for the Tribal hatchery program (see ISMP Step 1, Section 3.3.1). The APR will also include sessions on: (1) hatchery operations, (2) post-release survival and distribution, (3) habitat, and (4) spawning and natural recruitment. Prior to the workshop, the Tribe will coordinate with participating agencies and entities to ensure that the most current information will be presented and discussed at the workshop. The ISMP tool will then be populated with the most recent empirical data and analytical results to update population status and trends (see ISMP Step 2, Section 3.3.2).

In the second part of the workshop, the management team will review the discussions and conclusions from part one of the workshop regarding the Decision Guidelines (see ISMP Step 3, Section 3.3.3). The management team will include policy and technical personnel from collaborating agencies and entities, and will present conclusions and modifications to the Decision Guidelines as needed. The purpose of the Decision Guidelines is to assure that the long-term goals for conservation and harvest established in the conservation aquaculture program are met over time. The product of this portion of the workshop will be an updated annual action plan to guide and coordinate M&E activities during the coming year(s).

For the third and final part of the APR workshop, the annual action plan will be reviewed and updated as needed. Based on the action plan and workshop outcomes, each agency and entity involved in actively implementing the M&E Plan will review their planned hatchery and/or field M&E activities for the upcoming year. After the workshop, the facilitator will provide a draft workshop summary to all workshop participants, incorporating findings, conclusions and final decisions for review. Workshop participants will confirm (and if necessary correct) the workshop summary and the facilitator will produce and distribute a final workshop record. A final annual report will then be completed and distributed by Tribal staff. The ISMP database, management tools, Decision Guidelines and other associated products will be retained along with the workshop summary for reference in subsequent APR workshops.

In addition to this formal process, the participatory agencies will continue to communicate routinely throughout the year to coordinate the month-to-month logistics of program activities and reporting requirements.

3.2 Basis of the M&E Plan

Following decades of natural recruitment failure and unsuccessful attempts for modified hydropower operations to reverse the trend, considerable uncertainty remains regarding future natural production of Kootenai sturgeon. Although habitat restoration activities are expected to increase overall ecosystem productivity, habitat diversity and fish abundance; specifically when, and to what extent, these investments will contribute to these outcomes remains somewhat uncertain. The annually updated M&E Plan, which incorporates the APR and ISMP processes, will track program outcomes and guide future implementation.

Activities in this M&E Plan are prioritized based on three criteria:

1) Variables and metrics are needed to implement the four-step ISMP, and will impact management decisions;

2) Variables and metrics are likely to vary from year to year, with uncertainty about the "true" values; and

3) Variables and metrics can be monitored precisely enough to determine whether performance parameters are being achieved.

Specific variables, metrics, and M&E activities, along with the ISMP process are described in subsequent sections of this M&E Plan.

This M&E Plan provides a framework for open input and participation by all cooperating agencies and a structured process by which agreements can be reached to provide the most efficient implementation and evaluation of population restoration efforts. The ISMP will provide the cooperating agencies and entities with the necessary adaptive management framework. The program goals directly affected by and relevant to the ISMP are: (1) to ultimately restore and maintain a naturally-spawning, self-sustaining white sturgeon population in the Kootenai River, and (2) to provide future harvest opportunities for tribal and non-tribal fishers.

3.3 In-Season Management Procedure and Goals

The goal of the ISMP is to provide a structured decision-making framework that will guide hatchery operations, identify M&E needs, and support effective agency cooperation and communication consistent with the guidelines established each year. The Kootenai Tribe will implement the four-step ISMP (Figure 1) in cooperation with management agencies, research institutes, and stakeholders (as appropriate). The ISMP is formalized in database(s) and a set of management tools, as well as through the APR to assure consistency and accountability. The database will store and document data and assumptions, while management tools will use predictive models and Excel spreadsheets to arrive at outcomes from which Decision Guidelines and biological targets may be derived. The tools document the basis for these targets and establish expectations for all performance indicators. They also will help simplify the implementation process and document the rationale for recommended annual restoration actions. The Tribe's biologist responsible for implementation of in-season management will use these tools to prepare for the APR workshop, where analytical results will be presented and shared with all interested parties. The management tools used in the ISMP will be further refined over time through implementation of the ISMP and APR processes as new information is obtained and analyzed.

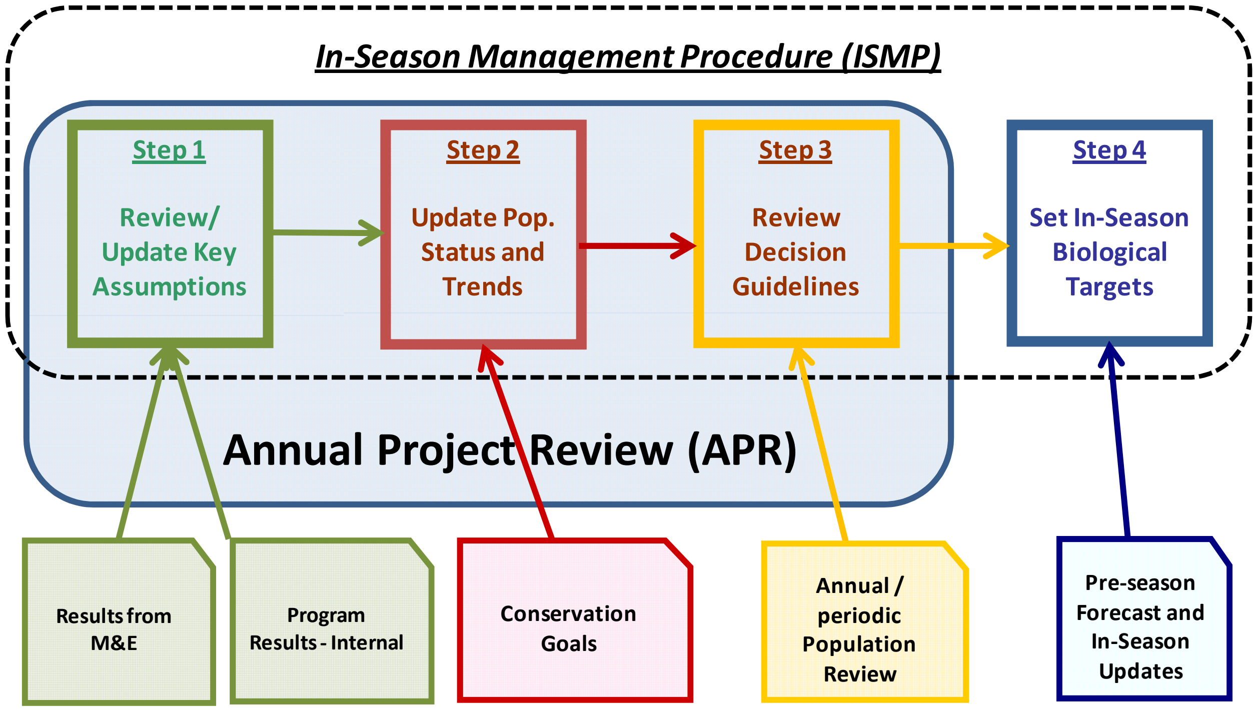

Figure 1. In-Season Management Procedure (ISMP) framework for the Kootenai Sturgeon M&E Plan.

This program has been designed to support flexible production and operations, to accommodate inherent system uncertainty, and to take into account the expected temporal variability in broodstock abundance as the numbers of remaining wild Kootenai River broodstock continue to decline. This flexibility is incorporated into the design and operation of current and proposed hatchery facilities and in the Decision Guidelines that determine annual hatchery production and the integration of future natural production. The four steps of the ISMP are presented below and discussed in more detail in Section 5 of this M&E Plan.

3.3.1 Step 1 - Update Key Assumptions

Annual ISMP attributes integrate a set of key assumptions (Table 9 in Section 5.1), which identify the current and estimated future values for each of these variables. Key assumptions address broodstock, aquaculture (pre-release), and post-release M&E activities.

3.3.2 Step 2 - Update Stock Status Information

In this step, the most recent stock status information will be entered into the database for both the hatchery and natural production components of the population (Table 10, Section 5.1). The initial predictive tool focuses on hatchery production and survival of hatchery-reared sturgeon. This tool will also be modified to integrate the contribution of any natural production into the population and program operations. This step will occur each year at the APR workshops.

3.3.3 Step 3 - Review Decision Guidelines

Once the key assumptions and annual production targets have been updated, a review of the Decision Guidelines (Table 11, Section 5.3) will be conducted to determine if alteration is needed. This adaptive management step will occur at the APR workshop. Although not expected to change frequently, the Decision Guidelines may need to be periodically altered to account for: (1) changes in conservation goals in the United States and Canada, (2) unequal goal achievement across the project area, (3) Libby Dam operations/habitat related issues, (4) new scientific discoveries, or (5) other changes in management or environmental conditions in the subbasin or the region.

The purpose of the Decision Guidelines is to assure that the sturgeon hatchery program meets annual and longer-term guidelines for abundance, composition, and distribution to restore and maintain a naturally spawning population. The ultimate goal of the Decision Guidelines for Kootenai River white sturgeon is to establish a naturally-reproducing population with an expanded geographic range within the Kootenai River increasingly similar to historical records.

The Decision Guidelines are based on a set of key assumptions about our capability to accurately detect and respond to annual variation in abundance and availability of hatchery produced and natural origin spawners. This M&E Plan identifies the information needed to update and apply the Decision Guidelines to meet program production targets, and describes how data will be collected to satisfy information requirements for successful management. The Tribe expects to meet resource goals over time as a result of implementing appropriate in-season management actions defined by the ISMP.

3.3.4 Step 4 - Set Biological Target for the Coming Year

With updated demographic status, data can then be used to set biological targets (broodstock needs, release strategy, and future harvest levels when appropriate) for the coming year (Table 11, Section 5.3). All updates will be entered into the analysis tool. The tool will then be used to generate expected outcomes for use in setting annual biological program targets and to evaluate progress towards achieving program objectives. For Kootenai sturgeon, on average, about 10% of the eggs fertilized per family will be released as Age-1 juveniles weighing more than 30 grams (g) to ensure they will adequately retain Passive Integrated Transponder (PIT) tags.

4 DATA COLLECTION

This section of the M&E Plan describes program data collection methods and activities that:

- Are needed to implement the four-step ISMP;
- May vary over time;
- Can be monitored precisely enough to ensure performance parameters are being achieved; and
- Can be used to adaptively manage project facilities and operations to meet program goals, objectives, and biological targets.

4.1 M&E OVERVIEW

Program efforts to restore Kootenai River white sturgeon will be assessed by implementing this M&E Plan, which is designed to evaluate population status in the wild and the effectiveness of recovery actions including aquaculture, flow, and habitat measures. Field monitoring components of this program are cooperatively implemented by the Kootenai Tribe, the IDFG, the BC Ministry, and Montana Department of Fish, Wildlife and Parks (MFWP) and each entities' subcontractors. The Master Plan outlined monitoring and evaluation elements specific to implementation of the conservation aquaculture program (KTOI 2010) and this document expands on that outline. Broader program-level M&E is also addressed by elements described in the U.S. Fish and Wildlife Service (USFWS) Recovery Plan (USFWS 1999), the current recovery implementation plan and schedule (Table 2) (KTOI 2005), and other project-specific plans, including the Kootenai River Habitat Restoration Program Master Plan (KTOI 2009).

The sturgeon population monitoring program includes three primary sampling components: adult stock assessment, juvenile stock assessment, and telemetry of adults. Stock assessment monitoring has been conducted in approximately its current form since the early 1990s (Ireland et al. 2002b). The monitoring program also employs egg and larval sampling and focused telemetry studies to evaluate the effectiveness of recovery specific actions and early life stage release experiments. Details of sampling methods and annual results are documented in an extensive series of annual reports (e.g., Paragamian et al. 1996; Rust and Wakkinen 2009).

Table 2. Sturgeon recovery and related habitat M&E strategy, measures, and tasks (KTOI 2005).

3A. Natural Spawning Assessments	
Measure 3A.1.	Conduct annual assessments of sturgeon spawning activities to index spawning activity, identify spawning periods, and cue sturgeon flow requests.
Task 3A.1.1.	*Implement standardized substrate mat sampling at index sites in known spawning areas.*
Task 3A.1.2.	*Implement standardized D-ring net larval sampling at index sites downstream from known spawning areas.*
3B. Wild Adult Assessments	
Measure 3B.1.	Conduct annual adult sturgeon assessments to estimate population status and obtain spawners for the hatchery program.
Task 3B.1.1.	*Capture adults during spring and early summer in areas of concentration downstream from Bonners Ferry using setlines, gillnets, and angling.*
Task 3B.1.2.	*Biological and mark-recapture sampling to estimate abundance, survival, and other population characteristics.*
Task 3B.1.3.	*Use ripe spawners for hatchery broodstock or other applications as appropriate.*
Task 3B.1.4.	*Tag adults with radio or acoustic and release for monitoring of spawning behaviour and movement patterns.*
Task 3B.1.5.	*Annual wild population and brood stock genetics sampling.*
3C. Juvenile Assessments	
Measure 3C.1.	Conduct periodic juvenile sturgeon assessments to estimate population status, index natural recruitment, and monitor hatchery program performance.
Task 3C.1.1.	*Capture juveniles during summer at standardized, spatially-stratified index sites throughout the U.S. and Canadian portions of the river using gillnets.*
Task 3C.1.2.	*Biological and mark-recapture sampling to estimate abundance and survival.*
Task 3C.1.3.	*Index natural recruitment based on marked-unmarked ratios.*
Task 3C.1.4.	*Evaluate dispersal from release sites, subsequent movements, habitat use, growth and survival of hatchery reared juveniles.*
Task 3C.1.5.	*Incorporate pectoral fin ray sampling from recaptures of large hatchery fish for aging method validation assessment.*
3D. Telemetry	
Measure 3D.1.	Monitor distribution and movements of a representative sample of acoustic-tagged juveniles and adults to assess juvenile and adult habitat use and movements and monitor biological response of adult sturgeon to spawning habitat enhancement projects.
Task 3D.1.1.	*Maintenance and operation of Vemco receiver arrays.*
Task 3D.1.2.	*Juvenile telemetry to define dispersal from hatchery release sites and subsequent juvenile habitat use, movements, and migration.*
Task 3D.1.3.	*Adult telemetry to define adult movements and habitat use in current spawning sites and the area of interest for habitat creation above Ambush Rock in Idaho.*
Task 3D.1.4.	*Installation and maintenance of a 3-D telemetry tracking array (acoustic positioning system) to monitor wild adult behavior near enhancement project structures.*
Task 3D.1.5.	*Focused program to monitor the 3D movements of these fish in the small piece of river comprising the Substrate Enhancement Pilot Project.*
3E. Habitat Assessment & Monitoring	
Measure 3E.1.	Measure and monitor physical conditions in critical habitat and potential spawning areas.
Task 3E.1.1.	*Map depth, velocity, and substrate in critical and potential spawning reaches to document baseline conditions.*
Task 3E.1.2.	*Develop detailed computer hydraulic models of current and potential spawning reaches and calibrate to Kootenai River habitat conditions.*
Task 3E.1.3.	*Periodically monitor changes in critical habitat parameters over time.*
3F. Data Management & Reporting	
Measure 3F.1.	Maintain a central repository for data collected by various organizations to facilitate systematic applications.
Task 3F.1.1.	*Annual data storage and management for adult and juvenile index monitoring and tagging programs.*
Task 3F.1.2.	*Periodic updates and reporting of estimates of adult population size and available breeders, population and hatchery genetics, and numbers and survival of hatchery and natural juveniles.*

4.1.1 Broodstock

Adult white sturgeon are captured annually by angling (KTOI) and setlines (IDFG, BC Ministry) from February through September. This sampling provides the basis to estimate status and trends of the remnant wild population, broodstock status and natural recruitment while collecting mature ripe fish for hatchery broodstock. In the future, this sampling will also assess recruitment of hatchery-origin fish to the adult population.

This sampling is focused primarily on the annual spawning component of the population, although both spawners and non-spawners are present in sample areas. Sampling is concentrated from February through April in staging areas between river kilometer (rkm) 205-215, from May through June in areas closer to spawning sites (up to rkm 229), and later in the year, closer to Kootenay Lake and in the Kootenay River delta. Population estimates and demographic rates are estimated periodically based on multiple mark-recapture methods and reported in periodic scientific reports or articles (Paragamian et al. 2005; Beamesderfer et al. 2009, 2011). Sampling typically includes 4,000-6,000 setline hours and 300-400 angling hours per year. Annual catch is typically 100-200 sturgeon, with an estimated annual capture probability of 10-19% (Beamesderfer et al. 2011a). Corresponding standard errors are approximately ±4% of the estimated annual abundance (990 in 2009) and ±3% of the estimated annual survival (0.946), based on multiple mark-recapture models.

The non-random sampling distribution of this effort is biased toward the riverine and spawning component of the population, and reflects the impracticality of implementing a more spatially-representative design. Sturgeon are simply not catchable enough in other times and areas to achieve reasonable sample rates with cost-effective sampling efforts. Non-random capture probabilities are ameliorated somewhat by the longevity of sturgeon, the long-term dataset, and the use of multiple mark-recapture models. However, this approach effectively trades off bias for precision. Capture probabilities are likely slight overestimates, while abundance and survival are slight underestimates (Beamesderfer et al. 2011). However, the magnitude of benefits from the additional sampling required to correct biases does not warrant the additional costs to more accurately document the continuing demise of the remnant wild population.

4.1.2 Juvenile Stock Assessment

Juvenile Kootenai sturgeon are primarily collected by gillnet, while small numbers are captured by angling or setlines. The catch of hatchery fish in the latter two gear types will increase substantially in the future as these fish recruit to vulnerable sizes. As of May 8, 2012, 25% to 30% of the Tribe’s angling catch has been hatchery-produced juveniles from 1995 to 2001 year classes.

Juvenile sampling is typically conducted from July to September at designated sites distributed throughout the 124-km meander reach from Kootenay Lake to Bonners Ferry. Crews from the IDFG typically sample 10-12 sites in the U.S. while BC Ministry crews typically sample 11-14 sites in British Columbia waters. Standard sites have been established from past experience, based on suitability for fishing gillnets and catch effectiveness. Each site is sampled on two or more occasions per year. Cumulative sampling effort is typically 400 to 600 gillnet hours per year. Annual catch over the last 10 years has ranged from 200 to over 1,000 sturgeon as the population has grown.

Abundance and demographic rates are estimated periodically based on multiple mark-recapture models and reported in periodic scientific reports or articles (Ireland et al. 2002; Justice et al. 2009; Beamesderfer et al. 2011a). All hatchery fish are marked with scute marks to distinguish hatchery and wild fish, and a subsample is PIT-tagged. Until 2004, all hatchery fish were PIT-tagged (KTOI 2004). From 2004-2007, approximately 20% of the total were PIT-tagged as releases included larger numbers of fish smaller than 20 grams (only fish 10 grams and larger were PIT-tagged). From 2008-2010 when fish were held longer and released at a larger size, about 95% of fish were PIT-tagged (everything 10 grams and larger). Since 2011, only fish 20 grams and larger are being PIT-tagged, which includes about 85% of annual production.

Based on updated mark-recapture analyses, annual capture probabilities are currently estimated to average 4-7% per year (Beamesderfer et al. 2011b). Corresponding standard errors are approximately ±10% of the estimated first year survival (0.03-0.47 for release years since 2000) and ±1% of the estimated average annual survival following the first year at large (0.95) based on multiple mark-recapture models.

Mark-recapture and telemetry data have confirmed that the majority of the juvenile population occurs in the sample area and that individuals regularly move among river segments within this area. Hence, the temporally and spatially-stratified sampling design is believed to provide reasonably representative sampling of the juvenile sturgeon population. Small sampling biases are likely introduced by lack of sampling in Kootenay Lake and the river upstream from Bonners Ferry. As this population continues to expand into these areas, additional areas will be sampled. Crews from the MFWP have recently been capturing increased numbers of juvenile sturgeon in the Montana portion of the river downstream from Kootenai Falls.

4.1.3 Telemetry

Daily and seasonal movements of adults tagged with acoustic transmitters have been monitored since 2003 with a fixed array of passive sonic receivers. Receivers are currently deployed from Kootenay Lake upstream into Montana. From 9 to 25 adult sturgeon have been tagged with sonic tags each year since 2006. With a tag life of several years, as many as 100 adults can carry active transmitters at any given time. Mature spawning fish are the main focus of this effort, which is being used primarily to evaluate spawning movements, distribution, and behavior in response to environmental cues and experimental flows that are intended to benefit sturgeon reproduction and recruitment. Thus, annual tagging involves predominantly ripe fish that are expected to spawn in the year of capture. However, the majority of fish with active tags do not spawn in a given year, enabling this monitoring effort to provide important demographic information on spawning periodicity, in addition to annual survival, habitat use, and fish movement and migration data.

4.1.4 International Cooperation

Kootenay River white sturgeon are listed as endangered in Canada under the federal Species at Risk Act (CDFO 2007). White sturgeon migrate frequently across the border into the Kootenay River and Kootenay Lake, where critical habitats also occur. The Tribe is leading the development of fish culture and habitat restoration projects and it contracts with the BC Ministry to provide white sturgeon capture and stock assessment services on Kootenay Lake and associated waters in Canada to assist in the restoration process. This successful relationship has been ongoing for over 15 years and is formalized through a contractual relationship. Data and databases are successfully shared, and personnel from the BC Ministry, Kootenai Tribe, IDFG, and MFWP freely communicate and work together in the field to ensure total coverage and cooperation concerning all aspects of Kootenai sturgeon research, monitoring, and evaluation.

Under contract with the Tribe, the BC Ministry is responsible for monitoring movements, habitat use, growth and survival of the Tribal hatchery progeny and wild progeny and adults in Canada. Additional cooperative components include telemetry projects to monitor adults and juveniles, tagging subjects in Canada for telemetry projects completed in Idaho, larval sampling, and other monitoring related to white sturgeon conservation aquaculture and recovery.

This plan describes program M&E activities and phases for Kootenai River white sturgeon in the following sections:

Report Section	M&E Activities / Program Phases	In River	In Hatchery
4.2	Broodstock collection and characterization	X	
4.3	Aquaculture (Pre-release)		X
4.4	Post-release	X	
4.5	Natural spawning and recruitment assessment	X	
4.6	Existing Kootenai River sturgeon M&E	X	X

Within each of these M&E Plan phases, the participating agencies and entities, M&E objectives, activities, monitored variables and metrics and methods are described.

Data collection will occur within the Kootenai River, Montana, and Idaho, and in the Kootenay River and Kootenay Lake in British Columbia (Figure 2) as a collaborative venture among regional agencies, including the Tribe, the IDFG, the BC Ministry, the MFWP, and associated subcontractors.

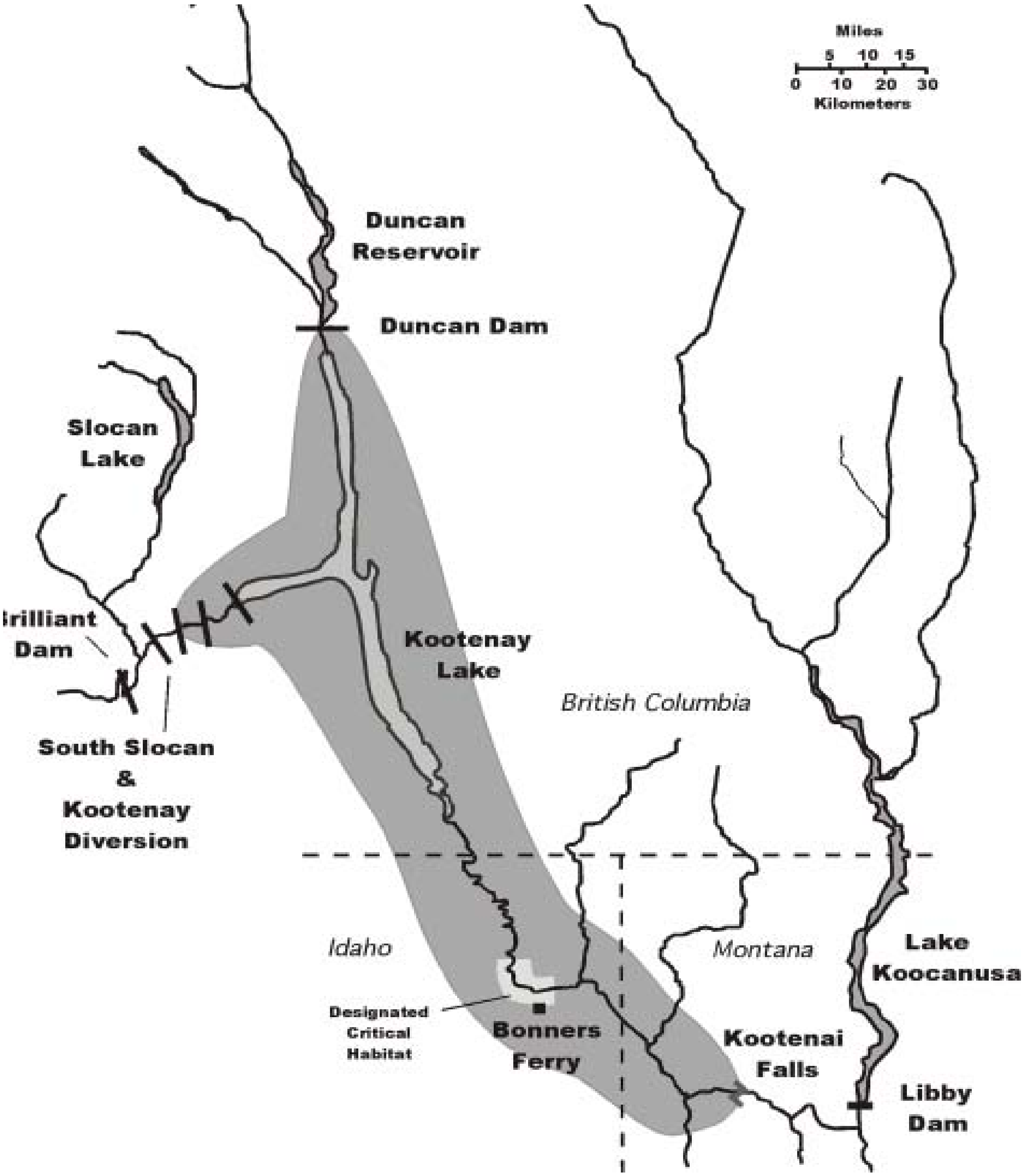

Figure 2. Location of Kootenai River white sturgeon habitat (dark shading) and designated critical habitat (light shading). Designated critical habitat corresponds to the proposed recovery area (KTOI and MFWP 2004).

4.2 BROODSTOCK POPULATION

This conservation aquaculture program has effectively forestalled demographic extinction and the future loss of locally adapted genotypes by spawning wild broodstock and releasing their offspring back into the river. Given the continuing failure of natural production, it is now apparent that the next sturgeon generation, whether naturally or hatchery produced, will depend on past, current, and future hatchery production until adequate natural production can be restored. Because this program is now responsible for founding future generations of this population, program decisions affecting past, current, and future incorporation of genetic material are critical.

Table 3 presents the participating entities, M&E objectives, activities, variables, and metrics that will be used to characterize the wild broodstock population and the biological and reproductive health, condition, and behavior of individual fish used as spawners in the conservation aquaculture program. Section 4.2.1 presents the methods associated with broodstock population M&E activities.

Table 3. Participating entities and M&E objectives, activities, variables, and metrics that will be used to characterize the wild broodstock population.

Participating Entities	• Kootenai Tribe of Idaho • IDFG • BC Ministry
M&E Objectives	1. Wild population (broodstock) monitoring: Sample and recapture adequate numbers of wild Kootenai River white sturgeon to accurately estimate or evaluate: • Survival • Growth • Biological condition • Abundance • Age class structure • Population status and trends • Tag retention Perform telemetry adequate to estimate: • Seasonal movements and migrations • General timing and locations of spawning • Effects of flow management • Effects of habitat restoration actions 2. Broodstock collection: • Maximize the temporal and geographic extent of annual broodstock capture to incorporate the maximum amount of genetic diversity into the annual production of families in the hatchery, and the recipient

	population over time • Meet program demographic and genetic objectives at annual and decadal scales • Maximize the inclusion of previously unspawned broodstock into the program breeding matrices
M&E Activities	• Collect broodstock to produce progeny groups • Perform visual examinations and/or gonadal biopsies to determine sexual maturity of male and female fish to determine broodstock suitability • Transport candidate broodstock to the hatchery • Telemetry system deployment, data collection, and analysis • Data analysis, annual reports, and ongoing communications with agency partners and other interested stakeholders
Variables	• Reproductive maturation • Abundance • Survival • Size and condition • Behavior and distribution
Metrics	• Females – reproductive stage/ova development • Males – flowing milt • Total number of adults captured • Number of adult males and females captured • Percent of captured adults taken for broodstock (M&F) • Survival of captured adults, male, and female broodstock • Length, weight, age, condition factor (K), relative weight (Wr) • Location and timing of captures, distribution patterns from telemetered fish; percent of tagged fish upstream from Bonners Ferry
ISMP Purpose	Resulting broodstock data and information will be used to update ISMP Steps 1-3.

4.2.1 Broodstock M&E Methods

The purpose of broodstock sampling is to evaluate changes in adult abundance, evaluate fish health, and tag an adequate sample for movement studies. A series of methods are performed as part of the annual wild broodstock assessments, including:

- Employ angling or baited setlines, fished from February through October.
- Sample adults from Shorty's Island to Delta to inform population estimates (specifically, measure length, weight, read and implant PIT tags; perform biopsies on adults to determine sex, level of maturity, and refine sex-specific reproductive periodicity estimates).

As provided in the 5-year M&E Plan (Table 2, KTOI 2005), the following measures and tasks for M&E of wild Kootenai River broodstock include:

3B. Wild Adult Assessments

Measure 3B.1. Conduct annual adult sturgeon assessments to estimate population status and obtain spawners for the hatchery program.

Task 3B.1.1. Capture adults during spring and early summer in areas of concentration downstream from Bonners Ferry using setlines, gillnets, and angling.

Task 3B.1.2. Biological and mark-recapture sampling to estimate abundance, survival, and other population characteristics.

Task 3B.1.3. Use ripe spawners for hatchery broodstock or other applications as appropriate.

Task 3B.1.4. Tag adults with radio or acoustic and release for monitoring of spawning behavior and movement patterns.

Task 3B.1.5. Annual wild population and brood stock genetics sampling.

Additional details concerning specific methods for M&E activities that address broodstock variables and metrics can be found at:

1) "KRRFM - Adult sturgeon assessment"; http://www.monitoringmethods.org/Method/Details/992

2) "KRRFM - PIT tagging"; http://www.monitoringmethods.org/Method/Details/998

3) "KRRFM - Sonic telemetry"; http://www.monitoringmethods.org/Method/Details/996

4) "KRRFM - Adult sturgeon movement modeling"; http://www.monitoringmethods.org/Method/Details/1029

5) "KRRFM - Adult sturgeon mortality, abundance, and year class strength analysis"

   http://www.monitoringmethods.org/Method/Details/1020

4.3 AQUACULTURE (PRE-RELEASE)

Discussion of aquaculture (pre-release) M&E activities is arranged below by ascending by life stage. Beginning with broodstock briefly held in captivity to spawn, pre-release metrics evaluate spawning and the survival and condition of broodstock, embryos, free embryos, exogenously feeding larvae, 6-month-old (Age 0), and 1-year-old juveniles held in the hatchery prior to release. Participating entities and the M&E objectives, activities, variables, and metrics associated with pre-release aspects of the program are provided in Table 4. Section 4.3.1 presents methods associated with pre-release M&E activities.

Table 4. Participating entities and the aquaculture M&E objectives, activities, variables, and metrics associated with pre-release aspects of the program.

Participating Entities	• Kootenai Tribe of Idaho • BC Ministry
M&E Objectives	Maximize survival and condition of captively held and/or reared: • Broodstock • Gametes • Embryos • Free embryos • Larvae • Age 0 juveniles • Age 1 juveniles in the hatchery prior to release to maximize the genetic diversity and resilience of annual release groups and program efforts in general.
M&E Activities	• Assess broodstock maturation and reproductive condition • Develop and implement best annual spawning matrices • Measure success of in-hatchery life stages from spawning to release of Age-1 fish • Monitor survival, growth, condition, and general health of all life stages in hatchery • Identify causes of mortality and factors limiting growth and develop solutions these limitations
Variables (by life stage)	• Broodstock: holding • Spawning: gamete viability, fecundity, egg take, spawning matrix variables • Embryos: egg density, fertilization success, survival • Free embryos: survival • Larvae on feed: survival • 6-month juveniles: condition and survival • Age-1: condition and survival, tagging, genetic variables
Metrics	• Broodstock (holding): survival, final maturation • Spawning (gamete viability): Female germinal vesicle breakdown (CVBD), polarity index (PI) values; male sperm motility • Spawning (fecundity, egg take): number of eggs per female (fecundity), number of eggs used for spawning, total number of fertilized eggs, annual ovulation success rate (vs. atresia) • Spawning (matrix variables): number of broodstock spawned, number of males and females spawned, M:F ratios, number of families produced • Embryos (egg density): number of eggs per incubation jar (density) • Embryos (fertilization success): percent fertilization • Embryos (survival): percent survival

	• Free embryos (survival): percent hatch and percent survival • Larvae on feed (survival): percent survival • 6-mo juveniles (condition and survival): percent survival, length, weight, K and Wr • Age-1 (condition and survival) percent survival, length, weight, K and Wr • Age-1 (tagging): pre-release tag retention • Age-1 (genetic variables): family contribution, effective populations size (Ne), number of breeders (Nb), diversity measures, genetic-based tagging
ISMP Purpose	Resulting aquaculture (pre-release) data and information will be used to update ISMP Steps 1-3.

4.3.1 Aquaculture (Pre-release) M&E Methods

A series of pre-release M&E variables, metrics, and methods are included in this M&E Plan (Table 5).

Table 5. Life stage, variables, metrics, and methods associated with pre-release (aquaculture) M&E activities.

Life Stage	Aquaculture Variables	Accompanying Metrics	Methods of Measurement
Broodstock	Holding	Survival, final maturation, fork length, total length, weight, genetics sample	Female egg size is measured in the field and if the egg diameter is more than 3 mm the fish is taken to the hatchery. Genetics samples are preserved in ethyl alcohol, or dry refrigerated, then shipped to UC Davis, CA for all broodstock
Spawning	Gamete viability	Females: Germinal vesicle breakdown (GVBD) Polarity Index (PI) values	Polarity index (PI) is the distance of the germinal vesicle from the edge of the egg divided by the total diameter of the egg from vegetal pole to animal pole. Germinal vesicle breakdown (GVBD) is determined by doing a progesterone assay on the eggs.
		Males: Sperm motility and density	Sperm motility and density determined by examination under microscope. Motility is measured by the amount of time the sperm stays motile. Density is given a value of high, medium, or low.
	Egg take	Number of eggs used for spawning	Egg take is measured by volume. The average number of eggs in three 2 ml samples is used.
		Total number of fertilized eggs	Fertilization is measured by following the egg stage development from days 1 through 3. The number of live eggs are divided by the total number of eggs observed for fertilization percentage
		Annual ovulation success rate (vs. atresia)	An annual spawning report is produced to record ovulation success rates. 100 percent of females that are hormone injected ovulate due to the monitoring of the Polarity Index (PI)
		Number of broodstock spawned	An annual spawning report is done to document number of males and females spawned, male to female ratios, and number of families produced
	Spawning matrix variables	Number of males and females spawned	Record number of individual male and female broodstock spawned.
		M:F ratios	Provide the ratio of the number of male broodstock to the number of female broodstock.
		Number of families produced	Record the number of families produced.

Life Stage	Aquaculture Variables	Accompanying Metrics	Methods of Measurement
		Number of eggs per incubation jar (density)	Egg density is measured by volume. The average number of eggs in three 2 ml samples is used.
Embryos	Egg density	Percent fertilization	Fertilization is measured by following the egg stage development from days 1 through 3. The number of live eggs are divided by the total number of eggs observed for fertilization percentage
	Fertilization success	Percent hatch	Hatching success is based on the number of eggs that reach the neuraltion stage in egg development. Eggs that reach neuralation are assumed to hatch due to the resilience of this egg stage.
	Survival	Percent hatch	Hatching success is based on the number of eggs that reach the neuraltion stage in egg development. Eggs that reach neuralation are assumed to hatch due to the resilience of this egg stage.
Free embryos	Survival	Percent survival	This metric must be monitored in the river since the free embryos are released at two to four days old from the hatchery.
		Percent survival	This metric is difficult to measure without compromising the health of the fish.
Larvae (on feed)	Survival	Percent survival, length, weight, *K* and *Wr*	Daily mortality recorded and subtracted from initial start count taken on age 6 month fish; subset of length and weight are taken
6-mo juveniles	Condition and survival	Percent survival, length, weight, *K* and *Wr*	Daily mortality recorded and subtracted from initial start count taken on age 6 month fish; subset of length and weight are taken
Age 1	Tagging	Pre-release tag retention	Pit tagging done on fish 20 grams and larger; all fish given a scute removal pattern indicative of year class
	Genetic variables	Family contribution, Effective population size(*Ne)*, number of breeders (*Nb*), diversity measures, genetic-based tagging	All hatchery fish are kept separate by family groups during rearing. Upon release the number of fish from each family group is recorded. Genetic sampling has been done from hatchery family groups in order to develop parentage testing.

4.4 Post-release

Participating entities and the M&E objectives, activities, variables, and metrics associated with post-release aspects of the program are provided in Table 6. Collectively, these variables and metrics will address the individual post-release growth, survival, and biological conditions of juveniles (≥ Age-1) and adult fish, and the effects of the program on the population's age class structure and future population abundance trajectories. Section 4.4.1 presents the methods associated with post-release M&E activities.

Table 6. Participating entities and the M&E objectives, activities, variables, and metrics associated with post-release aspects of the program.

Participating Entities	• Kootenai Tribe of Idaho • IDFG • MFWP • BC Ministry
M&E Objectives	Recapture adequate numbers of post-release hatchery produced fish to accurately estimate or evaluate: • Survival • Growth • Biological condition • Abundance • Age class structure • Population status and trends • Tag retention Perform telemetry adequate to estimate: • Seasonal movements and migrations • General timing and locations of spawning • Effects of flow management • Effects of habitat restoration actions
M&E Activities	• Monitor post-release survival, growth, condition, and general health of juveniles and adults as a function of release time and locations to optimize release strategies • Identify causes of mortality and factors limiting growth and survival, and develop solutions to these limitations • Monitor post-release genetic variables at individual, family, year class and population levels • Monitor age class and population genetic structure over time to evaluate success of attaining desired population trajectories and genetic signatures • Define and characterize seasonal habitat use, movements, and migrations to evaluate needs for natural spawning and recruitment

Variables	• Survival • Growth • Condition • Abundance • Future abundance trajectories • Age class structure • Genetic variables • Tag retention • Seasonal habitat use, migration and movement patterns, and spawning areas • Distribution • Sampling efficiency • Release locations, timing
Metrics	• Annual survival • Annual growth • Weight, length, biological condition factor, relative weight (Wr) • Juvenile and adult abundance • Modeled future juvenile and adult abundance trajectories • Length at age • Family contribution, effective population size (Ne), number of breeders (Nb), diversity measures, genetic based tagging • Tag retention, post-tagging survival, behavior, growth, and condition • Percent of tagged juveniles and potential spawners upstream from Bonners Ferry during spawning season • Annual capture probability • Growth, survival, movements as a function of release location and timing
ISMP Purpose	Resulting post-release data and information will be used to update ISMP Steps 1-3.

4.4.1 Post-release M&E Methods

Post-release M&E methods include early life stage (< Age-1) and juvenile (Age-1+) fish releases. The purpose of post-release sampling for early life stages is to test recruitment failure hypotheses by releasing free embryos and larvae over proper substrates. A series of methods are performed as part of the annual post-release sturgeon assessments:

- Cooperative efforts involve the Tribe, IDFG, MFWP and others.

- Eggs are currently hatched at the Tribal Sturgeon Hatchery, released as 1 to 4 day old free embryos (production will be added at Twin Rivers).

- Free embryos are stocked at 5 of 6 sites predetermined that met HSI criteria for substrate and flow conditions.
- When feasible, monitor drift/survival downstream with D-rings and 1/2 meter nets.
- Recruitment to gill nets in 3 years minimum appears to be best tool for evaluation.

The purpose of juvenile sampling is to evaluate trends in juvenile sturgeon abundance, brood year strength, and wild recruitment. Methods include:

- Fish multifilament gill nets (½-, ¾-, 1- 1½-, 2-, and 2½-inch stretch mesh panels) from July to October at 27 sites in Idaho and BC using standardized sites and protocols.
- Daytime sets checked every hour to reduce mortality. All fish are released alive.
- Measure fork (FL) and total length (TL), weight, PIT-tag numbers, fish condition and scute removal pattern.
- Wild juveniles aged by removing fin ray section.

As provided in the 5-year M&E Plan (Table 2, KTOI 2005), the following measures and tasks for M&E of juvenile sturgeon include:

3C. Juvenile Assessments

Measure 3C.1. Conduct periodic juvenile sturgeon assessments to estimate population status, index natural recruitment, and monitor hatchery program performance.

Task 3C.1.1. Capture juveniles during summer at standardized, spatially-stratified index sites throughout the U.S. and Canadian portions of the river using gillnets.

Task 3C.1.2. Biological and mark-recapture sampling to estimate abundance and survival.

Task 3C.1.3. Index natural recruitment based on marked-unmarked ratios.

Task 3C.1.4. Evaluate dispersal from release sites, subsequent movements, habitat use, growth and survival of hatchery reared juveniles.

Task 3C.1.5. Incorporate pectoral fin ray sampling from recaptures of large hatchery fish for aging method validation assessment.

3D. Telemetry

Measure 3D.1. Monitor distribution and movements of a representative sample of acoustic-tagged juveniles and adults to assess juvenile and adult habitat use and *movements and monitor biological response of adult sturgeon to spawning habitat enhancement projects.*

Task 3D.1.1. Maintenance and operation of Vemco receiver arrays.

Task 3D.1.2. Juvenile telemetry to define dispersal from hatchery release sites and subsequent juvenile habitat use, movements, and migration.

Task 3D.1.3. Adult telemetry to define adult movements and habitat use in current spawning sites and the area of interest for habitat creation above Ambush Rock in Idaho.

Task 3D.1.4. Installation and maintenance of a 3-D telemetry tracking array (acoustic positioning system) to monitor wild adult behavior near enhancement project structures.

Task 3D.1.5. Focused program to monitor the 3D movements of these fish in the small piece of river comprising the Substrate Enhancement Pilot Project.

3E. Habitat Assessment & Monitoring

Measure 3E.1. Measure and monitor physical conditions in critical habitat and potential spawning areas.

Task 3E.1.1. Map depth, velocity, and substrate in critical and potential spawning reaches to document baseline conditions.

Task 3E.1.2. Develop detailed computer hydraulic models of current and potential spawning reaches and calibrate to Kootenai River habitat conditions.

Task 3E.1.3. Periodically monitor changes in critical habitat parameters over time.

Additional details concerning specific methods for M&E activities that address post-release variables and metrics can be found at:

1) "KRRFM - Adult sturgeon assessment" http://www.monitoringmethods.org/Method/Details/992

2) "KRRFM – PIT-tagging" http://www.monitoringmethods.org/Method/Details/998

3) "KRRFM - Sonic telemetry" http://www.monitoringmethods.org/Method/Details/996

4) "KRRFM - Juvenile sturgeon gillnetting" http://www.monitoringmethods.org/Method/Details/995

5) "KRRFM - Adult sturgeon movement modeling " http://www.monitoringmethods.org/Method/Details/1029

6) "KRRFM - Adult sturgeon mortality, abundance, and year class strength analysis"
http://www.monitoringmethods.org/Method/Details/1020

7) "KRRFM - Juvenile sturgeon survival analysis"
http://www.monitoringmethods.org/Method/Details/1021

4.5 Natural Spawning and Recruitment

Restoration of successful natural spawning and recruitment is a critical component of this program because both are prerequisites to population down-listing, delisting, and recovery of Kootenai River white sturgeon under the U.S. Endangered Species Act (USFWS 1999). Therefore, the annual assessment of these functions is a fundamental component of this M&E Plan. The series of natural spawning and recruitment objectives, variables, and metrics shown in Table 7 largely address various naturally produced early life stages captured after spawning to determine their contribution to natural production and population recovery as a part of ongoing M&E activities. Section 4.5.1 presents the methods associated with natural spawning and recruitment M&E activities.

Table 7. Participating entities and M&E objectives, activities, variables, and metrics that will be used to characterize natural spawning and recruitment.

Participating Entities	• Kootenai Tribe of Idaho • IDFG • USGS • BC Ministry
M&E Objectives	• Determine (quantify) when, where, and the extent of natural spawning of Kootenai River white sturgeon • Determine (quantify) when, where, and the extent of natural recruitment of Kootenai River white sturgeon
M&E Activities	• Telemetry of late-stage mature adults • Sample early eggs, embryos, larvae and juveniles • Extrapolate natural production data to estimate
Variables	• Spawning success • Recruitment success
Metrics	• Number of naturally-produced eggs/embryos captured • Number of naturally-produced free embryos captured • Number of naturally-produced larvae captured • Number of naturally-produced juveniles (>Age-1) captured • Contribution of natural production to population age class structure
ISMP Purpose	Resulting natural spawning and recruitment data and information will be used to update ISMP Steps 1-3.

4.5.1 Natural Spawning and Recruitment M&E Methods

The purpose of free embryo (FE) and larval sampling is to test recruitment failure hypotheses by releasing FE over proper substrates.

- Cooperative effort with the Tribe, IDFG, MFWP and others.
- Eggs hatched at Tribal facility, released as 1 to 4 day old FE.
- Stocked at five of six predetermined sites that provide suitable substrate and flow conditions.
- When feasible, monitor drift/survival downstream with D-rings and ½-meter nets.

The purpose of juvenile sampling is to evaluate trends in juvenile sturgeon abundance, brood year strength, and wild recruitment.

- Cooperative effort with Kootenai Tribe, IDFG, MFWP and others.
- Eggs hatched at Tribal facility, released as 1 to 4 day old FE.
- Stocked at five of six sites predetermined that met HSI criteria substrate and flow conditions.
- When feasible, monitor drift/survival downstream with D-rings and ½-meter nets.
- Fish multifilament gill nets (½-, ¾-, 1-, 1½-, 2-, and 2½-inch stretch mesh panels) from July to October at 27 sites in Idaho and BC using standardized sites and protocols.
- Daytime sets checked every hour to reduce mortality. All fish are released alive.
- Measure fork length (FL) and total length (TL), weight, PIT-tag numbers, fish condition and scute removal pattern.

As provided in the 5-year M&E Plan (Table 2; KTOI 2005), the following measures and tasks for M&E of Kootenai sturgeon natural spawning and recruitment include:

3A. Natural Spawning Assessments

Measure 3A.1. Conduct annual assessments of sturgeon spawning activities to index spawning activity, identify spawning periods, and cue sturgeon flow requests.

Task 3A.1.1. Implement standardized substrate mat sampling at index sites in known spawning areas.

Task 3A.1.2. Implement standardized D-ring net larval sampling at index sites downstream from known spawning areas.

Additional details concerning methods for RM&E activities that address these natural spawning and recruitment variables and metrics can be found at:

1) "KRRFM - Adult sturgeon assessment"
   http://www.monitoringmethods.org/Method/Details/992

2) "KRRFM – PIT-tagging"
   http://www.monitoringmethods.org/Method/Details/998

3) "KRRFM - Sonic telemetry"
   http://www.monitoringmethods.org/Method/Details/996

4) "KRRFM - Juvenile sturgeon gillnetting"
   http://www.monitoringmethods.org/Method/Details/995

5) "KRRFM - Artificial substrate mat sampling"
   http://www.monitoringmethods.org/Method/Details/993

6) KRRFM - Larval sturgeon sampling"
   http://www.monitoringmethods.org/Method/Details/994

4.6 Existing Kootenai Sturgeon M&E

The Kootenai Sturgeon M&E program has been underway for over 20 years. Sections 4.1 through 4.5 accurately reflect the objectives, activities, variables, metrics and methods for each component of the M&E Plan. To avoid redundancy, we refer the reader to the appropriate sections of this M&E Plan for the information about ongoing M&E activities:

- M&E overview - Section 4.1
- Broodstock and wild adult sampling - Section 4.2.1
- Aquaculture (pre-release) program phase – Section 4.3.1
- Post-release program activities - Section 4.4.1
- Natural spawning and recruitment investigations - Section 4.5.1

Table 8 lists the agencies that currently participate with the Tribe in the program and will continue to be involved in the future.

Table 8. Participating agencies involved in Kootenai sturgeon M&E.

Participating agencies	Kootenai Tribe of Idaho IDFG BC Ministry MFWP USGS UC Davis-GVL

Additional details concerning existing M&E methods can be found at:

1) "KRRFM - Adult sturgeon assessment"
   http://www.monitoringmethods.org/Method/Details/992

2) "KRRFM – PIT-tagging"
   http://www.monitoringmethods.org/Method/Details/998

3) "KRRFM - Sonic telemetry"
   http://www.monitoringmethods.org/Method/Details/996

4) "KRRFM - Juvenile sturgeon gillnetting"
   http://www.monitoringmethods.org/Method/Details/995

5) "KRRFM - Artificial substrate mat sampling"
   http://www.monitoringmethods.org/Method/Details/993

6) KRRFM - Larval sturgeon sampling"
   http://www.monitoringmethods.org/Method/Details/994

7) "KRRFM - Adult sturgeon movement modeling "
   http://www.monitoringmethods.org/Method/Details/1029

8) "KRRFM - Adult sturgeon mortality, abundance, and year class strength analysis"
   http://www.monitoringmethods.org/Method/Details/1020

9) "KRRFM - Juvenile sturgeon survival analysis"
   http://www.monitoringmethods.org/Method/Details/1021

4.7 HABITAT

The changes to the Kootenai River ecosystem extend from physical habitat and ecological function loss to primary and secondary system productivity, nutrient availability, and possible contaminant dynamics (Northcote 1973; Ashley et al. 1997, 1999; Anders et al. 2002; Schindler et al. 2011). Some factors such as harvest, levee construction, and hydro development are obviously implicated; population collapse likely resulted from the combined impacts of these multiple factors rather than from the isolated effect of any single factor. The complex interactions of changes and their relative impacts on sturgeon are difficult to partition.

Effective long-term persistence and viability of a sustainable, naturally producing sturgeon population depends on significant conservation, population, and habitat restoration across the current ecosystem. Measures too narrowly focused on increasing numbers of one species are likely to fail if by concentrating on the symptom, they overlook the underlying causes. Ecosystem-based approaches are given wide lip service but rarely translated into specific, scale-appropriate activities. In sturgeon restoration actions, an ecosystem-based approach includes a combination of mainstem habitat protection, tributary and mainstem habitat restoration, fish population protection and recovery measures, conservation aquaculture, fish community and primary productivity improvements, and pollution control. The Tribe is implementing multiple projects to address ecosystem restoration. Monitoring and evaluation and adaptive management of these efforts will occur at multiple levels, including the project level and broader program work (e.g., ongoing development of the Kootenai River Adaptive Management Program (KTOI 2009, 2010, 2012). Ongoing habitat efforts include the following:

BPA Project(s)

- Kootenai Tribe "Kootenai River Habitat Restoration Program" Project 200200200

Metrics that are monitored during ongoing ecosystem restoration efforts include:

- KTOI - Bank erosion monitoring (ID: 1179)
- KTOI - Browse evaluation (ID: 1184)
- KTOI - Cover type mapping (ID: 1182)
- KTOI - Disturbance observation monitoring (ID: 1186)
- KTOI - Floodplain and channel morphology surveys (ID: 1178)
- KTOI - Floodplain herbaceous vegetation composition and cover (ID: 1310)
- KTOI - Floodplain substrate survey: volumetric bar samples (ID: 1180)
- KTOI - Floodplain woody vegetation composition and percent cover (ID: 1183)
- KTOI - Floodplain woody vegetation natural recruitment and regeneration (ID: 1311)
- KTOI - Greenline photo monitoring (ID: 1187)
- KTOI - Groundwater data collection (ID: 1214)
- KTOI - Mainstem stage data collection (ID: 1215)
- KTOI – Percent cover woody vegetation on streambanks (ID: 1312)
- KTOI - Side channel fish assemblage and population study (ID: 1212)
- KTOI - Structure monitoring (ID: 1181)
- KTOI - Substrate survey: underwater videography (ID: 1306)
- KTOI - Survival monitoring (ID: 1308)
- KTOI - Suspended sediment sampling (ID: 1213)
- KTOI - Model development and calibration (ID: 1216)

4.8 Existing Ecosystem Monitoring in the Kootenai River

Several additional Tribal projects are simultaneously monitoring and evaluating various aspects of the Kootenai River ecosystem and are listed below.

BPA Projects

- Kootenai Tribe "Kootenai River Ecosystem Restoration" 199404900
- IDFG "Kootenai River Resident Fish Mitigation" KRRFM 198806500

M&E activities as part of ongoing ecosystem restoration efforts include:

- KRRFM- Nutrient dosing BMP (ID: 1103)
- KTOI - Benthic macroinvertebrate sampling
- KTOI - Nutrient addition of N and P (ID: 1175)
- KTOI - Periphyton accrual and biomass sampling (ID: 1107)
- KTOI - Periphyton taxonomic community/density sampling (ID: 1114)
- KTOI - Water chemistry (ID: 1123)
- KRRFM- Fish biomonitoring data (ID: 1007)
- KTOI - Benthic macroinvertebrate analysis (ID: 1137)
- KTOI - Periphyton accrual and biomass sample analysis (ID: 1118)
- KTOI - Periphyton taxonomic community/density analysis (ID: 1117)
- KTOI - Water chemistry analysis (ID: 1136)

5 METRIC ESTIMATES & HYPOTHESIS TESTING

The purpose of the annual ISMP is to guide and evaluate hatchery-based population restoration activities for Kootenai River white sturgeon. The ISMP enables program personnel to adaptively incorporate M&E results into various operational aspects of the program to help: 1) monitor annual production and biological targets in the short term; and 2) produce and maintain a naturally-reproducing, self-sustaining sturgeon population in the Kootenai River in the long term.

This section of the M&E Plan defines the metrics used in the four-step ISMP and how they will be used. Different types of information are needed for each step. In Step 1, the key assumption parameters will be used to predict how the population will respond to future management actions (Section 5.1). In Step 2, the status and trend analysis, outcomes based on empirical data will be assembled, current status of the population will be established, and progress toward population goals will be analyzed (Section 5.2). From these parameters, the Decision Guidelines (Step 3) will be reviewed, and modified as needed. The Decision Guidelines (Table 11) set the management controls so that if the key assumptions are true, the biological targets for the populations should be met, and if the key assumptions prove false, they can be corrected (Section 5.3). In Step 4, updated Decision Guidelines outcomes will be used to assess how in-hatchery production annually translates into in-river population abundance and structure. In this step, progress towards the short- and long-term biological targets is also tracked. After each annual field season, as part of the APR, this information will be used to assess the management performance in terms of achieving biological program targets (Section 5.4).

At each step in the ISMP process, managers will annually describe and discuss analytical results, make changes as needed and record them in the ISMP database. At the end of each year, this information will be compiled in an annual report developed prior to and for use in the annual APR.

A key element of this plan is that all assumptions and parameters will be reviewed and challenged each year to assure the most current and reliable information is used in the decision-making process.

5.1 Key Assumptions (ISMP Step 1)

The key assumptions are a set of conditions that relate to future expectations (i.e., what is the basis for predictions about what will happen). Generally, these assumptions are based on empirical data and information collected over time. They represent the current understanding of how the system works and create testable hypotheses, the results of which can be used to guide in-season and long-term management actions. Key assumptions are grouped into four categories: 1) hatchery production, 2) natural production, 3) reproduction, and 4) harvest parameters. In the case of Kootenai sturgeon however, several decades may be required before the population could withstand any degree of sustainable harvest. Table 9 presents the initial suite of assumptions, which are discussed in more detail in sections 5.1.1 and 5.1.2

Table 9. Key assumptions for hatchery-reared and natural-origin components of a restored white sturgeon population.

	Variable Name	Hatchery-reared	Naturally Produced
Donor	Broodstock donor source	Kootenai River	Kootenai River
	Broodstock percent survival (field)	99	99
Hatchery	Broodstock percent survival (in hatchery)	99	99
	Number of broodstock (females: males) per family	1:1 to 1:4	Unknown
	Number of families	12-15 at Tribal Hatchery 16-20 at Twin Rivers Hatchery	-
	Number fertilized eggs	9,100/female	-
	Percent hatch	90	-
	Percent larval survival	50	-
	Percent YOY juvenile (Age 0 - 6 months) survival	50	-
	Percent survival Age-1 in hatchery	50	
Natural (in-river)	Percent survival, egg to 6 months	NA	~0%
	Percent Age-0+ survival in wild (assumed)	NA	Unknown
	Percent Age-1+ survival in wild	~12%	Unknown
	Percent ages 2 – 10+ annual survival	~95%	Unknown
	Estimated number of spawners	0 in 2012	~50 to <315[a]
	Spawner recruit ratio	Unknown	0[b]

[a] Annual variation expected. Lower estimate based on annual broodstock capture numbers; upper estimate based on assumptions of 900 adults, 50% M:F ratio, and average 2-year male and 5-year female reproductive periodicities.

[b] Assumes continued natural recruitment failure.

5.1.1 In-Hatchery Assumptions

In-hatchery operations will incorporate detailed record keeping and tracking of mortality at each life stage, from broodstock collection through spawning, rearing, and release of Age-1 (≥ 30 grams [g] in weight) fish. It is important to note that the number of fish collected for broodstock will vary from year to year due largely to inter-annual differences in broodstock availability. Annual broodstock availability may also differ due to other biological and logistical factors.

The size of the program is measured in terms of broodstock (number and composition), number of families produced, release numbers per family, and total number of fish released each year. Life stage-specific numbers are presented below on a per family basis. Total annual production is calculated by multiplying these estimates by the number of families produced during a given year.

In-hatchery variables to be monitored include:

Donor Stock

- **Definition**: The population from which broodstock and/or gametes are collected.
- **Assumed Value**: The Kootenai River population will provide broodstock needed for the program.

Broodstock Survival

- **Definition**: Percentage of fish used for broodstock surviving one year post-spawn.
- **Assumed Value**: 99%

Number of Females and Number of Males

- **Definition:** Ratio of females to males used for broodstock.
- **Assumed Value(s)**: Typically 1F X 2M, with gametes separately spawned in each cross. Annual male:female spawning ratios may vary from 1F X 1M to 1F X 4M, depending on in-season broodstock and gamete availability.
- **Number of Families Definition:** A cross of one female with one male. Each female will typically be crossed with two males, but individually. Thus, each female would produce two half-sibling families in this case.
- **Assumed Value**: A maximum of 30 families (including ½ sibling families) will be produced per year at both facilities combined. Annual production may involve 12 to 15 families at the Tribal Hatchery and 16-20 families at the Twin Rivers Hatchery.

Eggs/Female (Fecundity)

- **Definition**: Average number of eggs per female spawned.
- **Assumed Value**: Fecundity ranges up to several hundred thousand eggs in each Kootenai River white sturgeon. Only a fraction of those eggs will be incorporated from

each fish in annual hatchery production (approximately 10,000 eggs per female, per family, will be fertilized).

Number of Fertilized Eggs

- **Definition**: Total number of eggs successfully fertilized as determined by microscopic inspection at neuralation (post-4 cell stage). Parthenogenic cleavage can occur up to the 4-cell stage, potentially providing a false positive for fertilization.
- **Assumed Value**: Mean fertilization rate of 90%, with 10,000 eggs per female per family yields 9,000 fertilized eggs.

Percent Hatch

- **Definition**: Percentage of fertilized eggs that successfully incubate and hatch as free embryos.
- **Assumed Value**: 90% hatch of 9,000 fertilized eggs yields 8,100 free embryos.

Percent Larval Survival

- **Definition**: Percentage of fish that survive from the free embryo stage to the larval stage.
- **Assumed Value**: 50% survival of 8,100 free embryos yields 4,050 larvae on feed.

Percent YOY Survival (to 6 months in-hatchery)

- **Definition**: Percentage of fish that survive from the larval stage to 6-month juvenile.
- **Assumed Value**: 50% survival of 4,050 larvae yields 2,025 six-month old juveniles.

Percent Age-1 Survival (in-hatchery)

- **Definition**: Percentage of fish that survive from 6 months to 12 months
- **Assumed Value**: 50% survival of 2,025 fish from 6 months old to Age 1 yields 1,012 Age 1 fish, consistent with the proposed releases of up to 1,000 Age 1 fish (>30g) per family

5.1.2 In-river (Post-release) Production of Hatchery-produced Fish

Fertilized Egg to 6-month-old Juvenile

- **Definition:** Survival from egg to 6-month-old juvenile.
- **Assumed Value**: 0 % because only Age-1 fish will be released

Percent Age-0+ Survival (In-river)

- **Definition:** Survival during from 6 -12 months juvenile stage.
- **Assumed Value**: 0 % because only Age-1 fish will be released for annual production purposes.

Percent Age-1+ Survival (In-river)

- **Definition:** Survival during the 12 - 24 months sub-adult stage.

- **Assumed Value**: 60%

Percent Ages 2-10 Survival (In-river)

- **Definition:** Annual survival from 2 to 10 years old.
- **Assumed Value**: 90%

5.1.3 Natural Spawning

Number of Spawners

- **Definition:** Total number of sexually mature adults per year.
- **Assumed Value**: Generally older than 25 years of age.

Spawning Area

- **Definition:** Any area where spawning behavior is observed. This would entail direct observation, capture of congregating sexually mature adults, or inferences based on capture of eggs or free embryos.
- **Assumed Value**: Usual spawning reach is rkm 231 to 246, Shorty's Island upstream of Bonners Ferry.

Number of Adults per Spawning Area

- **Definition:** Number of sexually mature adults estimated to spawn in a common area
- **Assumed Value**: Estimated number of adult spawners in a given year estimated to be in a common area from mid-May to mid-July

Spawner per Recruit Ratio

- **Definition**: Number of F1 progeny surviving to reproductive status per P1 spawning adult.
- **Assumed Value**: Currently unknown.

Natural Mortality

- **Definition**: Percent of population that dies within a given year due to all natural causes.
- **Assumed Value**: 4% for adults, higher rates for younger life stages

5.1.4 Harvest

Fishing Mortality

- **Definition**: Percent of population that dies from fishing in a given year.
- **Assumed Value**: < 1% annually within the next 20 years.

5.2 Status and Trends (ISMP Step 2)

Status and trends represent actual outcomes (i.e., looking back at what happened). This information will be collected, reported annually, and incorporated into the historical record of outcomes. Observed outcomes will be analyzed each year as part of the APR, which also evaluates key assumptions and parameter estimates. Step 2 will be used to evaluate performance of the ISMP (e.g., Did we meet the biological targets? Were these targets correct?). Upon annual task completion and reporting, this information will be shared with the public and other management entities as part of the accountability responsibility. Standard attributes involved in status and trend monitoring are arranged into four categories: 1) hatchery production, 2) natural production, 3) reproduction, and 4) harvest, and are addressed below. In the case of Kootenai sturgeon, several decades may be required before the population could withstand any degree of sustainable harvest.

5.2.1 Hatchery Production

All hatchery fish will be marked with an artificial tag (e.g., PIT-tags) or with genetic-based parental assignment techniques following diagnostic genotyping. Thus, the origin (hatchery vs. wild) and year class of any hatchery-produced fish may be properly assigned. Comprehensive marking will enable determination of hatchery program success and will help characterize natural production, which will be identifiable as unmarked fish. Hatchery production targets are provided below in Table 10.

Table 10. Example of the ISMP predictive annual production tool for Kootenai River white sturgeon using empirical life stage-specific survival rates.

1 Family				Survival Rate		
Life Stage	Numbers	Fertilization Rate	Hatch Rate	Free Embryos	Larvae	Age 0 fish
Eggs	10,000	0.9				
Fertilized eggs	9,000		0.9			
Free embryos	8,100			0.5		
Larvae	4,050				0.5	
6-mo juveniles	2,025					0.5
Age 1 juveniles	1,013					
30 Families				Survival Rate		
Life Stage	Numbers	Fertilization Rate	Hatch Rate	Free Embryos	Larvae	Age 0 fish
Eggs	300,000	0.9				
Fertilized eggs	270,000		0.9			
Free embryos	243,000			0.5		
Larvae	121,500				0.5	
6-mo juveniles	60,750					0.5
Age 1 juveniles	30,375					

5.3 Review Decision Guidelines (ISMP Step 3)

Annual information presented in tables 10 and 11 will be provided at the APR. All available data will be used to update key assumptions (Step 1) and population status and trends (Step 2). To annually satisfy Step 3, the cooperating agencies and other entities will decide how to proceed with current Decision Guidelines and make adjustments to suit the goals of the program as needed. The group will then set specific numerical and biological targets and agree to their implementation for the coming year. The biological targets will determine hatchery production, harvest (at some point in the future when there is a harvestable population), and any adjustments to M&E as needed. The initial set of Decision Guidelines is presented below in Table 11.

Table 11. Initial program Decision Guidelines set for white sturgeon.

Variables	Annual Values
Donor source	Kootenai River
Percent broodstock from Kootenai River	100
Percent Kootenai River natural-origin broodstock	100
Families produced	12-15 at Tribal Hatchery 16-20 at Twin Rivers Hatchery
Age-0+ YOY released	None
Age-1 released	< 1,000/family < 30 families
Natural recruitment	None or insignificantly different from 0

5.4 In-Season Management informs Biological Targets (ISMP Step 4)

Currently, in-season management takes place several times each year. Typically, this incorporates input gathered at 2-day meetings of the Kootenai River White Sturgeon Recovery Team, which is headed by the USFWS. This Recovery Team consists of individuals from different agencies and partners including USFWS, IDFG, BC Ministry, MFWP, US Army Corps of Engineers, the Kootenai Tribe, and others. Most in-season management decisions currently involve hatchery production updates, determination of the annual release strategy, and discussion of upcoming research, monitoring, and evaluation needs. In the past, the frequency and timing of the Recovery Team meetings have been variable. The use of the formal ISMP process in concert with regularly the scheduled APR will provide greater consistency and predictability for in-season management coordination. As previously noted, Recovery Team members will be integrated into the APR and ISMP processes.

5.4.1 Hatchery Production

Hatchery production is closely monitored each year according to the following variables and biological targets.

Donor Stock

- **Definition**: The population from which broodstock and/or gametes are collected.
- **Biological Target**: ≤ 45 broodstock annually from both facilities combined.

Broodstock Survival

- **Definition**: Percentage of fish used for broodstock surviving one year post-spawn. **Biological Target**: 99%

Number of Females and Number of Males

- **Definition:** Ratio of females to males used for broodstock.
- **Biological Target**: Female:Male ratios of 1:1 to 1:4 per family.

Number of Families

- **Definition:** A cross of one female with one male. Each female will be individually crossed with one to four males. Thus, each female should produce from one to four distinct families.
- **Biological Target**: ≤ 30 annually from both facilities combined.

Eggs/Female (Fecundity)

- **Definition**: Average number of eggs per female spawned.

Biological Targets: Although individual female fecundity varies, 10,000 eggs per female are targeted to meet program biological objectives.

Number of Fertilized Eggs

- **Definition**: Number of eggs fertilized.
- **Biological Target**: 10,000 per female.

Hatch

- **Definition**: Percentage of fertilized eggs that successfully incubate and hatch.
- **Biological Target**: 50%

Larvae

- **Definition**: Percentage of fish that survive from hatch until fry stage.
- **Biological Target**: 50%

YOY (to 6 Months In-hatchery)

- **Definition**: Percentage of fish that survive from end of larval stage to 6-month juvenile.
- **Biological Target**: 50%

Age-1 (In-hatchery)

- **Definition**: Percentage of fish that survive from 6 months to 12 months.
- **Biological Target:** 50%

5.4.2 Natural Production

Tracking performance of the in-river population and its hatchery- and natural-origin components over time is a primary objective of this M&E Plan. Each year a full accounting of the in-river population will be obtained through stock reconstruction. The biological targets listed below will be estimated each year.

Fertilized Egg to 6-month-old Juvenile

- **Definition:** Survival from egg to 6-month-old juvenile.
- **Biological Target**: Unknown, currently close to 0%, but will have to be significantly > 0 to support natural production and recruitment to Age-1.

Age-0+ Survival (In-river)

- **Definition:** Survival during from 6 -12 month juvenile stage.
- **Assumed Value**: ~0%

Ages-1 - 3 (In-river)

- **Definition:** Survival during from 12 - 24 month juvenile stage.
- **Biological Target**: Unknown, but assumed minimum annual survival rate of 65% (Age-1 ~12%; Ages 2 and 3 ~95%) based on analogous survival rates of like-aged hatchery fish.

Percent Ages-4 - 25 Years (Estimated Average Age at Sexual Maturity) (In-river)

- **Definition:** Annual survival during 2 to 25 years old.
- **Biological Target**: Unknown, but assumed minimum: 90% annual survival based on analogous survival rate of like-aged hatchery fish.

5.4.3 Natural Spawning

Number of Spawners

- **Definition:** Total number of sexually mature adults per year.
- **Biological Target**: Unknown

Spawning Area

- **Definition:** Any area where spawning behavior is observed. This would entail observation or capture of congregating sexually mature adults.
- **Biological Target**: Areas that support natural recruitment through the larval swim-up-and-drift phase.

Number of Adults per Spawning Area

- **Definition:** Number of sexually mature adults estimated to spawn in a common area.
- **Biological Target**: Unknown, but expected to be annually variable.

Spawner per Recruit Ratio

- **Definition**: Number of F1 progeny surviving to reproductive status per P1 spawning adult.
- **Biological Target**: Minimum of 1:2 (spawner to recruit). This ratio is assumed to allow for rebuilding and sustaining a natural population in the presence of fluctuating natural mortality and harvest.

Natural Mortality

- **Definition**: Percent of adult population that dies within a given year due to natural causes.
- **Biological Target**: <5%

5.4.4 Harvest

In the case of Kootenai sturgeon, several decades may be required before the population could support any degree of sustainable harvest. Thus, no estimated harvest rates or future targets are provided in the M&E Plan at this time.

6 ADAPTIVE MANAGEMENT

The Kootenai sturgeon conservation aquaculture program includes checkpoints and evaluations at periodic, scheduled intervals as part of the adaptive management (AM) and implementation plans that are overseen by the Kootenai Tribe, in coordination with the Kootenai White Sturgeon Recovery Team. Rather than pursuing a speculative reductionist approach to key uncertainties, the conservation aquaculture program is pursuing an aggressive adaptive management strategy. Far from “trial and error”, this AM strategy involves a structured, iterative process designed to support optimal decision making in the face of uncertainty, with an aim to reducing uncertainty over time by learning via experimental management and system monitoring as originally conceived by Holling (1978) and Walters (1986) and reiterated by Ludwig and Walters (2002). A detailed decision tree and pathway for adaptively managing the conservation aquaculture program based on monitoring and evaluation of wild and hatchery-origin sturgeon are provided below in Figure 3 and Table 12, respectively.

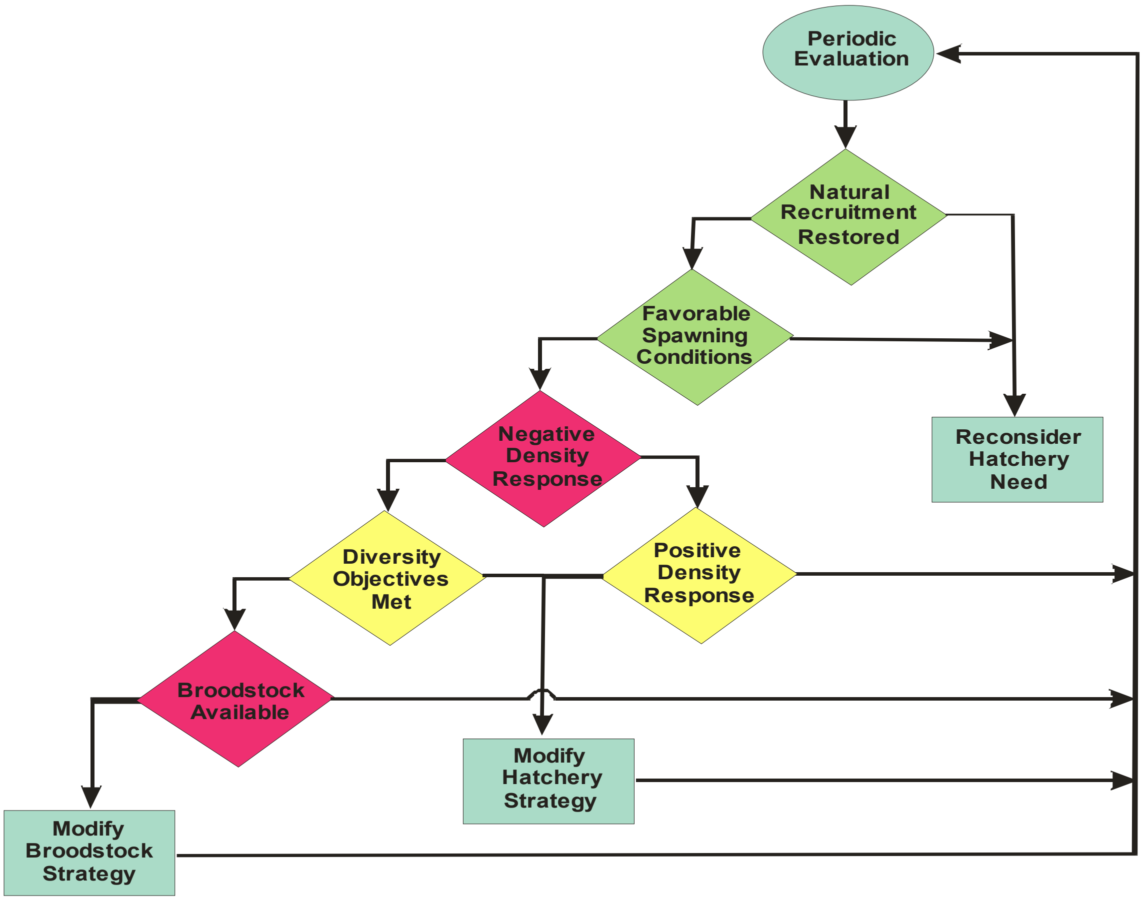

Figure 3. Monitoring and evaluation decision tree for Kootenai sturgeon conservation aquaculture program.

Table 12. Decision pathway guiding future monitoring and implementation of the Kootenai sturgeon aquaculture program.

Question 1:		Has substantial natural recruitment occurred?
	Metrics:	*Number/percentage of unmarked fish in juvenile sampling program.*
	Response:	*Re-evaluate appropriate level of hatchery supplementation based on frequency and magnitude of natural recruitment.*
Question 2:		Has the wild spawning distribution shifted to upstream areas of potentially more suitable spawning habitat?
	Metrics:	*Telemetry data on movements of mature fish during spawning periods.*
	Response:	*Re-evaluate whether wild broodstock, if limited, are best employed in the wild or the hatchery.*
Question 3:		Are wild spawner numbers adequate to continue to provide hatchery broodstock?
	Metrics:	*Catch per unit effort, annual number of broodstock collected, percentage of previously-unspawned individuals in annual adult sampling program*
	Response:	*Consider modification of broodstock collection program numbers, need for extended broodstock holding, or reduction in program based on cost/benefit analysis and progress toward objectives.*
Question 4:		Are broodstock numbers and mating strategies adequate to optimize genetic diversity?
	Metrics:	*Effective population size based on broodstock numbers, representation of genetic types in broodstock*
	Response:	*Consider increasing or decreasing annual broodstock numbers as appropriate.*
Question 5:		Has survival, growth or condition of age 1 or older juveniles declined substantially in response to increasing density?
	Metrics:	*Annual survival and growth rates estimated with mark-recapture data from juvenile monitoring program. Condition estimated from length-weight relationship. Size and age at maturation and reproductive periodicity of hatchery-origin fish.*
	Response:	*Consider reductions in annual releases, changes in release distribution, changes in family sizes, rearing fish to a larger size to avoid size-specific limitations, and fish removal to reduce biomass as appropriate based on risk/benefit calculation and progress toward objectives.*
Question 6:		Has juvenile sturgeon distribution or behavior changed substantially in response to increasing density?
	Metrics:	*Catch per unit effort by area, movement data from tagged fish.*
	Response:	*Weigh relative benefits of expanded distribution versus detriments of increased competition in considering program modifications.*
Question 7:		Are there other new data, information or developments that warrant consideration?
	Metrics:	*Associated with habitat, nutrient and other species monitoring efforts.*
	Response:	*Program refinements as appropriate.*

Key decision points for the sturgeon program can be triggered by the restoration, frequency, and magnitude of natural recruitment, changes in spawning distribution following habitat restoration activities, identification of effective alternatives such as larval releases, unavailable or senile broodstock, strong density-dependent habitat limitations, or delayed maturation of hatchery-origin fish.

Program termination or large substantive changes in program objectives and activities will be driven by monitoring and evaluation of the program and population. Termination of any program component or aspect can be triggered by either success or failure. Programs will be terminated when and if:

- A productive, naturally self-sustaining population of white sturgeon is restored in the Kootenai system.
- Conservation aquaculture activities significantly interfere with or otherwise preclude restoration of productive naturally self-sustaining populations of white sturgeon and burbot in the Kootenai system.
- Conservation and restoration objectives cannot be substantively achieved and programs cannot be reasonably adapted to achieve objectives.
- Benefits prove to be marginal and adaptations prove cost-prohibitive relative to program objectives and production targets.

It is currently difficult to foresee which specific factors, conditions or metrics might trigger a fundamental reconsideration of the conservation aquaculture program for sturgeon. However, it is expected that program objectives and activities will continue to be refined throughout their duration based on evolving conditions and new information.

6.7.1 Quantitative Benchmarks

Three levels of quantitative benchmarks are identified for the Kootenai sturgeon conservation aquaculture program:

- Working recovery criteria serve as interim recovery objectives. Criteria have been identified consistent with characteristics of a viable sturgeon population, including abundance, productivity, distribution, diversity, and use. Quantitative criteria are identified for abundance (2,500 adults for down-listing, 8,000-10,000 for delisting). Qualitative criteria are identified for other attributes where data and information are not yet sufficient to determine specific quantitative values. The Kootenai River White Sturgeon Recovery Team is expected to develop more explicit quantitative objectives as part of a planned revision of the Recovery Plan.
- Production targets identify numbers of broodstock, families, family size, size at release, and annual releases developed consistent with working criteria to guide hatchery planning and operations (Table 13). These numbers are based on working recovery criteria, and provide the basis for facility designs for the Kootenai sturgeon conservation aquaculture program.

Table 13. Current and expected future Kootenai sturgeon production values1 with and without the Twin Rivers Hatchery.

	Current Facilities[1]	Program Objective	Facility	
			Kootenai Tribal Sturgeon Hatchery	Twin Rivers Hatchery
Broodstock number	24	Up to 45	Up to 18	Up to 27
Families produced	12-18	Up to 30	Up to 12	Up to 18
Fish/family	1,000-1,500	500-1,000	500-1,000	500-1,000
Size at release	30 grams	30 grams	30 grams	30 grams
Total releases per year	15,000-20,000	15,000-30,000	6,000-12,000	9,000-18,000

[1] Estimates are based on Age-1 juvenile releases and no contribution from natural recruitment.

- Population Benchmarks provide reference values for monitoring and evaluating progress toward recovery criteria achieved by current production targets. Benchmarks identify quantitative values for key population attributes (Table 14). Targets for wild fish identify desired values based on recovery objectives. Targets for hatchery fish identify baseline values from current information. Triggers identify values that warrant reconsideration and possible adjustment of hatchery production targets under the adaptive management framework for the conservation aquaculture program.

Table 14. Program M&E benchmarks developed for monitoring and evaluating the response of Kootenai sturgeon population response to recovery measures.

Attribute	Target	Trigger
Adult abundance	8,000-10,000 (de-listing)	2,500 (down-listing)
Trend in adult abundance (annual rate of increase)	≥ 0%	Decreasing trend
Wild age structure (percent adults age 25 and greater)	30 < N < 50%[a]	<30% or > 50%
Wild recruitment at age 1 (annual average)	To be determined [b]	
Hatchery broodstock number (adults per generation)	≥ 1,000	< 900
First year survival (age 1 hatchery fish)	≥ 25% [c]	< 25%
Survival ages 2-5 (hatchery fish post release)	≥ 95% [d]	< 95%[d]
Growth rate (age 1-5 hatchery fish)	≥ 6 cm/yr [d]	< 6 cm/yr
Condition factor (Wr, relative weight)	≥ 95% [e]	< 95%
Juvenile sample rate (annual capture probability)	≥ 5% [d]	<5%
Spawner distribution (percent of tagged spawners upstream from Hwy 95 bridge)	≥ 40% [e]	<40%

[a] Based on stable equilibrium levels in Paragamian et al. (2005) model simulations.
[b] To be determined based on realized survival rates that produce adult targets.
[c] Minimum of 1999-2003 annual estimates for age 1 and 1+ releases of comparable size to current practice (Beamesderfer et al. 2011b)
[d] Based on baseline values reported in Beamesderfer et al. (2011)
[e] Criteria defined in the amended 2006 Libby Dam Biological Opinion (USFWS 2008)

6.7.2 Precision vs. Sample Rate

Current levels of sampling have been determined over time to provide an appropriate level of precision while meeting combined stock assessment and hatchery evaluation monitoring objectives. Figure 4 illustrates the effect of sample rate on the precision of annual survival estimates, based on a simple multiple mark-recapture model. Survival estimates are a key metric in evaluating hatchery performance and effects. Estimates of precision were calculated for a modeled population generated from specified release numbers and average annual survival rates and then sampled at a designated rate. Precision was estimated based on Seber (1982) as described in Beamesderfer (2008). Actual survival estimates for Kootenai sturgeon are based on a much more complicated version of this model, but the simple example below illustrates the nature of the relationships.

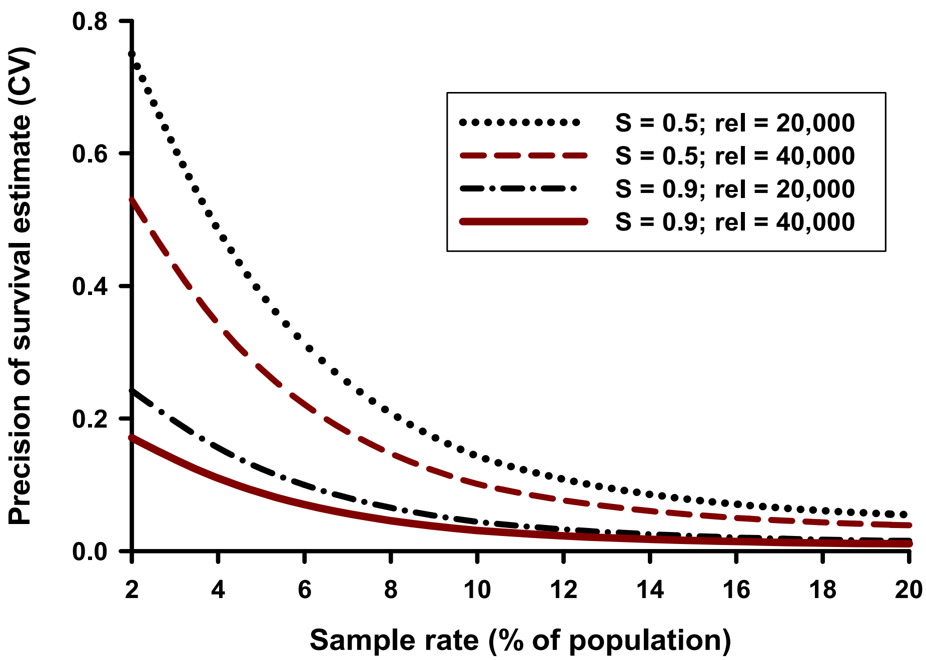

Figure 4. Example statistical analysis of the effects of annual release number and sampling rate on precision of annual survival estimates using a simple Cormack-Jolly-Seber mark-recapture model (6-year sampling interval).

The precision of survival estimates is related to the number of recaptures in the mark-recapture sample. Anything that increases the number of recaptures will increase precision. Thus, greater sample rates, release numbers, post-release survival, and number of sample years will all contribute to more precise estimates. Estimates of precision are relatively sensitive to increasing sample rates when sample rates are low. However, incremental increases in sample rates produce progressively smaller improvements as sample rates approach or exceed 5-10%. This function imposes practical constraints on our ability to increase sampling effort to reduce uncertainty in survival estimates to levels that do not have very large effects on future abundance projections. This example demonstrates that precision can also be improved by increasing the subject population size (i.e., through greater annual release numbers), as long as effects are not offset by density dependence. Thus, the benefits of greater release numbers, such as those that are planned following construction of the new hatchery, might include identification of the limits of sturgeon rearing capacity and increased precision of survival estimates and future demographic projections, in addition to the genetic and demographic benefits previously discussed.

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Appendix C

Monitoring and Evaluation Plan for Kootenai River Burbot

(Lota lota maculosa)

Monitoring and Evaluation Plan for Kootenai River Burbot

(Lota lota maculosa)

Prepared by the Kootenai Tribe of Idaho for the Northwest Power and Conservation Council and Bonneville Power Administration

August 2012

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The Kootenai Tribe of Idaho (Tribe or KTOI) would like to acknowledge that we produced this document based on the monitoring and evaluation (M&E) plans created for the Chief Joseph Dam Hatchery Program by the Confederated Tribes of the Colville Reservation and their consultant, D.J. Warren & Associates Inc. (Colville Tribes 2009a, 2009b). We believe their approach, which provided a framework for implementing and evaluating hatchery and field monitoring, and a process for multi-agency cooperation and management, with some modification, is well suited to characterize M&E activities associated with the Kootenai River Native Fish Conservation Aquaculture Program, and will help to ensure the program's success.

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1 INTRODUCTION

The Lower Kootenai River burbot (*Lota lota maculosa*) population historically had multiple components inhabiting Idaho, Montana, and British Columbia. These included: 1) fish that reared and spawned in the Kootenai River and tributaries (fluvial), 2) fish that reared and spawned in Kootenay Lake (lacustrine), and 3) fish that used both the river and lake to complete the life cycle (adfluvial). All three life history strategies are currently considered functionally extinct.

In 2001, the Kootenai Valley Resource Initiative (KVRI), led by the Kootenai Tribe of Idaho (Tribe or KTOI), was formed to develop a collaborative community-based approach to addressing local natural resource issues (Ireland and Perry 2008). Under the KVRI mandate, part of this approach included development of an innovative and collaborative process for burbot restoration in the Kootenai River. Since February 2002, the Kootenai Tribe has facilitated a collaborative process through KVRI to implement this project—Restoration of the Kootenai River Burbot Population. In 2002, the KVRI Burbot Subcommittee was formed to evaluate conservation aquaculture for burbot as part of an emerging conservation strategy to help restore Kootenai burbot. The KVRI Burbot Subcommittee, along with the U. S. Fish and Wildlife Service (USFWS) and additional committed stakeholders, proposed the Kootenai River drainage as a “pilot project” to develop, implement, and evaluate a conservation strategy for Lower Kootenai River burbot, in lieu of formal listing under the Endangered Species Act (ESA).

A multilateral conservation agreement was signed to ensure burbot population decline would be addressed. Many people have dedicated their time and energy to this process. There has been committed participation from federal agencies (Bonneville Power Administration [BPA], Corps of Engineers, USFWS); state agencies (Idaho Department of Fish and Game [IDFG], Montana Department of Fish, Wildlife and Parks [MFWP]); local governments (City of Bonners Ferry, Boundary County); Tribal government (KTOI); Canadian federal and provincial governments (BC Hydro, British Columbia Ministry of Forests, Lands, and Natural Resource Operations [BC Ministry]); academia (University of Idaho); congressional delegation staff, Idaho Governor’s Office of Species Conservation, KVRI board members and participants, private citizens, and conservation groups (American Wildlands, Idaho Conservation League, The Nature Conservancy).

The KVRI Burbot Subcommittee spent an enormous amount of time discussing issues, learning the biology and habitat requirements of the burbot, and ultimately building consensus among the agencies and stakeholders so that the Burbot Conservation Strategy (BCS) (KVRI 2005) would meet the needs of the species while addressing important social and economic issues. Interviews of local community members with life-long and multi-generational familiarity of historical burbot populations and fisheries provided valuable information to the Burbot Subcommittee during the preparation of the BCS. The BCS outlines a suite of adaptive recovery measures for rehabilitation of the burbot population, including physical habitat restoration, the development and implementation of a conservation aquaculture program and hydropower operations plan, monitoring and evaluation (M&E), and education and outreach. In August

2004, the KVRI Burbot Subcommittee completed the BCS and development of a Memorandum of Understanding (MOU) was begun by the policy representatives of the involved participants. The MOU was successfully negotiated in July 2005 and signed by 16 agencies and entities. It formalizes the commitment of the participants to implement the measures in the BCS, based on their respective authorities and responsibilities (KVRI 2005; Ireland and Perry 2008).

This Monitoring and Evaluation Plan for Kootenai River Burbot (Burbot M&E Plan) is an important component of the Kootenai River Native Fish Conservation Aquaculture Program (KTOI 2010) that provides a framework to guide the use of conservation aquaculture to restore the burbot population as recommended by the KVRI BCS (KVRI 2005). Following the framework and guidance of the BCS, this plan is composed of several research and monitoring elements, including: donor source population, aquaculture production, tagging strategies, sub-adults (release strategy and re-introduction), adults (release strategy and re-introduction), spawning and natural recruitment, and existing monitoring of habitat and biological community. This M&E Plan does not in any way supplant the BCS, but rather expands and elaborates on the implementation framework. This approach is necessary to incorporate achievements and research findings since the BCS inception in 2005. For instance, the collaborative effort has proven that large-scale aquaculture of burbot is a reality, and burbot have been stocked into the Kootenai River since 2009.

Also since 2005, several peer-reviewed publications have been completed which have helped guide development of production levels by life stage (Paragamian and Hansen 2009 and 2011). These and other advancements have provided the rationale for the design and scaling of the Twin Rivers Hatchery.

This M&E Plan identifies program goals and summarizes current data and initial assumptions that are guiding burbot restoration as well as the design and use of the Twin Rivers Hatchery to achieve these goals. The plan will ensure that hatchery operations produce high quality, disease-free fish that can survive in the receiving environment. It will guide the field data collection necessary to evaluate performance of fish in the wild, determine progress toward restoration, and guide production and research at the Twin Rivers Hatchery.

This plan acknowledges the importance of several other large-scale BPA-funded projects that will directly affect burbot restoration. The Kootenai River Habitat Restoration Program has commenced in areas known to have been used by burbot historically, and monitoring of these restored areas will be ongoing to track changes and confirm that habitat actions are effective. Also, long-term biological monitoring of the Lower Kootenai River and Kootenay Lake will provide important information pertaining to the effects of nutrient addition on ecosystem productivity and the aquatic community structure.

This M&E Plan is unusual in the fact that several governmental entities will be responsible for its execution. The Kootenai Tribe will be responsible for general program administration, hatchery production, and the execution of a four-step In-season Management Procedure (ISMP) and Annual Production Review (APR) to guide the restoration effort. The IDFG and BC Ministry will conduct field sampling and management activities within their respective countries. Also, through the Tribe and IDFG, the University of Idaho – Aquaculture Research Institute (UI-ARI) and the Idaho Cooperative Fish and Wildlife Research Unit (ID-CFWRU) will continue to develop and improve burbot culture and field sampling techniques, respectively, and Cramer Fish Sciences (CFS) will assist by lending expertise upon request.

Program actions will be actively managed using data and information provided from M&E activities described in this plan. The initial hatchery program size outlined herein is anticipated to meet program goals to restore adult abundance and natural recruitment. The ISMP facilitates input and participation from all cooperating agencies to ensure that hatchery production is compatible with conservation goals established for the burbot population in the Kootenai River. Additionally, M&E results will be used to determine whether the program's conservation goals are being achieved over the anticipated time frames.

Section 2 of this M&E Plan summarizes the program goals and objectives for burbot. Section 3 outlines the four-step ISMP. Section 4 identifies the variables and metrics that will be monitored to estimate and update key attributes/parameter values with adequate precision. Section 5 defines and lists initial target values for the program's key attributes used to make decisions concerning the hatchery, conservation, and potential future harvest goals. Section 6 describes the adaptive management platform for the plan. Section 7 provides a list of references.

2 PROGRAM OVERVIEW – BURBOT

This restoration effort is designed to re-establish a stable-sized burbot population with age class distributions sufficient to ensure long-term population viability and persistence. The ultimate program goal is to restore a naturally-reproducing burbot population as close to historical structure and abundance as possible that is in equilibrium with the carrying capacity of the present and future environment, and that can support tribal and non-tribal harvest.

This M&E Plan follows several articles listed in Section 8.0 - Conservation and Restoration Strategies of the KVRI BCS. The following BCS recommendations guide this M&E Plan:

- "Implement an aggressive adaptive program of experimental recovery measures."
- "Employ conservation aquaculture methods as a key near-term component for burbot protection and restoration."
- "Maintain a strong adaptive management scientific monitoring and evaluation program to guide implementation of population conservation and recovery activities."

To achieve these goals, the burbot program will be implemented in four phases, including aquaculture feasibility assessment, initial post-release evaluations, experimental evaluation phase, and a population rebuilding and management phase (KTOI 2010; Table 1). The burbot aquaculture program is currently in the second phase. Phases 1 and 2 have been guided by 5-year operational plans (Neufeld et al. 2009; 2011b).

2.1 PROJECT HISTORY

The Kootenai Tribal burbot project has been ongoing since the fall of 2001. Efforts began with broodstock and gamete collections conducted by the Tribe and the BC Ministry. Adult fish and gametes were transported to the Kootenai Tribal Hatchery in Bonners Ferry where spawning, egg incubation, and larval rearing were successful; however, no juveniles were produced, due to staff time and facility limitations. In 2003, efforts shifted to the UI-ARI in Moscow, Idaho, where initial work established the feasibility of captive burbot production through a series of empirical life-stage-specific studies examining spawning, semen cryopreservation, egg incubation, and larval and juvenile feeding (Cain et al. 2004; Jensen 2006; Jensen et al. 2008a; Jensen et al. 2008b; Jensen et al. 2008c).

Studies defining specific pathogen susceptibility and carrier status of burbot were also completed and provide a strong background for addressing burbot health concerns (Polinski et al. 2010a; Polinski et al. 2010c). In 2008, F1 progeny from the 2004 brood year successfully spawned and F2 progeny were cultured to the juvenile life stage. In 2009 and 2010, research addressed semi-intensive rearing methods (Barron et al. 2011a), size grading methods to suppress cannibalism during culture of larval and juvenile burbot (Barron et al. 2011b), the effects of temperature on larval and juvenile intensive culture performance (Barron et al. 2011c), and extended (up to 1 year) visible implant elastomer (VIE; Northwest Marine Technology, Shaw Island, WA, USA) tag retention. To date, three graduate students have completed MS degrees with research focused on specific objectives related to burbot culture development (Jensen 2006, Polinski 2009, Barron 2011).

The success of this project has allowed the KVRI Burbot Subcommittee to release progeny produced from a combination of on-site Moyie Lake gamete collections and captive Moyie Lake broodstock. Releases of burbot into the Kootenai River Subbasin (Canadian and US waters) to support conservation efforts have occurred in 2009, 2010, and 2011 and have included age 0, 1, 2, and 3 fish. Notably, 2010 releases included age 1, 2 and 3 burbot carrying both sonic (VemcoTM V9, Amirix Systems Inc. Halifax, Nova Scotia, Canada) and Passive Integrated Transponder tags (PIT; Destron Fearing TM, St. Paul, MN, USA). Jensen et al. (2010a) provides a detailed summary of program releases, and Neufeld et al. (2011a, 2011b) presents a summary of post-release distribution and movements. Releases completed in 2011 represent a milestone for the program, as nearly 50,000 larval burbot and over 21,000-tagged juvenile burbot were released into the Kootenai River.

As mentioned above, the Tribe's burbot conservation aquaculture program comprises four sequential implementation phases. These include: 1) aquaculture feasibility assessment, 2) post-release pilot study, 3) adaptive experimental evaluation, and 4) population rebuilding and management. The program is on schedule, currently implementing Phase 2 (Table 1).

Table 1. Proposed operational phases of the Kootenai River burbot aquaculture program listed in the KTOI Master Plan (2010).

Phase	Program Phase	Objective	Test Hypothesis	Status/Duration
1	Developmental aquaculture feasibility analysis	Develop efficient, reliable, and successful aquaculture apparatus and techniques for spawning, incubation, and rearing.	▪ It is feasible to spawn and rear significant numbers of burbot in a hatchery.	~5 years (successfully accomplished) 2004-2008
2	Developmental, post-release pilot study	Initial experimental releases and research to evaluate distribution, movements, habitat use, food habitats, and effective sampling methods by life stage.	▪ Effective sampling methods can be developed to monitor and sample significant numbers of hatchery fish following release. ▪ Some hatchery-produced fish can adapt to natural conditions. ▪ Life stage-specific habitat suitability and limitations can be evaluated using hatchery fish.	~ 5 years (currently on schedule) 2009-2013
3	Adaptive experimental evaluation phase	Implement population-level monitoring to evaluate post-release survival, growth, and maturation to identify restoration feasibility and requirements.	▪ Hatchery fish survive, grow and mature in sufficient numbers to reestablish a significant burbot population in the Kootenai system.	~ 5 years 2014-2018
4	Population rebuilding and management phase	Produce fish, monitor and evaluate success, reevaluate hatchery practices consistent with natural production objectives and outcomes.	▪ A naturally self-sustaining burbot population can be restored through a combination of habitat and hatchery actions.	2019 and beyond

Phase 1 (Developmental Aquaculture Feasibility Analysis) began in 2001. Focused efforts occurred primarily from 2004-2008, and this phase is now complete. Reliable, successful aquaculture apparatus and techniques were developed based on pioneering burbot aquaculture research. The progression of this burbot aquaculture program resembles the early years of the Tribe's successful white sturgeon program, operating since 1989. However, unlike sturgeon culture, burbot culture techniques did not exist prior to this program. Techniques to rear and spawn captive adults, cryopreserve semen, incubate and hatch embryos, intensively feed larval and juvenile burbot, and semi-intensively (fertilized, zooplankton-enhanced) rear fish in ponds have been developed as a result of a series of aquaculture experiments funded by this program (Cain et al. 2004; Jensen 2006; Jensen et al. 2008a; Jensen et al. 2008b; Jensen et al. 2008c; Jensen et al. 2011; Foltz et al. in prep). Additionally, burbot disease susceptibility has

now been well-characterized to circumvent fish health issues that may manifest under intensive conditions (Polinski 2009; Polinski et al. 2010a, 2010b, 2010c). This work continues to demonstrate the feasibility of burbot culture at a significant scale and has laid the groundwork for the next phase of the burbot aquaculture program.

Phase 2 (Developmental Post-release Pilot Study) involves annual releases of limited numbers of juvenile burbot to evaluate distribution, movements, habitat use, food habitats, and effective sampling methods by life stage. This 5-year phase was initiated with the first experimental release of 247 burbot during October and November of 2009. Currently, Phase 2 is nearing completion and is set to expire in 2013 with construction of the Twin Rivers Hatchery. Thirty of the fish released were 2 to 3 years old and implanted with ultrasonic transmitters. Monitoring these and future release groups will provide basic information on the biology and limiting factors for burbot under current river conditions. These pilot-study release groups also provide information regarding the suitability of hatchery-origin fish for larger-scale population rebuilding.

During this 5-year pilot study phase, the UI-ARI facility is being used to address two objectives. One objective is to rear approximately 5,000 Age-0 burbot per year for release and monitoring. Fish are released at 5 to 10 grams, which is the minimum size that can be permanently PIT-tagged with a reasonable potential for post-release survival. The second objective is to continue to develop and refine burbot culture methods and systems. Continued research on propagation methods is expected to pay future dividends in terms of increased effectiveness and reduced cost of burbot aquaculture. This production level and commitment of UI-ARI facilities and staff has reached the maximum extent of its burbot aquaculture efforts, as there are other critical research and developmental functions provided at this facility. These facility and production limitations are an important factor driving development of the proposed Tribal facility at Twin Rivers.

Phase 3 (Adaptive Experimental Evaluation) implements hatchery production and monitoring efforts to determine how well hatchery-produced burbot survive, grow, and mature in sufficient numbers to re-establish a significant population in the Kootenai system. This phase involves population-level monitoring efforts to address in-river questions and critical uncertainties. Phase 3 is distinguished from Phase 2 by the scale and intensity of production and monitoring efforts. Phase 2 involves limited research and monitoring of small-scale pilot-level releases with fish produced at the UI-ARI to provide qualitative assessments of behavior and biology of hatchery-reared fish. Phase 3 involves larger-scale, extensive quantitative monitoring using enough burbot to statistically evaluate post-release survival, growth, biological condition, and maturation. The Twin Rivers facility is needed in Phase 3 to consistently and reliably produce enough fish for a statistically robust evaluation and a phased scaling up of production to meet long-term objectives. One of the objectives of Phase 3 is to estimate key attributes such as post-release survival rates of hatchery-reared burbot with enough precision to maximize benefits of the ISMP to guide future production and to achieve program goals, objectives, and biological targets.

Phase 4 (Population Rebuilding) would implement a full-scale restoration program designed to achieve long-term population restoration goals. The proposed Twin Rivers facility is being designed to provide the flexibility to implement this phased, adaptive burbot restoration program. Hatchery systems will optimize flexibility and allow cost-effective modifications when necessary as the program unfolds. Flexibility will be enhanced by concurrent development of a joint sturgeon and burbot facility.

Based on initial modeling efforts, the program will have the capability to restore a natural reproducing, self-sustaining population if initial assumptions of key attributes and biological targets are realized (Table 2). At present, levels of aquaculture production needed for restoration are feasible if the Twin Rivers Hatchery is constructed. Further, early telemetry results provide survival rates of sub-adults (1-3 years old) used to derive outcomes of this modeling. However, the program has yet to determine if larval survival, 6-month old juvenile survival, and natural recruitment assumptions are feasible; future M&E activities will help define these important program attributes. The average number of burbot released to date during phases 1 and 2, and the number anticipated to be released annually at each life stage are also shown in Table 2.

Table 2. Past, current, and expected outcomes for each phase of the burbot conservation aquaculture program.

	Outcomes	Phase 1 2004-2008	Phase 2 2009-2013	Phase 3 2014-2018	Phase 4 2019 - Beyond
Hatchery	Average egg take	Feasibility	(353,000 – 4,500,000)	6 million	6 million
	Average larval release	Feasibility	(12,355 – 350,000)	TBD	TBD
	Average 6-mo. juvenile release	Feasibility	(247 – 20,183)	20,000 – 100,000	Up to 125,000
	Average Age-1+ release	Feasibility	50 - 100	TBD	TBD
In-river	Average annual Ages 1-3 abundance	Feasibility	6,000 (starting 2012)	32,000	63,000
	Average annual mature adults Ages 4 - 10+	Feasibility	~200	~8,000	17,500
Harvest	Idaho	None	None	None	TBD
	British Columbia	None	None	None	TBD

Note: Future estimates are based upon Age-0 6-month juvenile releases and no contribution from natural recruitment.

2.2 Program Objectives

Conservation and management of a naturally producing, self-sustaining burbot population is the primary long-term goal of this program. This goal initially requires the combined implementation of hatchery production and habitat restoration measures, both currently implemented by the Tribe and other collaborating agencies and entities. The proposed Twin Rivers Hatchery will be an integral program component contributing to a population that can once again support harvest at levels consistent with conservation of the species in the Kootenai River.

Program objectives for burbot restoration include the following:

- The interim goal is to produce and stock burbot at rates and frequencies to sustain a *minimum* population of 2,500 - 9,500 adults in the Kootenai River and South Arm of Kootenay Lake (KTOI 2010). This range includes the minimum population goal listed in the BCS and is the minimum abundance also suggested by Paragamian and Hansen (2008; 2011). This interim goal is a starting point to restore a population that once numbered in the tens to hundreds of thousands (Ahrens and Korman 2002; KVRI 2005).

- The long-term goal is to produce and stock burbot at rates and frequencies to sustain a *minimum* population of 17,500 adults in the Kootenai River and South Arm of Kootenay Lake (Paragamian and Hansen 2008; 2011).

- In conjunction with re-establishing adult abundance, the long-term goal is also to restore consistent natural recruitment in at least *three different spawning areas* that results in a juvenile population of sufficient size to support the adult burbot population goal. Initial results from sub-adult burbot telemetry indicate that hatchery-reared burbot are likely contributing to natural spawning, and therefore this is a reasonable goal (Neufeld et al. 2011a; Stephenson and Neufeld 2012).

3 In-Season Management and Annual Review

3.1 Annual Project Review

Following the recommendation of the KVRI BCS, an APR will be conducted through a workshop sponsored by the Tribe. This workshop will take place prior to making decisions about annual goals for broodstock management, gamete collection, aquaculture production, hatchery release strategies, harvest, and M&E activities. All cooperating agencies and stakeholders will be urged to participate. The purpose of the APR is to implement the four-step ISMP described in Section 3.3 with all stakeholders present to support information sharing, informed decision-making, and management to meet conservation objectives.

The agenda for the APR workshop will follow the steps outlined in the ISMP. The APR is a science-driven process that will result in an annual action plan that will be completed at the workshop. The APR participants will include appointed representatives from the cooperating agencies involved in this project. The workshop and completed action plan constitute the coordinated implementation component of the program.

The APR workshop will be conducted annually in January. At present, a workshop in January allows enough time to complete the previous year's M&E results for use in planning the upcoming year, while arriving at goals for broodstock and gamete collection before the main spawning period, which occurs in February. A facilitator selected by the Tribe will guide the workshop in order to address four fundamental questions:

1. Given the information provided, what are the best estimates for the key assumptions (see ISMP Step 1, Section 3.3.1)?

2. Do the Decision Guidelines need to be changed (see ISMP Step 3, Section 3.3.3)?

3. What are the biological targets for the coming year (see ISMP Step 4, Section 3.3.4)?

4. How can the M&E plan be improved in the coming year?

The first part of the workshop will be devoted to presentations of results from M&E activities related to the key assumptions for the Tribal hatchery program (see ISMP Step 1, Section 3.3.1). There will be sessions covering the following topics: 1) hatchery operations, 2) post-release survival and distribution, 3) habitat, 4) spawning and natural recruitment, and 5) harvest, if and when a fishery may be supported. Prior to the workshop, the Tribe will coordinate with cooperating agencies to ensure the most up-to-date information for each of these subjects will be presented and discussed. The ISMP tool will also be populated with the most recent data and analytical results used to update status and trends (see ISMP Step 2, Section 3.3.2).

In the second part of the workshop, the working group, which consists of policy and technical personnel, will meet to review the implications that conclusions from part one may have on the Decision Guidelines (see ISMP Step 3, Section 3.3.3). Participants will review and confirm conclusions and alternative modifications to the Decision Guidelines (see ISMP Step 3, Section 3.3.3) and finalize a set of biological targets for the upcoming year (see ISMP Step 4, Section 3.3.4). The purpose of the Decision Guidelines is to assure that the long-term goals established in the KVRI BCS, the Tribe's Hatchery Master Plan, and this M&E Plan are met over time. The product of the second part will be an updated action plan for the coming year.

The final step will be a review of parts 1 and 2 to ensure a consensus among the agencies and stakeholders has been reached. Each agency actively implementing the M&E Plan will review how the workshop will guide their respective hatchery and/or field M&E activities/research during the upcoming year. After the workshop, the facilitator will provide a draft summary to all workshop participants, incorporating findings, conclusions and final decisions for review. Workshop participants will confirm (and if necessary correct) the workshop summary and the facilitator will produce and distribute a final workshop record. A final annual report will then be completed and distributed by Tribal staff. The ISMP database, management tools, Decision Guidelines and other associated products will be retained along with the workshop summary for reference in subsequent APR workshops.

The current Burbot Technical Working Group will continue to communicate routinely throughout the year to coordinate logistics of program activities and reporting requirements.

3.2 Basis of the M&E Plan

Considerable uncertainty remains regarding future natural production of Kootenai River burbot following decades of habitat loss, natural recruitment failure, and several unsuccessful attempts to modify hydropower operations to reverse the trend. Although habitat restoration activities are expected to increase overall ecosystem productivity, habitat diversity, and fish abundance, specifically when and to what extent these investments will contribute to these outcomes remains somewhat uncertain. The annually updated M&E Plan for Kootenai burbot, which incorporates the APR and ISMP processes, will track program outcomes and guide future implementation.

Activities in this M&E Plan are prioritized based on three criteria:

1. Variables and metrics are needed to implement the four-step ISMP, and will impact management decisions;

2. Variables and metrics are likely to vary from year to year, with uncertainty about the "true" values; and

3. Variables and metrics can be monitored precisely enough to determine whether performance parameters are being achieved.

Variable, metrics, and M&E activities, along with the ISMP process, are presented and described in subsequent sections of this M&E Plan.

This M&E Plan provides a framework for open input and participation by all cooperating agencies and a structured process by which agreements can be reached to provide the most efficient implementation and evaluation of population restoration efforts. The ISMP will provide the cooperating agencies and entities with the necessary adaptive management framework. The program goals directly affected by and relevant to the ISMP are: 1) to ultimately restore and maintain a naturally-spawning, self-sustaining burbot population in the Kootenai River, and 2) to provide future harvest opportunities for tribal and non-tribal fishers.

3.3 In-Season Management Procedure and Goals

The goal of the ISMP is to provide a structured decision-making framework that will guide hatchery operations, identify M&E needs, and support effective agency cooperation and communication consistent with the guidelines established each year. The Kootenai Tribe will implement the four-step ISMP (Figure 1) in cooperation with management agencies, research institutes, and stakeholders (as appropriate). The ISMP procedure is formalized in database(s) and a set of management tools, as well as through the APR to assure consistency and accountability. The database will store and document data and assumptions, while management tools will use predictive models and Excel spreadsheets to arrive at outcomes from which decision guidelines and biological targets may be derived. The tools document the basis for these targets and establish expectations for all performance indicators. They also will help simplify the implementation process and document the rationale for recommended annual restoration actions. The Tribe's biologist responsible for implementing in-season management will use these tools to prepare for the APR workshop, where analytical results will be presented and shared with all interested parties. The management tools used in the ISMP will be further refined over time through implementation of the ISMP and APR processes as new information is obtained and analyzed.

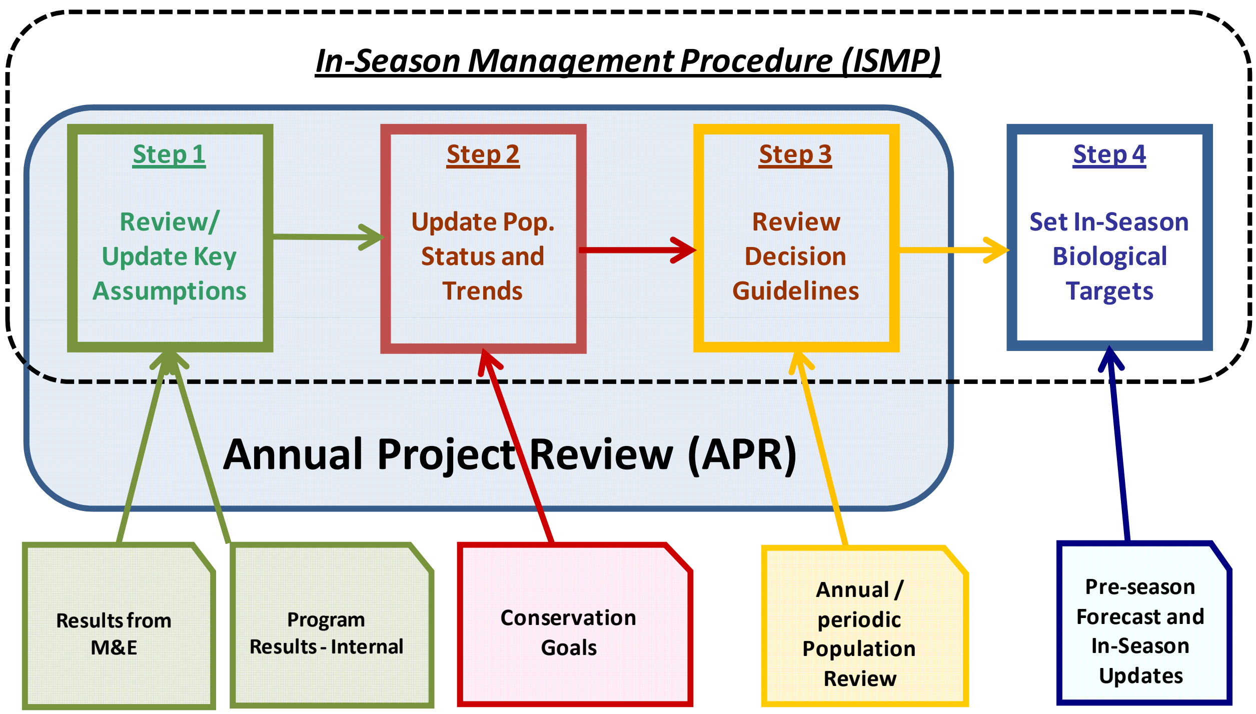


Figure 1. In-Season Management Procedure (ISMP) framework for the Kootenai River Burbot M&E Plan.

Due to inherent uncertainty and expected annual variability in abundance of natural-origin adult burbot returns, the hatchery program is designed for flexible production and operations. This flexibility is reflected in the design and operation of the hatchery facilities and in the Decision Guidelines that will determine the annual hatchery production in balance with the natural population component (Table 6).

3.3.1 Step 1 - Update Key Assumptions

The annual ISMP will integrate newly acquired data and analyses to update a set of key assumptions. Table 3 in Section 5.1 identifies the current and initial estimated future values for each of these parameters in each operational phase. The highlighted column indicates the phase that starts with anticipated start-up of Twin Rivers Hatchery.

3.3.2 Step 2 - Update Stock Status Information

In this step, the most recent stock status information will be entered into the database for both the hatchery and natural components of the population. The initial predictive tool focuses on hatchery production and survival of hatchery-reared burbot. Upon observation of natural recruitment, this tool will be modified to integrate the contribution of natural recruitment to the population. This step will occur at the APR workshop.

3.3.3 Step 3 - Review Decision Guidelines

Once the key assumptions and stock status have been updated, a review of the Decision Guidelines (see Table 6) will be conducted to determine if they need alteration. This adaptive management step will occur at the APR workshop. Although not expected to change frequently, the Decision Guidelines may need to be periodically altered to account for 1) changes in conservation goals in the United States and Canada, 2) unequal goal achievement across the project area, 3) Libby Dam operations/habitat related issues, 4) new scientific discoveries, or 5) other changes in management or environmental conditions in the subbasin or the region.

The purpose of the Decision Guidelines is to assure that hatchery programs and fisheries meet the guidelines for abundance, composition, and distribution to restore and maintain a natural spawning stock. The ultimate goal of the Decision Guidelines is to establish a naturally-reproducing population with a distribution similar to historical records. The Decision Guidelines are based on a set of key assumptions about our capability to accurately detect and respond to the annual abundance of hatchery and natural-origin spawners. This M&E Plan identifies the information needed to update and apply these guidelines and describes how data will be collected to derive this information. The Tribe expects to meet resource goals over time as a result of appropriate in-season management actions.

3.3.4 Step 4- Set Biological Target for the Coming Year

With updated stock status, the data can be used to set biological targets (broodstock needs, release strategy, etc.) for the coming year (see Section 5). The adult-abundance prediction will be updated at the APR. All updates will be entered into modeling and analysis tools (Table 5). The tool(s) then generate expected outcomes that are used to set hatchery production and biological targets for the program, and evaluate progress towards achieving program objectives.

4 DATA COLLECTION

The following metrics are necessary to populate the ISMP spreadsheets to calculate population status and trends, determine biological targets, and evaluate efficacy of Decision Guidelines governing the program. These metrics are essential to assessing the values of the key assumptions and to evaluating the Decision Guidelines. Section 5 defines the initial values for each of the key assumptions (Table 3).

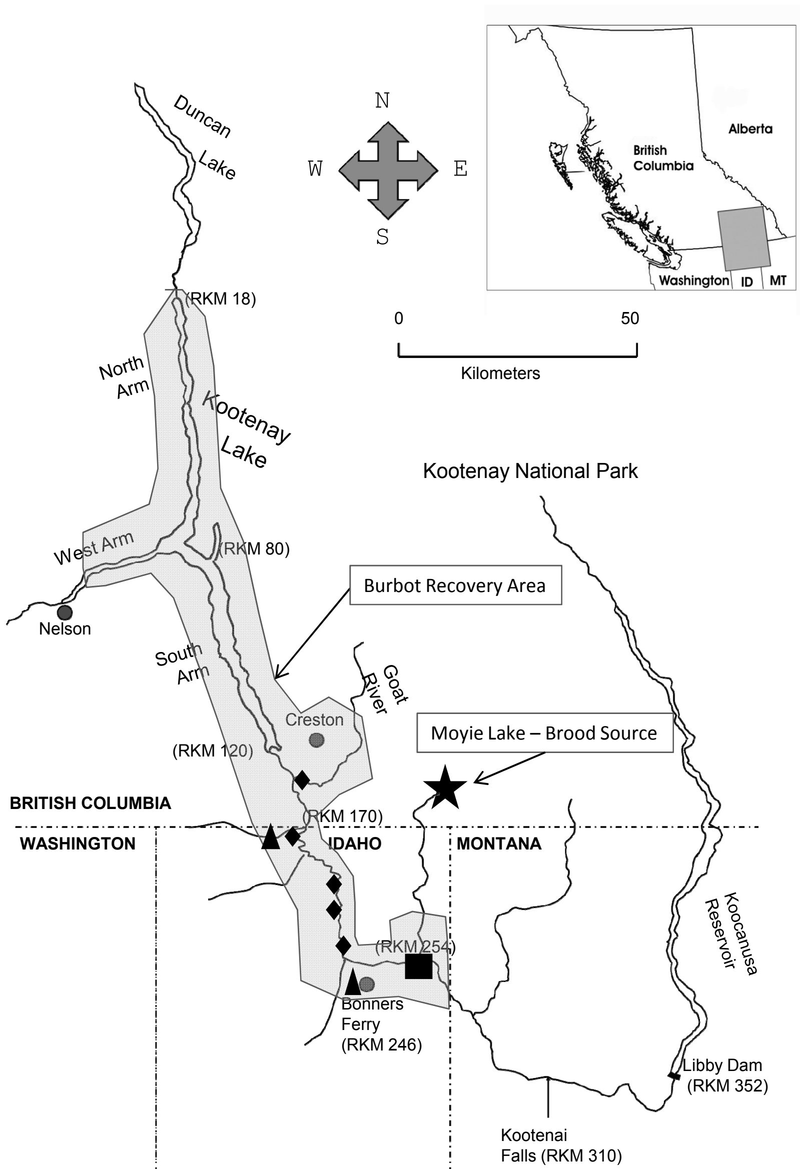
Program data collection is presented under the following headings:

- Metrics Monitored – Donor Source Population
- Metrics Monitored – Aquaculture
- Metrics Monitored – Tagging
- Metrics Monitored – Sub-adults
- Metrics Monitored – Mature Adults
- Metrics Monitored – Spawning / Natural Recruitment
- Metrics Monitored – Habitat
- Existing Kootenai River Monitoring Activities

4.1 METRICS MONITORED - DONOR SOURCE POPULATION

The primary objective for broodstock M&E is to estimate the number of spawning adults that may be available annually for use in the hatchery program without negative consequences to the natural-origin donor population. Currently, Moyie Lake, British Columbia (BC) provides all broodstock and gametes for hatchery production. Future production may use natural-origin progeny from hatchery-reared burbot collected from areas of the Kootenai River and Kootenay Lake where natural recruitment has been restored (Figure 2).

Ongoing monitoring of the Moyie Lake adult burbot population will continue to ensure over-harvest does not occur and that a viable and genetically diverse source remains available to the program. Burbot genetic analyses, population abundance estimates, location of Moyie Lake within the Kootenay River drainage, and recent behavior studies from experimental conservation aquaculture releases all indicate that Moyie Lake is a suitable brood source for reintroduction into the Kootenai River (Figure 2; Powell et al. 2008; Neufeld 2008; Neufeld et al. 2011a and 2011c).



Note: Black star denotes current broodstock collection site. Black square denotes future site of Twin Rivers Hatchery, and the current hatchery-reared burbot release site upriver of Bonners Ferry. Black diamonds denote other current hatchery-reared burbot release sites. Black triangles denote current extensive, natural pond rearing sites.

Figure 2. Location of the Kootenai River burbot recovery area.

Because of the need for the long-term use of Moyie Lake burbot as a broodstock source for recovery efforts, there was a need to evaluate population size and other biological indicators (Prince 2007; Neufeld 2008 and 2010; Neufeld and Spence 2009), the feasibility of capturing broodstock (Neufeld 2008 and 2010; Neufeld and Spence 2009) and the ability to collect and fertilize eggs from natural-origin spawners (Neufeld et al. 2011c). The success of these previous projects implemented since 2007 ultimately led to the first experimental releases of juvenile hatchery fish in the Kootenay River in 2009 (Jensen et al. 2010; Neufeld et al. 2011a and 2011b). Data from these first experimental hatchery releases identified initial survival, movements, and habitat use; high initial survival and dispersal from release locations will likely be suitable for ultimate recovery (Neufeld et al. 2011a).

Each February, Moyie Lake spawning adults are captured via angling, gametes are collected, eggs are fertilized on site, and the fertilized eggs are transported to Tribal facilities and/or UI-ARI for incubation and rearing following methods similar to those detailed in Neufeld et al. (2011c), recognizing that continued method refinements are expected in the future. Also, broodstock will be collected from the Moyie Lake adult burbot population to use as a captive brood source when required (based on facility capacity, breeding requirements and natural-origin population size), following trapping methods outlined in Neufeld and Spence (2004a) and Neufeld (2008). Once the lower Kootenai River adult population is deemed sufficient to support aquaculture objectives, efforts will transition to incorporate these Kootenai River burbot in order to take advantage of their genetic and phenotypic characteristics that allowed survival within the recipient environment. If progeny reared from Moyie Lake adults do not survive and/or reproduce in the lower Kootenai River / Lake, alternative donor populations will be considered.

During sampling efforts at Moyie Lake, all previously untagged adult burbot will be tagged, contributing to the mark-recapture sample used for annual population estimates (Neufeld 2008, Schwarz 2011). The ongoing nature of this work and history of the project will allow enough marked fish for preliminary population abundance estimates in the first year of the Phase 3 of the program (2013). However, there are several critical uncertainties surrounding these preliminary population estimates. A recent statistical review of the program (Schwarz 2011) identified key uncertainties that can be evaluated in the first 3 years of the study. Addressing these key uncertainties entails a telemetry component to evaluate mixing between basins and spawning sites, double tagging (Floy and PIT-tags) to evaluate tag loss, and spawning site tag mixing surveys (visual surveys and telemetry).

Participating agencies and other entities

- BC Ministry
- Kootenai Tribe of Idaho
- University of Idaho Aquaculture Research Institute
- Idaho Department of Fish and Game

Broodstock monitoring and evaluation objectives

- Provide mature adult burbot and fertilized eggs for conservation aquaculture operations;
- Describe donor stock population trends - age, growth, distribution and survival;
- Produce annual donor stock population estimates using mark-recapture;
- Use population indices and mortality factors to determine level of broodstock collection which still allows for successful recruitment and maintenance of fisheries on these systems; and
- Determine the location and general habitat characteristics of burbot spawning locations, and timing of spawning.

Broodstock monitoring and evaluation activities

- Annual fall trapping to provide captive broodstock and provide individuals for sonic tagging;
- Annual winter sampling to provide fertilized eggs for aquaculture operations, mark-recapture sample for population estimation;
- Telemetry system deployment, data collection and analysis (2013-2015); and
- Data analysis, annual reports, and ongoing communications with Technical Working Group.

BPA project(s)

- KTOI “Kootenai River Native Fish Conservation Aquaculture Program”- 198806400

Metrics to be monitored

- Adult abundance
- Mortality
- Growth and condition
- Fecundity and sperm motility
- Behavior and distribution

Variables estimated

- Donor source = Moyie Lake (Continual viability of donor population?)
- Broodstock survival percent (natural-origin)
- Number of broodstock used (Can donor population support aquaculture goals?)

- Number of fertilized eggs (Are female fecundity and male sperm motility adequate and accurately characterized to estimate annual hatchery production?)

ISMP purpose: Will be used to update ISMP Steps 1 – 3.

4.1.1 Methods

Angling will be used to collect spawning adults for on-site gamete collection as described by Neufeld et al. (2011c). Hoop nets may also be used to capture adult burbot for captive broodstock to be held at the hatchery. During sampling for gamete collection, adults will be tagged for mark-recapture population estimates. Telemetry will provide age-specific information on burbot distribution, behavior, and mortality.

4.1.1.1 Mark-Recapture / Population Estimate

During sampling, all previously untagged adult burbot will be tagged with both PIT and floy tags (PIT-tags KRRFM - PIT Tagging (ID: 998)), contributing to the mark-recapture sample used for annual population abundance estimates.

4.1.1.2 Population Structure

During sampling, all burbot will be tagged with an individual identification (PIT tags KRRFM - PIT Tagging (ID: 998)). Weight, length, and sex will be recorded for each burbot captured regardless of whether the individual is used in the aquaculture program.

4.1.1.3 Telemetry / Behavior

Telemetry studies will be conducted to determine mixing between the south and north basins of Moyie Lake as well as mixing of spawners between spawning sites. Spawning site selection and spawning behavior will also be evaluated. Technology used will be similar to other Kootenai River burbot telemetry projects (KRRFM - Sonic telemetry [ID: 996]).

4.2 Metrics Monitored – Aquaculture

Conservation aquaculture for burbot is a critical component for the recovery of this species within the Kootenai River subbasin of Idaho and British Columbia. The quality of the fish produced at hatchery facilities depends largely on the fish husbandry protocols used in hatchery operations. Thus, all rearing phases of the hatchery program will be monitored using best-management practices outlined in a hatchery operations manual that is being developed by UI-ARI and the Tribe. The hatchery will be operated to maximize survival at all life stages by implementing the most current fish health and disease prevention techniques.

In addition to producing adequate numbers of burbot to restore the population, research components will be maintained at Twin Rivers, while future research at the UI-ARI will continue to focus on refinement and improvement of burbot culture methods and applied reproductive biology. Specifically, efforts will focus on addressing ways to improve larval survival and transition to commercial feeds. Also, future research will evaluate the potential to enhance culture using constructed extensive/semi-intensive ponds. The Tribe, UI-ARI, and others have worked closely to develop burbot biocriteria and facility needs for the Twin Rivers Hatchery. This collaboration will continue as the Twin Rivers facility is constructed, and burbot culture methods are adapted and refined at the new facility.

Participating agencies and other entities

- Kootenai Tribe of Idaho – Twin Rivers Hatchery operation
- University of Idaho – Aquaculture Research Institute – Experimental / research
- Idaho Department of Fish and Game – Pond rearing

Aquaculture research, monitoring and evaluation objectives

- Optimize burbot culture in terms of quantity and quality.

Aquaculture research activities

- Conduct laboratory studies to evaluate and define dietary needs of larvae and juveniles.
- Conduct laboratory studies to optimize feeding rates and rearing densities.
- Conduct laboratory studies to evaluate the role of gut flora to enhance health and survival of intensively reared larval burbot.
- Conduct studies to determine capacity for enhanced rearing of burbot in extensive/semi-intensive ponds at the Twin River's facility through replicated trials.
- Produce larvae to compare hatchery rearing, natural pond rearing, net pen rearing.
- Produce sentinel adults for telemetry studies to determine dispersal, survival, habitat selection, and spawning by hatchery-reared burbot.

Aquaculture monitoring and evaluation activities

- Monitor survival across all life stages in hatchery.
- Identify causes of mortality and factors limiting growth and develop solutions these limitations.
- Monitor growth of fry, juveniles, and sub-adults.
- Kootenai Tribe "Kootenai River Native Fish Conservation Aquaculture Program" 198806400.

Metrics to be monitored during hatchery production

- Survival across all life stages
- Growth / Condition
- Density

Variables estimated

- Broodstock survival in hatchery
- Number of fertilized eggs
- Percent hatch success
- Percent larval survival
- Percent Young-of-Year (YOY) survival (in-hatchery)
- Percent Age-1 survival (in-hatchery)

ISMP purpose: Will be used to update ISMP Steps 1 – 3.

4.2.1 Methods

Each of the metrics listed below will be measured at the beginning and end of the life stage as deemed prudent. Mortality will be recorded daily and reported by hatchery staff in the annual hatchery report. A summary of all hatchery operations and data collection to be conducted as part of hatchery operations will be presented in the Program's Operations and Maintenance Manual (KTOI, in preparation).

- Survival across life stages
- Growth
- Feeding / Diet / Bioenergetics
- Density / Cannibalism

4.3 Tagging

Use of appropriate tags and tagging methods that do not compromise survival will be essential. Cost-effective batch marks are needed to determine fish origin (hatchery vs. natural). Long-term retention of tags with individual identification that do not compromise survival is also of paramount importance to future M&E efforts. Currently, UI-ARI in collaboration with the IDFG, is developing a genetically-based origin assignment technique based upon collecting genetic information from broodstock and then matching progeny back to parents used in the hatchery program. This will allow determination of fish origin (hatchery vs. natural) without additional tagging requirements. The UI-ARI has also evaluated the use of extended (up to one year) VIE tags (Northwest Marine Technology, Shaw Island, WA), which are currently being used to tag individuals too small for other tags. Color-coded VIE tags enable recaptured individuals to be identified by year class and release site. The UI-ARI has also evaluated surgical implantation of PIT-tags (Destron Fearing, St. Paul, MN) for long-term monitoring of individuals, providing survival, growth, and behavioral data. More important, PIT-tags enable evaluation of release strategies by comparing survival, growth, and reproduction, between and among release locations and seasons. Finally, to date, Age-1, -2 and -3 burbot have been successfully implanted with sonic transmitters (Vemco, Amirix Systems Inc., Halifax, Nova Scotia) and released into the Kootenai River, providing information about survival and dispersal. The combination of using appropriate tagging methods and employing appropriate field sampling techniques is an essential component of evaluating recovery strategies.

Participating agencies and other entities

- Kootenai Tribe of Idaho
- University of Idaho – Aquaculture Research Institute
- Idaho Department of Fish and Game
- BC Ministry

Tagging research, monitoring, and evaluation objectives

- Develop a genetic-based tagging program.
- Continue evaluation of batch marking techniques for different life stages to accommodate large-scale hatchery production and evaluation of stocking strategy.
- Determine best tagging methods that provide individual identification with the least negative effects on survival, growth, and reproduction.

Tagging research, monitoring, and evaluation activities

- Develop and implement a genetic based tagging program.
- Conduct laboratory studies evaluating tag retention, survival, and growth at different life stages.
- Evaluate artificial batch markers (VIE).
- Evaluate artificial marking techniques for individual identification (PIT-tag).
- Evaluate genetic markers for origin identification and genetic diversity assessments.
- KTOI “Kootenai River Native Fish Conservation Aquaculture Program”-198806400.
- IDFG “Kootenai River Resident Fish Mitigation”- 198806500.

Metrics to be monitored for tagging studies

- Post-tagging survival
- Post-tagging behavior
- Post-tagging growth / condition
- Tag retention

Variables estimated

None; however, this tagging research is an integral part of the program. Without proper tagging techniques, values for numerous parameters will be difficult to estimate with precision.

ISMP purpose: Without proper tagging techniques, much of the information needed in ISMP Steps 1 – 3 will not be available.

4.3.1 Methods

4.3.1.1 Batch Markers – Artificial

Studies will determine retention and negative effects of VIE tags on juvenile and sub-adult burbot.

4.3.1.2 Individual ID

KRRFM – PIT-Tagging (ID: 998)

4.3.1.3 Genetic Based Tagging

Collect tissue samples from all broodstock and a sub-sample of their progeny, and then determine accuracy of parental assignment via genetic techniques. This will allow differentiation between hatchery- and natural-origin burbot without an artificial tag.

KRRFM - Parental based tagging (ID: 1008)

4.4 Metrics Monitored – Sub-Adult Releases

Restoration of a functionally extinct or extirpated sub-population of fish evolves over time. Progress is predicated by initial survival of hatchery-reared or translocated individuals followed by assessing adaptation to the environment that results in reproduction and recruitment. Currently, hatchery-reared burbot provide research subjects to evaluate distribution, movements, habitat use, food habitats, and to determine effective sampling methods for the different life stages. UI-ARI production and tagging studies will be coupled with IDFG and BC Ministry population-level research and field monitoring of initial survival, growth, and maturation. Telemetry, fixed PIT-tag arrays and year-round sampling with multiple gears will initially provide survival, growth, and behavioral data, and then also recruitment data when natural spawning occurs. KTOI will provide field support if requested, and will participate in data analysis and restoration strategy development. Experimental releases of burbot of various sizes will identify life stage limitations and provide information necessary to guide habitat restoration efforts. Survival, growth, and maturation estimates will provide the needed quantitative basis to estimate the appropriate scale of production and release strategies to meet long-term population restoration objectives.

Evaluating reintroduction strategies is another major program objective for burbot. Release sites for hatchery-reared burbot in the Kootenai River extend from the mouth of the Moyie

River at river kilometer (RKM) 260 downriver to the Goat River (RKM 155). The eight release sites currently used were selected based on current and historical distribution and the likelihood that these habitats will optimize survival (Figure 2). Other sites may be used if studies indicate they are necessary to meet objectives. As larval and juvenile production expands, the number of sites will expand to include Kootenay Lake and several additional tributaries.

Participating agencies and other entities

- Idaho Department of Fish and Game
- Idaho Cooperative Fish and Wildlife Research Unit (ID-CFWRU)
- BC Ministry
- Kootenai Tribe of Idaho

Post-release monitoring and evaluation activities

- IDFG - Early life stages of burbot sampling and gear efficacy study using Herzog (Missouri) trawls, electrofishing, and small-mesh traps --- collaboration with the Idaho Cooperative Fish and Wildlife Research Unit (ID-CFWRU; Dr. Michael C. Quist).
- IDFG - Tributary spawning, rearing, habitat selection, and emigration of burbot by using fixed and mobile PIT-tag arrays --- collaboration with the Idaho Cooperative Fish and Wildlife Research Unit (ID-CFWRU; Dr. Michael C. Quist).
- BC Ministry and IDFG - Telemetry of age 1- to 3-year-old hatchery-reared burbot.

Sub-adult monitoring and evaluation objectives

- Survival
- Growth / Bioenergetics
- Ecology
    - Habitat selection by life stage
    - Diet by life stage
- Kootenai Tribe “Kootenai River Native Fish Conservation Aquaculture Program” 198806400
- IDFG “Kootenai River Resident Fish Mitigation” 198806500

Metrics to be monitored for sub-adult burbot (in-river)

- Annual survival
- Growth / Condition
- Bioenergetics

- Density
- Behavior – dispersal and habitat selection

Variables estimated

- Percent Age-0 survival in-river
- Percent Age-1 survival in-river
- Percent Age-2 survival in-river
- Percent Age-3 survival in-river

ISMP purpose: Will be used to update ISMP Steps 1 – 3.

4.4.1 Methods

4.4.1.1 Release Success

Larval, juvenile, and sub-adult burbot are currently stocked at six mainstem locations and in four tributaries. Release sites may expand to include multiple locations in Kootenay Lake.

- Site 1 KR - Mouth of Moyie River (RKM 260)
- Site 2 KR – Mouth of Deep Creek (RKM 240)
- Site 3 KR – Shorty's Island (RKM 230)
- Site 4 KR – Ferry Island (RKM 205)
- Site 5 KR – Mouth of Boundary Creek (RKM 170)
- Site 6 KR – Mouth of Goat River (RKM 130)
- Site 7 Boundary Creek, ID
- Site 8 Deep Creek, ID
- Site 9 Goat River, BC
- Site 10 Corn Creek, ID

Survival and growth will be compared to determine optimal mainstem and tributary stocking locations. All hatchery-origin burbot will be identified as such by genetic parental based tagging. A portion of hatchery-reared burbot will also be released at each site with an individually identifiable tag that will provide recapture data in a non-lethal manner.

4.4.1.2. Telemetry

Telemetry methods are well developed (Neufeld et al. 2011a) and will be used to tag and track hatchery sub-adults after release (for up to 4 years post-release; Neufeld et al. 2011a) as well as to tag hatchery and natural-origin adults captured after release in the wild to further evaluate response to habitat actions (Paragamian et al. 2005, Paragamian and Wakkinen 2008). An array of receivers was developed in 2004, with funding from BPA, USFWS, and other partners, to cover the entire Kootenai watershed from Kootenay Falls in Montana and downstream through Idaho and BC, including all of Kootenay Lake in BC. Forty Vemco VR2 sonic receivers are currently deployed in Kootenay Lake and River in BC with an additional 41 in the Kootenai River in Idaho and Montana; additional receivers will be deployed into the release tributaries in 2012. Following methods outlined in Neufeld and Rust (2009), receivers in Kootenay Lake are deployed both in lines crossing the width of the lake (gate or curtain system) to record movements past a chosen point, and individually to record fish near a specific location of interest. In the river, individual receivers are deployed at single monitoring locations because the range of a single receiver is great enough to cover the river width and thus create a gate or curtain system. The distance between gates in Kootenay Lake (9-11 km) is greater than in the Kootenai River (0.6-12 km). Development of this telemetry array initially focused on evaluating juvenile dispersal from hatchery release sites as part of conservation aquaculture monitoring and refinement (Neufeld and Rust 2009). However, the utility and cost saving provided by this array for monitoring adult sturgeon and burbot quickly became apparent and current BPA-funded telemetry projects for many species in the Kootenai now rely on this array (e.g., Neufeld and Rust 2009; Neufeld et al. 2011a).

KRRFM – PIT-tagging (ID: 998)
KRRFM - Sonic telemetry (ID: 996)

4.4.1.3. Sampling Gear

Hoop traps of various aperture and mesh sizes along with Herzog (Missouri) trawls, electrofishing, and other small-mesh traps will be used to capture juvenile and sub-adult burbot. Gear efficiency across seasons and time of day will be tested. Traps will be fished un-baited and baited with kokanee (*Oncorhynchus nerka*) spawner carcasses placed in marquisette bait bags. Trap locations will be recorded with a Global Positioning System receiver and depths by means of a recreational grade depth sounder. Captured burbot will be pulled from trapping depth following decompression procedures described in Neufeld and Spence (2004a). Upon retrieval, burbot will be placed in a plastic container filled with water. All burbot will be measured and searched for tags. Any untagged fish will be given a uniquely identifiable PIT-tag. Fish that meet criteria for surgical implantation of telemetry devices will be placed back into the trap and held until experienced personal implant the telemetry device. These fish will subsequently be tagged and released. Also, a fin-clip for DNA will be taken from all recaptured burbot.

KRRFM - Burbot adult and juvenile sampling (ID: 997)
KRRFM - Burbot sampling efficiency graduate research (ID: 1290)
KRRFM – PIT-tagging (ID: 998)

4.4.1.4. Tributary Use / Fixed PIT-Tag Arrays

Tributary spawning, rearing, habitat selection, and emigration of burbot will be evaluated by using fixed and mobile PIT-tag arrays and sonic telemetry.

KRRFM – PIT-tagging (ID: 998)
KRRFM - Sonic telemetry (ID: 996)

4.5 Metrics Monitored – Mature Adults

Data collected by field M&E of hatchery-reared and natural-origin burbot adults will be a critical component to evaluate program success. As discussed in Section 4.4 (sub-adults), hatchery-reared burbot are being released at eight different locations across a 130 km segment of the Kootenai River in Idaho and BC. Currently this includes four tributaries, Moyie River, Deep Creek, Boundary Creek and Goat River. Boundary Creek historically supported burbot spawning, and Goat River is believed to be the last spawning habitat for the remnant stock in the Lower Kootenai subbasin.

All parties involved in this endeavor are in agreement that the natural-origin stock in the recovery area is now functionally extinct; however, a very small remnant still exists. A very limited amount of natural reproduction may still be occurring in the Goat River, BC, and a few other historical spawning areas such as Ambush Rock (RKM 244.5) on the Kootenai River.

Participating agencies and other entities

- Idaho Department of Fish and Game
- Idaho Cooperative Fish and Wildlife Research Unit (ID-CFWRU)
- BC Ministry
- Kootenai Tribe of Idaho

Adult monitoring and evaluation objectives

- Quantify hatchery-reared, naturally-reared from hatchery-origin, and remnant natural-origin stock.
- Monitor behavior of each possible component.
- Determine whether donor stock sources support recovery goals.
- Provide population assessments to determine production goals.
- Determine if the release strategy has been effective.
- Determine if natural recruitment is occurring.
- Estimate harvest.
- Set management regulations.

Adult monitoring and evaluation activities

- Calculate population estimates using mark-recapture data.
- Population abundance trends and gear efficiency based upon CPUE.
- Annual survival rates
- Spawning / recruitment
- Monitor harvest
- Using these population parameters, future population trajectories may be constructed; these may then guide hatchery production and fisheries management decisions.
- Behavioral studies that focus on habitat selection, and behavioral response to environmental changes, both negative and positive
- The KVRI Kootenai River Burbot Conservation group and the technical working group will evaluate reintroduction strategies based on data.
- Kootenai Tribe “Kootenai River Native Conservation Aquaculture Program” 198806400
- IDFG “Kootenai River Resident Fish Mitigation” 198806500.

Metrics to be monitored for adult burbot (in-river)

- Abundance
- Annual Survival
- Growth / Condition
- Bioenergetics
- Density
- Behavior – movement and habitat selection
- Harvest

Variables estimated

- Percent annual survival Ages 4 – 10
- Number of adults – in river
- Number of adults – in lake
- Natural mortality
- Fishing mortality

ISMP purpose: Will be used to update ISMP Steps 1 – 3.

4.5.1 Methods

4.5.1.1 Adult Monitoring

Adults will be captured primarily using hoop nets (IDFG and BC Ministry). All burbot will be measured, weighed, inspected for batch marks and scanned for PIT-tags to determine origin (hatchery vs. natural), year class, and release site. If not previously tagged with an individual identifier, each captured fish will receive a PIT-tag.

KRRFM - Burbot adult and juvenile sampling (ID: 997)
KRRFM - Burbot sampling efficiency graduate research (ID: 1290)
KRRFM – PIT-tagging (ID: 998)
KRRFM - Burbot demographics analysis (ID: 1022)

4.5.1.2 Telemetry

Telemetry combined with trapping and other capture techniques currently under development will be used to identify movements and habitat use of hatchery-reared and natural-origin Kootenay River burbot to assess general behavior and dam operation modifications aimed at providing suitable conditions for successful recruitment from both natural- and hatchery-origin adult burbot. These projects use Vemco hydro-acoustic technology. A hydro-phone array extends throughout Kootenay Lake upriver to the Montana border.

KRRFM - Sonic telemetry (ID: 996)
KRRFM - Burbot movement response Libby Dam operations (ID: 1046)

4.5.1.3 Mark-Recapture / Population Estimate

All previously untagged adult burbot will be tagged (PIT tags) upon capture, contributing to the mark-recapture sample used for annual population estimates.

KRRFM - Burbot demographics analysis (ID: 1022)
KRRFM - Sonic telemetry (ID: 996)
KRRFM - Burbot movement response Libby Dam operations (ID: 1046)
KRRFM - Burbot adult and juvenile sampling (ID: 997) (Proposed)
KRRFM - Burbot sampling efficiency graduate research (ID: 1290)
KRRFM – PIT-tagging (ID: 998)

4.5.1.4 Harvest

An angler reporting system or a creel survey program will be needed.

KRRFM - Burbot demographics analysis (ID: 1022)

4.6 Metrics Monitored – Spawning / Natural Recruitment

All involved parties are in agreement that the natural-origin stock in the recovery area is now functionally extinct; however, a very small remnant still exists. Some natural reproduction may still be occurring in the Goat River, BC, and a few other historical spawning areas such as Ambush Rock (RKM 244.5) on the Kootenai River.

Participating agencies and other entities

- Idaho Department of Fish and Game
- Idaho Cooperative Fish and Wildlife Research Unit (ID-CFWRU)
- BC Ministry
- Kootenai Tribe of Idaho

Spawning monitoring, and evaluation objectives

- Quantify total spawner abundance.
- Quantify contribution of hatchery-reared, naturally-reared from hatchery-origin, and remnant natural-origin stock to the spawning population.
- Monitor spawning behavior of each component.
- Determine number of spawning locations.
- Determine if natural recruitment occurs to larval and juvenile stages.

Spawning monitoring, and evaluation activities

- Spawning population estimates based upon mark-recapture data or enumeration by visual counts or at fish weirs.
- Spawning site and microhabitat selection.
- KTOI "Kootenai River Native Fish Conservation Aquaculture" 198806400.
- IDFG "Kootenai River Resident Fish Mitigation" 198806500.

Metrics to be monitored for adult burbot (in-river)

- Annual spawner abundance
- Composition of spawning population
- Sex ratio
- Fecundity and sperm motility
- Spawning site selection
- Egg fertilization

- Egg hatch
- Larval survival
- Juvenile survival

Variables estimated

- Number of spawners
- Number of spawning locations
- Number of spawners per location
- Natural egg fertilization
- Natural egg hatch
- Natural larval survival
- Natural juvenile survival
- Natural egg abundance
- Natural larval abundance
- Natural juvenile abundance

If this program successfully restores natural spawning but does not rebuild a sustainable population structure, natural-origin adults may be incorporated into hatchery broodstock program. If so, then this section would include additional "Parameters Estimated" similar to Sections 4.1 and 4.2. Further, as long as the restored population is comprised of hatchery and natural production, both will be incorporated into the predictive tools. Natural production attributes and parameters will be similar to hatchery parameters, and then both components will be analyzed separately and in total to characterize the population.

ISMP purpose: Will be used to update ISMP Steps 1 – 3.

4.6.1 Methods

4.6.1.1 Annual Spawning Counts

Hoop nets will be placed at tributary mouths and fish weirs will be implemented at selected tributaries known to historically support burbot spawning. Visual counts will be conducted during day and spotlight surveys at night by foot or by boat at historical spawning locations and at any newly discovered spawning sites.

KRRFM – PIT-tagging (ID: 998)
KRRFM - Burbot adult and juvenile sampling (ID: 997) (Proposed)

4.6.1.2 Spawner Abundance

Optimally, direct enumeration will be employed. Mark-recapture may be employed when and where direct enumeration is not possible.

KRRFM – PIT-tagging (ID: 998)

4.6.1.3 Telemetry

Telemetry combined with trapping and other capture techniques currently under development will be used to identify movements and habitat use of hatchery-reared and natural-origin Kootenay River burbot. These efforts will assess general behavior and behavioral responses to dam operation modifications aimed at providing suitable conditions for successful recruitment from both natural- and hatchery-origin adult burbot. The telemetry projects use Vemco hydro-acoustic technology. A hydro-phone array extends throughout Kootenay Lake upriver to the Montana border.

KRRFM - Sonic telemetry (ID: 996)

4.7 HABITAT

As suggested by the KVRI BCS, addressing habitat needs is critical to burbot restoration. The following passage is found in Section 8 of the BCS:

> **"2. Develop a broad-based habitat restoration program to address altered ecosystem problems that have contributed to the burbot collapse.** Burbot declines are the result of an extended period of pervasive, large-scale changes in the Kootenai River and Kootenay Lake ecosystems. Declines, in some cases were exacerbated by past harvest (e.g. West Arm burbot fishery). The changes extend from physical habitat and ecological function loss to primary and secondary system productivity, nutrient availability, and possible contaminant dynamics. Some factors such as harvest, levee construction, and hydro development are obviously implicated; population collapse resulted from the combined impacts of these multiple factors, rather than from the isolated effect of any single factor. The complex interactions of changes and their relative impacts on burbot are difficult to partition. However, effective long-term persistence and viability of a sustainable, naturally producing burbot population depends on significant conservation and restoration across the current ecosystem. Measures narrowly focused on increasing numbers of one species are likely to fail if by concentrating on the symptom, they overlook the underlying causes. Ecosystem-based approaches are given wide lip service but rarely translated into specific, scale-appropriate activities. In this Conservation Strategy an ecosystem-based approach includes a combination of mainstem habitat protection, tributary and mainstem habitat restoration, fish population protection and recovery measures, conservation aquaculture, fish community and primary productivity improvements, and pollution control. This Conservation Strategy also exists as

part of a larger context of the Kootenai River Adaptive Management Program currently being developed (Anders et al. 2004)."

BPA project(s)

- Kootenai Tribe "Kootenai River Habitat Restoration Project Monitoring and Evaluation" 200200200

Metrics monitored during ongoing ecosystem restoration efforts

- KTOI - Bank erosion monitoring (ID: 1179)
- KTOI - Browse evaluation (ID: 1184)
- KTOI - Cover type mapping (ID: 1182)
- KTOI - Disturbance observation monitoring (ID: 1186)
- KTOI - Floodplain and channel morphology surveys (ID: 1178)
- KTOI - Floodplain herbaceous vegetation composition and cover (ID: 1310)
- KTOI - Floodplain substrate survey: volumetric bar samples (ID: 1180)
- KTOI - Floodplain woody vegetation composition and percent cover (ID: 1183)
- KTOI - Floodplain woody vegetation natural recruitment and regeneration (ID: 1311)
- KTOI - Greenline photo monitoring (ID: 1187)
- KTOI - Groundwater data collection (ID: 1214)
- KTOI - Mainstem stage data collection (ID: 1215)
- KTOI – Percent cover woody vegetation on streambanks (ID: 1312)
- KTOI - Side channel fish assemblage and population study (ID: 1212)
- KTOI - Structure monitoring (ID: 1181)
- KTOI - Substrate survey: underwater videography (ID: 1306)
- KTOI - Survival monitoring (ID: 1308)
- KTOI - Suspended sediment sampling (ID: 1213)
- KTOI - Model development and calibration (ID: 1216)

Variables estimated

None at this time; however, each of the above-listed metrics may directly affect many of the parameters and the associated values. As relationships become apparent, correlations and predictive models may be used to evaluate assumptions and Decision Guidelines for the burbot program.

ISMP purpose: Ongoing monitoring and restoration activities will be used to update and evaluate ISMP Steps 1 – 3.

4.8 EXISTING MONITORING IN THE KOOTENAI RIVER

All parties are in agreement that the natural-origin stock in the recovery area is now functionally extinct. In order to restore a viable population, hatchery-reared burbot from the Moyie Lake donor source, and eventually Kootenai River naturally produced burbot, must adapt to the current altered state of the Kootenai River and Kootenay Lake that has been implicated in the population's decline. Habitat restoration, nutrient addition, and river flow and temperature management are expected to provide an adequate environment that supports survival, growth, sexual maturation, and spawning by hatchery-reared individuals. Then ultimately, natural recruitment may be sustained.

IDFG has been conducting burbot population surveys since 1979 (Partridge 1983), long before functional extirpation occurred. As habitat change appears to have been the main cause for the decline of burbot and other species, the Tribe and IDFG have jointly managed the Kootenai Basin Biological Monitoring and Evaluation Program, assessing the health of the Kootenai system. Also, there are multiple habitat restoration projects within the project area that are expected to benefit burbot restoration efforts. Previously, IDFG investigated the effects of an altered hydrograph and thermograph on burbot behavior; it is likely this topic will be further addressed during restoration of a viable population.

BPA projects

- Kootenai Tribe "Kootenai River Ecosystem Restoration" 199404900
- IDFG "Kootenai River Resident Fish Mitigation" 198806500

Metrics monitored during ongoing ecosystem restoration efforts

- KRRFM- Nutrient dosing BMP (ID: 1103)
- KTOI - Benthic macroinvertebrate sampling
- KTOI - Nutrient addition of N and P (ID: 1175)
- KTOI - Periphyton accrual and biomass sampling (ID: 1107)
- KTOI - Periphyton taxonomic community/density sampling (ID: 1114)
- KTOI - Water chemistry (ID: 1123)
- KRRFM- Fish biomonitoring data (ID: 1007)
- KTOI - Benthic macroinvertebrate analysis (ID: 1137)
- KTOI - Periphyton accrual and biomass sample analysis (ID: 1118)
- KTOI - Periphyton taxonomic community/density analysis (ID: 1117)

- KTOI - Water chemistry analysis (ID: 1136)

Variables estimated

None at this time; however, each of the above-listed metrics will directly affect many of the parameters and the associated values. As relationships become apparent, correlations and predictive models may be used to evaluate key assumptions and Decision Guidelines of the program.

ISMP purpose: Ongoing monitoring and restoration activities will be used to update and evaluate ISMP Steps 1 – 3.

5 METRIC ESTIMATES & HYPOTHESIS TESTING

In general, the purpose of the ISMP is to guide the restoration of the burbot population. More specifically, the ISMP will aid in the transition from experimental phases to population rebuilding phases as the Twin Rivers Hatchery comes on line. Further, the ISMP will be valuable for the working group to adapt M&E results to phasing a hatchery-reared population into a naturally-reproducing population.

This section identifies and defines the variables and metrics used in the four-step ISMP and how they will be used. In Step 1, the key assumption parameters are used to predict how the population will respond to future management actions. In Step 2, the status and trend analysis, outcomes based on empirical data are assembled, the current status of the population is established, and progress toward population goals is analyzed (Section 5.2). From the predicted outcomes, the Decision Guidelines will be annually reviewed in Step 3, although they may not change. The Decision Guidelines set the management controls so that if the key assumptions are accurate, the biological targets set in Step 4 for the population may be met.

At each step in this process the working group will describe any and all analytical results and changes to parameter values and record them in the ISMP database. At the end of the season, this information will be compiled in an annual report developed prior to the APR.

A key element of this plan is that all assumptions and parameters will be reviewed and challenged each year to assure the most current and reliable information is used in the decision-making process.

5.1 KEY ASSUMPTIONS (ISMP STEP 1)

The key assumptions are a set of parameters that relate to future expectations (i.e., the basis for predictions about what will happen). Generally, these assumptions are based on current culture techniques, recent findings, and strategy goals. These form the basis for in-season and long-term restoration decisions. The parameters are grouped into four categories: 1) hatchery production, 2) natural production, 3) reproduction, and 4) harvest parameters. Each is described below and listed in Table 3.

Table 3. Initial key assumptions for hatchery-reared and natural-origin components of a restored burbot population.

	Variable Name	Phase 1 2004-2008	Phase 2 2009-2013	Phase 3 2014-2018	Phase 4 2019 +
Donor	Broodstock Donor Source	Variable	Moyie Lake	Moyie Lake	Moyie Lake and/or Kootenai R.
	Broodstock Percent Survival (field)	90	90	90	90
Hatchery	Broodstock Percent Survival (in hatchery)	50 - 100	50 - 100	80 - 100	80 - 100
	No. of Broodstock (females:males)	Variable	9 – 20: 18 - 40	30 : 60	30 : 60
	No. of Families (1 female:2 male = 2 families)	Variable	18 - 36	60	60
	Fertilized Eggs (Mean fecundity = 200,000 eggs / kg body weight)	Variable	3.0 – 5.0 million	6 million	6 million
	Percent Hatch	Variable	50 - 70	50 - 70	50 - 70
	Percent Larval Survival	Variable	20 (2012)	20	20
	Percent Fry Survival	Variable	25	25	25
	Percent YOY Juveniles (Age 0 - 6 months) Survival	Variable	20 – 30	20 – 30	20 – 30
	Percent Age-1 Survival in Hatchery	Variable	50 – 90	50 – 90	50 – 90
Natural (in-river)	Percent Egg to 6 Months Survival	-	unknown	unknown	unknown
	Percent Age-6 mo. to Age 1 (assumed)	-	20 - 35	20 - 35	20 - 35
	Percent Age-1+ Survival in Wild	-	40 - 70	40 - 70	40 - 70
	Percent Ages 2 – 10+ Annual Survival	-	40 - 70	40 - 70	40 - 70
	Minimum Number of Adults	-	-	2,500	17,500
	Number of Spawning Areas	-	-	≥ 3	≥ 3
	Number of Spawners per Spawning Area	-	-	TBD	TBD
	Natural Mortality (percent)	-	30 - 60	30 - 60	20 - 50
Harvest	Fishing Mortality (percent)	-	0	0	TBD

5.1.1 In-Hatchery Assumptions

In-hatchery operations will incorporate detailed record keeping and tracking of mortality at each stage from broodstock collection through release. It is important to note that the number of fish collected for broodstock will vary from year to year based on the annually determined biological targets.

The size of the program is measured in terms of broodstock (number and composition), number of families produced, and release numbers.

In-hatchery parameters to be monitored are:

Donor stock

- **Definition**: The population from which broodstock and/or gametes are collected.
- **Assumed Value**: Moyie Lake

Broodstock survival

- **Definition**: Percentage of fish used for broodstock surviving one year post-spawn.
- **Assumed Value**: 90%

Number of females: number of males

- **Definition:** Ratio of females to males used for broodstock.
- **Assumed Value**: 1:2 (30:60)

Number of families

- **Definition:** A cross of one female with one male. On average, each female will be crossed with two males, but individually. Thus, each female should produce two distinct families.
- **Assumed Value**: 60 (Twin Rivers Hatchery)

Eggs/female (fecundity)

- **Definition**: Average number of eggs per female spawned.
- **Assumed Value**: 200,000 (200,000 eggs per kg body weight; mean weight per female = 2.0 kg).

Number of fertilized eggs

- **Definition**: Total number of eggs successfully fertilized as determined under microscope.
- **Assumed Value**: 6,000,000 (Twin Rivers Hatchery)

Percent hatch

- **Definition**: Percentage of fertilized eggs that successfully incubate and hatch.
- **Assumed Value**: 50 - 70%

Percent larval survival

- **Definition**: Percentage of fish that survive from hatch until fry stage.
- **Assumed Value**: 20%

Percent YOY survival (to 6 months in-hatchery)

- **Definition**: Percentage of fish that survive from end of larval stage to 6 month juvenile.
- **Assumed Value**: 20 – 30%

Percent Age-1 survival (in-hatchery)

- **Definition**: Percentage of fish that survive from 6 months to 12 months.
- **Assumed Value**: 50 - 90%

5.1.2 Natural Production and In-river Survival for Hatchery-reared Burbot

Data on annual survival rates of burbot in the Kootenai system are available for adults, but not for juveniles. Adult survival of 40 to 70% was derived from historical data. Pyper et al. (2004) estimated an annual natural survival rate of the remnant Kootenai River population at 37%. This unsustainably low survival rate resembles that of over-exploited populations; however, the population experiences no harvest and densities are so low that illegal harvest is not suspected. This low survival rate may be explained by delayed mortality from past trapping efforts (B. Pyper, Cramer Fish Sciences, pers. comm., 2006). Ahrens and Korman (2002) estimated an annual natural survival of adults in the failed Kootenay Lake burbot population at 71%. More recently, Stephenson and Neufeld (2012) reported 63% survival 1-year post-release of transmittered 2- and 3 year-old, hatchery-reared, sentinel sub-adults. These estimates bracket the range of alternatives identified in Table 5.

Experience with other species and general fish population dynamics suggests that survival rates of hatchery-reared fish released at earlier life stages will be lower during the first year at large as released fish adapt to natural conditions. For planning purposes, we assumed the first year survival rate for Age-0 juveniles will be half the annual survival of 2- and 3-year-old sub-adults and adults. Thus, annual survival of hatchery-reared and natural-origin juveniles is assumed to be 20 to 35%. Annual survival for sub-adults (Ages 1-3) and adults (Ages 4+) is assumed to be similar based upon studies discussed in the previous paragraph.

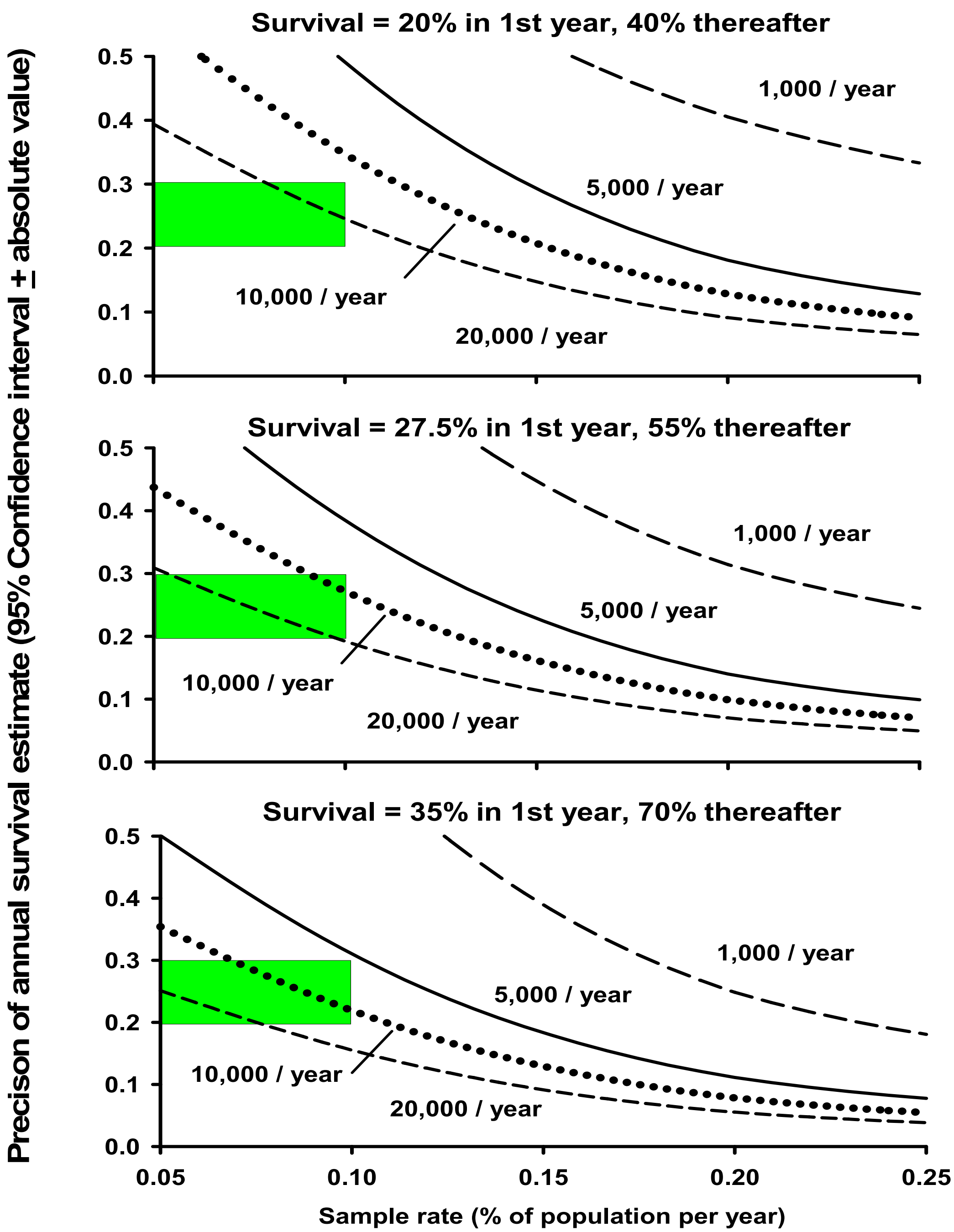
Population levels are extremely sensitive to moderate differences in annual survival. For instance, increases in annual survival from 40 to 70% result in a substantial difference in projected adult numbers from any given hatchery release level (Table 4).

Phase 2 annual experimental production targets of 10,000 to 20,000 Age-0 burbot are consistent with a statistical power analysis of the numbers required to provide reasonable estimates of precision (±20-30%) on estimates of annual survival at sampling (capture rates; 5-10%). Statistical power curves (Figure 3) illustrate tradeoffs between release number and sampling rate at three survival scenarios. This example is based on a simple Cormack-Jolly-Seber mark-recapture model formulation that is consistent with the annual mark-recapture sampling design of the monitoring program. Even moderately precise estimates of survival or trends in survival will require either large release numbers or large sample rates (large numbers of recaptured fish). Release numbers and/or sample rates would need to be increased substantially at lower survival rates in order to provide comparable levels of statistical precision. Release numbers and sampling effort will be adjusted adaptively as data are collected to provide the desired precision to evaluate this program.

Table 4 illustrates that UI-ARI production capabilities may be adequate to meet the very minimum conservation abundance objectives (2,500) under only the most optimistic of assumptions. This underscores the need for the Twin Rivers Hatchery in order to implement program expansion to rebuild and sustain a viable population. Although the historical size of the South Arm and Kootenai River burbot population is unknown, we believe that the minimum conservation abundance objectives at current and planned Phase 3 release levels are substantially less than the historical habitat capacity. Thus, the proposed phased approach protects from indiscriminate, large-scale hatchery production, and allows the program to grow adaptively as necessary.

Table 4. Sensitivity of burbot population size to production numbers and survival rates based on example release numbers of 2,000, 5,000, 10,000 and 20,000 Age-0 burbot.

Age	40% Annual Survival (20% survival age-0+, 40% thereafter)				55% Annual Survival (27.5% survival age-0+, 55% thereafter)				70% Annual Survival (35% survival age-0+, 70% thereafter)			
Rel no.	2,000	5,000	10,000	20,000	2,000	5,000	10,000	20,000	2,000	5,000	10,000	20,000
1	400	1000	2,000	4,000	550	1,375	2,750	5,500	700	1,750	3,500	7,000
2	160	400	800	1,600	303	756	1,513	3,025	490	1,225	2,450	4,900
3	64	160	320	640	166	416	832	1,664	343	858	1715	3430
4	266	64	128	256	92	229	458	915	240	600	1201	2401
5	10	26	51	102	50	126	252	503	168	420	840	1681
6	4	10	20	41	28	69	138	277	118	274	588	1176
7	2	4	8	16	15	38	76	152	82	206	412	824
8	1	2	3	7	8	21	42	84	58	144	288	576
9	0	1	1	3	5	12	23	46	40	101	202	404
10	0	0	1	1	3	6	13	25	28	71	141	282
11	0	0	0	0	1	3	7	14	20	49	99	198
12	0	0	0	0	1	2	4	8	14	35	49	138
13	0	0	0	0	0	1	2	4	10	24	48	98
14	0	0	0	0	0	1	1	2	7	17	34	68
15	0	0	0	0	0	0	1	1	5	12	24	47
Adults	**17**	**43**	**85**	**171**	**112**	**279**	**558**	**1117**	**549**	**1373**	**2746**	**5492**



Note: Estimated using a simple Cormack-Jolly-Seber mark-recapture model (6-year sampling interval). Confidence intervals are approximated based on two times the standard error of the estimate. The shaded box shows target precision and sampling rates

Figure 3. Power analysis of the effects of annual release number and sampling rate on 95% confidence intervals for survival under three different survival assumptions.

The only suitable population abundance reference point available is from historical harvests of West Arm Kootenay Lake recreational fisheries. Peak harvest levels, assumed to represent a minimum bound on a population estimate, occurred in 1969 with the harvest of 25,930 adult burbot in the West Arm fishery (Ahrens and Korman 2002; KVRI 2005). At an average size of approximately 70 centimeters (cm) and an average weight of 1.83 kilograms (kg), this catch translates into a total biomass of 47,400 kg of burbot. The projected adult biomass of proposed Kootenai releases of 10,000 to 20,000 burbot per year ranges from 100 to 9,000 kg at annual survival rates of 40-70% (Figure 4). Numbers and biomass of the proposed South Arm/Kootenai River burbot population produced currently and in Phase 3 do not exceed those of the extinct West Arm population. Although we don't know how the historical West and South Arm populations compared, this example clearly demonstrates that portions of the Kootenai system could produce very large numbers of burbot; thus, hatchery production should not exceed historical carrying capacity.

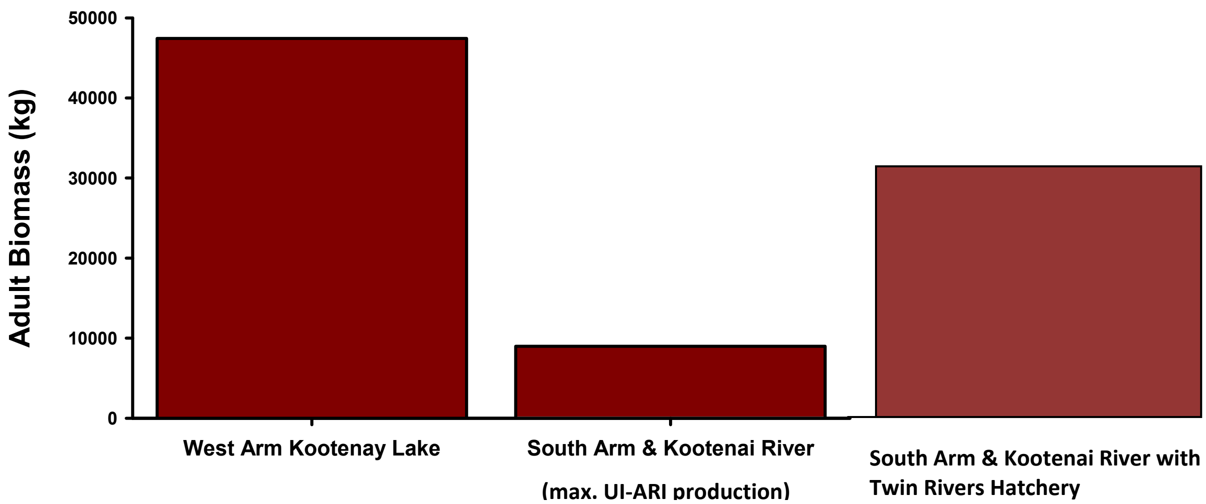


Figure 4. **Comparison of minimum estimates of population biomass in the West Arm Kootenay Lake burbot population with maximum estimates of potential population biomass of the hatchery-produced burbot population in the South Arm and Kootenai River burbot population.**

The Twin Rivers Hatchery is designed to provide the flexibility to scale up production in Phase 4 to a level of restoration closer to historical natural abundance. Twin Rivers Hatchery will also allow increased production of Age-0+ and Age-1+ burbot, providing flexibility in release strategies. Current release strategies are predicated on survival of Age-0+ juveniles. If post-release juvenile survival is poor, then a transition to releases of Age-1+ sub-adults may be needed for successful restoration. The UI-ARI facility simply cannot meet these challenges.

In-river parameters to be monitored are:

Fertilized egg to 6-month-old juvenile

- **Definition:** Survival from egg to 6-month-old juvenile.
- **Assumed Value**: Unknown

Percent Age-0+6-month-old to Age 1 survival (in-river)

- **Definition:** Survival during from 6 -12 month juvenile stage.
- **Assumed Value**: 20 – 35%

Percent Age-1+ survival (in-river)

- **Definition:** Survival during 12 - 24 months sub-adult stage.
- **Assumed Value**: 40 -70%

Percent Ages 2-10+ survival (in-river)

- **Definition:** Annual survival during 2 – 10 years old
- **Assumed Value**: 40 -70%

5.1.3 Natural Spawning

Number of spawners

- **Definition:** Total number of sexually mature adults per year.
- **Assumed Value**: 100% of adults 4+ years old.

Spawning area

- **Definition:** Any area where spawning behavior is observed. This would entail observation or capture of congregating sexually mature adults.
- **Assumed Value**: At least (1) congregation of mature adults.

Number of adults per spawning area

- **Definition:** Number of sexually mature adults estimated to spawn in a common area.
- **Assumed Value**: 100% of adults estimated in a common area or tributary from mid-January to mid-March.

Spawner per recruit ratio

- **Definition**: Number of F1 progeny surviving to reproductive status per P1 spawning adult.
- **Assumed Value**: 1:2 (spawner to recruit). This ratio is assumed to allow rebuilding and sustaining a natural population in the presence of fluctuating annual mortality and harvest.

Natural mortality

- **Definition**: Percent of population that dies within a given year due to natural causes.
- **Assumed Value**: 30 – 60%

5.1.4 Harvest

Fishing mortality

- **Definition**: Percent of adult population that dies from fishing in a given year.
- **Assumed Value**: TBD

5.2 STATUS AND TRENDS (ISMP STEP 2)

Status and trends represent actual outcomes (i.e., looking back at what happened). This information will be collected and reported annually and incorporated into the historical record of outcomes. These outcomes will be re-analyzed each year as part of the APR that will evaluate key assumptions and parameter estimates. It will also be used to evaluate performance of the ISMP (e.g., Did we meet the biological targets? Were these targets correct?). This information will also be shared with the public and other management entities as part of the accountability responsibility. The attributes involved in status and trend monitoring are arranged into four categories: 1) hatchery production, 2) natural production, 3) reproduction and 4) harvest.

An example of the ISMP predictive hatchery production data is shown in Table 5. This example lists initial parameters and currently known values that result in production of 6-month-old juveniles expected to meet program goals. These data were used to design and scale the burbot program at Twin Rivers Hatchery.

.

Table 5. Example ISMP predictive annual hatchery production tool for Kootenai River burbot using empirical life stage-specific survival rates for aquaculture.

1 Family		Survival Rate - Hatchery			
Life Stage	Numbers	Hatch	Larvae	Fry	Age-0 Juv
Eggs	100,000	0.6			
Hatched Larvae	60,000		0.2		
Feeding Larvae	12,000			0.25	
Fry	3,000				0.7
6-mo Juveniles	2,100				

60 Families		Survival Rate - Hatchery			
Life Stage	Numbers	Hatch	Larvae	Fry	Age-0 Juv
Eggs	6,000,000	0.6			
Hatched Larvae	3,600,000		0.2		
Feeding Larvae	720,000			0.25	
Fry	180,000				0.7
6-mo Juveniles[a]	126,000				

[a] Current releases consist mainly of larvae and 6-month old juveniles. This strategy is anticipated for the future.

(1) Year Class		Survival Rate – In-river			
Life Stage	Numbers	Age 1	Age 2	Age 3	Age 4 -10+
6-mo. Juveniles	126,000	0.275			
Age 1+	34,650		0.5		
Age 2+	17,325			0.63	
Age 3+	10,915				0.63
Age 4+	6,876				0.63
Age 5+	4,332				0.63
Age 6+	2,729				0.63
Age 7+	1,719				0.63
Age 8+	1,083				0.63
Age 9+	682				0.63
Age 10+	430				
Total Ages 4 - 10	17,851				

5.3 REVIEW DECISION GUIDELINES (ISMP STEP 3)

All available data will be used to update key assumptions (Step 1) as well as population status and trends (Step 2) before each APR. From this, cooperating agencies must decide whether to proceed with current Decision Guidelines or make adjustments to better address program goals. Moving forward, the cooperating agencies will determine biological targets for the coming year. These biological targets will determine annual hatchery production, harvest, and any needed adjustments to M&E activities. Table 6 displays the initial program Decision Guidelines for each phase.

Table 6. Initial KRNFCAP - Burbot Decision Guidelines for the phases of the program. Twin Rivers is expected to start production in Phase 3 (shaded).

Metrics	Phase 1 2004-2008	Phase 2 2009-2013	Phase 3 2014-2018	Phase 4 2019 +
Donor Source	Moyie Lake	Moyie Lake	Moyie Lake	Moyie Lake
Percent Broodstock from Donor Source	100	100	50-100	0-100
Percent KR Natural-origin Broodstock	0	0	0-50	0-100
Families Produced	-	Up to 36	Up to 60	Up to 60
Larvae Released	-	0 – 350,000	TBD	TBD
Age-0+ 6 mo.-old Juveniles Released	-	5,000 - 20,000	20,000 - 100,000	Up to 125,000
Age-1 Released	-	100 - 500	TBD	TBD
Minimum Number Mature Adults (Ages 4+)	-	-	2,500	17,500
Minimum Number of Spawning Areas	-	-	3	3
Natural Recruitment	-	Possible	Probable	Significant
Harvest				
Fishing Mortality	-	0	0	TBD

5.4 IN-SEASON MANAGEMENT TOWARD BIOLOGICAL TARGETS (ISMP STEP 4)

This information will be determined at the APR. Currently, in-season management takes place once per quarter, typically via teleconference. Most in-season management decisions currently involve hatchery production updates and determination of release strategy. This will change as needed, as the program evolves and as burbot are restored to the system.

5.4.1 Hatchery Production

All hatchery fish will be marked via an artificial tag or via a genetic based parental assignment. Thus, any hatchery-produced fish may be properly assigned to origin and year class. This will allow for determination of program success. Hatchery production targets are as follows:

Donor stock

- **Definition**: The population from which broodstock and/or gametes are collected
- B**iological Target**: Any stock that successfully adapts to the Kootenai River. Ideally, donor stock would be genetically similar or closely related.

Broodstock survival

- **Definition**: Percentage of fish used for broodstock surviving one year post-spawn
- **Biological Target**: 90%

Number of females: number of males

- **Definition:** Ratio of females to males used for broodstock
- **Biological Target**: 30 : 60 (various sizes and ages)

Number of families

- **Definition:** A cross of one female with one male. On average, each female will be crossed with two males, but individually. Thus, each female should produce two distinct families.
- **Biological Target**: 60 (Twin Rivers Hatchery)

Egg take/female (fecundity)

- **Definition**: Average number of eggs per female spawned
- **Biological Target**: 200,000 (200,000 eggs per kg body weight; mean weight per female = 2.0 kg)

Number of fertilized eggs

- **Definition**: Total number of eggs successfully fertilized as determined under microscope
- **Biological Target**: 6,000,000 (Twin Rivers Hatchery)

Hatch

- **Definition**: Percentage of fertilized eggs that successfully incubate and hatch
- **Biological Target**: 3.6 million

Larvae

- **Definition**: Percentage of fish that survive from hatch until fry stage
- **Biological Target**: 720,000

Fry

- **Definition**: Percentage of fish that survive from post- larval metamorphosis to 3-4 months
- **Biological Target**: 180,000

Young-of-Year (YOY) (to 6 months in-hatchery). The current release strategy is based on stocking 6-month-old juveniles.

- **Definition**: Percentage of fish that survive from end of larval stage to 6-month juvenile
- **Biological Target**: 65,000 – 126,000

Age-1 (in-hatchery). Age-1 in-hatchery production should be at the lower levels presented here to minimize density.

- **Definition**: Percentage of fish that survive from 6 months to 12 months
- **Biological Target**: 45,000 – 113,000

5.4.2 Natural Production

Each year, a full accounting of the in-river population will be obtained through stock reconstruction. The biological targets listed below will be estimated each year. Tracking performance of the in-river population and the hatchery- and natural-origin components over time is a primary objective of this monitoring plan.

Fertilized egg to 6-month-old juvenile

- **Definition:** Survival from egg to 6-month-old juvenile
- **Biological Target**: TBD

Age-0+ 6-month-old to Age-1 survival (in-river)

- **Definition:** Survival during from 6 -12 months juvenile stage
- **Assumed Value**: TBD

Ages-1 - 3 (in-river)

- **Definition:** Annual survival during sub-adult stage
- **Biological Target**: TBD

Percent Ages-4 - 10+ (in-river)

- **Definition:** Annual survival during 4 to 10 years old
- **Biological Target** (interim): Minimum 2,500 – 9,000

5.4.3 Natural Spawning

Number of spawners

- **Definition:** Total number of sexually mature adults per year
- **Biological Target** (interim): 2,500

Spawning area

- **Definition:** Any area where spawning behavior is observed. This would entail observation or capture of congregating sexually mature adults.
- **Biological Target**: ≥ 3

Number of adults per spawning area

- **Definition:** Number of sexually mature adults estimated to spawn in a common area
- **Biological Target**: TBD (likely distributed as smaller groups among a particular river and/or lake reach)

Spawner per recruit ratio

- **Definition**: Number of F1 progeny surviving to reproductive status per P1 spawning adult
- **Biological Target**: 1:2 (spawner to recruit). This ratio is assumed to allow rebuilding and sustaining a natural population in the presence of fluctuating annual mortality and harvest.

Natural mortality

- **Definition**: Percent of population that dies within a given year due to natural causes
- **Biological Target**: < 30%

5.4.4 Harvest

Fishing mortality

- **Definition**: Percent of population that dies from fishing in a given year
- **Biological Target**: TBD

6 Adaptive Management

Although no formal adaptive management (AM) plan has currently been prepared for the Kootenai River burbot program, annual reviews of critical variables and metrics as part of the ISMP and APR processes described in previous sections of this M&E Plan provide a solid AM foundation for the burbot culture components of the program. These features will ensure annual review and will appropriately adjust release numbers and modify culture techniques in response to annually updated age-specific survival rates, ages at first maturity for males and females, and spawning frequency or periodicity values for burbot in the Kootenai River. This M&E Plan also provides an array of abundance trajectories based on a range of post-release survival rates, and addresses the precision of mortality estimates as a function of sampling intensity (Figure 3).

The burbot program also includes a phased approach (Table 1), which ensures that the program cannot go forward without quantitative confirmation of suitable success measures. Furthermore, Phase 3 of the burbot program (the Adaptive Experimental Evaluation Phase) implements hatchery production and monitoring activities to determine how well hatchery produced burbot survive, grow, and mature, relative to the numbers needed to reestablish a future sustainable burbot population in the Kootenai River. This threshold-based, phased implementation approach also protects from indiscriminate, large-scale hatchery production, and allows the program to grow as necessary and as warranted by iterative, adaptive evaluations (by implementing program mechanisms described in this M&E Plan). Thus, this suite of direct adaptive feedback loops will continue to serve the program well, as reflected in the program's relatively short but successful history.

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Appendix D

Basis of Design Report

(Design drawings are provided under separate cover)

Kootenai Tribe of Idaho

Kootenai Hatchery Basis of Design Report

30% DESIGN

July 2012

TETRA TECH

Engineering & Architecture Services
1420 Fifth Avenue, Suite 600, Seattle, WA 98101-2357
Tel 206.883.9300 Fax 206.883.9301 www.tetratech.com

Kootenai Tribe of Idaho

KOOTENAI HATCHERY BASIS OF DESIGN REPORT

30% DESIGN

JULY 2012

Prepared for:
Kootenai Tribe of Idaho
Banners Ferry, Idaho

Prepared by:

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Project #135-3750004

Kootenai Tribe of Idaho

Kootenai Hatchery Basis of Design Report

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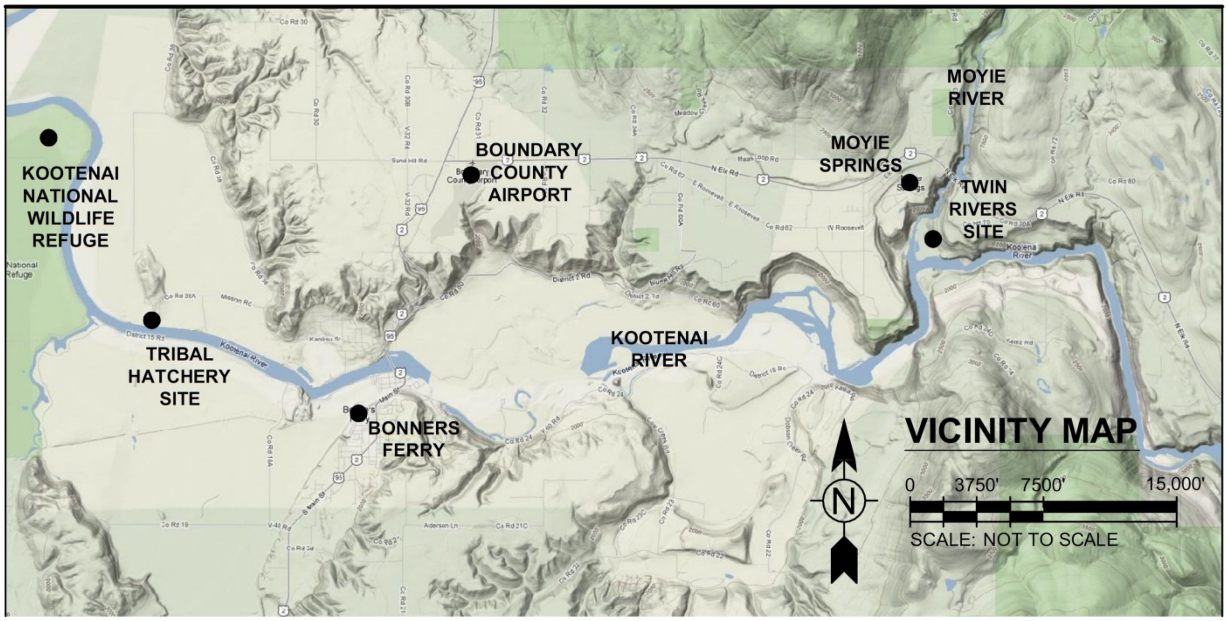

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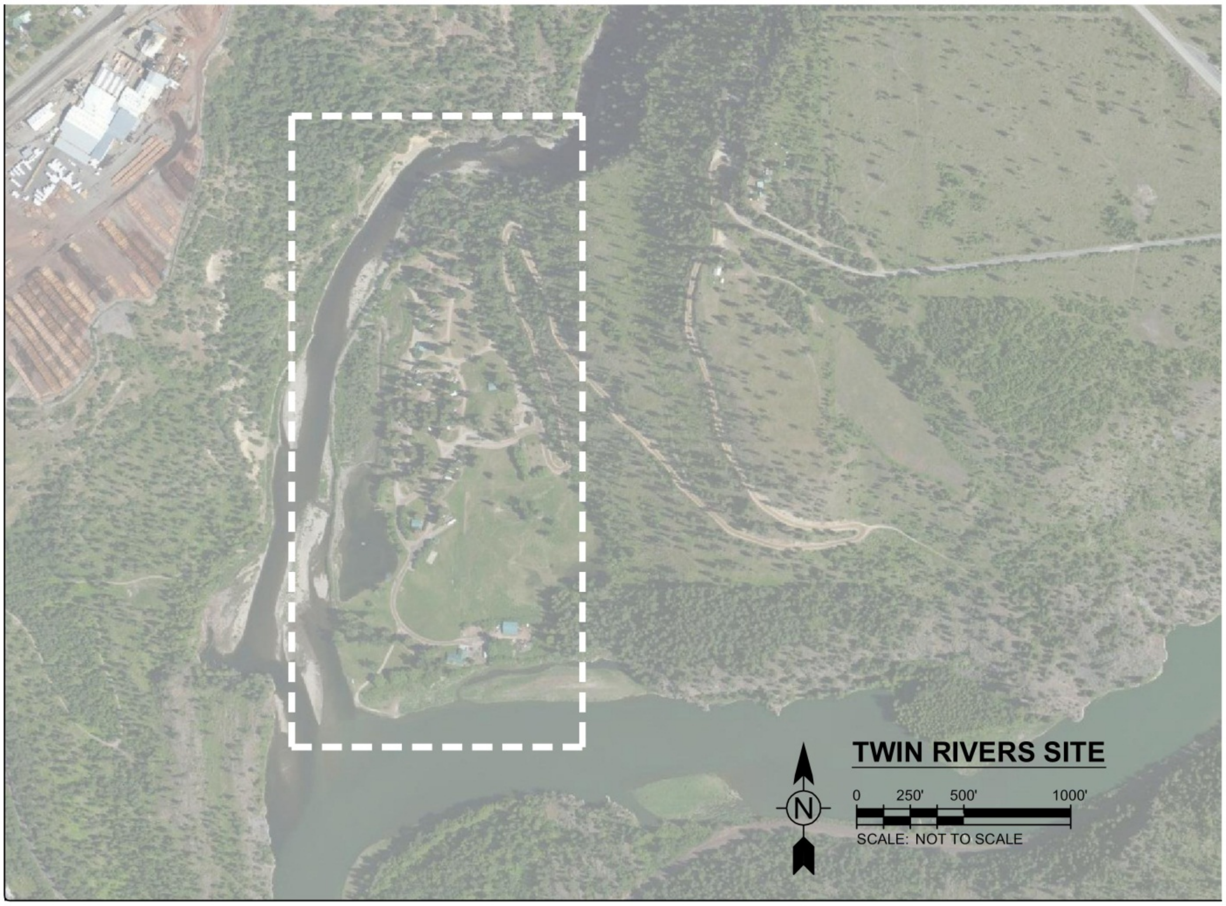

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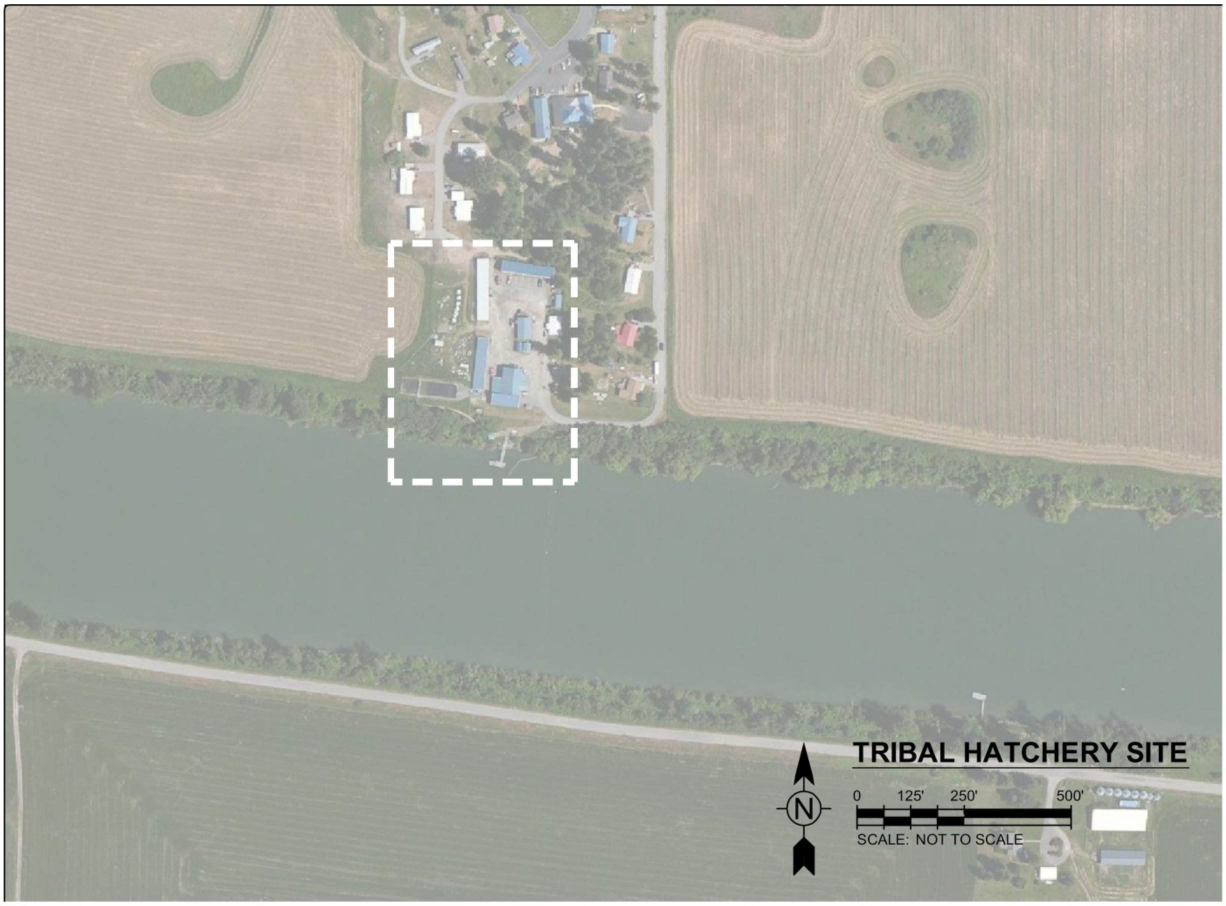
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CHAPTER 1.
PRODUCTION PROGRAMS AND WATER REQUIREMENTS

STEP TWO PLAN

As summarized in the Kootenai River Native Fish Conservation Aquaculture Program Master Plan Step 2 Document, the Northwest Power and Conservation Council (NPCC) Step-Review requirements include the development of a preliminary engineering design and estimate package to an accuracy level of ±25 to 35 percent. This project includes design and construction of a new fish hatchery on Tribal-owned land at the confluence of the Moyie and Kootenai rivers. The site proposed for the new Twin Rivers Hatchery offers high quality ground and surface water needed to support the program's aquaculture objectives for Kootenai River white sturgeon and burbot.

Proposed Twin Rivers Hatchery facilities include dual water supplies and filtration with treatment, chemical storage, boiler and chiller for temperature conditioning of process water, sand filtration, shop space, and building space rooms for electrical, communications, and mechanical equipment. Space is provided for sturgeon and burbot broodstock, incubation, juvenile rearing, dry storage (feed), and forage rooms/facilities, along with combined wet lab and necropsy operational space. Additionally, administrative/biological support facilities, and staff housing will be provided. The proposed project also includes the following modifications to the existing Tribal Sturgeon Hatchery: staff housing, conference room and additional administrative offices, multiple hatchery improvement promoting operations, safety, security and energy improvements, rearing sheds improvements, vehicle storage shed upgrades, and several site improvements.

Project actions will occur within an area known as the Twin Rivers site and at the Kootenai Tribal Hatchery. The Twin Rivers site is located at the confluence of the Moyie and Kootenai rivers near Moyie Springs, Idaho and the existing Kootenai Tribal Hatchery is located on the Kootenai Tribe of Idaho's Reservation land about two miles west of Bonners Ferry.

In developing the project scope, the following design criteria were emphasized by the Kootenai Tribe:

- Existing RV resort operations should be preserved to the greatest extent possible without compromising aquaculture functions
- All new facilities should be well above flood elevation (approximately elevation 1786 feet) to prevent water damage
- Mature trees are to be retained to the greatest extent possible
- Available groundwater should be used to provide pathogen-free rearing water
- Hatchery facilities must be secure, with controlled public access
- Sturgeon culture facilities must be relatively isolated from burbot culture facilities to minimize pathogen vectors
- Operator housing should be available on-site

PRODUCTION PROGRAMS

The production programs for both sturgeon and burbot for the two hatchery facilities present import detailed information relating production criteria and life stage are summarized in Attachments A and B.

BIOLOGICAL DESIGN CRITERIA AND WATER REQUIREMENTS

The biological design criteria and water requirement are presented in detail for both sturgeon and burbot in Attachments A and B.

CHAPTER 2.
RIVER WATER SUPPLY

River water for the new Twin Rivers Hatchery will come from two separate river sources: the Moyie River intake and the Kootenai River intake. Both of these intakes will be capable of providing all the water necessary to operate the new hatchery at full production levels. The redundancy of the intakes along with the production groundwater wells is to provide a dependable source of water for the hatchery regardless of the river conditions in either Moyie or Kootenai rivers.

DESIGN CRITERIA

Based on the bio-criteria spreadsheet developed for the Twin River Hatchery operation, the anticipated flow rate through the hatchery during full production periods will be approximately 2.9 cubic feet per second. Intake screens, pumps, valves, and pipelines will be designed to supply 3.3 cubic feet per second to the hatchery. Each of the intakes will have two complete, separate systems to provide a backup in the event one of the systems requires maintenance work.

Design of the intake structures for both the Moyie and Kootenai River intakes will meet all current state and federal design criteria for intake screens. Design criteria for the intake screens will include:

- Approach Velocity: Less than 0.4 feet per second.
- Screen Material: Corrosion resistant and durable stainless steel or aluminum.
- Opening Size: 3/32-inch circular holes or 3/32-inch diagonal for square holes or 1/16-inch slots.
- Open Area: Minimum open area of screen material equals 27 percent.
- Screen Type: Actively cleaned screen since design flow greater than 3 cubic feet per second.
- Cleaning Frequency: Every 5 minutes during high debris periods.

Juvenile fish must be able to swim away from the intake screen face when it is located in the river or inside a pump station. At the proposed Kootenai River intake, the screen will be anchored in the active river channel which will allow the fish to swim away from the screen in any direction. At the proposed Moyie River intake, an overflow bypass pipe and open channel will provide a return route back to the river.

INTAKE STRUCTURES

Due to the site conditions at the proposed Kootenai River and Moyie River water intake sites, two different types of intake structures will be designed. An exposed river screen will be installed in the Kootenai River and an enclosed screen with piped inflow will be installed on the Moyie River.

Kootenai River Intake Structure

Layout of the Kootenai River intake structure includes a concrete base with two cone screens and a pipeline to the pump station. In this section of the Kootenai River, the north bank of the channel has a very gradual slope forcing the intake structure base and screens to be located approximately 80 feet from the water's edge at low flow. This distance is needed to located the intake in at least 4 feet of water depth to maintain at least 18 inches of water above the top of the cone screen.

Two cone screens will be provided, each capable of providing the design flow rate of 3.3 cfs. The screens, which are 5-foot 6-inch diameter, and 2 feet high, will have 50 percent open area (1/16th-inch wedgewire with 1/16th-inch spaces). The approach velocity at the design flow rate is 0.12 ft/sec, 39 percent lower than the 0.2 ft/sec standard. The slot velocity is 0.246 ft/sec, 51 percent lower than the 0.5 ft/sec standard. Most of the time both screens will be in service, reducing these velocities by half.

The screens are all stainless steel construction, and are fitted with three rotating brush arms, which are driven by a hydraulic motor mounted within the screen. The hydraulic motor is equipped with a rotation sensor that will send an alarm signal to the screen control system, which is located in a Pump Control Building on the shoreline out of the flood zone. The hydraulic lines and the sensor wire will be encased within an 8-inch diameter HDPE pipe between the screens and the Pump Control Building. The hydraulic fluid is a synthetic mineral oil that is biodegradable and meets aquatic toxicity (L-50) test.

The screens for the Kootenai River intake are designed to be removable without a diver required. The screens rest on top of the intake slab, with a 16-inch diameter outlet pipe inserted into an 18-inch diameter outlet elbow encased in the slab. A lifting assembly has two 1 foot wide lifting plates that rest in 4-inch deep recesses in the support slab. The lifting assembly is guided into place with 8-inch diameter steel pipes that slide up and down on 6-inch diameter steel guide pipes bolted to the support slab. A chain extends from the top of the lifting assembly to a keeper near the platform at the base of a pile-supported, one ton capacity jib crane. The chain can be attached to the hoist, which can then be rotated directly over the screen to allow the raising of the screen for inspection or maintenance. The screen (430 lbs) can be lowered onto the floating dock, or directly into a boat adjacent to the dock.

Steel pilings on the upstream side of the base slab for the screens will support a short, reinforced section of floating dock that will help protect the intake structure from damage from floating debris in the river. The floating dock on the north side of the screens provides access to the platform at the base of the jib crane.

Conveyance of river water from the intake structure to the pump station will be through an 18-inch HDPE pipeline. Total drop in elevation of the pipeline between the intake and pump station will equal 1.0 feet with the pipe lower at the pump station than at the intake structure. The entire pipeline will be buried under the channel gravels to the edge of channel and under the floodplain terrace to the pump station.

Moyie River Intake Structure

Layout of the Moyie River intake structure includes an intake vault and trashrack, and a gravity pipeline to the combined pump station and intake screen. Due to the exposed bedrock vertical bank at the water intake location, it was determined that building the pump station and intake screens away from the intake site would be easier to build and maintain.

A hydraulic control in the Moyie River has formed at the tailout of the scour pool along the toe of the vertical bedrock bank. Based on the size of material in the bottom of the scour pool, it appears that the discharge in the river keeps the small gravel, sand and fine material cleaned out of the pool due to the turbulence created by the bedrock outcrop. This absence of small material is an ideal location for a water intake as these smaller materials will naturally be absent from the water column at this location.

Near the downstream end of the scour pool, a deep section of pool is located just downstream of a bedrock outcrop into the pool. In this deep pool section, a precast concrete vault would be installed as close to the vertical bedrock bank as possible. At the present time, fractured bedrock pieces from the slope above the river have slid into the pool and created a sloped channel edge to the bottom of the pool.

Removal of these pieces of fractured bedrock will hopefully reveal a good location to set the rectangular concrete vault.

Dimensions of the concrete vault will be 13 feet long by 6 feet wide by 11 feet high and will be positioned with the top at or near the 2-year average flood flow water level. The top of vault has grated openings for access into the intake vault for maintenance activities. On the river side of the vault, a trash rack will be installed to keep rocks and large wood material from entering the intake structure. The intake will have two sections of trash rack, each measuring 4 feet wide and 5 feet tall, for a total screen area of 40 square feet. The trash rack will have vertical 1/4-inch thick plates with 1-inch openings. Assuming a low water level and the design flowrate of 3.3 cfs, the approach velocity to the screen at the design flow rate is 0.14 ft/sec, 30 percent lower than the 0.2 ft/sec standard. The slot velocity is 0.17ft/sec, 66 percent lower than the 0.5 ft/sec standard.

The concrete vault will be fitted with a 20-inch diameter steel flanged outlet for connecting the 20-inch HDPE pipeline conveying the flow to the screens upstream of the pump station. Flow velocity in the intake pipeline at the design flowrate is approximately 1.5 ft/sec. The intake screens in the Moyie Pump Station are discussed in the following section.

PUMP STATIONS AND VALVE VAULTS

Both of the pump stations will be designed to create gravity flow from the river water source to the pump bays within each pump station. Gravity flow from the Kootenai River will be from the intake screens to the pump station, a distance of approximately 360 feet. Gravity flow from the Moyie River will be from the intake trash rack structure to a screening facility that is immediately upstream of the pump station, a distance of approximately 430 feet.

Kootenai River Pump Station

Location of the Kootenai River pump station will be near the edge of the floodplain terrace before it transitions into the upland terrace along the northern edge of the Kootenai River. This location was chosen to keep the structure above the anticipated flood levels of the Kootenai River and to hide the structure among the riparian vegetation. This area of the RV Resort is very popular and keeping the structure out of the main use areas is important.

Construction of the Kootenai River pump station will utilize a precast concrete circular vault to install the submersible pumps. The precast vault will be 12 feet in diameter and 27 feet deep. The gravity supply line from the intake structure will enter the pump station approximately 3 feet above the bottom. This places the suction intakes of the pumps at an elevation approximately 10 feet below the low water level in the Kootenai River. This will provide adequate submergence of the pump under all operating conditions for motor cooling and good hydraulic conditions for the pump.

The pumps are rail-mounted submersible solids handling pumps. Two pumps are each sized to pump the design flowrate of 1,500 gpm @ 60 ft TDH, 30 HP. A third pump is sized for more efficient operation at lower flowrates (400 gpm @ 30 ft, 5 HP). The pumps will be equipped with VFDs, located in the Pump Control Building approximately 50feet away. Pump speed will be manually adjusted to provide the desired flowrate. The pre-cast cover of the pump station has hatches for pump removal.

The pump discharge lines pass through a valve vault where check valves and isolation valves will be located. The check valves will prevent water in the pipeline to the hatchery building from reversing flow back to the wetwell when the pumps are turned off. The check valves will be equipped with a position switch that will detect a closed valve on an operating pump, and send a shut-down alarm to the pump control system. A pressure transducer will be provided upstream of the check valve. The pressure information will be used to monitor the operation and discharge rate of the submersible pumps.

After leaving the vault, the two 8-inch discharge lines from the larger pumps and the 6-inch discharge line from the smaller pump connect into a 10-inch pipeline to the influent sedimentation tank (further discussed in the section “Kootenai River pipeline”).

Moyie River Pump Station

The location of the Moyie River pump station will be on the outer edge of the dike along the edge of the river at the north end of the project site. A majority of the structure will be constructed in the bank where several campsites are presently located in the RV Resort. Only a small portion of the structure will extend beyond the edge of the dike and this will be where the pipeline from the intake vault will enter the lower portion of the pump station.

Construction of the Moyie River pump station will be completed using a cast-in-place concrete structure. Dimensions of the cast-in-place structure will be 20.5 feet long by 20.5 feet wide by 16 feet deep. Water from the intake pipeline will enter the screen bay, which contains two cone screens, and is located on the “river side” of the pump station structure. The cone screens are similar to those described for the Kootenai River intake, except these will be bolted to a concrete pad. The screen controls, including the hydraulic power unit, will be located in the Pump Control Building, located approximately 60 feet from the screen bay. The screen bay can be dewatered by shutting the sluice gate on the river intake line, and opening the 12-inch diameter drainage sluice gate at the downstream end of the screen bay.

Water that does not pass through the cone screens will overflow the screen bay via an adjustable, 1-foot 6 inches wide weir gate into a 35 square foot pool. The weir gate has an operating range of 2 feet 3 inches and can be used to regulate the amount of flow entering the screen bay. The pool is drained by a 12-inch HDPE pipeline that exits the structure approximately 2 feet above the floor of the pool. This return pipeline connects with the drain line from the screen bay, and is routed back to the Moyie River. The return pipeline to the Moyie River will meet all federal fish passage criteria for safe fish passage, in terms of flow velocity, depth, and discharge conditions.

Water that passes through the cone screens is routed to the wetwell via 16-inch diameter steel pipes embedded in the screen bay foundation slab. The configuration of the submersible pumps in the Moyie River Pump Station is similar to that described for the Kootenai Pump Station. Two large pumps (1,500 gpm @ 21 ft TDH, 15 HP) and a smaller pump (600 gpm @16 ft TDH, 5 HP). The VFDs for these pumps are located in the Pump Control Building.

Hatches are located in the concrete slab at grade level over the pumps. A one-ton capacity jib crane, mounted on the cover slab, can access the pumps as well as the screens, and load this equipment directly into the back of a truck parked over the valve vault. The screens can be access by removing a 7-foot square grated opening in the cover slab over each screen.

The discharge lines from the pump station are also configured similar to the Kootenai Pump Station, passing through a valve vault (essentially identical to the vault described for the Kootenai Pump Station), and connecting into the 10-inch Moyie River pipeline for conveyance to the influent sedimentation tank.

RIVER WATER PIPELINES

Conveyance of water from the Kootenai River and Moyie River pump stations to the influent sedimentation tank will be through 10-inch high pressure (AWWA C-900) pipe. Both river water pipelines rise gradually from the valve vaults to the discharge into the influent sedimentation tank, the

Kootenai River pipeline rising approximately 9 feet while the Moyie River pipeline will rise approximately 3 feet.

Kootenai River Pipeline

The Kootenai River pipeline will be routed from the pump station to the and influent sedimentation tank along the main access road to the southern half of the RV Resort. This location was chosen to minimize disturbance of the existing site utilities in place for the RV Resort. As the pipeline approaches the new RV Resort clubhouse, the pipeline veers off the main access road and turns north. This alignment bisects the existing pasture and is between the proposed staff housing and burbot ponds. Just past the proposed staff housing, the pipeline veers to the east and will be located on the existing access road along the eastern edge of the property at the toe of the hill slope. The pipeline follows the access road to the new influent sedimentation basin. Overall length of the pipeline between the Kootenai River pump station and influent sedimentation basin will be approximately 2,000 feet.

Moyie River Pipeline

The Moyie River pipeline will be routed from the pump station to the influent sedimentation tank along the existing main access road to the northern portion of the RV Resort. As the pipeline leaves the pump station, it will parallel the road in a southeast direction until it turns south when the road parallels the toe of the hill slope. The pipeline follows the existing access road to the new influent sedimentation basin. Overall length of the pipeline between the Moyie River pump station and influent sedimentation tank will be approximately 400 feet.

RIVER WATER TREATMENT SYSTEMS

Use of river water in the hatchery will require the removal of any sand and silt that passed through the intake screens. During a majority of the year, the amount of material in the river water pumped through the pump stations will be very low due to the natural clarity of the Kootenai and Moyie Rivers. However, during spring runoff periods and summer/fall storm runoff periods, the amount of material passing through the intake screens will be much higher.

Influent Sedimentation Tank

To remove the sand and silt that passes through the intake screens, an influent sedimentation tank will be constructed that will remove a significant amount of this material from the river water before it enters the drum filters. This increases the efficiency and lowers the backwashing necessary for the drum filters, thus lowering energy requirements for the high pressure well water used in the backwashing. The sedimentation tank will be divided into two separate settling bays, each 30 feet wide, 120 feet long, and an average depth of 5.1 feet (the floor slopes 1.5 percent to the downstream end). Having two separate sedimentation bays will allow one bay to be cleaned while the other bay remains in service. At the design flowrate of 1,500 gpm, a single bay will provide approximately 1.5 hours of detention time, and an overflow rate of 600 gpm/ft^2 (0.42 gpm/ft^2). This will remove suspended fine sand down to approximately 50 microns in size, according to water treatment industry guidelines. Weirs are placed at the influent and effluent ends of the tank to create optimum settling conditions in the tank.

At this time, it is anticipated that the sedimentation tank will provide adequate removal of sand and silt from the water column without the use of coagulant chemicals. No chemical treatment is planned in the sedimentation tank to accelerate the settling of the sand and silt particles. This will avoid altering the natural water chemistry of the river water prior to use in the hatchery. The sedimentation basins will be covered with a pre-engineered metal roof to prevent falling leaves and pine needles from landing in the tank, as well as to limit algae growth and water temperature increase.

Ramps adjacent to the sedimentation bays allow access into bays by backhoes, bobcats, and other equipment for the removal of the collected sediment. The ramps are sloped at 15 percent and are approximately 34 feet long. The bay would first be drained after it is taken out of service, by removing the stop logs at the effluent end of the bay. The 12- by 12-inch sluice gate in each effluent channel will allow the drainage to enter an overflow structure and then enter an 18-inch diameter HDPE river water overflow line which connects to the 18-inch diameter discharge line from the effluent sedimentation tank and is routed to the Moyie River outfall. After the excess water is drained off of the surface of the sedimentation bay, the sediment would be loaded into dump trucks for removal from the site. The effluent channel of each sedimentation bay is equipped with an 18- by 18-inch sluice gate controlling flow to the drum filters. The water level in the drum filter bays must not be allowed to rise above levels that could interfere with the backwashing of the filter, therefore the sedimentation tank effluent channels are equipped with 5-foot 0-inch overflow weirs. Overflow enters the overflow structure and then the 18-inch river water overflow line discussed previously.

Drum Filters

Two stainless steel drum filters will be provided to remove most of the remaining suspended sediment in the flow from the influent sedimentation tank. The drum filters selected as the basis of design are 6 feet, 8 inches in diameter, and 9 feet, 11 inches long, and has 35 individually replaceable filter panels. The filter panels are constructed using a polyester fabric on a polyethylene grid for removal of the smaller particles from the water column. The filter panels can be designed to achieve a wide variety of filtration efficiency. At this time, it is anticipated that the drum screens for the Twin Rivers hatchery will be rated for the removal of 100 micron material. The filter panels must eventually be replaced, depending upon the sediment load and the ability to remove the collected material from the filter panels.

Water from the influent sedimentation basin will enter the center of the drum filters. The drum rotates slowly (2.9 rpm) while the water flows through the filter panels and enters the clearwell around the screen. Overflow from the drum filter clearwell passes over a 10-foot 6-inch long effluent weir and into a channel leading to the booster pump station. All flow through the drum filters will be due to gravity created by the lowered water surface in the clearwell of the booster pump station.

Filter backwashing is performed on a timed cycle. A 3-inch diameter ground water line provides spray water to the drum filters. Each filter is equipped with a 7.5 Hp booster pump that increases the pressure of the spray water to 100/160 psi (2-speed motor). The spray header is located on the outside of the filter fabric and washes the accumulated particles off the fabric and into a collection trough within the drum. The trough conveys the backwash flow (approximately 39 gpm) to a 6-inch drain line that is routed to the effluent sedimentation tank.

BOOSTER PUMP STATION

The booster pump station supplies the hatchery with filtered river water at sufficient pressure to allow further treatment of the water (sand filtration, UV disinfection, heating/cooling, etc.) prior to use. The treatment requirements for the river water had not been finalized at the time of this report, therefore a conservative estimate of the required pressure is 45 psi at the design flowrate of 1,500 gpm.

The booster pumps will be multi-stage vertical turbine pumps. Two pumps will each have sufficient capacity to provide the design flowrate (1,500 gpm @45 psi, 50 HP). A smaller vertical turbine pump will be provided to allow efficient pumping coverage at the low end of the pumping range (400 gpm @ 15 psi, 5 HP). The pumps will be equipped with VFDs. The pump control system will adjust the speed of the pump to maintain a desired pressure in the river water lines supplying the headboxes, where mixing of the various water sources occurs.

The effluent channel from the drum screens enters the clearwell below the cover slab of the station, which supports the motors and discharge piping from the booster pumps. The clearwell has sufficient capacity to avoid wide fluctuations in level that could be caused by sudden changes in flowrate into the clearwell, or in the pumping rate out of the clearwell. The 8-inch discharge lines from the large pumps and the 6-inch line from the small pump are each equipped with a pressure transducer, a check valve (fitted with a position switch to shutdown the pump if no flow is detected), and a butterfly isolation valve. The discharge piping elbows down and passes through the cover slab and enters the clearwell, where it combines into a 10-inch river water pipeline to the hatchery.

A 6-inch branch line (located near the SW corner of the hatchery building) will provide low pressure water supply to the burbot ponds. A manually-adjusted flow control valve will be used to adjust the flow to the burbot ponds. Preliminary flow demand is assumed to be 10 gpm per pond, however flow rates may increase during pond cleaning or flushing activities.

The booster pump station and the drum filters will be enclosed within a concrete masonary unit (CMU) building with a pre-engineered metal roof. This will provide freeze protection for the exposed piping, as well as weather protection for the equipment, including the electrical power and control systems. Skylights (4 ft x 4 ft) will be provided on the roof above each of the booster pumps, to allow a crane to access the pumps for removal, if necessary.

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CHAPTER 3.
WELL WATER SUPPLY

DESIGN CRITERIA

The design of the ground water supply system is based on previous ground water analysis work performed for the project including the report *"Ground Water Feasibility Study, Twin Rivers Aquaculture Facility"* dated February 19, 2010, and *Hatchery Well Installation and Testing, Twin Rivers Aquaculture Facility*, both prepared by Associated Earth Sciences, Inc. (AESI) (Attachment D). Ground water will be utilized for hatchery processes included incubation, rearing, and broodstock collection and holding in addition to providing backwash water for the drum filters. Groundwater demand will vary considerably during the year with peak demand in the 250 to 300 gpm range.

WELL FIELD DESIGN

Based on the well testing by AESI, hatchery wells HW-2 and HW-3 can produce a sustained 400 gpm water supply concurrently with a drawdown of less than 10 feet. Consequently, development of wells at those locations is proposed. A pitless well unit providing 3 feet of cover depth on the discharge pipe is provided. Based on the well report and to provide the required design flow, design data for the wells are as follows:

	HW-2	HW-3
Casing Diameter	8-inch	8-inch
Pump Column Diameter	5-inch	5-inch
Ground Elevation	1794	1794
Well Depths (Feet Below Ground Surface)		
Groundwater	15.0	13.8
Top of Well Screen	70	70
Bottom of Well Screen	80	85
Bottom of Well	100	95

Well pump sizing was based on providing a total design flow of 300 gpm within a residual pressure range of 8 and 15 psi. Pump design data is as follows:

- Pump: Goulds Model 6DHLO 3 stage 10 Hp, (or equal).
- Design point at low groundwater and 15 psi residual pressure: 272 gpm @ 96.5 TDH.
- Design point at high groundwater and 8 psi residual pressure: 340 gpm @ 74.0 TDH.
- Elevation at discharge: 1811.0.

PIPELINE DESIGN

In general, GW pipelines were sized to maintain velocities of less than 5 fps at peak flows. Pipe material is proposed to be PVC pressure pipe per ASTM C900 DR 25. The main GW pipe from the well head to the hatchery building is sized at a nominal 6-inch diameter with velocities of 3.2 fps at 300 gpm. The approximately 40 gpm required by the drum filter backwash is provided through a 3-inch branch line. The GW supply piping to the burbot ponds varies from 6-inch to a minimum size of 3-inch.

A hydropneumatic tank will be installed in the mechanical room of the hatchery and will function as a buffer for variations in demand. The required volume will be approximately 3,000 gpm. The control system will activate the well pump when water drawn from the tank causes the pressure to decrease below a preset level.

CHAPTER 4.
HATCHERY PROCESS WATER TREATMENT

GENERAL

The design purpose of the process water cooling and heating systems is to raise or lower temperatures of ground water or river water for optimum burbot and sturgeon incubation and rearing. The cooling is accomplished with a closed loop chiller system that uses chillers, pumps and piping to circulate mechanically chilled glycol-water solution through separate heat exchangers for the cooling of ground water and river water. Heating is provided with a closed loop hot water system that uses boilers, pumps and piping to circulate treated hot boiler water through separate heat exchangers for the heating of ground water and river water. The equipment is all located in the Chiller, Boiler and Heat Exchanger rooms shown on the Drawings. The cooling and heating systems are described in more detail below.

Burbot cooling demands occur January through May, peaking in March. There is no sturgeon cooling requirement. River water and ground water are supplied in pressure piping from the adjacent Filtration room and cooled in separate heat exchangers to keep the flow streams separate. The cooled water is then piped to separate ground water and river water head boxes for distribution to the burbot incubation and rearing areas through separate piping systems. The river and ground water supplies from the Filtration room as well as downstream head boxes and piping distribution systems to the incubation and rearing areas are described elsewhere in the Basis of Design.

The burbot heating requirement occurs April through August with a peak in July and August. Kootenai sturgeon heating duration is April through July with its peak in May. Similar to the cooling system described above, the heated ground water and river water streams are kept separate by using separate heat exchangers.

In addition to the heating and cooling of ground and river water, there are energy recovery systems that use process water that has already passed through the incubation and rearing systems pumping it back to energy recovery heat exchangers. These permit the incoming ambient ground and river water to be precooled or preheated before passing through the primary heat exchangers.

Finally, the chiller system uses an outdoor dry cooler for rejecting heat to the outdoors when temperature conditions require. However, since the process water cooling demand occurs in the colder months of the year, an ancillary piping loop and diverter valves are included to allow the glycol/water mixture to bypass the chiller and be cooled in the dry cooler. This provides cooled water at a lower cost when outdoor temperatures are sufficiently low.

COOLED PROCESS WATER

The process water cooling is accomplished using a system of chillers, dry-cooler, pumps, piping, valves and heat exchangers. See the Process Water Cooling Diagram in the Drawings in conjunction with the following description.

The chillers are planned to be two packaged units to match the type and manufacturer (Carrier) provided at the Tribal Sturgeon Hatchery. This reduces suppliers and maintenance parts needed to support operation at both hatcheries. The specification will be written around this manufacturer with allowance for alternates if cost or other conditions warrant. One chiller is sized for peak load and the other chiller provides full backup capability.

The two chillers consist of dual screw compressors using R134a refrigerant. Each unit has two refrigerant circuits allowing partial load backup and turn down capability of 10 to 1 ratio. The units are nominally 106 ton total capacity each at standard conditions. However, using a discharge temperature close to freezing and sufficient glycol mixture for freeze protection in the outdoor dry-cooler reduces the chiller capacity to about 55 tons each. The process water cooling requirement is for water temperatures down to 35°F which when considering approach temperatures in the heat exchangers, requires as close to 32°F glycol/water temperature as possible. Lower than 32°F would create the potential for freezing the process water in the heat exchangers. A chiller leaving water temperature of 33°F was chosen for system operation. Therefore, 33°F glycol/water mixture leaves the chiller and is pumped to the cooled river water and cooled ground water heat exchangers. These are designated as CRWHX and CGWHX respectively on the Drawings.

The CRWHX heat exchanger is sized for the worst case process river water cooling condition. This occurs for burbot broodstock and rearing in March. The river water cooling requirement for burbot broodstock is 60 gpm reduced from 40.8°F ambient down to 35.6°F desired supply temperature. However, the rearing river water requirement is 100 gpm cooled from 40.8°F down to 39.2°F. Since the colder Broodstock river water occurs at the same time, the rearing river water will have to be cooled to 35.6, then mixed with ambient at point of use for its final temperature. This reduces the rate of cooled rearing water to 30 gpm for a total of 90 gpm cooled river water. The chilling capacity required for this is 234 mBh or 20 tons.

The heat exchanger is sized for a chilled glycol solution supply temperature of 33°F. This requires a rather tight 2.6°F heat exchanger approach temperature (difference between the leaving process river water and the entering chilled glycol solution). For the 30 percent design, the heat exchanger is sized for ~50 percent larger capacity or 150 gpm. This will be reduced if necessary as design is refined.

The CGWHX heat exchanger is sized for the worst case process ground water cooling condition. This occurs for burbot incubation and early rearing in March. The ground water cooling requirement for burbot incubation is 7 gpm reduced from 47.3°F ambient to 39.2°F desired supply temperature. However, the early rearing ground water requirement is 45 gpm cooled from 47.3°F down to 40.8°F. Since the colder Incubation ground water occurs at the same time, the rearing ground water will have to be cooled to 39.2, then mixed with ambient at point of use for its final temperature. This reduces the rate of cooled rearing water to 36 gpm for a total of 43 gpm cooled ground water. The chilling capacity for this is 174 mBh or 15 tons.

The heat exchanger is sized for a chilled glycol solution supply temperature of 33°F. This requires a 6.2°F approach temperature. For the 30 percent design, the heat exchanger is sized for ~50 percent larger capacity or 65 gpm. This will be reduced if necessary as design is refined.

In addition to the two cooling heat exchangers above, there are two matching units that are designed for heat recovery from the process stream. Used cooled river water and ground water are collected in sumps after use in the incubators or rearing tanks. The water is then pumped back to the heat exchanger room and passed through their respective energy recovery heat exchangers, CRWERHX and CGWERHX, to precool the fresh incoming river or ground water. This saves the energy that would otherwise be used to cool the new incoming process water entirely and continuously with the chillers.

As one additional cooling method, the dry cooler is used to cool process water when outdoor temperatures permit. In normal operation, the chillers remove heat from the chilled water loop with the condensers on each chiller unit. The condenser water is then pumped/piped to the dry cooler for rejection of the heat to the outside air. Due to the time of year that process water cooling occurs (January – May), it may be possible under the proper conditions to use the dry cooler to cool the process water instead of the chillers.

This alternate cooling is provided in the design by using diverter valves to divert the chilled glycol solution flow from the chillers to the dry cooler. The dry cooler then cools the glycol solution by passing cold outside air over the piping in the dry cooler and circulating it to the cooled water heat exchangers. The chillers are not operating during this “free cooling” mode.

HEATED PROCESS WATER

The process water heating is accomplished using boilers, pumps, piping, valves and heat exchangers. See the Process Water Heating Diagram in the Drawings in conjunction with the following description.

The three boilers are propane gas-fired condensing packaged units to match the type and manufacture (Aerco) provided at the Tribal Hatchery. This reduces suppliers and maintenance parts needed to support operation at both hatcheries. The specification will be written around this manufacturer with allowance for alternates if cost or other conditions warrant.

Two boilers are sized for peak load and the third boiler provides 50 percent backup capability. Each unit has multiple module heating sections allowing partial load backup and turn down capability of 16 to 1 ratio. The units are nominally 747 mBh input each with total firm capacity of about 1,500 mBh with two units on line. The boiler capacity also includes HVAC heating requirement discussed elsewhere in the Basis of Design. They can also be operate at 90^{o}F leaving water temperature for a 90 percent or greater efficiency. Hot heating supply water leaves the boiler at 90^{o}F and is pumped to the heated process river water and ground water heat exchangers. These are designated as HRWHX and HGWHX respectively on the Drawings.

Presently, the proposed fuel source is propane. Contact has been initiated with the local natural gas company, Avista, to determine if natural gas can be obtained at a lower cost. The local natural gas supply ends on the west side of the Moyie River, so does not extend to the site. Propane is assumed for the 30 percent design and will be further evaluated as design progresses.

The HRWHX heat exchanger is sized for the worst case process river water heating condition. This occurs for burbot rearing and Kootenai sturgeon broodstock in April. The river water heating requirement for sturgeon broodstock is 60 gpm raised from 44.9^{o}F ambient to 53.6^{o}F supply temperature. The heated river water supply to the burbot rearing is 80 gpm raised from 44.9^{o}F to 49^{o}F. Since the warmer sturgeon broodstock river water occurs at the same time as the burbot rearing, the rearing river water will have to be heated to 53.6, then mixed with ambient for its final temperature. This reduces the rate of heated burbot rearing water to 40 gpm for a combined total of 100 gpm heated river water. The boiler capacity required for this is 435 mBh.

The heat exchanger is sized for a boiler water supply temperature of 90^{o}F and return of 70^{o}F. This provides a large 36^{o}F heat exchanger approach temperature (difference between the leaving process river water and the entering boiler water). The large approach temperature reduces the physical size and cost of the heating water heat exchangers as compared to the cooled water heat exchangers. For the 30 percent design, the heat exchanger is sized for ~50 percent larger capacity or 150 gpm. This will be reduced if necessary as design is refined.

The HGWHX heat exchanger is sized for the worst case process ground water heating condition. This condition occurs for burbot early rearing combined with sturgeon incubation in June. The ground water heating requirement for burbot is 45 gpm raised from 50^{o}F ambient to 54.1^{o}F supply temperature. The heated ground water supply to sturgeon incubation is 90 gpm raised from 50^{o}F to 53.6^{o}F. Since the ground water will have to be heated to the higher temperature of 54.1^{o}F, the sturgeon incubation water will have to be mixed with ambient ground water for its final temperature. This reduces the rate of heated sturgeon incubation water to 80 gpm for a combined total of 125 gpm heated ground water. The boiler capacity for this is 256 mBh.

The heat exchanger is sized for a boiler water supply temperature of 90°F and return of 70°F. This provides a large 36°F heat exchanger approach temperature (difference between the leaving process ground water and the entering boiler water). For the 30 percent design, the heat exchanger is sized for ~20 percent larger capacity or 150 gpm. This will be reduced if necessary as design is refined.

CHAPTER 5.
SITE ANALYSIS AND LAYOUT

EXISTING CONDITIONS

The location of the proposed Twin Rivers Hatchery is on an historical floodplain terrace at the confluence of the Moyie and Kootenai rivers. The shape of the terrace is roughly triangular, with a hill slope along the east edge, the Moyie River along the west edge and the Kootenai River along the south edge. The elevation of the floodplain terrace above the ordinary high water of the Moyie and Kootenai Rivers is between 5 and 8 feet.

Site topography was surveyed in 2007 by JRS Surveying from Bonners Ferry, Idaho, using a local coordinate system. This topographic map was used for the preliminary layout of the hatchery facilities during the Step 1 Master Plan design study. In January 2012, the original topographic survey was converted to state plane coordinates for completion of the Step 2 preliminary design. This conversion was also done to assist with the collection of data to be incorporated into the water surface elevation modeling required for the design of the river intakes.

At the present time, the floodplain terrace at the confluence of the Moyie and Kootenai rivers has been developed into an RV resort. Most of the RV sites are near the middle of the site, with camping sites to the north along the Moyie River and a large open area to the south along the Kootenai River. Most of the northern half of the site is vegetated with mature cottonwood, larch, Douglas fir and cedar trees, with several varieties of brush growing between the RV sites. Open areas are primarily manicured lawn for use by guests at the RV resort.

The proposed Twin Rivers Hatchery will be in the northern portion of the floodplain terrace north of the RV office and clubhouse. Most of the area to be used for the hatchery is currently open area; about fourteen RV sites and four campsites will be eliminated during the construction. Construction of the hatchery buildings and facilities will require removal of 60 to 65 mature trees. Relocation of the primary power supply line to the site will be required to eliminate a conflict with the hatchery facilities. The primary water supply for the RV sites will also have to be relocated, as the current well is near the northern tip of the property.

DESIGN CRITERIA

The following design criteria were used to develop the proposed site plan:

- Provide two surface water intakes to supply water to the hatchery facilities.
- Provide three production wells for groundwater supply to the hatchery facilities.
- Provide an influent sedimentation basin with drum screen to clarify the water supply.
- Provide the hatchery building with spawning, egg incubation and early rearing facilities.
- Provide the hatchery building with office and laboratory space to manage hatchery operations.
- Provide outdoor ponds for juvenile rearing.
- Provide a sedimentation basin to clarify hatchery effluent prior to its discharge to the Moyie River.

- Provide a vehicle storage building and maintenance shop adjacent to the hatchery building.
- Provide perimeter fencing around the main hatchery complex for security.
- Provide paved areas for vehicle circulation around the hatchery building, vehicle storage building, influent and effluent sedimentation basins and driveways to staff residences.
- Provide two residences for hatchery staff.
- Provide grading improvements and new gravel surfacing to the existing boat ramp. Create a new temporary boat access for a portable dock at the mouth of the Moyie River by clearing and surfacing approximately 1700 feet of the top of the dike along the River.
- Install upgraded site utilities, including power, phone, sewer and internet.
- Arrange site elements to maximize the efficiency of process water transmission and distribution systems.
- Arrange site elements to allow safe and efficient handling and transfer of fish and eggs.
- Provide treatment of storm runoff from paved parking areas prior to discharge from the site.
- Maintain good pedestrian circulation while providing site security with perimeter fencing and gates.
- Maintain operation of the RV resort during construction and during full-scale hatchery operations.

BENEFITS AND CONSTRAINTS

The following site features will be advantageous to development of the new hatchery facility:

- A geotechnical investigation has been completed and preliminary indications are that the soil conditions are well-drained sands and gravels suitable for structural fill and support of building and structure foundations.
- The historical floodplain terrace slopes gradually toward the Moyie River to the west and toward the Kootenai River to the south from the proposed hatchery site, offering the following benefits:
  - The gradual slope will allow gravity flow from the hatchery building and rearing ponds to the effluent sedimentation pond and into the Moyie River.
  - The gradual slope will minimize the amount of excavation required during construction of the proposed hatchery.
- The new portable boat access at the Moyie River confluence will facilitate sturgeon broodstock loading and unloading during the March to June collection season. With the improved boat ramp, river access will be provided for outplanting and monitoring activities by Tribal biologists.

The following constraints must be considered during development of the new hatchery facility:

- Access to the site is by a gravel road with two sharp switchbacks that may limit the overall length of materials that can be transported to the project site.
- During flows greater than 60,000 cubic feet per second in the Kootenai River, the lowland areas inside the RV resort are inundated with groundwater, creating open water ponds.
- Numerous large trees on the sites where the hatchery buildings are planned must be removed.

- Existing overhead power lines supplying power to the RV resort must be relocated to avoid conflict with the new hatchery buildings.
- All hatchery facilities must be designed to minimize impact on the existing infrastructure of the RV resort.

SITE ACCESS AND CIRCULATION

Access to the proposed Twin Rivers Hatchery from Bonners Ferry will use US Highway 95 north, turning east on US Highway 2, then passing through the town of Moyie Springs and across the Moyie River canyon. Approximately 0.5 miles past the Moyie Canyon bridge, the access route turns south on Twin Rivers Road. The road makes a sharp turn to the right and then goes west through a recent clear cut. The road is paved for approximately 0.5 miles to the top of the hill above the RV resort. After turning to gravel, the road drops 600 feet in 3,000 feet of road length, resulting in an average gradient of 5 percent. Within 500 feet of the top of the hill, the road makes a 180-degree switchback turn. A second 180-degree switchback turn is located 2,000 feet from the top, and a third is located 2,500 feet from the top. The road enters the RV resort near the center of the property along the eastern edge of the parcel.

A well-developed system of roads has been constructed to provide access within the RV resort. These roads are graveled and are suitable for all-season travel when plowed in the winter.

Layout of the proposed hatchery facility was completed using the existing system of roads to minimize the construction of new roads. Approximately 800 feet of existing gravel roads will be removed during construction of the new hatchery facilities.

Within the main hatchery compound, paved access will be provided around all sides of the hatchery building, vehicle storage building, influent and effluent sedimentation ponds, rearing ponds and hatchery staff residences, with adequate clearances for two vehicles to pass. Most of the surfaced areas of the site will be graded to drain at 2 to 4 percent slopes.

Public pedestrian circulation will be limited to the south and west edges of the hatchery site, the main parking area and the area around the office building. Security fencing, gates and signage will be used to limit public access to the operational hatchery facilities.

BOAT LAUNCH

To facilitate sturgeon broodstock loading/unloading, temporary boat access will be created near the mouth of the Moyie River, a site that will be accessible during spring high flows when the Kootenai River launch site typically is inundated. An existing single lane track along the top of the Moyie dike will be cleared of encroaching vegetation and graded to the extent needed for occasional vehicle access. Approximately 1,700 feet of improved dike road will be used to transport sturgeon broodstock to and from the hatchery and to haul the temporary dock. An 8-foot by 20-foot portable dock mounted on skids will be temporarily moved into place on the Moyie during broodstock collection season. It is expected to be in place between March and June, after which it will be hauled from the river to the hatchery yard by a forklift or small tractor for storage until its next deployment. Up to four posts will be installed on the dike to secure the dock when it is deployed. When positioned, lines will secure the floating structure to the posts.

The existing informal earthen boat launch, access road and parking area on the Kootenai River will be graded and portions surfaced with gravel. The existing parking area will be enlarged and graveled to accommodate 10 vehicles with trailers. Gravel will be applied to the existing access road as well. The launch area will be graded above the ordinary high water mark; further improvements are not proposed.

Recreational boat launching will continue to be the primary use of this site in addition to some use by Tribal biologists for juvenile outplanting and proposed monitoring and evaluation activities.

CHAPTER 6.
BURBOT BROODSTOCK HOLDING AND SPAWNING

DESIGN CRITERIA

All design criteria elements relating to burbot broodstock holding and spawning are presented in Attachment B**,** Biocriteria for Kootenai Burbot and Live Feed.

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CHAPTER 7.
STURGEON BROODSTOCK HOLDING AND SPAWING

DESIGN CRITERIA

All design criteria elements relating to sturgeon broodstock holding and spawning are presented in Attachment A, Biocriteria for Kootenai Sturgeon Production.

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CHAPTER 8.
HATCHERY BUILDINGS

Two primary buildings are proposed at the hatchery site which will support ongoing hatchery operations. The Hatchery Building will house hatchery administrative functions and facilities to accommodate visitors and meetings, as well as hatchery operations and maintenance functions and crew facilities. The Vehicle Storage Building will house vehicles and boats and one bay of this building will be heated and ventilated to accommodate light duty vehicle maintenance.

ARCHITECTURAL DESIGN CRITERIA

Necessary building, sanitary and land use permits will be obtained through the Boundary County Building Department and will include code compliance. The property is located just outside the boundary of the City of Moiye Springs and is zoned Residential Rural. It is assumed that a land use variance or zoning modification will be required.

All buildings will be designed to comply with the current edition (2009) of the following codes, as adopted by the State of Idaho:

- International Building Code
- International Energy Code.
- International Mechanical Code.
- International Plumbing Code.
- National Fire Code.
- National Electric Code.

Both the Vehicle Storage Building and Hatchery Building will be constructed of cost effective, durable materials with proven performance in the anticipated climatic conditions and the industrial nature of the facility. Sustainable design features will be incorporated into the design of these facilities and the architectural character of the site and existing facilities. Anticipated materials include CMU, wood, metal, glass with flat or low-slope roofs using membrane or metal roofing. Exterior building finishes will be of natural colors to blend with the surrounding environment and lessen their prominence in a manner compatible with the recreational nature of the site.

Hatchery Building

The Hatchery Building will be a single story 32,270 SF structure located north of the primary entrance and offices. Road Access will be controlled by the location of the campground office, and the fenced and gated enclosure around the hatchery grounds will control unescorted pedestrian access. The site area south of the building will be developed for employee and visitor parking.

This building will be classified as an F-2 occupancy. Allowable area for F-2 construction varies by construction type. For type II B construction (noncombustible and non-rated) the allowable area is 23,000 SF. For combustible and non- rated, the allowable area is 13,000 SF. In order to meet the area requirements it is assumed that the 60 foot yard requirements will be satisfied on three sides of the building. A sprinkler system is not required, but a fire alarm system should be provided.

Construction

The Hatchery Building will be a single story 32,270 SF structure located north of the primary entrance and offices. Road Access will be controlled by the location of the campground office, and the fenced and gated enclosure around the hatchery grounds will control unescorted pedestrian access. The site area south of the building will be developed for employee and visitor parking. Typically ceiling height in the hatchery operations area will be a minimum of 12 feet. Ceilings in offices or lockers will be 9 feet.

TABLE 8-1.
TWIN RIVERS SITE PROGRAM SUMMARY

Revision Date: 02/17/2012	Staff		Tank		Area			
Name of Space	Full Time	Part Time	Number	Size	Quantity	Size (SF)	Total (SF)	Comments
Twin Rivers Hatchery Building								
Administration & Shared			**24**					
Open Office	3				1	375	375	Natural daylighting
Private Office	1				1	125	125	Natural daylighting
Conference Room					1	307	307	Include kitchenette. Natural daylighting.
Men’s Restroom/Shower					1	225	225	
Women’s Restroom/Shower					1	225	225	
Office Storage					1	30	30	
Janitor					1	40	40	
Dry Work Room					1	238	238	Natural daylighting
Lockers					1	182	182	
Wet Laboratory	1		12	4' Dia	1	1,540	1,540	Needs access from burbot & sturgeon sides.
			12	8'x2'x 18"				
MudRoom/ Vestibules					3	130	390	
NET	5		24		13	_	3,630	
CIRCULATION AND STRUCTURE							726	
GROSS							4,356	

TABLE 8-1 (CONTINUED). TWIN RIVERS SITE PROGRAM SUMMARY								
Revision Date: 02/17/2012	Staff		Tank		Area			
Name of Space	Full Time	Part Time	Number	Size	Quantity	Size (SF)	Total (SF)	Comments
Sturgeon Ops								
Sturgeon Rearing	1		28	8' Dia	1	5,400	5,400	Indirect daylight
			5	6' Dia				
Sturgeon Incubation	1		36	8'x2'-6"	1	2,500	2,500	Indirect daylight
Sturgeon Broodstock	1		6	15' Dia	1	3,050	3,050	Indirect daylight. 12'-0" height clear to B.O. structure
Sturgeon Forage			1	10' Dia	1	300	300	
Sturgeon Work Area			12	8'x2'-6"	1	425	425	
			12	4' Dia				
Dry Storage					1	400	400	
Mud Room					1	150	150	
NET	3		81		7	_	12,225	
CIRCULATION AND STRUCTURE							1,834	
GROSS							14,059	
Burbot Ops								
Burbot Rearing			24	4' Dia	1	2,250	2,250	Indirect daylight
Burbot Incubaton			20	3' Dia	1	1,600	1,600	Indirect daylight
Burbot Broodstock			6	6' Dia	1	1,175	1,175	Indirect daylight
Burbot Forage			1	10' Dia	1	425	425	
Burbot Spawning			1	6' Dia	1	225	225	
Cryo/Disinfect/Necropsy/Equip					1	400	400	
Dry Food					1	275	275	
Live Feed					1	550	550	Keep away from broodstock.
Mechanical/pumps					1	125	125	
NET			51		6	_	7,025	

TABLE 8-1 (CONTINUED).
TWIN RIVERS SITE PROGRAM SUMMARY

Revision Date: 02/17/2012	Staff		Tank		Area			
Name of Space	Full Time	Part Time	Number	Size	Quantity	Size (SF)	Total (SF)	Comments
CIRCULATION AND STRUCTURE							1,054	
GROSS							8,079	
Services								
Water Treatment					1	616	616	Near sediment pond
Chemical Storage					1	100	100	
Boiler					1	408	408	
Chiller					1	408	408	
Sand Filtration					1	760	760	
Shop					1	605	605	Natural daylighting
Electrical Room					1	386	386	
Comm Room					1	72	72	
Mechanical Room					1	1077	1077	
NET					9	_	3,425	
CIRCULATION AND STRUCTURE							343	
GROSS							3,768	
GROSS BUILDING AREA							**30,261**	
Vehicle Shop and Storage Building								
Vehicle Maintenance					1	720	720	Heated. Welding.
Vehicle Storage					10	720	7,200	
NET					11	_	7,920	
CIRCULATION AND STRUCTURE							1,188	
GROSS							**9,108**	
Exterior Facilities								
Generator					1	400	400	
Chiller					1	400	400	
Water Treatment Sediment Pond				60' x 120'	1	8,000	8,000	
Effluent Treatment					1	1,000	1,000	
Burbot Ponds				60' x 60'	6	3,600	21,600	

Building Components

Clean Room

A vestibule and disinfection zone prior to entering Sturgeon Work Room. Provided with storage shelves for equipment, lockers for personal equipment and benches for changing.

Sturgeon BroodStock

Captured sturgeon broodstock are kept in the (five) 15-foot diameter tanks. The sixth tank is reserved for egg removal. Sturgeon can be transported between the tanks through an overhead crane rail, capacity 500 lbs.

Sturgeon Workroom

After the eggs have been removed from the sturgeon broodstock they are initially handled and prepped in this room. Includes wire storage racks, sterilizing dishwasher, utility sink and stainless steel work counter, as well as (four) 2-foot-6-inch by 8-foot 0-inch tanks.

Sturgeon Incubation Room

After the eggs have been prepped in the Sturgeon Workroom, they are brought into the Sturgeon Incubation Room for incubation until they hatch. Contains thirty-six 2-foot-6-inch by 8-foot 0-inch tanks.

Sturgeon Rearing

After the eggs hatch the fry are transferred to the Sturgeon Rearing room, which contains (twenty-eight) 6-foot diameter tanks and (five) 4-foot diameter tanks.

Sturgeon Forage

Sturgeon broodstock will be fed live trout, kept in a single 10-foot diameter tank.

Dry Storage – Sturgeon

Food storage for sturgeon in the rearing stage.

Wet Lab

This room will accommodate controlled experimentation of tank and water variables, cleaning protocols etc. for improvement of fish culture for both sturgeon and burbot.

Burbot Broodstock

After capture, adult broodstock are kept in (six) 6-foot diameter tanks.

Burbot Spawning

Burbot spawning and egg retrieval are accommodated with a single 6-foot diameter tank.

Burbot Incubation

The Burbot Incubation Room holds (twenty) 3-foot diameter tanks.

This area will have a raised floor of galvanized steel grating to allow for tank re-configuration.

Burbot Rearing

The Burbot Rearing room holds (twenty-four) 4-foot diameter tanks.

This area will have a raised floor of galvanized steel grating to allow for tank re-configuration.

Burbot Forage

One 10-foot diameter tank for trout.

Live Feed

Feed culture tanks for burbot in the rearing stage

Cyro/Necropsy and Disinfectant

Multipurpose room for analysis of stock rearing morbidity issues.

Dry Food - Burbot

Dry food storage for burbot.

Water Treatment

As described in Chapter 5, water from the Kootenai River may require fine filtration and ultraviolet disinfection at some times of year.

The Water Treatment room will include heat exchangers for cooling the process water and space for possible future treatment facilities, including oxygen generation equipment and potable water systems.

Chiller Room

The chilling of incubation and transfer tank flow will require a chiller. If more cooling is desired during late winter, the reservoir water could be used with a water-to-water heat exchanger to chill groundwater.

Food Storage and Handling

The food storage area will be in the southwest corner of the Hatchery Building, with a capacity to store 28 pallets of food and room for sorting pallets of different-size feed.

Two feed storage rooms have been provided. One for bulk storage of dry feed and a second for possible storage of start tank feed. If less food storage is desired by the hatchery operator, one room could be used for storage of other materials and equipment.

Shop

The Hatchery Building will contain shop area sufficient for repair of pumps and other equipment. Space will also be provided for carpentry and welding.

Work Room

The work room will include a fume hood and space for such laboratory equipment as a balance and under-counter refrigerator. Countertops will be acid resistant, but epoxy tops are not required.

Crew Areas

Crew facilities include a crew work area, lunch/break/meeting room, and restrooms with showers and lockers.

VEHICLE STORAGE BUILDING

The 7,260 SF vehicle storage building will house boats and vehicles used by Hatchery staff. It will consist of (eleven) 33- by 20-foot wide bays, with one bay enclosed, insulated and heated for use as a minor vehicle repair shop. Welding could occur at this shop.

Construction type will be type II B, construction will be non-combustible and non-rated. The steel frame and substructure will be a pre-engineered metal building, with a low slope metal roof shedding to the north.

A 4-foot tall CM wainscot is proposed for the perimeter of the building to reduce damage to finishes. Metal siding or cement board, or a combination, will be used above the wainscot.

SEDIMENT POND

The sediment pond canopy is designed to reduce UV exposure of the water, and to reduce leaf and needle debris from getting into the pond. It will utilize a pre-engineered metal building structure, with 14 ft clear to the bottom of the structure, and a low slope metal roof. The sediment pond will be divided into two ponds, with access for each pond for cleaning by ramp. The pumps and drum screens for water drawn from the pond will be housed in a CMU pump building.

RESIDENCES

There will be (two) 3 bedroom residences provided. Each residence is approximately 2,000 SF with a 600 SF garage attached. Construction will be wood framed, with a pre-engineered wood roof structure. The buildings will sit on stem foundation walls.

VISITOR CENTER

The visitor center is located just West of the existing Campground offices, just off the primary access road. The visitor center is a small amphitheater seating 20-30 people on concrete benches set into a berm. The focus will be a small covered structure with interpretive panels that will allow people to learn about the hatchery all year round, and it will allow for scheduled presentations by hatchery staff.

ARCHITECTURAL CHARACTER

The architectural character of the facilities is currently envisioned as a blend of contemporary sustainable industrial design incorporating some elements with rustic visual characteristics. Flat roofs and attached canopies to provide snow control and summer shading will be used. Single ply membrane roofing will be used on flat roofs, metal on sloped roofs.

MECHANICAL DESIGN CRITERIA

Hatchery Building

The Hatchery Building will be served by three distinct systems, with one system serving the sturgeon areas, one serving the burbot and support areas and one serving the office area.

The sturgeon and burbot areas will be heated and ventilated only. Ventilation will be supplied to achieve six air changes per hour in all hatchery and support areas, with a minimum supply air temperature of 40 degrees F. 100 percent outside air will be supplied via rooftop heat recovery units (HRUs) using sensible heat wheels, Variable Frequency Drive (VFD) controlled fans and hot water coils. Hot water is supplied from process boilers. The supply air ducts for the larger hatchery areas will be provided with control dampers that will allow the ventilation air to be modulated to deliver full ventilation when the space is in use and to minimize air when the space is not. Spot heating is provided by water coil unit heaters distributed around the hatchery. Unit heaters will be normally off, but will provide heat for operator comfort on demand. As with the HRU's the unit heater hot water will be provided from the process boilers through a reverse return hot water loop.

The office area of the Hatchery Building will be served by a Variable Refrigerant Flow (VRF) heat pump system that will allow for efficient, individual control of space temperature and heat recovery between spaces. Most spaces will be served by concealed ceiling mounted units, with a wall mounted unit in the Communications Room. Outdoor air will be provided by a small, ceiling mounted HRU with an enthalpy wheel. The fume hood in the dry work room will be provided with both a supply and exhaust fan to ensure proper pressurization.

Plumbing will follow the International Plumbing Code. Hose bibs with hot and cold water will be provided at approximately 50 foot increments in the hatchery areas. Domestic hot water will be provided with a circulation pump.

Vehicle Storage Building

The Vehicle Storage Building will be provided with a propane fired unit heater. A 3-inch flue will penetrate the roof.

Sediment Pond

The Sediment Pond building will be provided with two 5 kW capacity electric unit heaters.

Residences

The Residences will be provided with propane fired furnaces with air distribution located in the crawlspace. Propane fired water heaters will produce domestic hot water.

ELECTRICAL DESIGN CRITERIA

The Hatchery Building will be fed from a new 3-phase electrical service. Individual feeders from the Hatchery will provide 3-phase power to the Vehicle Storage Building, Sediment Pond Canopy and Pump Station, Well Pumps, Burbot Pond electrical equipment, site lighting, and the Moyie Intake Pump Station. A standby diesel-powered generator will be dedicated to the Hatchery and all the supporting facilities it feeds with the exception of the Vehicle Storage Building.

CHAPTER 9.
EXTERIOR BURBOT PONDS

The exterior ponds are presented on the 30 percent design documents to display the physical space requirement for six ponds, each measuring 8.5 meters square at pond bottom with a design water depth of 1-2 meters. These burbot pond preliminary design includes pond wall slope of 3:1 with circulation spacing of 16 feet between ponds.

Each pond will include a cast-in-place discharge structure including a screened stoplog water surface control structure.

DESIGN CRITERIA

The burbot holding criteria are presented in Attachment B, Biocriteria for Kootenai Burbot and Live Feed.

DETAILS

Drawings 20–C-60 and 20-C-61 show plan and section views of typical ponds.

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CHAPTER 10.
HATCHERY EFFFLUENT TREATMENT

The primary pollutant targeted for control in fish hatchery effluent is total suspended solids (TSS). TSS will be made up mostly of fish feces and uneaten feed

DESIGN CRITERIA

Production goals at Twin Rivers Hatchery are 1,276 pounds of sturgeon and 2,420 pounds of burbot, for a total of 3,696 pounds (1,680 kg). On August 23, 2004, the USEPA issued a new final rule (40 CFR Part 451) which applies to aquaculture facilities producing more than 100,000 pounds of fish per year. The final rule is administered through the National Pollutant Discharge Elimination System (NPDES) permit process. For new facilities such as Twin Rivers (those commencing construction after September 22, 2004), New Source Performance Standards (NSPS) are applicable.

The NSPS do not provide numeric limits on pollutant discharge, but rather establish narrative requirements, including the application of "best available demonstrated control technology" for all pollutants. Major emphasis is placed on the removal of solids from the effluent stream and on the development and implementation of a site specific Best Management Plan (BMP). The BMP is designed to prevent the discharge of spilled chemicals and the discharge of pollutants as a result of structural failure, to provide proper training of personnel, and to maintain thorough record keeping. Careful control and monitoring of water temperatures and feed rates to optimize feed conversion ratios and reduce uneaten feed quantity are also critical components of the BMP.

Due to the relatively low level of fish production at the Twin Rivers Hatchery, the Idaho Department of Environmental Quality (IDEQ) has indicated that gravity settling of the hatchery effluent will provide a sufficient level of treatment prior to returning this water to the Moyie River. IDEQ's sizing criteria for the settling tank limits the tank's overflow rate to no higher than 0.0065 ft/sec (2.92 gpm/sf) under peak flow conditions. The effluent flow rate is assumed to be equal to the design flowrate of the hatchery (1,500 gpm). At the maximum allowable overflow rate of 0.0065 ft/sec, a sedimentation tank with a surface area of 508 sf would be required to treat 1,500 gpm.

EFFLUENT SEDIMENTATION TANK

All effluent from the hatchery, as well as the discharge of the burbot pond drainage pump station, and the backwash flow from the drum filters, will be routed to the effluent sedimentation tank. These drainage pipelines enter the drainage control structure immediately upstream of the effluent sedimentation tank. The flow exits the drainage control structure via two 18-inch square sluice gates, each gate controlling flow to the influent channel of a bay of the effluent sedimentation tank.

The effluent sedimentation tank will be divided into two separate settling bays, each 19 feet 6 inches wide, 40 feet long, and an average depth of 5.2 feet (the floor slopes 1.5 percent to the downstream end). Having two separate sedimentation bays will allow one bay to be cleaned while the other bay remains in service. At the design flowrate of 1,500 gpm, a single bay will provide approximately 0.35 hours of detention time, and an overflow rate of 0.0042 ft/sec, 35.4 percent lower than the maximum allowable overflow rate of 0.0065 ft/sec. If both bays are in service, the detention time would be 0.7 hours, and the overflow rate would be 0.0021 ft/sec, 68% lower than the maximum allowable rate. The surface area of a single bay is 780 sf, 53 percent higher than the IDEQ specified area. Weirs are placed at the influent and effluent ends of the bays to create optimum settling conditions in the tank.

As with the influent sedimentation tank discussed earlier, ramps are located adjacent to the sedimentation bays to allow access into the bays by backhoes, bobcats, and other equipment for the removal of the collected sediment. The ramps for the effluent sedimentation tank are sloped at 20 percent and are approximately 54 feet long. A bay would first be drained after it is taken out of service, by removing the stop logs at the effluent end of the bay. The drainage would enter the effluent channel, and exit the channel via an 18-inch effluent discharge line that leads to an outfall on the Moyie River (see the next section). The influent channel to the sedimentation bay has a 12- by 12-inch sluice gate for draining sediment which may have collected in the channel. After the excess water is drained off of the surface of the sedimentation bay, the sediment would be loaded into dump trucks for removal from the site.

The floor of each bay will slope to a 4-foot square, 2 foot deep sump with a grated cover near the divider wall between the two bays. After most of the collected sediment in the tank has been removed with the heavy equipment, the grating could be removed, and a portable pump could be lowered into the sump A discharge hose on the sump pump could be dropped into a small tanker truck (e.g., 2,000 gal). Remaining material in the tank (and influent channel) could then be hosed down to the sump and then be pumped into the tanker truck for off-site disposal.

EFFLUENT PIPELINE

An 18-inch diameter HDPE pipeline will exit the effluent channel of the effluent sedimentation tank and combine with the 18-inch diameter HDPE overflow line from the influent sedimentation tank near the northwest corner of the effluent sedimentation tank. The 18-inch diameter HDPE effluent pipeline will then be routed at a moderate slope (0.74 percent) to an outfall location along the Moyie River, a distance of approximately 540 feet from the effluent tank.

The selected outfall location on the Moyie River is characterized by a deep scour pool formed by the Moyie River as it flows in an easterly direction into the toe of the dike on the hatchery side of the river. This location is more suitable for an outfall than areas further upstream (toward the effluent sedimentation tank), as the Moyie River channel during low flow is confined along the western bank in these areas. The river along the western bank is a shallow riffle. A very gradual gravel bar extends from the toe of the dike on the eastern side of the channel to the center of the channel. An outfall in this area would result in a long, shallow, and slow surface drainage across the gravel bar to reach the western side of the channel. The selected outfall location in the deep scour pool will allow the discharge outlet to be hidden under 2 to 3 feet of water depth. The bank areas of the outfall will be protected with riprap.

The effluent pipeline will be routed along the eastern side of the dike to reduce the volume of excavation for the pipeline and to prevent the complete rebuilding of the dike along the pipeline route.

CHAPTER 11.
HATCHERY UTILITIES

ELECTRICAL POWER

Power for the facilities in the vicinity of the Twin Rivers Hatchery will be provided from Northern Lights, Inc. (NLI). NLI serves the existing single-phase services in the vicinity of the Twin Rivers Hatchery, which consist of a campground-laundry-water well service, a combined residence and office structure, and an additional residence located near the Kootenai River. Each existing service is fed underground from pad-mounted transformers, which are served by an underground primary.

Hatchery Site

The source for the existing underground primary is an existing overhead primary transmission line extending from Highway 2, approximately one mile from the Hatchery Site. The transmission near the highway is 3-phase, but the line tapped near the highway and extending to the Hatchery is single–phase. The nature and size of the load at the Hatchery necessitate a 3-phase power source. Based on discussions with NLI in 2008, the estimated cost to upgrade the primary transmission from single to 3-phase was $98,000. This estimate does not include the new utility transformers that will be needed for the Hatchery and supporting facility services. Contact has been made with Jen Lanaville at Northern Lights.

A standby diesel generator is planned as a back-up power source for the Twin Rivers Hatchery and supporting facilities, including the Moyie Intake Pump Station. The generator will be located outside the Hatchery Building in its own weatherproof, sound attenuated enclosure. The fuel tank will be located beneath the generator. It will be dual-wall construction with leak detection, and large enough to carry the expected load for 3 days.

Kootenai Intake Pump Station

Due to the distance between the Twin Rivers Hatchery and the Kootenai Intake Pump Station, a separate 3-phase utility service is planned for the Pump Station. A dedicate standby diesel generator is planned as a back-up power source for the Kootenai Intake Pump Station. The generator will be located outside the Control Building in its own weatherproof, sound attenuated enclosure. The fuel tank will be located beneath the generator. It will be dual-wall construction with leak detection, and large enough to carry the expected load for 3 days.

COMMUNICATIONS

Building entrance telephone service will be provided to the building from the Local Exchange Carrier Frontier Communications (formerly GTE). Underground communications conduits will be extended from the existing communications pedestal located near the entrance road to the Hatchery building and new residences. Contact has been made with Jack Knaggs at Frontier Communications, who indicated that high speed internet service is available at the site. Typically new services that require up to 1,000 feet of new cable are installed at no charge, assuming the owner provides the path and 4-inch conduit. Longer distances and work involving existing service relocation are billed on a time and material basis. Existing service cable relocation is expected on this project. As a general rule, a new grounding pedestal is required every 500 feet of service cable.

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CHAPTER 12.
TRIBAL HATCHERY IMPROVEMENTS

INTRODUCTION

The existing hatchery complex is adjacent to the Kootenai Tribal Village and is a group of loosely organized structures that has been slowly developed over the last twenty years. Numerous improvements and additions are proposed to provide minimal functionality.

NEW HATCHERY HOUSING AND STAFF OFFICES

Housing will be constructed for hatchery personnel to ensure that staff is in close proximity at all times during operations. The proposed housing unit consists of a one bedroom unit attached to a small office annex. The staff office annex has space for four staff, with a small kitchenette and ADA accessible restroom. The facilities will be ADA accessible. Housing and office spaces will each be provided with an independently metered, gas fired furnace.

OFFICE ADDITION

The existing offices will be expanded to the south to provide a conference room and three offices. Facilities will be ADA accessible. The existing electrical service will be relocated and designed to feed the two Rearing Sheds as well as the Office, as in the existing configuration, except the Shop will no longer be fed from this meter.

A new fire alarm system is planned for the Office.

The Office window AC units will be removed and wall mounted Variable Refrigerant Flow (VRF) heat pump units will be added to provide primary heating and cooling. The current baseboard heating system will be retained for use as a secondary source of heat. Operable windows will be provided for outdoor air.

HATCHERY BUILDING IMPROVEMENTS

The hatchery building is an older pole building that has been retrofitted for its current use. The facility includes rearing and incubation tanks for sturgeon and a forage tank, and an office an storage mezzanine. The interior finish of the tank room exterior walls is polyisocyanurate panels with taped joints nailed to horizontal wood girts between the primary columns. The proposed improvements include:

- An internal dividing wall between forage and sturgeon tanks.
- Conversion of an unused and unfinished room into a mud room
- Removal of approximately three-fourths of the exterior wall metal panels to add additional polyisocyanurate insulation, a weather barrier and re-installation of the existing siding.
- Addition of 8-foot Fiberglass Reinforced Plastic (FRP) wainscot on the walls up to 8 feet above finished floor (AFF) in the tank rooms to improve room cleanability.
- Selected lighting upgrades for improved efficiency
- New exterior doors and keypad entry locks
- A new fire alarm system

- The existing propeller ventilation fan will be replaced.

TREATMENT BUILDING

This building is relatively new and no improvements are anticipated with the exception of a new fire alarm system. The current 1/2-inch copper water supply along the north wall will be replaced with a 1-inch schedule 80 PVC line. that will provide water to Rearing Sheds 1 and 2 and the Vehicle Storage Shed.

REARING SHED 1 IMPROVEMENTS

Rearing Shed 1 is a pre-engineered metal building housing sturgeon rearing tanks. It will be expanded to provide a sturgeon egg collection work zone and mud room, and a crane rail will be added over the tanks in order to facilitate fish transport. Translucent panels will be added to the east wall to provide daylight. A wall mounted, gas fired heater will be provided for the work zone.

A new fire alarm system is planned for Rearing Sheds 1 and 2.

The current 1/2-inch, hose-fed copper water supply will be replaced with a 1-inch schedule 80 PVC line. The new line will enter the building through the existing exterior hose bib locations. A 1/2-inch cold water supply will be added to the sink in the sturgeon egg collection work zone.

REARING SHED 2 IMPROVEMENTS

Rearing Shed 2 is identical to Rearing Shed 1, except the insulation system is sprayed on instead of batt insulation with a vapor barrier. This insulation is falling off and could be hazardous to the fish stock. The scope of work for this building includes phased removal of the existing insulation, installation of new batt insulation with vapor barrier, the addition of an 8-foot tall FRP wainscot for wash down, and the addition of translucent clerestories for natural light.

The current 1/2-inch hose fed copper water supply will be replaced with a 1-inch schedule 80 PVC line. The new line will enter the building through the existing exterior hose bib locations.

VEHICLE STORAGE SHED ADDITION AND IMPROVEMENTS

The existing vehicle storage building is open to the south and provides little protection to the vehicles stored within. The scope for this building is to expand the building 8 feet to the south, provide new overhead doors in the south face of this addition, and add a storage facility adjacent to the east end of this building. This storage building addition will allow the removal of temporary storage sheds from the site.

The existing electrical service capacity for Vehicle Storage will need to be increased. Replacing the existing feeder from the Office service with a new feeder from the new Housing facility will provide a more direct route for the feeder and free some capacity on the existing Office service.

A new fire alarm system is planned for the Vehicle Storage and Shop facilities.

The current 1/2-inch hose fed copper water supply along the north wall will be replaced with a 1-inch schedule 80 PVC line. The new line will enter the building through the existing exterior hose bib locations and terminate at two new hose bibs.

SITE IMPROVEMENTS

A heater for freeze protection will be installed for the Drum Screen. The power source for the heater will be a spare circuit in the Treatment Building. All new equipment at the dock area requiring electrical power will be fed from spare circuits in the Treatment Building.

Fish Transport

The fish transport system will consist of a crane rail from the exiting dock to a landing on the pump building service access road. The crane rail will be supported off of existing piles at the dock, and a new pile at the water line, and a new foundation supported column adjacent to the access road. The crane rail will be sized for 750 lb loads. The rail will be electrically operated with a lifting hoist and a cogged rail attached to the support beam. The rail will be controlled with a pendant mounted controller.

The existing dock will be extended with a 300 sf extension, with area lights and paver outlet.

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Kootenai Tribe of Idaho

Kootenai Hatchery Basis of Design Report

ATTACHMENT A.
BIOCRITERIA FOR KOOTENAI STURGEON PRODUCTION

Attachment A – Biocriteria for Kootenai Sturgeon Production

Biocriteria for Kootenai sturgeon production at the Tribal Sturgeon Hatchery.

Aquaculture Function/ Life Stage	Broodstock (holding/collection)	Spawning and Fertilization	Incubation and Hatch	Early Rearing (Larvae onto feed)	Rearing (on feed, up to 4 -5 months)	Rearing (YOY through 18 months)	Release	Forage Fish Rearing
General	Adjacent broodstock holding / spawning areas (improve broodstock transport at boat ramp)	Spawning room with egg de-adhesion and fertilization area	NA	Hatched embryos transferred in water from hatching jars to fry rearing tanks	NA	Rearing space needed (each family is reared in 2 tanks to allow for variable growth)	Separate pre-release data collection and work-up area with data logging	Rainbow trout
Time/Months	February-June (year round if necessary)	May-June	May-July	July-September	September-November	November-November (year round)	October - December	February-June
Water Temp Range (ºC)	8 to 16° C	14 ± 2° C	14 ± 2° C	14 ± 2° C	Ambient river	Ambient river or heated; <16° during summer, ambient fall and winter or heated	Variable	Ambient
Other Water Quality Requirements	Silt and pathogen free river water	Silt and pathogen free (for river water)	Silt and pathogen free river water	Silt and pathogen free	Silt and pathogen free	Silt and pathogen free	Thermal tempering	Silt and pathogen free river water
Densities by Life Stage	< 5 broodstock per tank. 3 tanks w/ 3-4 females ea. 1 tank w/ 4-5 males ea. 2 isolation tanks (most sperm collected in field)	10,000 eggs per family; 20,000 per female	10,000 eggs / jar / family	Result of hatch success per family	2,000 fry / tank	1,000 four month-old fish/tank	NA	NA
Holding/ Production Goals (#) (average)	6 females / 12 males = 12 families	10,000 x 0.9 = 9,000 fertilized eggs per family	9,000 x 0.9 = 8,100 larvae per family	# Beginning = 8,100 # End of stage = 4,050 (per family)	# Beginning = 4,050 # End of stage = 2,025 (per family)	# Beginning = 2,025 # End of stage = 1,000 (per family)	500 - 1,000 fish/family X 12 families/year = 6,000 - 12,000	NA

Aquaculture Function/ Life Stage	Broodstock (holding/collection)	Spawning and Fertilization	Incubation and Hatch	Early Rearing (Larvae onto feed)	Rearing (on feed, up to 4 -5 months)	Rearing (YOY through 18 months)	Release	Forage Fish Rearing
Survival Assumptions by Life Stage (Average %)	99%	90%	90% (Family dependent)	50% (Family dependent)	50%	50%	NA	NA
Holding Unit Size and Description	15' dia. X 3' deep (4000 gal. ea.) 4' side wall	Not applicable to facility design	McDonald jar battery	Rectangular tanks (8'x2'x18" deep)	8' dia x 4' h (1,200 gal)	8' dia. tanks, 1,000 fish per tank	NA	10' dia x 4.5' h
Number of Tanks and Water Exchange/ Flow Rates	6 tanks, 6.6 hour exchange, 10 gpm/ tank-1 empty for ops flex (may expand at Twin)	Not applicable to facility design	24 jars (multiple batches)	24 tanks, R=2, Flow 2 gpm/tank	24 - 8' dia, @ 8 gpm	24 - 8' dia, @ 8 gpm	NA	(3) 10' x 4.5' h tank
Total Flow - GPM	60 gpm	1 gpm	48 gpm	48 gpm	8 gpm /tank (192 gpm total)	8 gpm /tank (192 gpm total)	NA	10 gpm / tank 30 gpm
Water Source	Kootenai River	Kootenai River	Kootenai River	Kootenai River	Kootenai River	Kootenai River	NA	Kootenai River
Water Treatment	Sediment filtration, ozone, UV, water tempering, proper fish densities	Egg disinfection (iodophore)	Sediment filtration, ozone, UV, proper egg densities, incubator flows	Sediment filtration, ozone, UV, proper fish densities	Sediment filtration, ozone, UV, chill, proper fish densities	Filtration, ozone, UV, proper fish densities	NA	Filtration, ozone, UV, proper fish densities

Biocriteria for Kootenai sturgeon production at the Twin Rivers Hatchery.

Aquaculture Function/ Life Stage	Broodstock (holding/collection)	Spawning and Fertilization	Incubation and Hatch	Early Rearing (Larvae onto feed)	Rearing (on feed, up to 4 months)	Rearing (YOY through 18 months)	Release	Forage Fish Rearing
General	Adjacent broodstock holding spawning areas (improve broodstock transport at boat ramp)	Spawning room with egg de-adhesion and fertilization area	NA	Hatched embryos transferred in water from hatching jars to fry rearing tanks	NA	Rearing space needed (each family is reared in 2 tanks to allow for variable growth)	Separate pre-release data collection and work-up area with data logging	Rainbow trout
Time / Months	February-June	May-June	May-July	July-September	September-November	November-November (year round)	October - November	Year round
Water Temp Range (°C)	8 to 16° C	14 ± 2° C	14 ± 2° C	14 ± 2° C	Ambient river or heated; <16° during summer (chill), ambient fall and winter or heated	Ambient river or heated; <16° during summer (chill), ambient fall and winter or heated	Variable	Groundwater
Other Water Quality Requirements	Silt and pathogen free		Silt and pathogen free	Silt and pathogen free	Silt and pathogen free	Silt and pathogen free	Thermal tempering	Silt and pathogen free
Densities by Life Stage	≤ 5 broodstock per tank. 3 tanks w/ 3-4 females ea. 1 tank w/ 4-5 males ea. 2 isolation tanks (most sperm collected in field)	10,000 eggs per family; 20,000 per female	10,000 eggs / jar / family	Result of hatch success per family	2,000 fry / tank	1,000 four month-old fish/tank	NA	NA
Holding/ Production Goals (#) (average)	9 females / 18 males = 18 families	10,000 x 0.9 = 9,000 fertilized eggs per family	9,000 x 0.9 = 8,100 larvae per family	# Beginning = 8,100 # End of stage = 4,050 (per family)	# Beginning = 4,050 # End of stage = 2,025 (per family)	# Beginning = 2,025 # End of stage = 1,000 (per family)	500 - 1,000 fish/family X 18 families/ year = 9,000 - 18,000	NA

Aquaculture Function/ Life Stage	Broodstock (holding/collection)	Spawning and Fertilization	Incubation and Hatch	Early Rearing (Larvae onto feed)	Rearing (on feed, up to 4 months)	Rearing (YOY through 18 months)	Release	Forage Fish Rearing
Survival Assumptions by Life Stage (Average %)	99%	90%	90% (Family dependent)	50% (Family dependent)	50%	50%	Variable	NA
Holding Unit Size and Description	15' dia. X 3' deep (4,000 gal. ea.)	NA to facility design	McDonald jar battery (3 L volume)	Rectangular tanks (8'x2'x18" deep)	8' dia. x 4.5' h (1800 gal.)	8' dia. x 4.5' h (1800 gal.)	NA	No incubation trays
# Tanks and Water Exchange/ Flow Rates	6 tanks, 6.6 hour exchange- 10 gpm/tank 1 empty for operations flexibility (flexibility to hold males and hold broodstock for extended periods)	NA to facility design	36 jars R=1 / min; 2.5 GPM/ tank	36 tanks, R=2, flow 6 GPM/ tank	36 - 8' dia. 1 to 3 hour exchange, 10 GPM/ tank	36 - 8' dia. 1 to 3 hour exchange, 10 GPM/ tank	NA	(1) 10' dia in Sturgeon side and (1) 10' dia in burbot side
Total Flow - GPM	60 GPM	10 GPM	90 GPM	216 GPM	360 GPM	360 GPM	NA	10 GPM groundwater; 50 GPM surface water
Water Source	All Sources	All Sources	Ground and/or Kootenai River	All sources (priority Kootenai, Moyie)	All sources (priority Kootenai, Moyie)	All sources (priority Kootenai, Moyie)	NA	Groundwater preferred
Water Treatment	Filtration, ozone, UV, proper fish densities, tempering	Egg disinfection (iodophore)	Filtration, ozone, UV, proper egg densities, incubator flows	Filtration, ozone, UV, proper fish densities	Filtration, ozone, UV, proper fish densities	Filtration, ozone, UV, proper fish densities	NA	NA

ATTACHMENT B.
BIOCRITERIA FOR KOOTENAI BURBOT AND LIVE FEED

Attachment B – Biocriteria for Kootenai Burbot Production

Biocriteria for burbot and live feed.

Aquaculture Function/Life Stage	Broodstock (collection, holding)	Spawning and Fertilization	Incubation and Hatch	Larval Rearing	Fry Rearing (on feed, up to 4 months)	Rearing (YOY) Fingerling	Rearing (juveniles-Age 1+)	Pond	Live Feed*	
									Rotifers for Production	*Artemia* GSL 90+
Time / Months	Collect from donor source, hold 3 to 12 months.	January-March (currently 100% field collection)	January-April	March-June	June-August	August-January	January-December	April-November	March-June	April-July
Water Temp Range (°C)	Year-round range: 2-20˚C	2-4˚C	4-6˚C (below 5˚C for incubation)	6-10˚C (increase to 8 or above for feeding)	10-20˚C	Ambient; but less than 20˚C	Ambient; but less than 20˚C	8-20˚C	18-25˚C	28˚C
Other WQ Requirements	pH 8-8.5, DO $\geq$ 6 ppm, Buffering capacity @ ARI > 150 ppm CaCO3	As above	As above	2 ppt NaCl	As above	As above	As above	> 6 ppm DO, pH 7-9	pH 7-8 salinity 15 ppt	pH 7-8 5-30 ppt seawater
Densities by Life Stage	Minimize, 15 adults/tank	Minimize, 15 adults/tank	100K-300K per incubator; hatch holding at 1500/L	<1,000/L Recommended	10-250/L	5-10/L	1-10/L	100-1,000/m^2 (older than 45 d on live feed)	Variable	Variable
Production Goals (weight)	0.5-3.0-kg fish should be mature	NA	NA	<0.1 g/fish	0.1-1.5 g/fish	1.5-25 g/fish	25-250 g/fish	TBD	up to 300 mil/day up to 25x/day	up to 100 mil/day up to 5x/day
Average Survival Assumptions by Life Stage	90%	Fertilize eggs within 5 minutes of collection	60 ± 10%	20 ± 5%	25 ± 5%	70 ± 20%	80 - 90%	Dependent on life stage at time of stocking	NA	NA

Aquaculture Function/Life Stage	Broodstock (collection, holding)	Spawning and Fertilization	Incubation and Hatch	Larval Rearing	Fry Rearing (on feed, up to 4 months)	Rearing (YOY) Fingerling	Rearing (juveniles-Age 1+)	Pond	Live Feed*	
									Rotifers for Production	*Artemia* GSL 90+
Average Number of Eggs or Fish	60 males/30 females - (Portion may be field collection of gametes)	200,000 eggs/female x 30 females = 6,000,000 eggs	6,000,000 x 60% = 3,600,000 hatchlings	720,000	180,000	126,000	48,000 (Assuming 50% of 6-mo. juv. stocked and 50% retained to Age-1)	Dependent on no. stocked and life stage at time of stocking	Maintain 1,000-1,500/ml	NA
Holding Unit Size and Description	Fiberglass circular tanks 1800 L (6 ft. dia. X 3 ft. deep)	NA	1-L Imhoff cones or larger (may change in future)	Insulated circular tanks 500 L, low flows required, 400-micron mesh screening required	Insulated circular tanks 500 L, low flows required, 400 micron mesh required	Circular tanks 900 L	Circular tanks 900 L	TBD at time of final design.	400 sq ft.	200 sq ft.
Holding Unit Quantity	(6) 6 ft. dia. x 3 ft. deep, including egg collection provisions (i.e. water level alarm)	NA	60 jars	(30) 3 ft. dia x 2.5 ft. deep	(30) 3 ft. dia x 2.5 ft. deep	(32) 4 ft. dia. x 2.5 ft. deep (tranistion into larger tanks)	(32) 4 ft. dia x 2.5 ft. deep	6 outdoor ponds	At least primary and backup systems	Hatchers and holding tanks
Water Exchange/Flow Rates	R = 1/hr; 10 GPM/tank		500 ml/min. ea. (may increase in future) R = 2 min/L	R = 1 minimum; 0.5-1.0 L/min or ~30-60 L/hr.	R = 2-8 L/min	R =8 L/min (will change to R = 1 or less)	R=1; 900L tanks flow need ~15 L/min	TBD at time of final design.	Access to fresh and saltwater; 200 GPD	Access to fresh and saltwater; 200 GPD
Total Flow - GPM	60 GPM	NA	7 GPM	up to 45 GPM		45-100 GPM	100 GPM	TBD at time of final design.	See above	See above

Aquaculture Function/Life Stage	Broodstock (collection, holding)	Spawning and Fertilization	Incubation and Hatch	Larval Rearing	Fry Rearing (on feed, up to 4 months)	Rearing (YOY) Fingerling	Rearing (juveniles-Age 1+)	Pond	Live Feed*	
									Rotifers for Production	*Artemia* GSL 90+
Water source	Moyie/Kootenai River water	Moyie/Kootenai River water and (Ground Water at time of spawning if volitional spawning in tank used.)	Groundwater	Groundwater	Ambient groundwater, introduce surface water toward end	Ambient river or ground water to Each Tank	Ambient river or ground water to Each Tank	Unfiltered/untreated Kootenai or Moyie River water for filling/ground water for tempering	Groundwater RO, Rearing system recycling 600-800%/d. 5 GPM/ recirc system Acclimating-stagnant-100 L /d Washing-1000 L / d, salt water reservoir up to 1000G	Groundwater RO, Rearing system recycling 600-800%/d. 5 GPM/ recirc system Acclimating-stagnant-100 L /d Washing-1000 L / d, salt water reservoir up to 1000G
Water Treatments	Ambient temps for holding; chill as needed to induce spawning	Filter, iodine disinfect and chill	De-gas, chill, hydrogen peroxide during incubation and hatch	De-gas and chill, possible hydrogen peroxide treatments and salinity for live feed (salinity for larvae stage only)		Blend rw/gw, filter and disinfect	Blend rw/gw, filter, disinfect and heat	alum, aeration	Chill or Heat, oxygen supp. and LP air	Chill or Heat, oxygen supp. and LP air
Other		A portion of gamete collection to occur at Moyie Lake. Proportion will likely vary over time.		Automated feed delivery	Automated feed delivery	Automated feed delivery	Automated feed delivery	Predator netting, shading/green house, otter control	Water storage tank 500-1000 Gal for filtered water plumbed to areas, oversized floor drains, forced air.	Lighting 2000 lux or 200 ft-candles. Photo-period 16 light:8 dark. In room separate from rotifers. Forced air.

*Note: Forage fish tankage and flows are shown under sturgeon water budget

ATTACHMENT C.
GEOTECHNICAL ENGINEERING EVALUATION

***DRAFT* REPORT**
Geotechnical Engineering Evaluation
Proposed Twin Rivers Hatchery
County Road No. 70
Moyie Springs, Idaho

PREPARED FOR:
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TETRA TECH

KOOTENAI TRIBE OF IDAHO

PREPARED BY:
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April 28, 2010

IDAHO   MONTANA   NEVADA   OREGON   UTAH   WASHINGTON   WYOMING
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***DRAFT* REPORT**
Geotechnical Engineering Evaluation
Proposed Twin Rivers Hatchery
County Road No. 70
Moyie Springs, Idaho

INTRODUCTION

The purpose of our geotechnical engineering evaluation was to assess the subsurface conditions within the proposed project area to prepare geotechnical recommendations to assist project planning, design and construction of the proposed Twin Rivers Hatchery. We accomplished the following services referencing the authorized proposal dated January 29, 2010, and the executed agreement between Tetra Tech and STRATA dated March 4, 2010.

1. STRATA accomplished a site visit to meet with Twin Rivers Resort staff (occupant) and outline proposed exploration locations. STRATA staked each location and reviewed private utility conflicts with resort staff. STRATA also coordinated exploration with a utility locating company to help reduce potential for damage to existing utilities.
2. STRATA performed subsurface exploration at the property by advancing a combination of exploratory borings and test pits. Prior to exploration, we prepared a proposed exploration sketch for Tetra Tech's review based on agreed-upon locations between STRATA and resort staff as discussed in Item 1 above. STRATA subcontracted exploratory equipment and operators to advance borings and test pits. We logged the subsurface profiles, visually described and classified the soil encountered referencing the *Unified Soil Classification System* (USCS). Soil samples were retained for laboratory testing.

   2a. STRATA advanced 3 exploratory borings to depths between 13.2 and 21.5 feet below the existing ground surface. Standard Penetration Tests (SPT) were obtained at approximate 5-foot-intervals in each boring. SPT N-values were obtained by advancing the split-spoon samplers 6 to 18 inches below the sampling interval using a 140 pound hammer with a 30-inch drop height. Borings were backfilled with on-site cuttings and received a bentonite seal.

   2b. STRATA advanced 14 exploratory test pits using a rubber-tired backhoe. Test pits were advanced 4.0 and 12.0 feet below the ground surface. We also evaluated the subsurface soil referencing the USDA *Soil Textural Subgroup Classification System*, which is used by Panhandle Health District (PHD) to help size drainfields and establish system setbacks. Test pits were loosely backfilled and slightly heaped to provide camber to help accommodate future backfill settlement.
3. STRATA installed standpipe piezometers in each boring and in select test pits. Piezometers consisted of 1-inch, schedule 40 PVC, screened over the anticipated groundwater fluctuation interval.
4. STRATA performed laboratory testing referencing *ASTM International* (ASTM) test standards. The laboratory testing program included the following:

- Grain-size distributions
- In-situ unit weight and moisture
- Atterberg limits
- Proctor density relationships
- pH
- Resistivity

5. STRATA performed engineering analyses to provide geotechnical design and construction recommendations for:

   - **Earthwork**
     - Site subgrade preparation
     - Excavation characteristics
     - Structural fill criteria
     - Compaction requirements
     - Utility construction
     - Rip-rap considerations (boat ramp area)
   - **Foundations**
     - Recommended foundation bearing soil
     - Foundation design criteria including:
       - Allowable conventional foundation bearing pressure
       - Coefficient of foundation base sliding friction (f_s)
       - Allowable bearing pressure increase for transient loading
       - Estimated foundation settlement
       - Foundation drainage
     - Seismicity
       - IBC Site Class
       - Spectral response accelerations
       - Liquefaction Potential
     - Concrete Slab-on-Grade Floors
       - Modulus of subgrade reaction
       - Moisture protection and vapor retarders
       - Recommended slab subgrade
     - Lateral Earth Pressures (LEPs)
       - Static and dynamic LEPs
         1. At-rest LEP
         2. Active LEP
         3. Passive LEP
   - **Site Surface and Subsurface Drainage**
     - Foundation and below-grade wall drainage
     - Site grading recommendations near structures
     - Allowable stormwater infiltration rate
   - **Pavements**
     - Recommended pavement section subgrade
     - Pavement section thickness design
     - Unpaved road section
   - **Additional Recommended Services**

6. STRATA prepared this draft geotechnical evaluation for project team review. Once we receive review comments, we will incorporate pertinent design team feedback and provide 4 copies of our geotechnical report of findings and opinions including exploration logs, laboratory test results and other related visual aids.

PROJECT UNDERSTANDING

The hatchery design and operations concept is currently being developed and design is ongoing. However, most required facilities and structures have been delineated although their exact locations and configurations are not finalized. The proposed project generally incorporates the following aspects:

- 6 burbot tanks
- 4 sturgeon tanks
- Sediment pond to remove sediment from water before discharge
- Access road and boat ramp improvements at the Kootenai River
- River intakes, including:
  - Moyie River intake screen, pump station and pipeline to the hatchery
  - Kootenai River intake screen, pump station and pipeline to the hatchery
- Hatchery structure, including:
  - Fish brood stock and spawning areas
  - Fish incubation
  - Fish rearing
  - Staff offices and conference room
  - Janitor, restroom, showers and miscellaneous storage
  - Water treatment facilities
  - Multi-purpose laboratory
  - Vehicle storage, maintenance and shop
  - Mechanical and utility rooms

<u>Outdoor Tanks and Sediment Pond Structures</u>

These exterior tank/reservoir structures will be cast-in-place concrete with ringwall or mat foundations. Each will extend approximately 4 to 8 feet below grade, depending upon system hydraulics and groundwater levels. We understand Tetra Tech will attempt to design below-grade structures that exist above seasonal high groundwater levels, although the tank embedment depths could vary. Permanent dewatering measures are not anticipated for the exterior tanks.

Boat Ramp and Access Improvements

The road near the resort entrance and close to the proposed hatchery building may be improved with asphalt pavement immediately adjacent to the hatchery facility. Another access road will be improved with gravel surfacing extending south towards the boat ramp. The boat ramp will be precast Portland cement concrete planks with gravel ingress, egress and rip-rap or other slope armoring and erosion protection.

Pipelines

Water intake structures will be constructed for both the Moyie and Kootenai Rivers. The Kootenai River intake structure will connect to a pump station approximately 17 feet below grade in its current planned location. The Kootenai pump station will route river influent to the facility through and below the boat ramp access roadway through the RV Park to the hatchery. The Moyie River intake screen will be routed to a below-grade pump station at a currently unknown depth. The Moyie River influent will then be routed below a separate access road to the hatchery facility. Both influent lines will be pressurized and will be shallow (assumed less than 4 feet).

Hatchery Structure

The hatchery building will house several fish, administrative and maintenance facilities within one structure. We understand this structure will have cast-in-place concrete foundations with reinforced masonry walls and a wood framed roof structure. The flooring systems are expected to be concrete slabs and may be combined with mat foundations for some interior fish rearing, breeding, spawning or water treatment structures and/or tanks. There may be minor below-grade tanks and vaults, however, we understand these structures are not currently planned to extend more than 8 feet below grade. Electrical and water utility improvements are expected to be minor. Minor gravity sewer may be planned for the new septic system, but has not yet been designed.

Based on a preliminary foundation load schematic you provided on March 19, 2010, we understand the proposed hatchery structure isolated column footing loads will be on the order of

100 kips. In addition, loads to continuous strip footings under the CMU walls are estimated at 4 kips per lineal foot (klf). The anticipated point loads along continuous footing locations (i.e. pilaster foundations) will be approximately 60 kips. We estimate below-grade tanks will induce a contact pressure of approximately 500 pounds per square foot (psf), based on static water column height and unit weight of concrete.

FIELD AND LABORATORY EVALUATION

Site Exploration

We evaluated the site subsurface conditions by observing 14 exploratory test pits and 3 exploratory borings near proposed structures for the project. Exploration locations presented on Plate 1, *Site Plan* are approximate and were located in the field by measuring from existing site features and by referencing available aerial photographs and site features. A field engineer and assistant project engineer from our Coeur d'Alene office observed fieldwork on February 23, 2010. These staff visually described, classified and logged the subsurface conditions encountered during exploration referencing the USCS and the USDA *Soil Textural Subgroup Classification System*. Appendix A presents exploratory boring logs, test pit logs, and USCS and *USDA Soil Textural Subgroup Classification System* explanations, which should be used to help interpret soil terms used on the logs and throughout this report.

Borings were advanced 13.2 to 21.5 feet beneath the ground surface using a Mobile B40 drill rig equipped with hollow-stem augers. SPTs and soil samples were collected within borings at approximate 5-foot-intervals. A standpipe piezometer was installed in each boring and boring excavations were loosely backfilled with soil cuttings and received a bentonite seal following completion. We labeled and staked each boring location.

Test pits were advanced to depths of 4 to 12 feet using a Deere 310E backhoe equipped with standard soil excavation teeth. We obtained subsurface soil samples within the test pits for laboratory testing and to assist soil classification. Many test pits experienced caving conditions which did not allow for deeper excavation depths. STRATA performed single-ring infiltration testing in select test pits to help correlate soil infiltration rates. Standpipe piezometers were installed in select test pits and test pits were loosely backfilled following completion. Plate 1 illustrates test pit locations in which standpipe piezometers were installed. We labeled and staked each test pit and we recommend they be surveyed and re-located prior to mass grading.

Prior to, or during site grading, we recommend the loose test pit backfill be completely removed to undisturbed, medium dense, native soil and replaced with structural fill according to the recommendations presented herein.

Subsurface Conditions

In general, two soil types were encountered at the project site; surficial native sands and silts and deeper native gravel with sand soil. The site geology is indicative of alluvial deposits resulting from fluctuating river deposition, seasonal flooding and subsequent erosion. Bedrock was not encountered within the depths or locations explored. The following sections briefly summarize soil conditions encountered during fieldwork.

Surficial Sand and Silt

The upper 3 to 9 feet of the soil profile consisted of native sand, silty sand, sandy silt and silt. In general, these upper soil were tan to brown and in loose to medium dense condition. The soil fraction passing the No. 200 sieve (fines content) ranged from 18 to 92 percent in the upper soil profile. We suspect these surficial soil are variable overbank deposits resulting from seasonal flooding and sediment deposition. The surficial silt and sand soil are generally loose and exhibit moderate to poor foundation support characteristics.

Deeper Native Gravel

Surficial silt and sand was underlain by poorly-graded gravel with sand encountered between 3 to 18 feet beneath the ground surface. Gravel was brown, medium dense to dense, moist to saturated and extended to the test pit and boring termination depths. These deeper gravel sediments likely comprise glacial outwash combined with high-energy depositional sediments from the Moyie River, and exhibit good to excellent geotechnical characteristics for foundation support and soil reusability.

Groundwater

Groundwater was encountered in TP-7 and B-3 during fieldwork. Soil mottling was observed in some test pits between 4 to 6 feet, which implies that groundwater at the site has the potential to rise to these levels. Subsequent groundwater monitoring identified groundwater in B-3 at a depth of 13.3 feet beneath the ground surface. The following table summarizes existing groundwater monitoring data to date:

Table 1. Groundwater Monitoring Data

Location	Depth to Groundwater March 15, 2010[1]	Depth to Groundwater March 30, 2010[1]
TP-2	N.E.[2]	N.E.
TP-3	N.E.	N.E.
TP-4	N.E.	N.E.
TP-5	N.E.	N.E.
TP-6	N.E.	N.E.
TP-8	N.E.	N.E.
TP-9	N.E.	N.E.
B-1	N.E.	N.E.
B-2	N.E.	N.E.
B-3	14.0	13.3

1. Feet below existing ground surface
2. N.E. = Not encountered

Groundwater has the potential to vary with seasonal fluctuations in precipitation, irrigation, infiltration and project site developments. Specifically, groundwater could fluctuate at certain times of the year as a result of water level variations in the adjacent Kootenai River and Moyie River channels. To provide a more accurate estimate of seasonal high groundwater and potential water variations at the project site, we recommend groundwater continue to be monitored on a bi-weekly or weekly basis. STRATA is retained to provide groundwater monitoring services through spring runoff, 2010.

Laboratory Testing

We tested select soil samples to help evaluate their engineering characteristics and to assist soil classification. We completed the following laboratory tests:

- Grain-size distributions
- In-situ unit weight and moisture
- Atterberg limits
- Proctor density relationships
- pH
- Resistivity

Appendix B presents laboratory test results. Index laboratory test results are summarized on the exploration logs in Appendix A. We performed laboratory testing referencing applicable ASTM test standards. STRATA will retain the soil samples in our laboratory for a 90-day period following the date of the final report. At the end of the 90-day period we will dispose of the samples unless we receive written notification to retain the samples for a longer time period.

DISCUSSION

Based on our field and laboratory evaluation, our opinion is the project site is suitable for the proposed construction, provided our recommendations are incorporated into project plans and specifications and are followed and verified during construction. However, as summarized herein, we identified several site characteristics which will affect project planning, design and construction. The following list briefly summarizes these conditions; subsequent report sections provide specific geotechnical recommendations to address such conditions.

- The shallow silt and sand encountered in the upper 3 to 9 feet at the site is loose and will require soil improvements be constructed beneath proposed shallow foundations.
- Gravel encountered at the site can be re-used as structural fill, however particles in excess of 3 inches in diameter must be screened prior to re-use.
- The shallow silt and sand encountered at the site can be reused as structural fill. However if reused, the soil can be difficult to moisture-condition, place and compact and may cause earthwork challenges if over optimum soil moisture conditions exist.
- A slight liquefaction hazard exists at the site due to groundwater conditions and the presence of loose sand soil.
- Depending upon final site grades, bearing depths for structures and the construction schedule, high groundwater conditions may require dewatering to construct below-grade tanks and/or lift stations.

As site planning and design is ongoing, we recommend STRATA review substantially complete design plans once structure locations, loading and site configurations are better developed. Upon receiving substantially complete design documents, STRATA can review the recommendations provided herein and provide design revisions, if necessary.

GEOTECHNICAL OPINIONS AND RECOMMENDATIONS

The following geotechnical recommendations are presented to assist planning, design, and construction of the proposed Twin Rivers Hatchery project in Moyie Springs, Idaho. We based our geotechnical recommendations on our experience with similar soil and geologic conditions, findings from our field and laboratory evaluation and our project understanding. If development plans change, we should be contacted to review the project modifications and revise our recommendations, if necessary. Additionally, if unforeseen conditions are exposed during construction, STRATA should be retained to review our recommendations and provide any necessary revisions or modifications.

The subsurface conditions encountered have the potential to vary across the site. Such soil condition variations could negatively impact project schedules and costs. If conditions are encountered during construction that differ from what we present herein, STRATA should be contacted to identify the changed conditions, review our recommendations and provide any necessary report revisions or modifications.

Earthwork

<u>Excavation Characteristics and Equipment</u>

We anticipate the on-site soil may be excavated using conventional soil excavation techniques. In general, slopes and excavations must be excavated, shored or braced in accordance with the *Occupational Safety and Health Administration* (OSHA) specifications and local codes. The on-site soil is generally classified as type “C” soil according to OSHA requirements. As such, we recommend provisions be made to allow temporary excavations of any type and soil to be sloped back to at least 1.5H:1V (horizontal to vertical). Construction vibrations from nearby equipment can cause any excavation to slough or cave within the clean sand and gravel sediments, but especially the upper surficial soil. Ultimately, it is the selected contractor’s responsibility to provide safe, stable excavations.

Excavations may encounter groundwater and must be planned carefully, allowing water collection points and utilizing conventional sumps and pumps to remove groundwater or nuisance water from runoff or precipitation. If soil excavations in silt and fine sand soil are not immediately backfilled, they may degrade when exposed to runoff and require overexcavation and replacement with granular fill. We recommend construction activities and excavation backfilling be performed as rapidly as possible following excavation to reduce the potential for subgrades to degrade under construction traffic. Groundwater infiltration to excavations has a high potential to cause sloughing and instability in the surficial sand and silt, and to a lesser extent, the underlying gravel soil.

<u>Site Preparation</u>

We recommend all soil containing vegetation and organics (topsoil) be removed below any planned improvement, structure or fill area. We typically observed 2 to 6 inches of vegetation and organics in exploration locations. However, isolated, thicker soil zones containing vegetation and organics were encountered, such as near tree root systems. The contractor should expect isolated areas of thicker topsoil. In areas containing large roots, but less than 3 percent (by weight) organic and vegetative matter, we recommend removing roots larger than ½-inch in diameter from beneath all site developments or from structural fill. Stripping soil with vegetation and organics must extend laterally at least 5 feet outside of planned development areas or pavements. Although not encountered, if uncontrolled fill is identified in the development area, it must be completely removed to medium dense or dense native soil.

Following site stripping, the native soil subgrade shall be proof compacted using a minimum of 5 passes with a 10-ton vibratory roller as observed by STRATA. If smaller equipment is used, additional passes may be necessary at STRATA's discretion. Subgrade preparations can often help identify areas susceptible to subgrade pumping and rutting. Pumping or rutting subgrade areas should be removed to a depth of 12 inches below the subgrade. The excavation from removing such pumping and rutting areas (overexcavation) should be replaced with granular subbase, placed and compacted as recommended throughout this report. Following the above site preparation procedures, structural fill may be placed over the proof compacted subgrade. We recommend STRATA observe proof compaction efforts to help confirm soil conditions between exploration locations and to help identify pumping, rutting or otherwise disturbed or unstable soil areas.

<u>Structural Fill</u>

All fill for the planned development must be placed as structural fill. Surficial silty sand, sand, silt and deeper gravel soil encountered during exploration may be reused as structural fill. However, earthwork contractors must plan for appropriate time and site areas to moisture-condition the surficial silt, silty sand and sand with silt, as this soil can be difficult to moisture-condition and compact if over optimum soil moisture content exists. Recommended structural fill products and their allowable uses are described in Table 2 below. Structural fill products are provided referencing the latest edition of the *Idaho Standards for Public Works Construction* (ISPWC).

Table 2. Structural Fill Products and Allowable Uses

Structural Fill Product	Allowable Use	Material Specifications
Unsatisfactory Soil	**NONE**	• Soil classified as CL, CH, MH, OH, OL or PT may not be used at the project site. • Any soil type not maintaining moisture contents within 3 percent of optimum during compaction is unsatisfactory soil. • Any soil containing more than 3 percent (by weight) organics or other deleterious substances (wood, metal, plastic, waste, etc) is unsatisfactory soil.
Non-Structural Fill (Landscape Fill)	Any area that will not contain structures (typically landscape areas). Includes utility trench backfill outside of any structure or flatwork	• Soil classified as GP, GM, GW, GC SP, SM, SW, SC, CL or ML according to the USCS. • Soil may not contain particles larger than 12-inches in median diameter. Soil must be reasonably free from deleterious substances.
General Structural Fill	All site grading, structural fill, utility trench backfill	• Soil classified as GP, GM, GW, SP, SM, SW or ML referencing the USCS. • May not contain particles larger than 3-inches in median diameter. • Must be inert earth material with less than 3 percent (by weight) organics or other deleterious substances. • Soil must be moisture conditioned appropriately to achieve required compaction.
Uncrushed Aggregates (Subbase)	Temporary haul roads, staging areas, overexcavations, structural fill, soil improvements	• Must meet requirements in ISPWC *Section 801 – UNCRUSHED AGGREGATES.*
Crushed Aggregate (Base Course)	Concrete slab support, asphalt pavement section support, structural fill, soil improvements	• Must meet requirements in ISPWC *Section 802 – CRUSHED AGGREGATES.*
Pipe Bedding	Trench backfill within 1-foot of any utility pipe	• Must meet requirements in ISPWC *Section 305 –PIPE BEDDING* (Type II).
Drainage Course (Drain rock)	Foundation drainage system	• Must meet requirements in ISPWC *Section 801 – UNCRUSHED AGGREGATES* for *Drain Rock – 3-inches.*

Structural fill should be compacted to a minimum of 95 percent of the maximum dry density of the soil referencing ASTM D 1557 (Modified Proctor). Fill placed outside the building or pavement envelope can be placed as non-structural fill (i.e. landscape fill), providing there are no structures (sidewalk, curbs, signs, etc.) planned directly above the landscape fill. We recommend landscape fill be compacted to a minimum of 85 percent of the maximum dry density of the soil according to ASTM D 1557 (Modified Proctor). Stemwall backfill must also be compacted to structural fill requirements presented above.

All structural fill should be moisture-conditioned to near optimum moisture content and placed in maximum 12-inch-thick, loose lifts. Structural fill within 2 vertical or horizontal feet of any structure should not contain particles larger than 6 inches in any dimension. The above compaction and structural fill requirements assume large compaction equipment such as vibratory rollers with drum energy of 10 tons or greater is used to attempt compaction. If smaller or lighter compaction equipment is provided, the lift thickness should be reduced.

Any material with greater than 30 percent retained above the ¾-inch sieve is too coarse for Proctor density testing and therefore must be compacted using a “method specification” developed during construction based on the material characteristics and the contractor’s means and methods. At a minimum, STRATA recommends oversized soil be placed in maximum 12-inch lifts and compacted with 5 complete passes (over and back) of a 10-ton, vibratory or grid roller. Vibratory rollers must have a dynamic force of at least 30,000 pounds per impact, per vibration and at least 1,000 vibrations per minute. Oversized soil must be compacted to a dense, interlocking and unyielding surface. We recommend STRATA review the soil and aggregate material planned for fill use and monitor compaction effort during construction.

Utility Trench Construction

Structural fill for backfilling utility trenches should conform to the structural fill recommendations presented in this report. All bedding should conform to ISPWC *Section 305, Type II Pipe Bedding.* Loose soil must be removed from the base of utility trenches prior to placing pipe bedding. Based on our observations during excavation, loose soil and sloughing will be likely at the base of utility trenches. In addition, if water is encountered, it must be removed from the base of the utility trench before placing pipe bedding. We recommend utility pipes be placed on at least 4 inches of bedding placed over undisturbed native soil, structural fill or otherwise supported according to the pipe manufacturer’s specifications and ISPWC requirements. The on-site native soil may be screened and processed for bedding, providing it meets ISPWC requirements.

After bedding the pipe, place structural fill and compact it from the pipe invert to 1-foot above the top of the pipe with tamping bars and/or plate compactors to render the backfill in a firm and unyielding condition. Thoroughly place and compact bedding below pipe haunches or the zone between the pipe invert and the spring line. To accomplish backfilling, the distance between the side of the pipe at the spring line and the trench wall should be at least 12 inches. The remainder of the utility trench should be backfilled in accordance with the *Structural Fill* section of this report.

<u>Rip-Rap Considerations</u>

The following outlines considerations with respect to rip-rap material planned for the proposed boat ramp improvements at the south end of the project:

- We recommend submerged rip-rap placed near the boat ramp area meet the following criteria:
  - 6-inch-minus clean, coarse gravel and cobbles
  - Rip-rap should contain less than 10 percent particles smaller than 2 inches in median diameter. Particles in rip-rap that are smaller than 2 inches in median diameter may be susceptible to erosion. Particles eroded from the rip-rap matrix can help destabilize the layer.
  - Rip-rap should be as angular as practical to help increase particle interlocking and to help strengthen the layer.
- A non-woven geotextile fabric should be placed below all rip-rap material and shall be sized according to the proposed construction equipment and particle size to avoid fabric damage during construction. We recommend the following minimum specifications for non-woven geotextile fabric:
  - <u>Mullen Burst Strength</u> (ASTM D 3786) – 250 pounds per square inch (psi) or greater
  - <u>Grab Tensile Strength</u> (ASTM D 4632) – 125 pounds or greater
  - <u>Puncture Strength</u> (ASTM D 4833) – 75 pounds or greater
- A 12-inch-deep, 12-inch-wide trench should be excavated below the subgrade around the entirety of the area to be rip-rapped. The geotextile fabric should be placed into the base of the trench to create a thickened edge for the rip-rap layer. The rip-rap layer should extend a minimum of 2 feet beyond the trench containing non-woven geotextile fabric
- Rip-rap should be consolidated during placement using large equipment such as backhoes or trackhoes to seat the layer into the native soil and help embed the particles at the rip-rap/native soil interface.
- The above rip-rap considerations assume water velocities less than 15 feet per second. Higher stream velocities will require rip-rap with greater particle diameter.
- Rip-rap maintenance is paramount to protect against ongoing erosion and sedimentation.

- On-site native gravel may be suitable for re-use as rip-rap material providing it is processed to meet the required grain-size as presented below.
- We recommend rip-rap extend at least 2 feet higher in elevation above the normal high water mark for the Kootenai River in the boat ramp vicinity. Rip-rap should extend above the normal high water mark in an effort to help reduce erosion from boat wake or other temporary isolated water currents.
- We do not recommend rip-rap be placed on slopes steeper than 3H:1V. If rip-rap will be placed on slopes steeper than 3H:1V, STRATA should be contacted to review rip-rap stability considerations.

The above considerations are intended to help reduce the potential for soil around the rip-rap perimeter to be eroded, which could undermine the layer. Thus, we recommend the rip-rap layer extend completely to the proposed boat ramp and in all areas that may be susceptible to seasonal, channelized water flow near boat ramp areas. STRATA is not responsible for erosion of soil particles outside rip-rap areas that could undermine the rip-rap layer. We recommend Tetra Tech carefully review the expected stream flow velocities to verify the maximum velocities we assumed for rip-rap design are not exceeded.

<u>Geotextiles</u>

As discussed in several report sections above, geotextile fabric will be required in overexcavations, below the pavement section and in soil improvements. Geotextiles shall be installed in strict accordance with manufacturer's specifications. Geotextile fabric should be placed flat against any prepared subgrade or excavation sidewall. Geotextile shall be placed, where specified, everywhere native soil would come into contact with aggregate or drain rock. Geotextiles should be overlapped a minimum of 12 inches and pulled taut.

Woven geotextile fabric is required in overexcavations, in soil improvements, at slab subgrade and at the pavement subgrade. Non-woven geotextiles are required wherever drain rock, rip-rap, or other drainage aggregate contacts native soil and requires separation to help prevent soil infiltration. Any project woven or non-woven geotextile shall meet or exceed the following minimum properties:

- <u>Mullen Burst Strength</u> (ASTM D 3786) – 450 pounds per square inch (psi) or greater
- <u>Grab Tensile Strength</u> (ASTM D 4632) – 175 pounds or greater
- <u>Puncture Strength</u> (ASTM D 4833) – 90 pounds or greater
- <u>Flow Rate</u> (non-woven only)(ASTM D 4491) – 100 gallons per minute per square foot

- Apparent Opening Size (woven only) (ASTM D 4751) – US Sieve 30 to 50
- Permittivity (woven only) (ASTM D 4491) – 0.1 sec^{-1}

Foundation Design

We recommend continuous wall footings, column foundations and mat foundations for the proposed structures be placed over the bearing soil recommended in Table 3:

Table 3. Foundation Bearing Soil

Foundation Type	Foundation Loads	Bearing Soil
Column Footings (point loads)	60 to 100 kips	3 feet of soil improvements over native soil compacted to structural fill requirements[1]
Continuous Footings (line loads)	Up to 5 kips per lineal foot	1-foot of soil improvements over native soil compacted to structural fill requirements[1]
Mat Foundations for Below-Grade Tanks	1,000 to 2,000 psf	Native soil or structural fill compacted to structural fill requirements[1]

1. Native soil must be scarified, moisture-conditioned and compacted to structural fill requirements to a minimum depth of 8 inches below the base of the soil improvement.

Soil improvements are required below foundations due to the compressible nature of the surficial silt and sand, the moderate structural loads and the structural foundation settlement criteria. Soil improvements generally consist of excavating below and beyond each foundation, placing geotextile fabric and replacing the excavation with granular subbase or crushed aggregate placed and compacted to the requirements presented herein. Specifically, soil improvements must adhere to the following requirements:

1. Soil improvements must extend a minimum of 1-foot laterally (measured from the edge of footing) for every 1-foot of vertical thickness.
2. Soil improvements shall not be constructed over soil containing vegetation and organics, uncontrolled fill, disturbed native soil or otherwise unsuitable soil as determined by STRATA during construction. Soil improvements shall be constructed over one of the following conditions:
    a. Native soil that has been compacted to structural fill requirements to a minimum depth of 8 inches below the foundation bearing surface.

b. Structural fill placed and compacted according to this report and placed over proof compacted native soil as discussed in the *Site Preparation* section of this report.

3. The soil improvement excavation shall receive *woven* geotextile fabric everywhere granular subbase or crushed aggregate will contact native soil, including the excavation sidewalls. Woven geotextile fabric shall consist of material meeting the requirements outlined in the *Geotextiles* section of this report.
4. All soil improvements shall be constructed with granular subbase or crushed aggregate meeting the criteria presented in Table 2. All soil improvement backfill shall be compacted to at least 95 percent of Modified Proctor.
5. The soil improvements discussed above must extend to the footing bearing surface. The footing bearing surface shall be free of loose soil, debris, standing water and any other material that does not meet the criteria for granular subbase or crushed aggregate as shown in Table 2.
6. Foundation concrete shall be placed directly over compacted soil improvements constructed as presented herein.

Foundations should bear at least 30 inches below the final exterior grade to help reduce frost effects. Interior foundations should maintain at least 4 inches of compacted aggregate base between the slab base and top of footings. We recommend all footing excavations and compacted structural fill be observed and monitored by STRATA to verify the excavations have been accomplished to the recommended bearing soil and structural fill placements have occurred in accordance with our report recommendations. If the above earthwork and site preparation recommendations are followed, we recommend an allowable foundation bearing pressure of 3,000 psf be used for footing design. This allowable bearing pressure can be increased 30 percent to account for transitory live-loads such as wind or seismic forces.

Foundations bearing on soil improvements prepared as described herein may utilize a coefficient of sliding friction (f_s) of 0.45 applied to vertical dead-load forces to resist lateral loads. This assumes concrete is cast directly over bearing soil recommended herein. Below-grade stemwalls and tanks should be backfilled with imported structural fill as described in the *Structural Fill* section of this report. If the above geotechnical recommendations and all site preparation procedures are followed, we estimate total and differential foundation settlement will be less than 1-inch and ½-inch, respectively, for continuous foundations over a 30-foot-span, or between isolated footings. Minimum footing widths should be consistent with the latest edition of the *International Building Code* (IBC).

We recommend shallow foundations be drained by constructing a foundation and wall drainage system. Typical schematics showing foundation drainage systems are provided on Plate 2, *Foundation and Wall Drain Schematic*. Foundation drains should never be connected to roof drains and should be routed to stormwater disposal facilities designed by the civil engineer. Kootenai Tribe of Indians (KTOI) and Tetra Tech may elect to omit foundation drains, in certain areas, depending upon the operations for certain portions of the structure. Foundation drains help route water away from the structure and reduce the potential for soil saturation and increasing moisture contents in slabs. KTOI and Tetra Tech must carefully consider the risks associated with reduced foundation drainage if such systems are omitted. Further, we understand below-grade tank walls may be too low to allow foundation drains to daylight without mechanical pumping. Accordingly, we recommend Tetra Tech consider designing below-grade tank walls for hydrostatic, saturated conditions. STRATA's groundwater observations to date indicate groundwater during seasonal high runoff may be on the order of 10 to 12 feet below existing grades. However, the observed flood elevation is only 3 to 5 feet below current grades and STRATA observed soil mottling at 4 to 6 feet below grade. Accordingly, we recommend 4 feet be considered maximum groundwater elevation for the vicinity of the hatchery structure and below-grade tanks. Seasonal high groundwater may be higher in lower elevations at the site, and may correspond to the 100-year flood elevation.

Seismicity

Section 1615 of the IBC outlines the procedure for evaluating site ground motions and design spectral response accelerations. STRATA utilized site soil and geologic data and the project location to establish earthquake loading criteria at the site referencing *Section 1615* of the 2003 IBC. Based on our understanding of site conditions and experience in the area of this project, we recommend a Site Class of "C" be utilized as a basis for structural seismic design. The Maximum Considered Earthquake (MCE) maps from the IBC were referenced to develop the MCE Response Spectra for Site Class C as presented in Figure 1 below. This response spectrum assumes a 5 percent critical damping ratio in accordance with the IBC, *Section 1615*. A site specific study was not performed. The structural designer may use the spectral response at period T = 0 to estimate peak ground acceleration at the site.

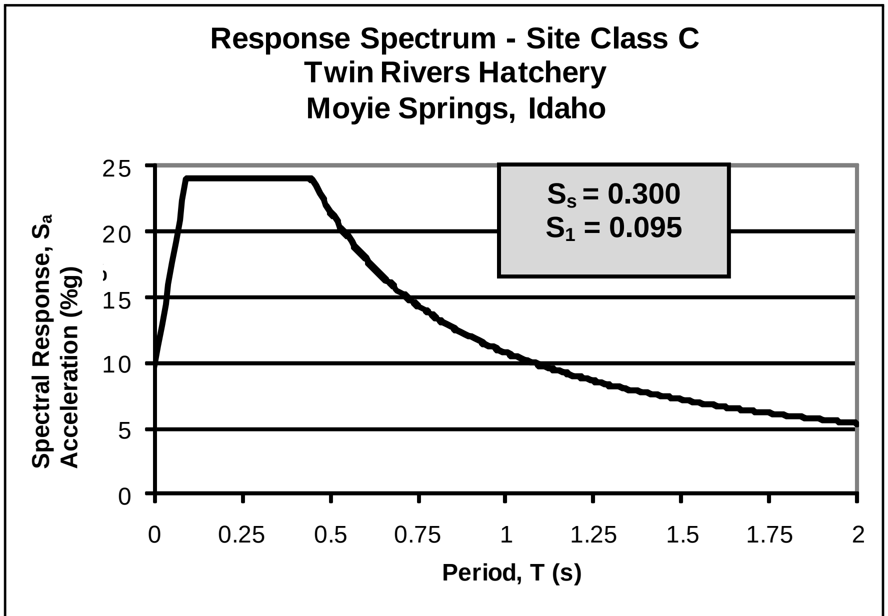


Figure 1. IBC MCE Response Spectrum, Twin Rivers Hatchery, Moyie Springs, Idaho

Liquefaction Potential and Impacts

The underlying native loose silt and sand layers are potentially susceptible to liquefaction when they are saturated during high groundwater conditions coupled with a substantial seismic event. Liquefaction is defined as the rapid loss of soil shear strength in cohesionless soil when subjected to rapid and dynamic vibrations and manifests as excess soil pore water pressure caused by the dynamic loading. Liquefiable soils are most commonly evaluated using N-value, the fluctuation and presence of groundwater and the potential for a seismic event to trigger liquefaction. The standard of practice for evaluating liquefaction potential is generally dictated by the following two publications, which STRATA used to evaluation liquefaction potential:

- *Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils,* April 2001. Journal of Geotechnical and Geoenvironmental Engineering. T.L. Youd and I.M. Idriss.
- *Recent Advances in Soil Liquefaction Engineering and Seismic Site Response Evaluation,* 2001. Proceedings: Fourth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics Symposium. R.B. Seed, et al.

STRATA performed analyses referencing the recommendations and evaluation methods outlined in the above documents to estimate liquefaction probability for the saturated sand soil below proposed foundations. To trigger liquefaction, an earthquake (or equivalent loading) must occur, the soil must be susceptible to liquefaction (typically loose, clean sand) and the soil must be saturated at the time the earthquake occurs. We assumed the SPT N-value in B-3 at 15 feet represents the worst-case scenario for liquefaction; we used this data point for our analyses. We corrected the N-value in this location for overburden, borehole diameter, rod length, sampler diameter, hammer efficiency and for soil fines content. This analysis results in the soils' estimated *resistance* to liquefaction ($N_{1(60),CS}$). We also established the *driving force* for liquefaction (Cyclic Stress Ratio, CSR) based on the peak ground acceleration for an earthquake with a 5 percent probability of occurrence in 50 years (recurrence interval of approximately 1,000 years). We compared the resistance to liquefaction against the driving force, resulting in an estimated probability of liquefaction of approximately 80 percent. However, this probability of liquefaction *is only valid if, and when the "design" earthquake occurs.* Earthquake energy that is less than the design earthquake may not trigger liquefaction. Thus, our opinion is the risk of soil liquefaction is high, but the probability of the design earthquake occurring may be infrequent relative to the structure's design life.

STRATA also evaluated impacts to the proposed development, if liquefaction occurs. Based on our analyses and the relatively thin layer of saturated loose sand at the site, our opinion is vertical settlement from soil densification due to liquefaction will be less than 0.25 inches. The gravel soil below the loose sand is not liquefaction susceptible. Further, our opinion is other impacts, such as ground instability, are not likely based on our geologic reconnaissance, exploration and experience. Also, loose soil adjacent to submerged structures has the potential to liquefy to the point that the soil would induce lateral pressures on saturated, below-grade walls that are in excess of the equivalent fluid pressure (EFP) provided herein. EFPs during full liquefaction conditions approach the buoyant unit weight of the soil (~85 pcf). EFPs during liquefaction should not be misconstrued as the dynamic EFPs provided in subsequent report sections. Based on our discussions, Tetra Tech will attempt to design below-grade basins above the seasonal high groundwater table. Thus, it does not appear that below-grade basin walls will be saturated for the majority of the year (if ever), depending upon the final basin embedment depth.

In summary, our opinion is the risk of negative impacts to the structure from liquefaction is low, primarily due to the design earthquake recurrence interval relative to the design life of the structure. Further, if liquefaction occurs, our opinion is that vertical deflection (settlement) from soil densification will be less than 0.25 inches, and thus, we assume damage to structures carries a low risk. However, the KTOI and Tetra Tech should carefully evaluate site design as it relates to earthquake and liquefaction risk. STRATA is available to discuss the risk of damage to structures with the project team, or to discuss potential liquefaction mitigation measures.

Concrete Slab-on-Grade Floors

Concrete slab-on-grade floors should be supported by at least 6 inches of crushed aggregate meeting ISPWC requirements, placed over proof-recompacted native soil or structural fill as described in the *Earthwork* section above. Subgrade areas that become soft, wet or disturbed during slab subgrade preparations must be moisture-conditioned and recompacted, or overexcavated to medium dense soil and replaced with granular structural fill.

Crushed aggregate below slabs should be compacted to structural fill requirements. The slab's supporting aggregate course and any vapor retarders should be constructed once the majority of underslab plumbing and utilities are completed. Floor slabs and supporting crushed aggregate thicknesses must be designed for the anticipated use and equipment or storage loading conditions. Based on correlations to our field and laboratory test results, if our recommendations are followed, we recommend concrete slab design utilize an allowable modulus of subgrade reaction (k) of 275 pounds per cubic inch (pci). To realize the estimated subgrade modulus, drained conditions and a minimum of 6 inches of aggregate support must be provided.

Interior floor slabs may be susceptible to moisture migration caused by subsurface capillary action and vapor pressure. Moisture migration through floor slabs can break down a floor covering, its adhesive, or cause various other floor-covering performance problems. Often, these moisture problems were associated with either no moisture protection below the slab or alternatively, subslab penetrations were not sealed per the manufacturer's recommendations and allowed vapor to damage the flooring system through the penetrations. Therefore, we recommend moisture protection beneath concrete slab-on-grade floors. This could consist of thick, puncture proof polyethylene sheeting covered with an additional 2-inch-thick layer of clean, coarse sand placed between the aggregate base course and the concrete slab-on-grade floors. An example of this material is Stego Wrap™, a 15-mil retarder. If construction staging allows, the vapor retarder can be placed at the native soil subgrade provided the contractor can avoid punctures during aggregate base placement. Form stakes, piping or other sub-slab penetrations must never penetrate the vapor retarder. Any structure that penetrates the vapor retarder must be carefully designed and constructed to reduce vapor transport through such penetrations.

The specific location of vapor barriers has been discussed in the architectural, structural, construction and geotechnical engineering community and differing opinions exist. The following presents considerations for placing a vapor barrier either directly below the slab or alternatively below an aggregate or sand blotter layer.

Considerations for placing aggregate sand blotter:

- The blotter layer reduces the potential for punctures through the vapor retarder.
- Studies have shown that placing a blotter layer reduces the potential for slab curling from differential slab moisture curing conditions.
- Studies have shown a blotter layer may cause less slab shrinkage from drying effects.
- A blotter layer allows concrete to lose moisture quicker. This reduces the potential for premature slab finishing, which has been shown to cause slab delamination for high slump concrete.
- A blotter layer decreases the time that the slab can be floated and finished and accelerates water loss from wet concrete.

Considerations for placing concrete directly over the vapor barrier:

- Reduces construction cost by omitting aggregate or sand blotter.
- Provides better slab bottom curing due to the presence of moisture at the concrete vapor retarder interface. However, differential curing can occur that could cause slab curling.
- Provides less chance for retaining slab moisture or moisture from rainfall and construction water. Water that exists in a granular layer could eventually be transmitted through the concrete and damage floor coverings.

Ultimately, the location of the vapor retarder (if a vapor retarder is specified) should be carefully considered by the owner and architect. Pros and cons exist about whether to place a granular blotter layer below the vapor retarder. ASTM E 1643 and *American Concrete Institute* (ACI) Committee 302 are 2 publications that provide considerations for vapor retarder locations. Studies have shown that decreased water cement ratios, higher strength concrete and good construction finishing practices significantly decrease any negative impacts associated with the above options for vapor retarder locations.

Tetra Tech and KTOI may desire to reduce the project budget by omitting a vapor retarder system below certain concrete slab-on-grade floors as there may be slab areas where moisture intrusion will not impact the slab's performance or any overlying floor coverings or equipment. However, buildings and associated utilities can act as conduits for moisture and water vapor that naturally exists in the soil. We recommend Tetra Tech and KTOI carefully consider the risks of excluding a vapor retarder prior to omitting such a system. Where floor coverings or equipment must be protected from damage by moist floor conditions, we strongly suggest a vapor retarder be installed. Even if these recommendations are used, water vapor migration through the concrete floor slab is still possible. Floor covering should be selected accordingly. Manufacturer's recommendations should be strictly followed. Where vapor retarders are utilized, the flooring and concrete slab contractors as well as the plastic sheeting manufacturer should be consulted regarding additional slab cure time requirements and/or the potential for slab curling.

Lateral Earth Pressures

Static Conditions

All foundation wall systems and below-grade structures should be designed to resist lateral earth pressures from the retained soil behind the structure and surcharge from equipment, slopes, or vehicles adjacent to the walls. Any retaining wall should be designed against overturning, sliding and global wall failure. We recommend lateral earth pressures for conventional wall systems be estimated using the following static EFPs from Table 4 and Table 5 below.

Table 4. Allowable Coulomb Equivalent Fluid Pressures (unsaturated, moist conditions)[1]

Coulomb Lateral Earth Pressure Case	Equivalent Fluid Pressure (EFP)[2]
At rest case (no wall movement)	50 pcf
Active case (wall movement away from soil mass)	35 pcf
Passive case (wall movement toward soil mass)	400 pcf [3]

1. Assumes structural backfill behind the wall, placed according to the *Earthwork* section.
2. Includes soil moist unit weight of 130 pounds per cubic foot (pcf).
3. Has been corrected for ½-inch of lateral deflection.

Table 5. Allowable Coulomb Equivalent Fluid Pressures (submerged, buoyant)[1]

Coulomb Lateral Earth Pressure Case	Equivalent Fluid Pressure (EFP)[2]
At rest case (no wall movement)	35 pcf
Active case (wall movement away from soil mass)	25 pcf
Passive case (wall movement toward soil mass)	275 pcf [3]

1. Assumes structural backfill behind the wall, placed according to the *Earthwork* section.
2. Includes soil buoyant unit weight of 85 pounds per cubic foot (pcf). Excludes the unit weight of water.
3. Has been corrected for ½-inch of lateral deflection.

Lateral surcharge pressures due to equipment, slopes, storage loads, etc. have not been included in the above lateral earth pressure recommendations. The lateral earth pressure coefficient of 0.5, acting over the entire wall height, could be used to estimate the lateral earth pressure induced on walls due to adjacent surcharge loads from equipment and the slope behind the structure. Additionally, any below-grade wall should be drained according to Plate 2.

Seismic/Dynamic Conditions

Dynamic lateral earth pressures are a function of several factors including the presence of groundwater, magnitude of ground shaking, soil strength and soil permeability. Dynamic lateral earth pressures are *additive* to the above static lateral earth pressures, but act as an inverted triangle in lieu of the traditional static earth pressure distribution. *Hydrodynamic* forces were not accounted for due to the apparent absence of groundwater and assumed drained conditions on walls. Based on the current IBC, the peak ground acceleration near the site is estimated at 0.096 times the acceleration of gravity (0.096g).

The design of below-grade walls should account for dynamic load influences. The dynamic EFPs for at rest and active conditions should be added to the above static EFPs, but as an inverted triangle distribution. The dynamic EFPs for passive resistance should be *subtracted* from the static resistance and acts as a conventional triangle. The seismic component of at rest and active pressure is assumed to have its resultant acting at 0.63 times the wall height measured from the base of the wall, whereas the resultant dynamic component of passive pressure acts at 0.33 times the wall height measured from the base of the wall. Below, Table 6 presents EFPs during dynamic loading (excludes static loads) for the unsaturated backfill soil.

Table 6. Seismic/Dynamic Equivalent Fluid Pressures

Coulomb Lateral Earth Pressure Case	Equivalent Fluid Pressure (EFP)[1]
At rest case (no wall movement)	+40 pcf[1]
Active case (wall movement away from soil mass)	+15 pcf[1]
Passive case [2] (wall movement toward soil mass)	-200 pcf [1]

1. Dynamic EFPs are the same for both unsaturated and submerged conditions. Excludes hydrodynamic pressures.
2. Includes soil moist unit weight and excludes the unit weight of water.
3. Passive resistance has been provided for ½-inch of lateral movement.

Site Surface and Subsurface Drainage

Any runoff from precipitation or other runoff must not be allowed to infiltrate the soil adjacent to footings or structures. We recommend the ground surface outside of any structure be sloped a minimum of 5 percent away for a minimum of 10 feet to rapidly convey surface water or roof runoff away from foundations; however, this slope may not meet the American's with Disabilities Act (ADA) slope and grade requirements for hardscapes. At a minimum, STRATA recommends the ground surface adjacent to any structure be sloped a minimum of 2 percent away from foundations. Collected stormwater must not be allowed to saturate the soil at the pavement subgrade. Stormwater should be routed away from buildings and pavement subgrades and should be disposed of in a suitable location greater than 25 feet from any building and in a suitable location as determined by the civil engineer.

STRATA performed infiltration testing on the on-site soil in select test pits. Infiltration test results verified with the soil fraction passing the No. 200 sieve (fines content). Our infiltration tests indicated the on-site silty sand, sand, silt and sandy silt accepted stormwater at rates between ½-inch per hour (in/hr) and 20 in/hr. Due to the variability of on-site soil infiltration rates, we recommend civil design rely upon the following information in Table 7 to help design stormwater infiltration facilities. Stormwater facilities shall not be constructed into uncontrolled fill if encountered during construction.

Table 7. Recommended *Allowable* Soil Infiltration Rate

Soil Type[1]	Recommended Design Infiltration Rate[2]
Silt	1.0 in/hr
Sandy Silt	2.5 in/hr
Silty Sand	8.0 in/hr
Poorly-graded Sand	15 in/hr
Poorly-graded Gravel	30 in/hr

1. According to the USCS.
2. Includes a safety factor of about 2.0 and accounts for high groundwater conditions.

Stormwater facility design may rely upon the following information for facilities installed at least 1-foot into the recommended soil. The exploratory test pit logs in Appendix A should be referenced to identify soil types and locations. Based on exploration results, soil infiltration generally increases rather than decreases with depth; thus, stormwater infiltration is not expected to be inhibited by layers with lower infiltration rates that exist below the soil to receive stormwater. However, as specific stormwater disposal locations and structures have yet to be developed, we recommend STRATA be retained to either review the recommendations provided above or advance additional exploration in the footprint of each stormwater disposal facility. Finally, the above infiltration rates assume high groundwater conditions, but that there will be more than 4 feet of hydraulic head between the water level in the stormwater disposal facility and the elevation at the top of the receiving soil layer. If less than 4 feet of head will exist between the high water level of the stormwater facility and the top of the receiving soil layer, we recommend the above infiltration rates be reduced by a factor of 67 percent to account for lower hydraulic head conditions in the stormwater facility.

Soil Corrosivity

Based on laboratory test results, the native silt and sand soil at the site maintains a slightly acidic pH (5.9) and is moderately corrosive (resistivity = 3,805 oh/cm). Therefore, careful selection of material for utility piping must account for some possible loss of wall thickness due to corrosion for steel piping. Concrete reinforcing steel should maintain appropriate (IBC) earth and form clearances at all times. Where possible, position reinforcing steel with the maximum available clearance from native soil. Therefore, in our opinion and experience, Type I-II concrete is appropriate for site construction.

Pavement Section Thickness

The following pavement design is provided referencing the *American Association of State Highway and Transportation Officials* (AASHTO) *Guide for Design of Pavement Structures* (1993). STRATA assumed traffic loading and design parameters based on typical pavement design criteria in the northern Idaho area and our discussions with Tetra Tech regarding traffic loading. The following sections present our design parameters and references as well as the resulting pavement recommendations.

Table 8 and 9 provide design inputs and traffic loading used for flexible pavement design.

Table 8. Pavement Design Parameters

Design Parameter	Value Used	References
Reliability (R)	90%	Assumed
Standard Deviation (S)	0.45	AASHTO 1993
Initial Serviceability (PSI_i)	4.0	Typical north Idaho area values
Terminal Serviceability (PSI_z)	2.2	Typical north Idaho area values
Traffic Loading	75,000 ESALS[1]	See discussion below
Design Life	20 years	Assumed
Resilient Modulus (M_r)	5,000 psi[2]	Based on visual estimates (see paragraph below)
Asphalt Layer Coefficient (a_1)	0.42	Figure 2.5 AASHTO 1993
Top Course Layer Coefficient (a_2)	0.12	Figure 2.6 AASHTO 1993
Top Course Drainage Coefficient (m_2)	1.0	Table 2.4 AASHTO 1993 for "fair" drainage, 1 to 5 percent saturation

1 – Equivalent Single Axle Loads (ESALs)
2 – Pounds per square inch (psi)

Table 9. Traffic Loading Assumptions

Pavement Section Area	Traffic Loading Parameters	Frequency[1] or Value Used	EALF[2]
Standard-Duty Section	Passenger Vehicles	400 trips per week	0.005
	Garbage Trucks	2 trips per week	0.65
	Tour Buses	4 trips per week	1.1
	Recreational Vehicles	10 trips per week	0.8
	Sludge/Sediment Trucks	4 trips per week	1.0
	Annual Growth Factor	1.0%	
	Construction Traffic[3]	**None**	
	Design Life	20 years	

1. One trip is one pass by the vehicle.
2. Equivalent Axle Load Factor; loading by one vehicle trip.
3. Construction traffic does not include light passenger or light (less than 4,000 lbs gross vehicle weight) construction equipment.

Based on our experience with California Bearing Ratio (CBR) and resilient modulus testing, we estimate the anticipated native silt and sand subgrade will have a resilient modulus value of at least 5,000 psi, provided the subgrade soil is proof-compacted as recommended in the *Site Preparation* section of this report. Based on the above pavement design parameters, Table 10 provides our flexible pavement design recommendations. In addition, Table 11 provides and unpaved roadway design section recommendations.

Table 10. Flexible Pavement Section Design

Pavement Section Material	Recommended Thickness (inches)	Material Specifications
Asphalt Concrete	2.5	Hot-mix asphalt (HMA) conforming to Section 810 – PLANT MIX PAVEMENT of the ISPWC and having a nominal maximum particle size of ¾-inch to ½-inch.
Crushed Aggregate	10	Crushed aggregate should conform to Section 802 – CRUSHED AGGREGATE from the ISPWC and could consist of either 2-inch or ¾-inch nominal maximum particle size aggregate.

Table 11. Unpaved Roadway Section Design

Pavement Section Material	Recommended Thickness (inches)	Material Specifications
Crushed Aggregate	3	Crushed aggregate should conform to Section 802 – CRUSHED AGGREGATE from the ISPWC and could consist of either 2-inch or ¾-inch nominal maximum particle size aggregate.
Uncrushed Aggregates (Subbase)	9[1]	Uncrushed aggregates should conform to Section 801 – UNCRUSHED AGGREGATES from the ISPWC and could consist of either 8-inch to 3-inch nominal maximum particle size aggregate.

1. The unpaved roadway section can be combined into 12 inches of *Crushed Aggregate*.

The above pavement sections assume the subgrade will be prepared as described in the *Site Preparation* section of this report and that a woven geotextile meeting the criteria in the *Geotextiles* report section is placed at the proof-compacted subgrade. We recommend STRATA be retained to observe the pavement subgrade at the time of construction to verify our assumed design conditions or any possible changes and to help identify soft, rutting or pumping soil areas.

GEOTECHNICAL DESIGN CONTINUITY

The information contained in this report is based on anticipated structural loads and ongoing development plans. Additionally, changes in the final floor elevation, floor and footing configuration, structural loads and site geometry can alter our opinions and design recommendations. Therefore, we recommend STRATA provide geotechnical continuity through final project planning and design as individual design aspects become available. STRATA is retained to review geotechnical-related sections of the project plans and specifications to verify the plans and specifications are commensurate with our geotechnical recommendations. We further recommend STRATA be retained to observe earthwork and subgrade preparations to verify the conditions encountered during exploration are encountered during construction. Verifying the subsurface conditions during construction is an important part of the geotechnical design process. If a firm other than STRATA is selected to observe and interpret the subsurface conditions during construction, KTOI must notify the selected firm of these responsibilities and require the firm to interpret and implement our report as the geotechnical engineer-of-record for the project.

Construction Observation and Monitoring

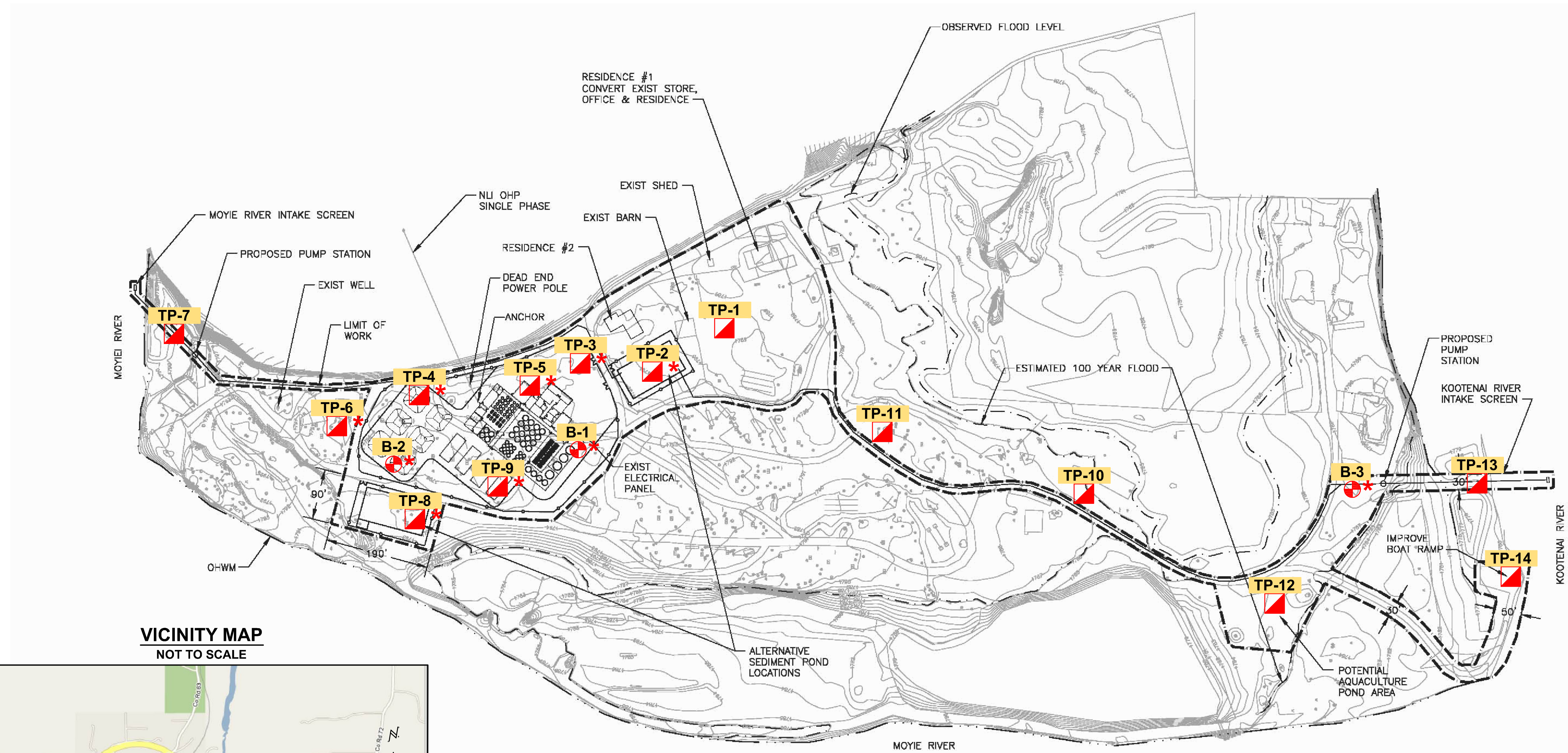
Our opinion is the success of the proposed construction will be dependent upon following our report recommendations, providing good construction practices and the necessary construction monitoring, testing and consultation to verify the work is completed as recommended. We recommend STRATA provide construction monitoring, testing and consultation services to verify the report recommendations are being followed. If we are not retained to verify our recommendations are followed, we cannot be responsible for designer or contractor errors, omissions or misinterpretations of our report recommendations.

EVALUATION LIMITATIONS

This report has been prepared to assist planning, design and construction of the proposed Twin Rivers Hatchery to be located at the confluence of the Kootenai and Moyie Rivers near Moyie Springs, Idaho. Our services consist of professional opinions and recommendations made in accordance with generally accepted geotechnical engineering principles and practices as they exist at this time and in the area of this report. The geotechnical recommendations provided herein are based on the premise that STRATA will continue our project involvement during construction to verify compliance with our recommendations and to confirm conditions between exploration locations. This acknowledgement is in lieu of any express or implied warranty.

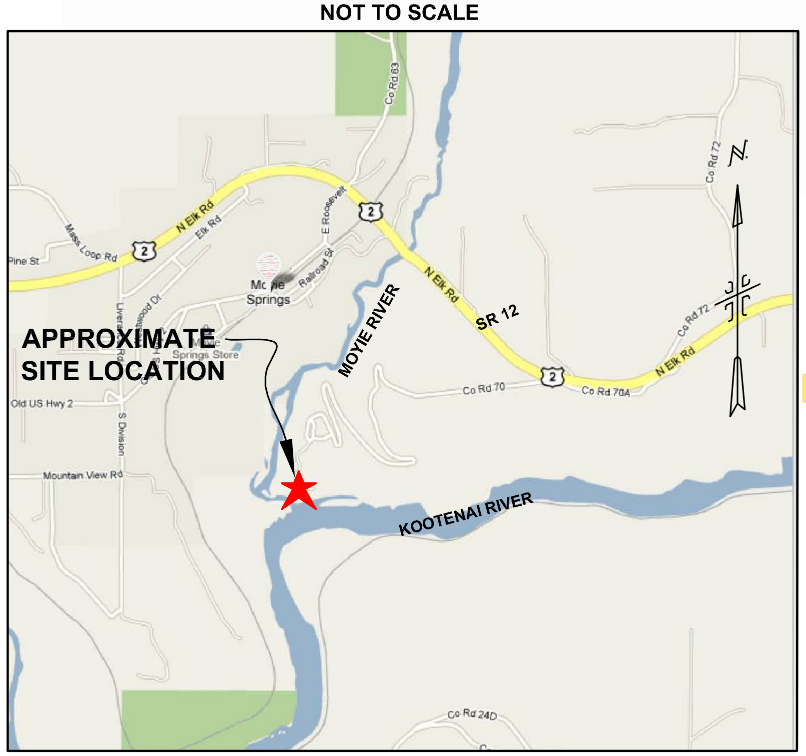
The following plates and appendices accompany and complete this report:

Plate 1:	Site Plan
Plate 2:	Foundation and Wall Drain Schematic
Appendix A:	USCS Explanation
Appendix B:	Laboratory Test Results



VICINITY MAP

NOT TO SCALE



LEGEND

B-1 — Approximate Location of Boring Observed by STRATA on February 23, 2010.

TP-2 — Approximate Location of Test Pit Observed by STRATA on February 23, 2010.

* Standpipe Piezometer Installed in Test Pit or Boring.

0 100 200 400

SCALE: 1 inch = 200 ft

SITE PLAN
Kootenai Tribe of Idaho
Twin Rivers Hatchery
Moyie Springs, Idaho

STRATA
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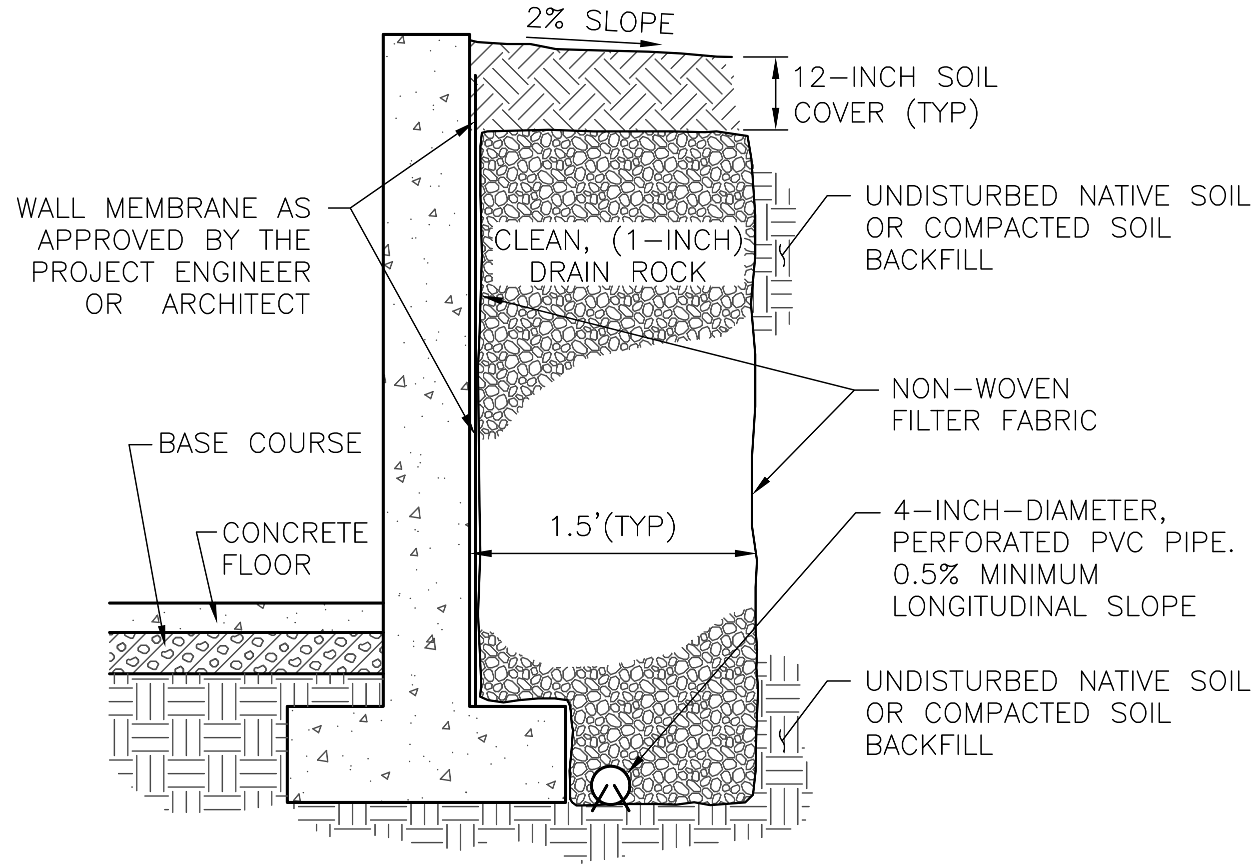
TETRTE C10007A	PLATE: 1

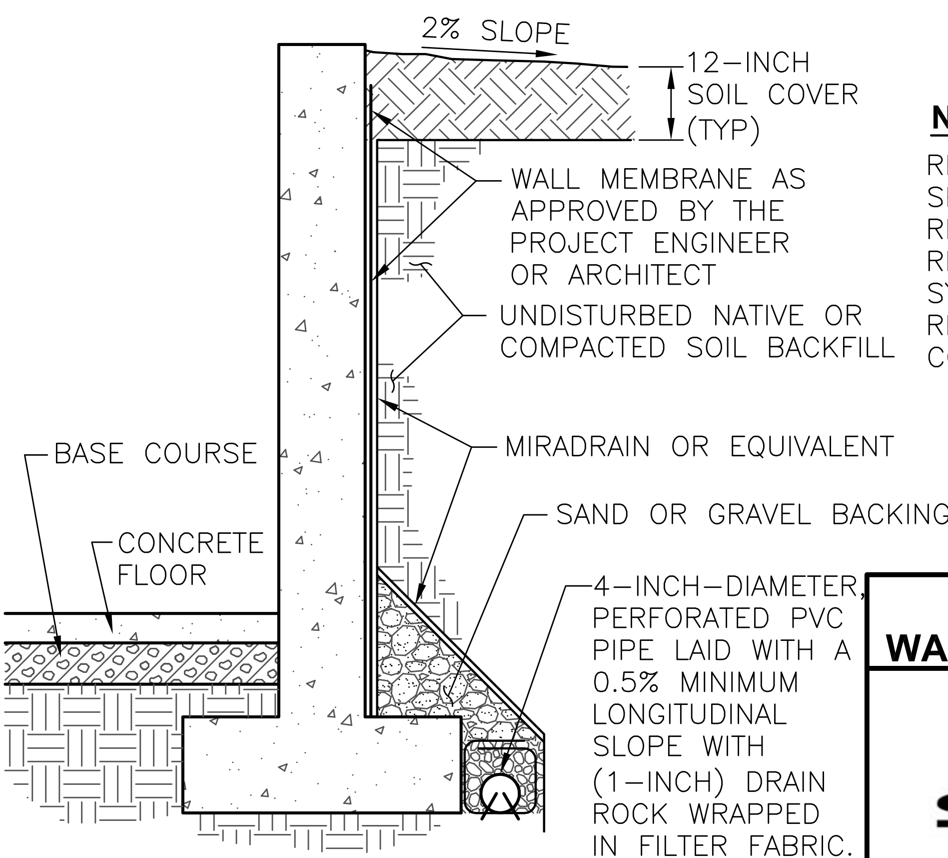
THIS PLAN COMPRISES A PORTION OF STRATA'S REPORT AND THE TEXT OF THE REPORT CONTAINS ESSENTIAL INFORMATION: BEFORE UTILIZING THIS PLAN FOR ANY PURPOSE WHATSOEVER, THE REPORT SHOULD BE READ COMPLETELY. THIS PLAN IS INTENDED TO HELP VISUALIZE THE INFORMATION PROVIDED IN THE REPORT. THESE LOCATIONS AND INFORMATION WERE ADDED TO EXISTING PLANS OF THE SITE PREVIOUSLY PREPARED BY OTHERS AND NO CHECK OF ACCURACY, CURRENCY, APPROPRIATENESS, ETC., OF INFORMATION PROVIDED BY OTHERS WAS PERFORMED, SINCE SUCH CHECKS WERE NOT PART OF STRATA'S SCOPE OF SERVICES.

Reference: Site Plan Provided by Tetra Tech, Date: 7-2009.

NOTE:

THIS DRAWINGS' CROSS-SECTIONS MAY BE USED FOR GRAVITY WALLS. THIS IS NOT A STRUCTURAL DETAIL.





NOTE:

REFER TO MANUFACTURER'S SPECIFICATIONS AND TEXT OF REPORT FOR INFORMATION REGARDING DRAINAGE SYSTEM, WALL DESIGN AND RELATED GEOTECHNICAL CONSIDERATIONS.

INFORMATIONAL ONLY (NOT TO SCALE)

FOUNDATION AND WALL DRAIN SCHEMATIC

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TETRTE C10007A	PLATE 2

DRAFT APPENDIX A

Exploratory Logs and
Unified Soil Classification System (USCS)

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TETRTE C10007A

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	SPT Blows Per 6 Inches	SPT $N_{(60)}$	Dry Density (pcf)	Moisture Content (%)	% Passing No. 200 Sieve	REMARKS Note: BGS = Below Ground Surface
(SM) Silty SAND (Native). Brown,loose, moist.	0.0	SM								Trace vegetation and organics observed at ground surface.
					1 2 1	3				
	2.5									
	5.0				1 1 1	2		12.9	37.0	
	7.5									
(SP) Poorly-graded SAND with Gravel. Brown, medium dense, moist.	10.0	SP			3 4 5	5				Corrected to 2-inch outside diameter SPT.
	12.5									
(GP) Poorly-graded GRAVEL with Sand. Brown, medium dense to dense, moist.	15.0	GP								

Client: TETRTE	**Boring Number:** B-1
Project: C10007A	**Date Drilled:** 02-23-2010
Drill Rig: Mobile B40	**Borehole Diameter:** 8-inch OD
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC

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EXPLORATORY BORING LOG

(Continued Next Page)

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	SPT Blows Per 6 Inches	SPT $N_{(60)}$	Dry Density (pcf)	Moisture Content (%)	% Passing No. 200 Sieve	REMARKS Note: BGS = Below Ground Surface
(GP) Poorly-graded GRAVEL with Sand. Brown, medium dense to dense, moist. *(continued)*	15.0	GP		■	50/5"	50+				Boring terminated at 16.5 feet BGS. Standpipe peizometer installed to 16.5 feet BGS.
Borehole Terminated at 16.5 Feet.										

Client: TETRTE	**Boring Number:** B-1	STRATA A Professional Services Corporation Integrity from the Ground Up	**EXPLORATORY BORING LOG**
Project: C10007A	**Date Drilled:** 02-23-2010		
Drill Rig: Mobile B40	**Borehole Diameter:** 8-inch OD		
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC		Sheet 2 Of 2

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	SPT Blows Per 6 Inches	SPT $N_{(60)}$	Dry Density (pcf)	Moisture Content (%)	% Passing No. 200 Sieve	REMARKS Note: BGS = Below Ground Surface
(SM) Silty SAND(Native). Light brown, loose, moist.	0.0	SM								Trace vegetation and organics observed at ground surface.
	2.0–3.5			Sample	2 2 2	4				
	5.0–6.5			Sample	1 1 2	3		4.2		
(GP) Poorly-graded GRAVEL with Sand. Brown, medium dense to dense, moist.	9.5	GP								
	10.0–11.4			Sample	27 30 50/5"	50+				Very slow drilling at 11.0 feet BGS.
	13.2									Boring terminated at 13.2 feet BGS due to practical auger refusal. Standpipe peizometer installed to 13.2 feet BGS.

Depth scale: 0.0, 2.5, 5.0, 7.5, 10.0, 12.5

Borehole Terminated at 13.2 Feet.

Client: TETRTE	**Boring Number:** B-2	**EXPLORATORY BORING LOG**
Project: C10007A	**Date Drilled:** 02-23-2010	
Drill Rig: Mobile B40	**Borehole Diameter:** 8-inch OD	
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC	Sheet 1 Of 1

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USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	SPT Blows Per 6 Inches	SPT $N_{(60)}$	Dry Density (pcf)	Moisture Content (%)	% Passing No. 200 Sieve	REMARKS Note: BGS = Below Ground Surface
(GP-GM) Poorly-graded GRAVEL with Silt and Sand (Fill). Dark brown, loose, moist.	0	GP-GM								Trace vegetation and organics observed at ground surface.
(SM) Silty SAND (Native). Brown, loose, moist to wet.		SM		▮	1 1 1	2				
	5			▮	1 1 1	2				
	10			▮	1 1 3	4		23.5	43.9	
(SP) Poorly-graded SAND with Gravel. Brown, loose, saturated.	03-30-10 (groundwater)	SP								
	15			▮	1 1 1	2				No sample recovered
(GP) Poorly-graded GRAVEL with Sand. Brown, medium dense to dense, saturated.	20	GP		▮	7 35 50/5"	50+				6-inches of heave in sample .
										Boring terminated at 21.5 feet BGS. Standpipe peizometer installed to 21.5 feet BGS.

Borehole Terminated at 21.5 Feet.

Client: TETRTE	**Boring Number:** B-3
Project: C10007A	**Date Drilled:** 02-23-2010
Drill Rig: Mobile B40	**Borehole Diameter:** 8-inch OD
Depth to Groundwater: 13.3'	**Logged By:** AKL/JPC

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EXPLORATORY BORING LOG

Sheet 1 Of 1

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(SM) Silty SAND (Native). Brown, medium dense, moist.	0.0 2.5	SM		BG	B-1					Trace vegetation observed at ground surface.
(GP) Poorly-graded GRAVEL with Sand. Brown, medium dense to dense, moist.	5.0 7.5	GP			A-2b					Gravel and cobbles from 2 to 6 inches in diameter observed throughout. Soil very gravelly; downgraded from A-1 to A-2-b. Test pit terminated due to caving conditions.

Test Pit Terminated at 9.0 Feet.

Client: TETRTE	**Test Pit Number:** TP-1
Project: C10007A	**Date Excavated:** 02-22-2010
Backhoe: Deere 310E	**Bucket Width:** 18 inches
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC

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EXPLORATORY TEST PIT LOG

Sheet 1 Of 1

STRATA BH / TP / WELL - STRATA.GPJ - 04/12/10 09:07 - P:\GINT\PROJECTS\TETRTE C10007A LOGS B-1 THRU 3 TP-1 THRU 14.GPJ

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(ML) SILT (Native). Brown to tan, loose to medium dense, moist.	0.0									Significant vegetation and organics observed to 2 inches BGS.
	2.5	ML			B-2					Organic debris observed to 3.0 feet BGS due to buried tree stump.
				BG		92.0		16.6		
(GP) Poorly-graded GRAVEL with Sand. Brown, medium dense to dense, moist.	5.0									Gravel and cobbles from 2 to 6 inches in diameter observed throughout.
				BK				2.2		
	7.5									
		GP			A-2b					Soil very gravelly; downgraded from A-1 to A-2-b.
	10.0									
Test Pit Terminated at 12.0 Feet.										Test pit terminated due to caving conditions. Standpipe piezometer installed to 12.0 feet BGS.

Client: TETRTE	**Test Pit Number:** TP-2
Project: C10007A	**Date Excavated:** 02-23-2010
Backhoe: Deere 310E	**Bucket Width:** 18 inches
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC

STRATA
A Professional Services Corporation
Integrity from the Ground Up

EXPLORATORY TEST PIT LOG

Sheet 1 Of 1

STRATA BH / TP / WELL - STRATA.GPJ - 04/12/10 09:07 - P:\GINT\PROJECTS\TETRTE C10007A LOGS B-1 THRU 3 TP-1 THRU 14.GPJ

EXPLORATORY TEST PIT LOG

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(SM) Silty SAND (Native). Brown, loose to medium dense, moist.	0.0 – 8.0	SM		BG	B-1					Trace vegetation observed at ground surface. Organic debris observed in the top 3 feet due to buried tree stump.
(GP) Poorly-graded GRAVEL with Sand. Brown, medium dense to dense, moist.	8.0 – 12.0	GP			A-2b					Gravel and cobbles from 2 to 6 inches in diameter observed throughout. Soil very gravelly; downgraded from A-1 to A-2-b. Test pit terminated due to caving conditions. Standpipe piezometer installed to 12 feet BGS.

Depth scale (ft): 0.0, 2.5, 5.0, 7.5, 10.0

Test Pit Terminated at 12.0 Feet.

Client: TETRTE	**Test Pit Number:** TP-3
Project: C10007A	**Date Excavated:** 02-23-2010
Backhoe: Deere 310E	**Bucket Width:** 18 inches
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC

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EXPLORATORY TEST PIT LOG

Sheet 1 Of 1

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(SM) Silty SAND (Native). Brown to tan, loose to medium dense, moist.	0.0									Significant vegetation observed (roots) to 2 feet BGS.
	2.5				B-1					
		SM		BG		21.5		10.0		Atterberg Limits: NP
	5.0									
										Gravel and cobbles from 2 to 3 inches in diameter observed throughout.
(GP) Poorly-graded GRAVEL with Sand. Brown, medium dense to dense, moist.	7.5									
		GP			A-2b					Soil very gravelly; downgraded from A-1 to A-2-b.
	10.0									
										Test pit terminated due to caving conditions. Standpipe piezometer installed to 12.0 feet BGS.

Test Pit Terminated at 12.0 Feet.

Client: TETRTE	**Test Pit Number:** TP-4
Project: C10007A	**Date Excavated:** 02-23-2010
Backhoe: Deere 310E	**Bucket Width:** 18 inches
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC

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EXPLORATORY TEST PIT LOG

Sheet 1 Of 1

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(ML) Sandy SILT (Native). Brown, loose to medium dense, moist.	0.0	ML		RG	B-2	57.4	73.4	14.9		Trace vegetation observed at ground surface.
	2.5									
	5.0									
(GP) Poorly-graded GRAVEL with Sand. Brown, medium dense to dense, moist.	7.5	GP			A-2b					Gravel and cobbles from 1 to 4 inches in diameter observed throughout. Soil very gravelly; downgraded from A-1 to A-2-b.
	10.0									Test pit terminated due to caving conditions. Standpipe piezometer installed to 12.0 feet BGS.

Test Pit Terminated at 12.0 Feet.

Client: TETRTE	**Test Pit Number:** TP-5	STRATA A Professional Services Corporation Integrity from the Ground Up	**EXPLORATORY TEST PIT LOG**
Project: C10007A	**Date Excavated:** 02-23-2010		
Backhoe: Deere 310E	**Bucket Width:** 18 inches		
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC		Sheet 1 Of 1

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(SM) Silty SAND (Native). Brown, medium dense, moist.	0.0									Significant vegetation and organics observed to 6 inches BGS.
	2.5				B-1					
		SM		BG						
				BK						
	5.0					35.2		8.7		
(GP) Poorly-graded GRAVEL with Sand. Tan, medium dense, moist.										Gravel and cobbles from 1 to 3 inches in diameter observed throughout.
	7.5									
					A-2b					Soil very gravelly; downgraded from A-1 to A-2-b.
		GP								
	10.0									
										Test pit terminated due to caving conditions.
Test Pit Terminated at 12.0 Feet.										Standpipe piezometer installed to 12.0 feet BGS.

Client: TETRTE	**Test Pit Number:** TP-6
Project: C10007A	**Date Excavated:** 02-23-2010
Backhoe: Deere 310E	**Bucket Width:** 18 inches
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC

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EXPLORATORY TEST PIT LOG

Sheet 1 Of 1

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(SM) Silty SAND (Native). Brown, loose, moist.	0	SM								
(GP) Poorly-graded GRAVEL with Sand. Brown, medium dense to dense, moist.					B-1					
	1									Large cobbles and boulders encountered from 1.0 to 2.0 feet BGS.
	2									
	3	GP			A-2b					Soil very gravelly; downgraded from A-1 to A-2-b.
	4									
	5									
	6									Test pit terminated due to boulder refusal.

Test Pit Terminated at 6.0 Feet.

Client: TETRTE	**Test Pit Number:** TP-7	STRATA A Professional Services Corporation Integrity from the Ground Up	**EXPLORATORY TEST PIT LOG**
Project: C10007A	**Date Excavated:** 02-22-2010		
Backhoe: Deere 310E	**Bucket Width:** 18 inches		
Depth to Groundwater: 6'	**Logged By:** AKL/JPC		Sheet 1 Of 1

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(SM) Silty SAND (Native). Tan to brown, loose to medium dense, moist.	0.0									Trace vegetation observed at ground surface.
	2.5	SM			B-1					
				BG		30.9		18.6		Atterberg Limits: NP
	5.0									
(GP) Poorly-graded GRAVEL with Sand. Brown, medium dense, moist.					A2-b					Soil very gravelly; downgraded from A-1 to A-2-b.
	7.5	GP								
	10.0									Test pit terminated due to caving conditions. Standpipe piezometer installed to 12.0 feet BGS.

Test Pit Terminated at 12.0 Feet.

Client: TETRTE	**Test Pit Number:** TP-8	STRATA A Professional Services Corporation Integrity from the Ground Up	**EXPLORATORY TEST PIT LOG**
Project: C10007A	**Date Excavated:** 02-23-2010		
Backhoe: Deere 310E	**Bucket Width:** 18 inches		Sheet 1 Of 1
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC		

STRATA BH / TP / WELL - STRATA.GPJ - 04/12/10 09:07 - P:\GINT\PROJECTS\TETRTE C10007A LOGS B-1 THRU 3 TP-1 THRU 14.GPJ

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(SM) Silty SAND (Native). Brown, loose to medium dense, moist.	0.0	SM								Trace vegetation observed at ground surface.
				BG	B-1	18.8	99.2	7.7		Atterberg Limits: NP
	2.5			BK		22.0		10.7		
(SP) Poorly-graded SAND. Tan, medium dense, moist.	5.0	SP			A2-a					
	7.5									
	10.0									Test pit terminated due to caving conditions.

Test Pit Terminated at 12.0 Feet.

Client: TETRTE	**Test Pit Number:** TP-9	**EXPLORATORY TEST PIT LOG**
Project: C10007A	**Date Excavated:** 02-22-2010	
Backhoe: Deere 310E	**Bucket Width:** 18 inches	
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC	Sheet 1 Of 1

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USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(ML) SILT (Native). Brown, loose to medium dense, moist.	0									Trace vegetation observed to 1-inch BGS.
	1									
	2	ML		BK		90.1		31.8		Atterberg Limits: NP pH: 5.9 Resistivity: 3,805 ohm-cm
	3									
(SP) Poorly-graded SAND with Gravel. Tan, medium dense, moist.	4	SP								Test pit terminated due to caving conditions.

Test Pit Terminated at 4.5 Feet.

Client: TETRTE	**Test Pit Number:** TP-10	**EXPLORATORY TEST PIT LOG**
Project: C10007A	**Date Excavated:** 02-22-2010	
Backhoe: Deere 310E	**Bucket Width:** 18 inches	
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC	Sheet 1 Of 1

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USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(SM) Silty SAND (Native). Brown, loose to medium dense, moist.	0									Significant vegetation and organics observed to 2 inches BGS.
	1									
	2	SM			B-1					
	3			BG		76.8		18.3		
	4									Test pit terminated due to caving conditions.
Test Pit Terminated at 4.0 Feet.										

Client: TETRTE	**Test Pit Number:** TP-11	STRATA A Professional Services Corporation Integrity from the Ground Up	**EXPLORATORY TEST PIT LOG**
Project: C10007A	**Date Excavated:** 02-22-2010		
Backhoe: Deere 310E	**Bucket Width:** 18 inches		
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC		Sheet 1 Of 1

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(SM) Silty SAND (Native). Brown, loose to medium dense, moist.	0.0 2.5 5.0 7.5	SM			B-1					Trace vegetation observed at ground surface. Test pit terminated due to caving conditions.

Test Pit Terminated at 8.0 Feet.

Client: TETRTE	**Test Pit Number:** TP-12	STRATA A Professional Services Corporation Integrity from the Ground Up	**EXPLORATORY TEST PIT LOG**
Project: C10007A	**Date Excavated:** 02-22-2010		
Backhoe: Deere 310E	**Bucket Width:** 18 inches		
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC		Sheet 1 Of 1

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(SM) Silty SAND. Brown, loose to medium dense, moist.	0 1 2 3 4 5 6	SM			B-1					Trace to moderate vegetation and organics observed to 24 inches BGS. Test pit terminated due to caving conditions.

Test Pit Terminated at 6.0 Feet.

Client: TETRTE	**Test Pit Number:** TP-13	STRATA A Professional Services Corporation Integrity from the Ground Up	**EXPLORATORY TEST PIT LOG**
Project: C10007A	**Date Excavated:** 02-22-2010		
Backhoe: Deere 310E	**Bucket Width:** 18 inches		
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC		Sheet 1 Of 1

USCS Description	DEPTH (ft)	U.S.C.S. CLASS	SYMBOL	Sample Type	USDA SOIL Textural Classification	% Passing No. 200 Sieve	Dry Density (pcf)	Moisture Content (%)	Pocket Pen. (tsf)	REMARKS Note: BGS = Below Ground Surface
(SM) Silty SAND (Native). Brown, loose to medium dense, moist.	0 – 3	SM			B-1					Trace vegetation and organics observed to 2 inches BGS.
(GP) Poorly-graded GRAVEL with Sand. Brown, medium dense to dense, moist.	3 – 4	GP			A-2a					Soil very gravelly; downgraded from A-1 to A-2a. Test pit terminated due to caving conditions.

Test Pit Terminated at 4.0 Feet.

Client: TETRTE	**Test Pit Number:** TP-14	STRATA A Professional Services Corporation Integrity from the Ground Up	**EXPLORATORY TEST PIT LOG**
Project: C10007A	**Date Excavated:** 02-22-2010		
Backhoe: Deere 310E	**Bucket Width:** 18 inches		
Depth to Groundwater: N.E.	**Logged By:** AKL/JPC		Sheet 1 Of 1

UNIFIED SOILS CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL NAMES
COARSE GRAINED SOILS	GRAVELS	CLEAN GRAVELS		GW	Well–Graded Gravel, Gravel–Sand Mixtures.
				GP	Poorly–Graded Gravel, Gravel–Sand Mixtures.
		GRAVELS WITH FINES		GM	Silty Gravel, Gravel–Sand–Silt Mixtures.
				GC	Clayey Gravel, Gravel–Sand–Clay Mixtures.
	SANDS	CLEAN SANDS		SW	Well–Graded Sand, Gravelly Sand.
				SP	Poorly–Graded Sand, Gravelly Sand.
		SANDS WITH FINES		SM	Silty Sand, Sand–Silt Mixtures.
				SC	Clayey Sand, Sand–Clay Mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS LIQUID LIMIT LESS THAN 50%			ML	Inorganic Silt, Sandy or Clayey Silt.
				CL	Inorganic Clay of Low to Medium Plasticity, Sandy or Silty Clay.
				OL	Organic Silt and Clay of Low Plasticity.
	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50%			MH	Inorganic Silt, Micaceous Silt, Plastic Silt.
				CH	Inorganic Clay of High Plasticity, Fat Clay.
				OH	Organic Clay of Medium to High Plasticity.
				PT	Peat, Muck and Other Highly Organic Soils.

SOIL CLASSIFICATION CHART

BORING LOG SYMBOLS	GROUNDWATER SYMBOLS	TEST PIT LOG SYMBOLS
Standard 2–Inch OD Split–Spoon Sample	Groundwater After 24 Hours	BG Baggie Sample
California Modified 3–Inch OD Split–Spoon Sample	Groundwater at Time of Drilling	BK Bulk Sample
Rock Core		RG Ring Sample
Shelby Tube 3–Inch OD Undisturbed Sample		

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DRAFT APPENDIX B

Laboratory Test Results

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MOISTURE-DENSITY RELATIONSHIP CURVE

AASHTO T 180
Method C

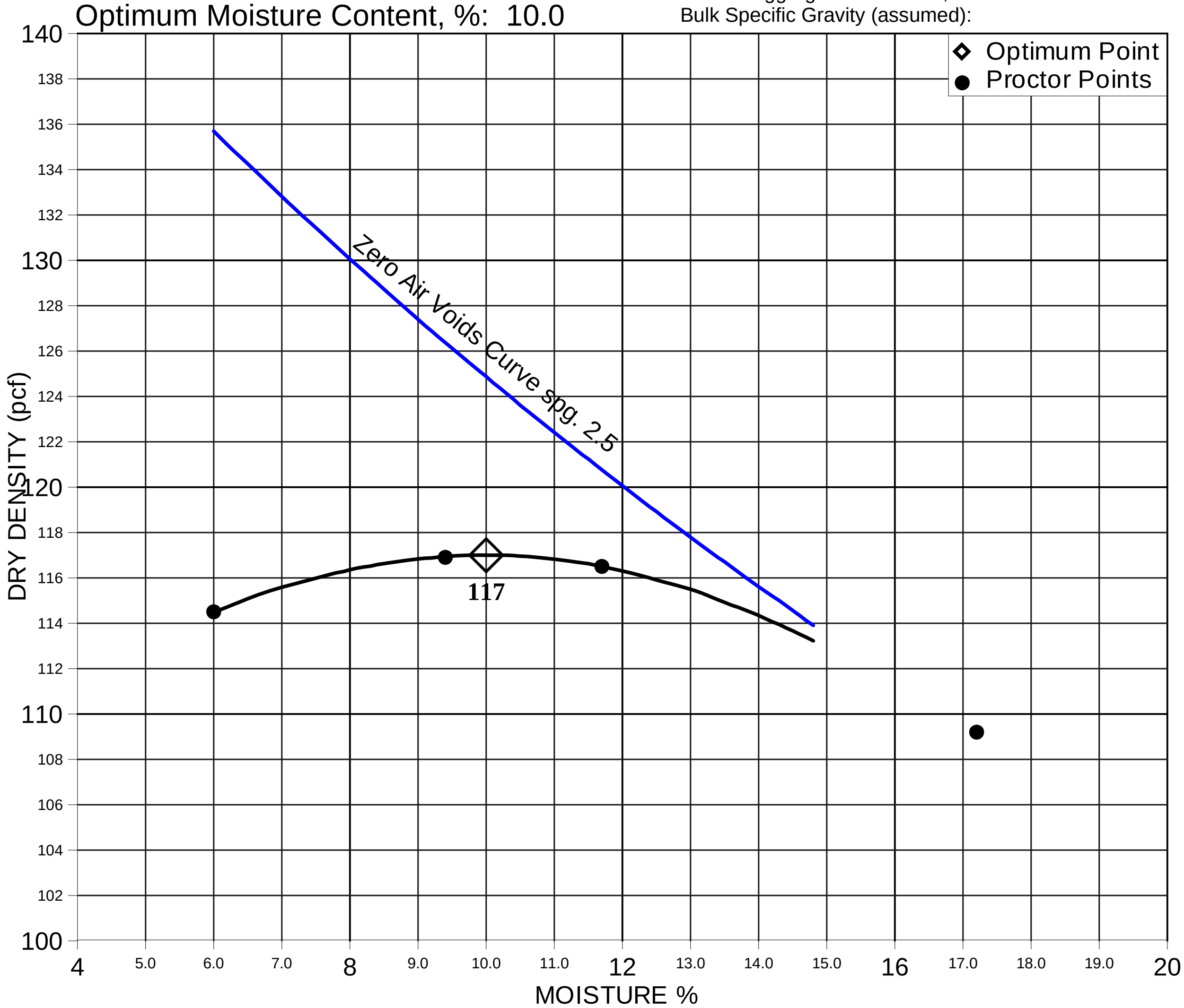
Project: Twin Rivers Hatchery, Moyie Springs, Idaho
Client: Tetra Tech, Inc.
File Name: TETRTE C10007A
Date Tested: March 16, 2010
Tested By: JP Cardin
Sample Number: SL022210-9
Sample Location: Test Pit TP-10 at 2.0 Feet
Sample Description: Brown SILT

GRADING ANALYSIS

SCREEN SIZE	% PASSING	AS TESTED
6 inch		
4 inch		
2 inch		
3/4 inch	100	100
3/8 inch		
#4 screen		

Corrected Dry Density, pcf:
Corrected Moisture Content, %:
Coarse Aggregate Correction, %:
Bulk Specific Gravity (assumed):

Maximum Dry Density, pcf : 117.0
Optimum Moisture Content, %: 10.0



Reviewed By ____________________

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MOISTURE-DENSITY RELATIONSHIP CURVE

AASHTO T 180
Method D

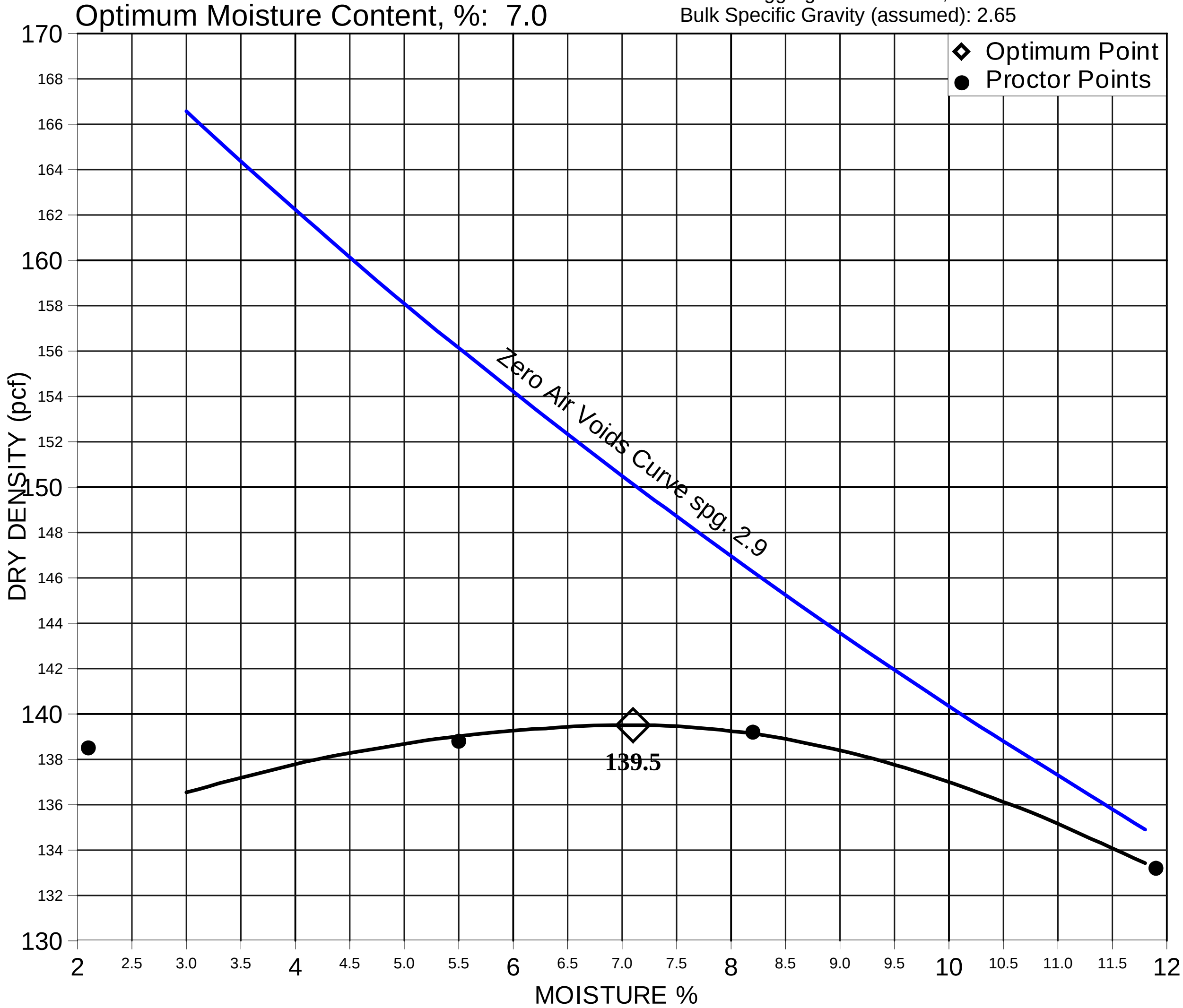
Project: Twin Rivers Hatchery, Moyie Springs, Idaho
Client: Tetra Tech, Inc.
File Name: TETRTE C10007A
Date Tested: March 16, 2010
Tested By: JP Cardin
Sample Number: SL022210-2
Sample Location: Test Pit TP-2 at 6.0 to 6.5 Feet
Sample Description: Poorly-Graded GRAVEL with Sand

GRADING ANALYSIS

SCREEN SIZE	% PASSING	AS TESTED
6 inch		
4 inch		
2 inch	100	
3/4 inch	59	100
3/8 inch		
#4 screen		

Corrected Dry Density, pcf: 144.0
Corrected Moisture Content, %: 7.0
Coarse Aggregate Correction, %: 30
Bulk Specific Gravity (assumed): 2.65

Maximum Dry Density, pcf : 139.5
Optimum Moisture Content, %: 7.0



Reviewed By ____________________

**Note: Sample too coarse for Proctor testing per method.
Test accomplished per Geotechnical Engineer's request.**

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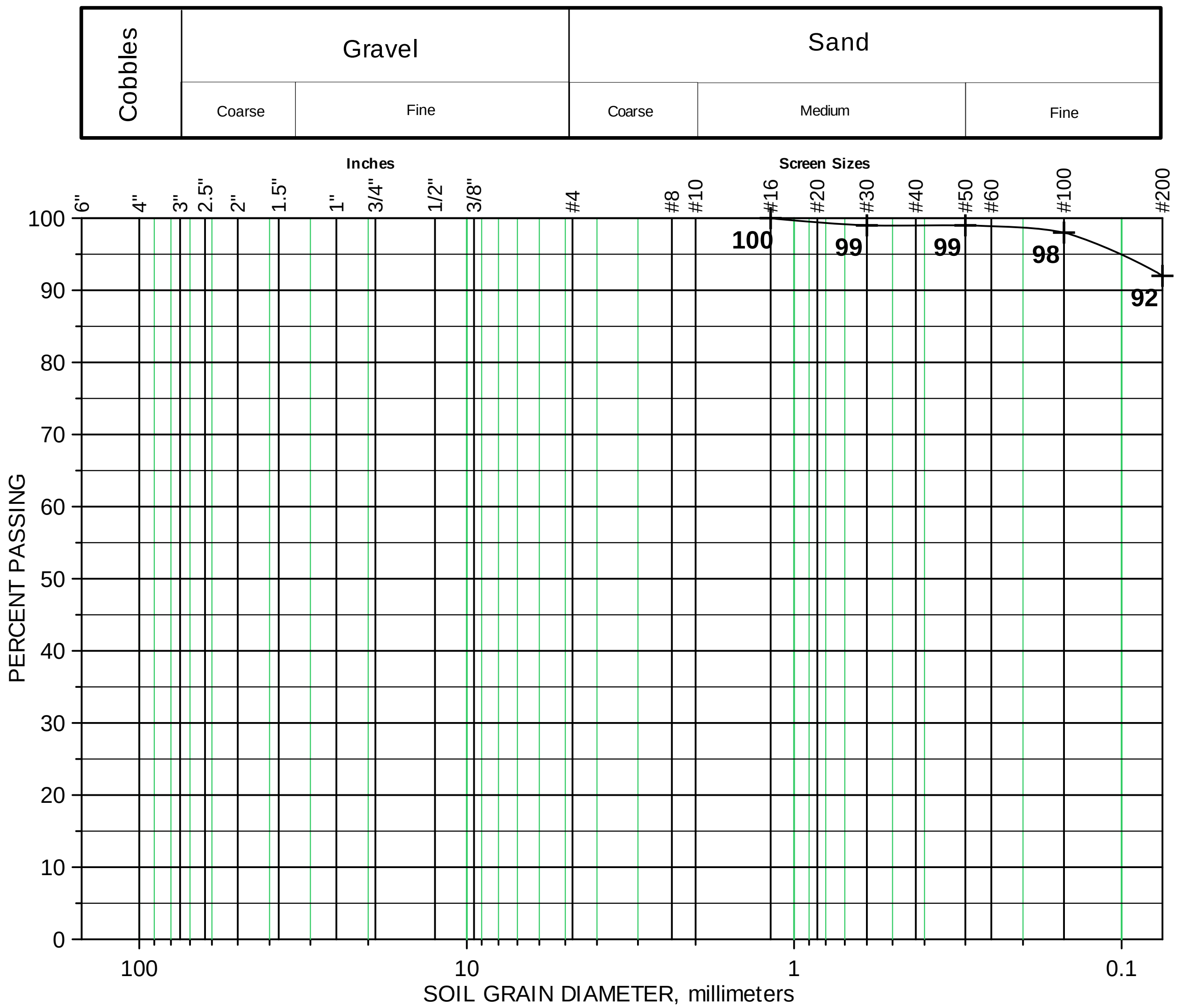
GRADATION ANALYSIS

ASTM D 422

Project: Twin Rivers Hatchery, Moyie Springs, Idaho
Client: Tetra Tech, Inc.
File: TETRTE C10007A
Sample No.: SL022210-2
Sample Location: Test Pit TP-2 at 4.0 Feet
Description: Brown SILT
Date Tested: March 16, 2010



Reviewed by:________________________

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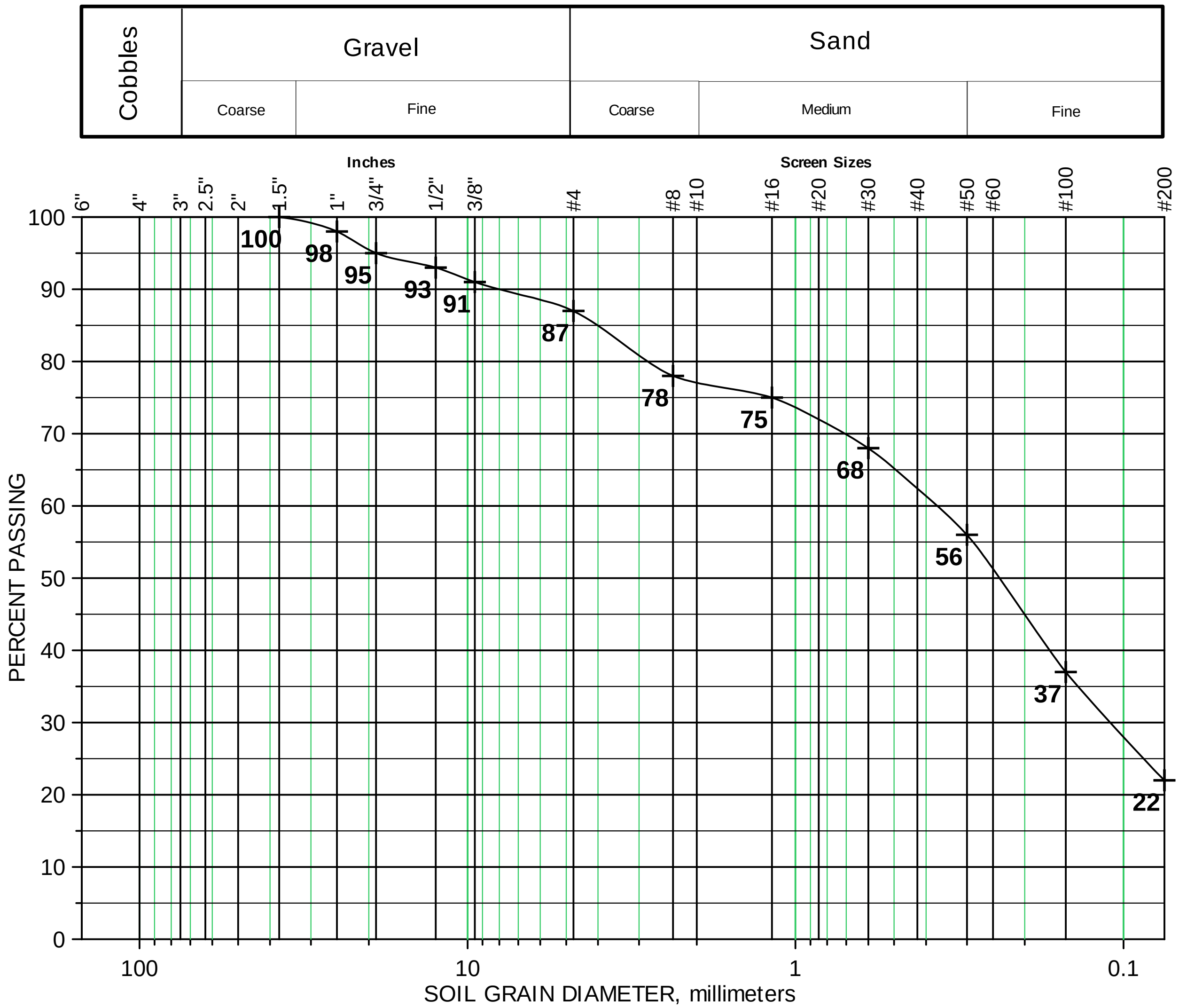
GRADATION ANALYSIS

ASTM D 422

Project: Twin Rivers Hatchery, Moyie Springs, Idaho
Client: Tetra Tech, Inc.
File: TETRTE C10007A
Sample No.: SL022210-8
Sample Location: Test Pit TP-9 at 2.5 to 3.5 Feet
Description: Brown Silty SAND
Date Tested: March 16, 2010



Reviewed by:__________________________

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March 16, 2010
File: TETRTE C10007A

Mr. Mirek Wazny, P.E.
Tetra Tech, Inc.
1235 N. Post Street, Suite 101
Spokane, WA 99204

Project:	Twin Rivers Hatchery, Moyie Springs, Idaho
Material:	Brown Silty SAND
Date Sampled:	February 22, 2010
Date Tested:	March 16, 2010
Location:	TP-10 at 1.5 to 3.0 feet

REPORT OF SOIL RESISTIVITY AND pH
AASHTO T-288, T-289

Sample ID: SL022210-9
pH = 5.9
Minimum Resistivity = 3805 ohm/cm

Sincerely,
STRATA, INC.

Cole Warrick, P.G.
Laboratory Manager

ATTACHMENT D.
TWIN RIVERS WELL REPORT

Note: Appendices A through D of the Twin Rivers Well Report are available on request from Tetra Tech, Inc.

September 23, 2010
Project No. EH090381B

Tetra Tech, Inc.
1420 Fifth Avenue, Suite 600
Seattle, Washington 98101-3941

Attention: John McGlenn, P.E.

Subject: Hatchery Well Installation and Testing
Twin Rivers Aquaculture Facility
Moyie Springs, Idaho

INTRODUCTION AND PURPOSE

This report presents the results of Associated Earth Sciences, Inc.'s (AESI's) hydrogeologic services regarding the installation and testing of three hatchery wells (HW1, HW2 and HW3) at the proposed Twin Rivers Aquaculture Facility to be located near the community of Moyie Springs in north-central Idaho. This report summarizes the results of our well drilling and testing services and provides conclusions and recommendations regarding the potential to develop a ground water resource for the proposed facility. The approximate location of the proposed aquaculture facility is shown on the "Vicinity Map," Figure 1. The general layout of the proposed facility, including the locations of the hatchery wells, an existing drinking water well (TR-1) and existing and proposed on-site structures is shown on the "Site Plan," Figure 2.

We understand that Tetra Tech, Inc. is in the processe of designing an aquaculture facility (hatchery) to be located near the confluence of the Kootenai and Moyie Rivers in Section 15, Township 62 north, Range 2 east. The primary source of water for the aquaculture facility will be surface water obtained from the nearby Kootenai and Moyie Rivers. However, we also understand that approximately 200 to 400 gallons per minute (gpm) of ground water will be needed for temperature control and other fish-rearing activities at the facility.

AESI previously evaluated the geologic and hydrogeologic setting of the project area and developed conclusions and recommendations regarding the ability to install wells at the site capable of producing the required volume of ground water. The details of our previous services were provided to Tetra Tech in our report *"Ground Water Feasibility Study, Twin Rivers Aquaculture Facility"* dated February 19, 2010.

The primary purpose of our services for this phase of the project was to observe the installation and testing of three hatchery wells and evaluate the well testing information in regard to developing a 200 to 400 gpm ground water source for the proposed aquaculture facility. Our detailed scope of our services is described below:

1. Develop a general conceptual design of the proposed hatchery wells and assist Tetra Tech in obtaining cost estimates from two local well drillers for the installation and testing of the wells.

2. Assist representatives of Tetra Tech in determining locations for the hatchery wells and coordinating drilling and testing activities with the selected well driller.

3. Observe and document the well drilling activities for the hatchery wells.

   - Compile a detailed log of the wells based on examination of drill cuttings, soil samples obtained by the well driller, the driller's log, and our observations of the drilling operations.

   - Work with the well driller to select an appropriate slot size for the well screens.

   - Document the well screen assemblages, including the depth interval, slot width, and length for the screen installed in the wells. Review the well screen development activities documented by the well driller.

4. Observe stepped- and constant-pumping rate aquifer tests in the hatchery wells.

5. Measure and record water level drawdown and recovery in the pumping wells and other appropriate nearby wells during the aquifer tests. Water level changes were monitored using pressure transducers and data loggers, and were hand measured using an electronic water level probe.

6. Measure and record ground water quality parameters (temperature, pH, turbidity, dissolved oxygen, and specific conductance) in the well discharge periodically during the constant-pumping rate tests.

7. Obtain water samples from the hatchery wells near the end of the constant pumping-rate aquifer tests. The water samples were submitted to a certified analytical laboratory for analyses of parameters pertinent to the operation of the hatchery.

8. Analyze the well drilling and aquifer testing data to evaluate the following aquifer and well parameters:

   - Aquifer thickness.

   - Hydraulic conductivity and transmissivity.

   - Aquifer specific yield.

   - Well efficiency, specific capacity and safe yield.

   - Radius of influence and potential well interference effects on nearby wells.

9. Prepare a summary technical report that documents and describes subsurface conditions encountered in the hatchery wells, the well installation and testing procedures, and water quality testing results.

WELL INSTALLATION AND AQUIFER TESTING ACTIVITIES

Drilling Methodology and Well Construction

Hatchery wells HW1, HW2 and HW3 were completed at the locations shown on Figure 2 by Minden Water Wells, Inc., of Moyie Springs, Idaho, using a truck-mounted air-rotary drill rig (Photo 1). Each well included the installation of a temporary 12-inch-diameter casing to a depth of approximately 38 feet. The 12-inch-diameter casing was installed to facilitate the installation of a sanitary surface seal. The remaining portions of the borings were completed by drilling and installing 8-inch-diamater casing to their final completion depths. Each well was completed with 7.5-inch-diameter stainless steel well screens ranging between 10 and 15 feet in length. Well screen slot-size openings were determined, in part, from in-field soil-grain size analyses (sieves) completed for several soil samples of potential aquifer material obtained from each well. Each well screen was developed using air-lift methodology.

Photo 1. Drill rig set up on HW1.

All depths referenced in this report are relative to ground surface unless otherwise indicated. All elevations referenced in this report are relative to mean sea level unless otherwise indicated. Geologic and well construction logs for the hatchery wells are included in Attachment A. Copies of the soil sieve data are presented in Attachment B. The following is a summary of the pertinent well installation and construction details.

<u>Hatchery Well HW1</u>

Hatchery Well No. 1 is located in the northwestern portion of the project area approximately 350 feet east of the Moyie River at a ground surface elevation of approximately 1,793 feet (Figure 2). HW1 was drilled to a total depth of 98 feet on April 25 and 26 2010. The following is a summary of the construction details for HW1.

- HW1 encountered approximately 98 feet of a well graded mixture of gravel and sand, with occasional boulders and with some lenses of silt (Attachment A). The gravel and sand material encountered in HW1 appears to be relatively recent (post-glacial) alluvial deposits associated with the Kootenai and Moyie Rivers.

- The gravel and sand sediments became water-bearing between the depths of roughly 10 to 15 feet. Subsurface conditions encountered in the HW1 boring did not indicate the presence of a low permeability zone acting as a confining layer for the encountered aquifer. Therefore, it appears that the aquifer encountered in HW1 is unconfined (water table) in nature.

- Eight-inch-diameter steel casing was initially installed to a depth of 98 feet and then retracted to a depth of 78 feet to expose the well screen assemblage.

- A well screen assemblage consisting of 2-feet of steel tail pipe, 10-feet of 60-slot screen, 5-feet of 80-slot screen and 4-feet of steel riser pipe with k-packer was installed and developed in the well between 76 and 97 feet on April 27, 2010 (Attachment A).

- The static water level was at a depth of 13.5 feet just prior to starting a stepped-pumping rate test in HW1 on April 28, 2010. The well was pumped at a maximum rate of 84 gpm and experienced 56 feet of water level drawdown. Additional details regarding the aquifer tests are presented in later sections of this report.

- In an attempt to improve the yield of HW1, the well screen assemblage was removed from the well and installed at a shallower depth. The well screen removed from HW1 was slightly bent (Photo 2) but otherwise intact and was reinstalled in the boring. The new well screen assemblage modified to consist of a steel bottom plate, 10-feet of 60-slot screen, 5-feet of 80-slot screen and 2-feet of steel riser pipe with k-packer set between depths of 68 and 85 feet (Attachment A).

Photo 2. HW1 well screen just prior to being re-installed.

- A 24-hour aquifer test was completed in HW1 with the new well screen assemblage. The well was pumped at a rate of approximately 83 gpm for 24 hours and experienced roughly 40 feet of water level drawdown.

<u>Hatchery Well HW2</u>

Hatchery Well No. 2 is located in the northwestern portion of the project area approximately 59 feet north of HW1 at a ground surface elevation of approximately 1,794 feet (Figure 2). HW2 was drilled to a total depth of 100 feet on April 28 and 29 2010. The following is a summary of the construction details for HW2.

- HW2 encountered approximately 100 feet of a well graded mixture of gravel and sand, with occasional boulders and with some lenses of silt (Attachment A). The gravel and sand material encountered in HW2 appears to be relatively recent (post-glacial) alluvial deposits associated with the Kootenai and Moyie Rivers.

- The gravel and sand sediments became water-bearing between the depths of roughly 10 to 15 feet. Subsurface conditions encountered in the HW2 boring did not indicate the presence of a low permeability zone acting as a confining layer for the encountered aquifer. Therefore, it appears that the aquifer encountered in HW2 is unconfined (water table) in nature.

- Eight-inch-diameter steel casing was initially installed to a depth of 100 feet and then retracted to a depth of 70 feet to expose the well screen assemblage.

- A well screen assemblage consisting of 2-feet of steel tail pipe with bottom plate, 10-feet of 100-slot screen, and 2-feet of steel riser pipe with k-packer was installed and developed in the well between 68 and 82 feet on April 29, 2010 (Attachment A).
- The static water level was at a depth of 15 feet just prior to starting the aquifer testing program in HW2 on April 30, 2010. The well was pumped at a maximum rate of 233 gpm and experienced less than 3 feet of water level drawdown. Additional details regarding the aquifer tests are presented in later sections of this report.

<u>Hatchery Well HW3</u>

Hatchery Well No. 3 is located in the northwestern portion of the project area approximately 126 feet north of HW1 and 67 feet north of HW2 at a ground surface elevation of approximately 1,794 feet (Figure 2). HW3 was drilled to a total depth of 95 feet on May 24 and 25, 2010. The following is a summary of the construction details for HW3.

- HW3 encountered approximately 95 feet of a well graded mixture of gravel and sand, with occasional boulders and with some lenses of silt (Attachment A). The upper approximately 20 feet of the sediments encountered appeared to contain more silt/clay than the lower 75 feet (Attachment A). The gravel and sand material encountered in HW3 appears to be relatively recent (post-glacial) alluvial deposits associated with the Kootenai and Moyie Rivers.

- The gravel and sand sediments became water-bearing between the depths of roughly 10 to 15 feet. Subsurface conditions encountered in the HW3 boring did not indicate the presence of a low permeability zone acting as a confining layer for the encountered aquifer. Therefore, it appears that the aquifer encountered in HW3 is unconfined (water table) in nature.

- Eight-inch-diameter steel casing was initially installed to a depth of 95 feet and then retracted to a depth of 71 feet to expose the well screen assemblage.

- A well screen assemblage consisting of a steel bottom plate, 15-feet of 80-slot screen, and 2-feet of steel riser pipe with k-packer was installed and developed in the well between 68 and 85 feet on May 26, 2010 (Attachment A).

- The static water level was at a depth of 13.8 feet just prior to starting the aquifer testing program in HW3 on May 26, 2010. The well was pumped at a maximum rate of 325 gpm and experienced 6.4 feet of water level drawdown. Additional details regarding the aquifer tests are presented in later sections of this report.

Aquifer Testing and Analyses

General

Stepped- and constant-pumping rate aquifer tests were conducted in each hatchery well between April 28 and May 28, 2010. Discharge rates were determined using an inline flow meter installed by the well drillers. Discharge water was conveyed roughly 200 feet west of the wells towards the Moyie River where it was allowed to infiltrate during the aquifer tests. A summary of the water levels measured in the hatchery wells during the stepped-pumping rate tests is presented in Table 1. Aquifer testing field data sheets for the stepped- and constant-pumping rate aquifer tests are included in Attachment C.

Stepped-Pumping Rate Aquifer Test Results

Stepped-pumping rate aquifer tests were conducted on each hatchery well to estimate a safe pumping rate for the subsequent constant-pumping rate test. During the HW1 step-test the pumping rate was increased at 60-minute time intervals for four steps until a maximum pumping rate was obtained. During the HW2 and HW3 step-tests the pumping rate was increased at approximate 30-minute time intervals for four steps until a maximum pumping rate was obtained. The maximum pumping rate in each well ranged between the maximum that the installed pump would produce and the maximum pumping rate the well could sustain without dewatering the pump. During each step of the tests, the water level drawdown in the well was relatively stable prior to increasing the pumping rate for the next step.

Table 1
Stepped-Pumping Rate Test Results

Well	Step 1		Step 2		Step 3		Step 4	
	Rate (gpm)	Drawdown (feet)	Rate (gpm)	Drawdown (feet)	Rate (gpm)	Drawdown (feet)	Rate (gpm)	Drawdown (feet)
HW1	66	43	76	50	84	56	--	--
HW2	40	0.5	130	1.2	180	1.9	234	2.7
HW3	113	1.5	143	2.6	198	3.2	220	3.7

gpm = gallons per minute.
-- = Not tested.

The pumping water levels in the hatchery wells were relatively stable near the end of the stepped-pumping rate tests. Furthermore, the pumping water levels in the wells recovered to pre-pumping levels within approximately 30 minutes following the conclusion of the stepped-pumping rate tests. Based on the results of the stepped-pumping rate test, it was concluded that wells could be safely pumped at rates ranging about 84 gpm in HW1 and over 200 gpm in HW2 and HW3 without dewatering the well pumps.

Constant-Pumping Rate Aquifer Test Results

Constant-pumping rate tests were conducted in HW1, HW2 and HW3 at rates of 83 gpm, 224 gpm and 325 gpm, respectively. Three of the constant rate tests were conducted for 1440 minutes (24 hours). An additional 110 minute test was completed in HW1. Water level drawdown and recovery data were obtained from the pumping wells during the constant-pumping rate aquifer tests using pressure transducer/data logger systems installed at the wellheads. Water level drawdown and recovery data were also obtained from the hatchery wells using a water level indicator probe. A summary of the maximum water level drawdown observed in each well is presented in Table 2.

Table 2
Summary of Water Level Drawdown and Aquifer Data

Well	Pumping Rate (gpm)	Pumping Time (min)	Total Water Level Drawdown (feet)	Specific Capacity (gpm/ft)	Aquifer Transmissivity[1] (ft^2/d)	Aquifer Hydraulic Conductivity (ft/d)	Aquifer Specific Yield
HW1	83	110	55.82	1.5	2,230[2]	25	--
HW1	83	1440	38.33	2.2	1,650 – 2,240	19 - 25	--
HW2	224	1440	2.65	84.5	58,500 – 83,000	665 - 940	--
HW3	325	1440	6.43	50.5	33,750 – 58,700	380 - 670	0.0012

ft^2/d = square feet per day.
ft/d = feet per day.
[1]) Calculated using the Theis and or Hantush-Jacob method for unconfined/leaky aquifers unless otherwise noted.
[2] Calculated using the Jacob methodology for unconfined aquifers.

The water levels in each hatchery well dropped to near their maximum drawdown within 60 minutes of the start of the well pumps. The water levels remained near their maximum drawdown in the hatchery wells for the duration of the aquifer tests. Approximately 1.3 feet of water level drawdown was observed in HW1 during the HW2 constant-rate test. Approximately 0.8 feet and 1.3 feet of water level drawdown were observed in HW1 and HW2, respectively, during the HW3 constant-rate test (Attachment C). No aquifer boundary conditions were detected in the water level drawdown data collected during the hatchery well aquifer tests.

Well Specific Capacity and Efficiency

The specific capacity of a production well is the volume of water the well is able to produce per unit length of water level drawdown in the well. For example, the static water level in HW2 was 17.24 feet below the casing rim prior to starting the constant-pumping rate test. The water level dropped to a depth of 19.89 feet at the conclusion of the test. Dividing the average pumping rate (224 gpm) by the total water level drawdown (2.65 feet), the calculated specific capacity of HW2 is approximately 84.5 gpm per foot (gpm/ft) of water level drawdown. Based on the aquifer test results, HW2 appears to be capable of producing approximately 84.5 gpm for each foot of drawdown below the static water level, up to the available water level drawdown above the pump. A summary of the specific capacities for the hatchery wells is presented in Table 2.

A pumping well efficiency is the ratio between the water level in the pumping well and the ground water level in the aquifer just outside of the pumping well screen. In a 100 percent efficient well the water level in the well boring would be the same as the ground water level just outside of the well screen. However, incomplete well development, energy losses as the water passes through the well screen and other factors often result in more water level drawdown in the well than just outside of the well screen. Determining the water level in the aquifer just outside of the well screen is done by plotting the water level drawdown observed in two or more observations wells on a distance-drawdown graph and then extrapolating a line from the observation wells back to the zero point of the graph (pumping well location).

We only had water level drawdown data in two observation wells (HW1 and HW2) during the HW3 aquifer test; therefore, we were only able to estimate the well efficiency of HW3. The water level data in HW1 and HW2 extrapolated back to HW3 indicates that the water level drawdown in the aquifer adjacent to the HW3 well screen would have been roughly 4.2 feet at the end of the HW3 constant-pumping rate test. The measured water level in HW3 was 6.43 feet. Therefore, HW3 is roughly 65% (4.2/6.43= 0.65) efficient.

Well Radius of Influence

The radius of influence (cone of water level depression) for a well is generally estimated by analyzing total drawdown in two or more nearby observation wells completed in the same aquifer at the conclusion of a constant-pumping rate test. The maximum water level drawdown observed in HW3 was approximately 6.4 feet (Table 2). A water level drawdown of approximately 1.3 feet was observed in HW2, located approximately 67 feet to the south of HW3, and a water level drawdown of approximately 0.8 feet was observed in HW1, located approximately 126 feet south of HW3 during the constant-pumping rate test. The measured water level drawdown in these two observation wells indicates a radius of influence of approximately 1,700 feet for HW3 at a pumping rate of 325 gpm. It should be noted that less than 1 foot of water level drawdown could be expected at a distance of approximately 300 feet from HW3 at the same pumping rate.

Aquifer Parameters

Transmissivity is a measure of the amount of water that can be transmitted horizontally by the full saturated thickness of the aquifer under a hydraulic gradient (slope) of 1. Transmissivity values for the unconfined aquifer encountered in HW2 were estimated using the Theis and/or Hantush-Jacob methods for unconfined/leaky aquifers utilizing water level drawdown in the pumping wells and observation wells. Based on the results of the aquifer test, the calculated transmissivity of the unconfined aquifer that underlies the project area ranges from approximately 1,650 square feet per day (ft^2/d) near HW1 to approximately 83,000 ft^2/d per day near HW2 (Table 2).

Hydraulic conductivity is a measure of the rate at which water can move through an aquifer and is equal to the transmissivity divided by the saturated thickness of the unit. The unconfined aquifer encountered in the hatchery wells is at least 88 feet thick in the vicinity of the wells (Attachment A). Based on an estimated aquifer thickness of 88 feet, the transmissivity values correspond to hydraulic conductivity values ranging from approximately 19 feet per day (ft/d) near HW1 to 940 ft/d near HW2 (Table 2). The estimated hydraulic conductivity value is typical of coarse-grained open-work alluvial gravel and sand aquifers. The significantly lower hydraulic conductivity values estimated from the HW1 aquifer testing data indicates that the formation contains a significant amounts of fine-grained material that is reducing the aquifer permeability.

Aquifer specific yield is the quantity of water which a unit volume of aquifer, after being saturated, will yield by gravity. It is typically expressed either as a ratio or as a percentage of the volume of the aquifer. Specific yield is a measure of the water available to wells. The aquifer drawdown data obtained during the HW3 aquifer test was used to estimate a value of 0.0012 for specific yield of the shallow aquifer that underlies the project site (Table 2).

GROUND WATER QUALITY

General

Ground water samples were obtained periodically from each hatchery well during the aquifer tests at gate valves installed by the well drillers near the wellheads. In-field water quality parameters (temperature, pH, specific conductance, dissolved oxygen and turbidity) were measured in the water samples obtained from the wells using Yellow Springs Instruments (YSI) water quality meters. Ground water samples were also obtained near the end of the constant rate tests in HW1, HW2 and HW3 and submitted to an analytical laboratory for chemical analyses of pertinent water chemistry parameters. A summary of the in-field measured ground water quality parameters is presented in Table 3. A summary of the ground water chemistry for the hatchery wells is presented in Table 4. Analytical laboratory data sheets describing the ground water chemistry data in detail are presented in Attachment D. Descriptions of the in-field measured ground water quality data and the water chemistry information are presented below.

In-Field Ground Water Quality Parameters

The water quality parameters measured in water samples obtained from hatchery wells were within the expected ranges for normal ground water. The ground water temperatures measured in hatchery wells during the constant pumping-rate aquifer tests were generally in the expected/normal range for ground water in the north-central Idaho area (Table 3).

Electrical conductance is a measure of the ability to conduct an electrical current through a given solution and is used to indicate the total salt content, or total dissolved solids (TDS), for a given water at a specific site. The more salts in the water, the better conductor it becomes. The strength of the electrical current is dependent upon the temperature of the solution and type and concentration of ion within the solution. The specific conductance (conductivity) of water is a function of the types and quantities of dissolved substances it contains, normalized to a unit length and unit cross section at a specified temperature.

The State of Idaho has established a secondary maximum contaminant level (SMCL) of 700 micro Siemens per centimeter (µS/cm) for specific conductance in drinking water supplies. SMCLs are not health-risk based and are generally established based on aesthetics such as taste, odor, and staining potential. Values of specific conductance in fresh ground water typically are less than 1,000 µS/cm. The specific conductance measured periodically in the hatchery wells during the constant-pumping rate tests were significantly less than the SMCL and stable (Table 3).

Table 3
In-Field Ground Water Quality Parameters – Hatchery Wells

Parameter	Units	Hatchery Wells			Drinking Water Criteria[(1)]
		HW1	HW2	HW3	
Specific Conductance	mS/cm	163	130	115	700
Dissolved Oxygen	mg/L	7.8	8.2	7.2	NE
	% Sat	73	77	66	NE
pH	--	7.1	6.7	6.7	NE
Temperature	°C	9.5	9.6	9.8	NE
Turbidity	NTU	0.4	0.5	0.3	1

º C = degrees Centigrade.
µS/cm = micro Siemens per centimeter.
mg/l = milligrams per liter.
NE = None established.
Sat = Saturation
(1) Idaho State secondary maximum contaminant levels.

Dissolved oxygen in shallow ground water is typically less than 4 milligrams per liter (mg/l). The dissolved oxygen values measured in hatchery wells during the constant-pumping rate aquifer tests were elevated with respect to typical values of shallow ground water (Table 3). However, it should be noted that dissolved oxygen was measured in the discharge water from near the wellhead after it was pumped from the well. It is likely that significant aeration of the discharge water occurred while the ground water was pumped up the pump column to the sampling port/gate valve.

Fresh ground water pH generally ranges between 6.5 and 8.0. Ground water pH values measured in the hatchery wells during the constant-pumping rate test were within the typical normal limits for shallow ground water (Table 3). Turbidity is cloudiness in water due to suspended and colloidal organic and inorganic material. Turbidity levels in ground water are regulated for public water supplies primarily because it interferes with the ability of chlorine to disinfect and it may promote the formation of disinfection byproducts in chlorinated water. The turbidity levels in the hatchery wells were all within acceptable levels for potable water supplies by the conclusion of the aquifer tests (Table 3).

Ground Water Chemistry

Water samples obtained from each hatchery well near the end of the constant-pumping rate aquifer tests were submitted to Anatek Labs, Inc. of Spokane, Washington for chemical analyses of pertinent inorganic compounds, pesticides and polychlorinated biphenyls (PCB). With the exception of sodium in HW3 (40.4 mg/l), inorganic compounds, pesticides and PCB were either not detected or were detected at concentration less than their respective primary MCL, secondary MCL and/or advisory drinking water standard (Table 4, Appendix D).

Table 4
Ground Water Chemistry – Hatchery Wells

Parameter	Units	Hatchery Wells			Drinking Water Criteria[1]
		HW1	HW2	HW3	
Alkalinity	mg/L	76	47	47.5	NE
Aluminum	mg/L	ND	ND	0.0474	NE
Ammonia	mg/L	ND	ND	ND	NE
Arsenic	mg/L	ND	ND	ND	0.01
Barium	mg/L	0.0103	0.00586	0.0231	2.0
Cadmium	mg/L	ND	ND	ND	0.005
Calcium	mg/L	12.7	7.67	95.6	NE
Carbon Dioxide	mg/L	3.52	7.04	6.16	NE
Chloride	mg/L	3.18	2.88	2.86	250
Chlorine Residual	mg/L	ND	0.05	0.01	NE
Chromium	mg/L	ND	ND	0.0102	0.1
Copper	mg/L	ND	ND	0.00419	1.3
Fluoride	mg/L	0.265	ND	ND	4.0
Hardness	mg/L	73	26	52	NE
Cyanide	mg/L	ND	ND	ND	0.2
Iron	mg/L	0.0226	ND	0.0384	0.3
Lead	mg/L	ND	ND	ND	0.015
Magnesium	mg/L	1.97	1.45	30.2	NE
Manganese	mg/L	0.0015	ND	0.00780	0.05
Mercury	µg/L	ND	0.00880	ND	2.0
Nickel	mg/L	ND	ND	ND	0.1
Nitrate+ Nitrite	mg/L	0.69	0.367	0.360	10.0
Nitrate	mg/L	0.69	0.367	0.360	10.0
Nitrite	mg/L	ND	ND	ND	1.0
Potassium	mg/L	0.883	0.554	8.1	NE
Salinity	ppt	0.09	0.06	0.06	NE
Selenium	mg/L	0.00773	0.00717	ND	0.05
Silver	mg/L	ND	ND	ND	0.1
Sodium	mg/L	4.03	1.92	40.4	20
Sulfide	mg/L	0.6	0.6	ND	NE
Sulfate	mg/L	6.23	4.58	4.53	250
TDS	mg/L	74	ND	ND	500
TSS	mg/L	ND	ND	ND	NE
TKN	mg/L	ND	ND	ND	NE
Total Phosphorus	mg/L	ND	0.0180	0.0407	NE
Zinc	mg/L	0.0302	0.0114	0.0785	5.0

º C = degrees Centigrade.
µS/cm = micro Siemens per centimeter.
mg/l = milligrams per liter.
ppt = parts per thousand.
TDS = Total Dissolved Solids
TSS = Total Suspended Solids
[1] US EPA primary and secondary maximum contaminant levels and advisory levels.

CONCLUSIONS AND RECOMMENDATIONS

General

The aquifer testing data indicated that HW1, HW2 and HW3 can be safely pumped at sustained rates of 83, 224, and 325 gpm, respectively. At these pumping rates, the water level drawdown had stabilized in each well and approximately 16, 50 and 47 feet of water column was remaining above the top of the well screen assemblages in HW1, HW2 and HW3, respectively (Attachment A). The aquifer testing information also indicates that well interference water level drawdowns of less than 5 feet should be observed in the hatchery wells and that less than one foot of interference drawdown can be expected in the domestic well (TR-1) located approximately 550 feet north of HW3 (Figure 2).

It appears that HW1 is capable of a maximum pumping rate of roughly 83 gpm due to the minimal water column (16 feet) remaining over the top of the well screen assemblage at that pumping rate. However, both HW2 and HW3 had a significant amount of water column remaining above their well screen assemblages at pumping rates of 224 and 325 gpm, respectively. Therefore, both HW2 and HW3 appear to be capable of being pumped at rates greater than 224 and 325 gpm.

The HW2 and HW3 specific capacities (Table 2) were used to estimate potential additional water level drawdown due to pumping at rates greater than their tested rates. The specific capacity of HW2 was estimated at 84.5 gpm/ft at a pumping rate of 224 gpm (Table 2). Pumping HW2 at 400 gpm would be 176 gpm greater than its tested rate. Pumping an additional 176 gpm from HW2 would result in approximately 2 additional feet of water level drawdown based on the HW2 estimated specific capacity. However, well specific capacities generally decrease with increase pumping rates. As a conservative measure, the predicted additional water level drawdown was double to 4 feet, resulting in a total predicted water level drawdown of approximately 7 feet at a 400 gpm pumping rate. Therefore, roughly 40 feet of water column would still remain over the top of the well screen assemblage at a pumping rate of 400 gpm.

A similar analysis was completed for HW3 using its well specific capacity of 50.5 gpm/ft and the 75 gpm of additional pumping rate needed to reach 400 gpm. Based on this analysis, it appears that there would be approximately 9.4 feet of total water level drawdown in HW3 at a pumping rate of 400 gpm. This would result in roughly 38 feet of water column remaining above the HW3 well screen assemblage.

Based on the analyses presented above, it appears that HW2 and HW3 may be capable of being pumped concurrently at a rate of approximately 400 gpm (combined rate of 800 gpm) and still have significant available water column left to account of seasonal ground water fluctuations and potential well interference effects, assuming that the well pumps are installed near the top of the well screen assemblages.

The aquifer testing data indicated that steady-state conditions were achieved in the hatchery wells by the end of the aquifer tests. However, short-term aquifer tests sometimes do not indicate the presence of aquifer boundaries that may affect the well after weeks or months of pumping. Therefore, we recommend that water levels in the hatchery wells be measured and recorded at least weekly during normal operation or on a daily basis if the well is pumped continuously for longer than 1 day. The water levels should be measured with an accuracy of 0.1 feet or better, and measurement depths should be referenced to the same datum/measuring point at the well when each measurement is made. Each time a measurement is made, the time, data, water depth, and present pumping rate should be recorded. A long-term decline of the water level in the well (for a constant-pumping rate) may indicate effects greater than those indicated by our pump test and analysis.

Water Quality

The in-field measured water quality parameters and chemical analytical data obtained from TW2 during the aquifer test indicate excellent water quality. With the exception of sodium in HW3, no parameters were detected at concentrations greater than their respective primary MCL, secondary MCL and/or advisory level.

Sodium was quantified at a concentration of 40.4 mg/l in the water sample obtained from HW3 near the end of the constant pumping-rate test (Table 4). The US EPA recommends that sodium not exceed 30 to 60 mg/l in drinking water based on esthetics (taste). The US EPA has also established an advisory limit of 20 mg/l in drinking water supplies for those individuals restricted to a total sodium intake of 500 mg/day. The US EPA indicates that this advisory limit should not be extrapolated to the entire population.

It should be noted that the concentrations of sodium, calcium, magnesium and potassium detected in HW3 are roughly 10 times the concentrations detected in both HW1 and HW2. As previously discussed, the Twin Rivers Aquaculture wells are located within 150 feet of each other and in the same shallow aquifer (Figure 2). Elevated concentrations of sodium and chloride in ground water can be indicator parameters for potential contamination from septic system drainfields. However, the chloride concentrations detected in the hatchery wells are relatively low and representative of typical background ground water quality (Table 4). It is also possible that the elevated concentrations of sodium, calcium, magnesium and potassium detected in HW3 are the result of laboratory contamination and are not indicative of background water quality at the project site. Therefore, we recommend that additional water samples be obtained from the hatchery wells and submitted for analyses of sodium, calcium, magnesium and potassium after the production pumps have been installed in the wells.

LIMITATIONS

We prepared this report for use by Tetra Tech, Inc. and their representatives regarding the potential to use the three hatchery wells as a source of water for the proposed Twin Rivers Aquaculture Facility located in Moyie Springs, Idaho. The information presented in this report is based on the above-described research, field activities, and limited reconnaissance. Aquifer characteristics at different locations at the site may vary.

Within the limitations of scope, schedule, and budget, AESI attempted to execute these services in accordance with generally accepted professional principles in the field of hydrogeology at the time this report was prepared. No warranty, express or implied, is made.

We have enjoyed working with you and are confident that these recommendations will aid in the successful completion of your project. If you should have any questions, or require further assistance, please do not hesitate to call.

Sincerely,
ASSOCIATED EARTH SCIENCES, INC.
Everett, Washington

Charles S. Lindsay, L.G., L.E.G., L.Hg.
Principal Geologist/Hydrogeologist

Attachments:
Figure 1: Vicinity Map
Figure 2: Site Plan
Attachment A: Geologic & Well Construction Log
Attachment B: Soil Sieve Data
Attachment C: Aquifer Pumping Test Data Sheets
Attachment D: Laboratory Data Sheets

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ATTACHMENT A

Geologic & Well Construction Log

ATTACHMENT B

Soil Sieve Data

ATTACHMENT C

Aquifer Pumping Test Data Sheets

ATTACHMENT D

Chemical Analytical Data Sheets

ATTACHMENT E.
TOPOGRAPHIC AND IMPROVEMENT MAP

TOPOGRAPHIC AND IMPROVEMENT MAP
OF
TWIN RIVERS RESORT
SECTIONS 15 AND 22
TOWNSHIP 62 NORTH, RANGE 2 EAST, B.M.
BOUNDARY COUNTY, IDAHO
FOR
KOOTENAI TRIBE OF IDAHO
SHEET 1 OF 7

PRELIMINARY

LEGEND

- INDICATES POWER POLE
- INDICATES GUY ANCHOR
- INDICATES FIRE PIT
- INDICATES SIGN
- INDICATES PHONE PEDESTAL
- INDICATES POWER PEDESTAL/METER
- INDICATES WATER SPIGOT
- INDICATES SATTELITE DISH
- INDICATES UNDERGROUND POWER & WATER
- INDICATES WELL CASING
- OHWM INDICATES ORDINARY HIGH WATER MARK
- INDICATES PROPANE TANK
- INDICATES SANITARY SEWER CLEANOUT
- INDICATES BASKETBALL HOOP
- INDICATES STUMP
- INDICATES APPROXIMATE BOUNDARY

TREE LEGEND

1	15" DBH FIR	1796.87
2	16" DBH CEDAR	1795.60
3	18" DBH PINE	1796.87
4	13" DBH LARCH	1795.61
5	12" DBH PINE	1794.98
6	18" DBH LARCH	1794.94
7	14" DBH CEDAR	1794.91
8	17" DBH CEDAR	1794.70
9	13" DBH CEDAR	1795.41
10	19" DBH CEDAR	1794.82
11	15" DBH FIR	1794.77
12	18" DBH CEDAR	1793.57
13	23" DBH CEDAR	1791.96
14	22" DBH CEDAR	1791.42
15	20" DBH CEDAR	1791.53
16	36" DBH CEDAR	1791.82
17	13" DBH CEDAR	1791.77

BOTANICAL TREE NAMES

BIRCH = BETULA NIGRA
CEDAR = CEDRUS
COTTONWOOD = POPULUS FREEMONTII
DOUGLAS FIR (D. FIR) = ABIES
GRAND FIR (G. FIR) = ABIES
LARCH = LARIX DECIDUA
MAPLE = ACER
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POPLAR = POPULUS ALBA
SPRUCE = PICEA GLAUCA
WILLOW = SALIX

SHEET 1 OF 7

SHEET 2 OF 7

J.R.S. SURVEYING, INC.
PO BOX 3099-6476 MAIN
BONNERS FERRY, ID. 83805
(208) 267-7555

TOPOGRAPHIC MAP

FOR: KOOTENAI TRIBE OF IDAHO	REVISION NO. 1
DWN BY: MSS/KK	DATE: 01-15-08
SEC.S 15 & 22, T62N, R2E, B.M.	SHEET 1 OF 7
BOUNDARY COUNTY, IDAHO	JOB NO. 07-94


PRELIMINARY
TOPOGRAPHIC AND IMPROVEMENT MAP
OF
TWIN RIVERS RESORT
SECTIONS 15 AND 22
TOWNSHIP 62 NORTH, RANGE 2 EAST, B.M.
BOUNDARY COUNTY, IDAHO
FOR
KOOTENAI TRIBE OF IDAHO
SHEET 2 OF 7
SHEET 1 OF 7
SHEET 2 OF 7
SHEET 3 OF 7
GEODETIC NORTH
SCALE: ONE INCH = 30 FEET
VERTICAL DATUM = NAVD88
MOYIE RIVER
CREEK
OHWM
TOP OF BANK
ROAD
SHRUB LINE
OHD UTILITIES
(ALSO UG POWER)
POWER HOOKUP
STRUCTURE FOR POWER PANELS
CONC. PAD
RESTROOMS LAUNDRY SHOWERS
18" GATE VALVE
48" VERT. CMP
4' HIGH WIRE FENCE
BARN
SHED
SMALL CONIFERS
BUSH
LEGEND
INDICATES POWER POLE
INDICATES GUY ANCHOR
INDICATES FIRE PIT
INDICATES SIGN
INDICATES PHONE PEDESTAL
INDICATES POWER PEDESTAL/METER
INDICATES WATER SPIGOT
INDICATES SATTELITE DISH
INDICATES UNDERGROUND POWER & WATER
INDICATES WELL CASING
OHWM INDICATES ORDINARY HIGH WATER MARK
INDICATES PROPANE TANK
INDICATES SANITARY SEWER CLEANOUT
INDICATES BASKETBALL HOOP
INDICATES STUMP
INDICATES APPROXIMATE BOUNDARY
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SPRUCE = PICEA GLAUCA
WILLOW = SALIX
R.S. SURVEYING, INC.
BONNERS FERRY, ID. 83805
(208) 267-7555
TOPOGRAPHIC MAP
REVISION NO. 1
DATE: 01-15-08
SHEET 2 OF 7
JOB NO. 07-94
BOUNDARY COUNTY, IDAHO


PRELIMINARY
TOPOGRAPHIC AND IMPROVEMENT MAP
OF
TWIN RIVERS RESORT
SECTIONS 15 AND 22
TOWNSHIP 62 NORTH, RANGE 2 EAST, B.M.
BOUNDARY COUNTY, IDAHO
FOR
KOOTENAI TRIBE OF IDAHO
SHEET 3 OF 7
GEODETIC NORTH
SCALE: ONE INCH = 30 FEET
VERTICAL DATUM = NAVD88
SHEET 2 OF 7
SHEET 3 OF 7
SHEET 4 OF 7
SHEET 5 OF 7
MOYIE RIVER
POND
CREEK
ROAD
VOLLEYBALL NET
TIRE SWING
BOLLARDS
JUNGLE GYM
HORSE SHOE PITS
CIRCUIT BREAKER BOX
RV DUMP STATION
4' HIGH WIRE FENCE
LEGEND
INDICATES POWER POLE
INDICATES GUY ANCHOR
INDICATES FIRE PIT
INDICATES SIGN
INDICATES PHONE PEDESTAL
INDICATES POWER PEDESTAL/METER
INDICATES WATER SPIGOT
INDICATES SATTELITE DISH
INDICATES UNDERGROUND POWER & WATER
INDICATES WELL CASING
OHWM INDICATES ORDINARY HIGH WATER MARK
INDICATES PROPANE TANK
INDICATES SANITARY SEWER CLEANOUT
INDICATES BASKETBALL HOOP
INDICATES STUMP
INDICATES APPROXIMATE BOUNDARY
TREE LEGEND
18 26" DBH CEDAR 1791.58
19 32" DBH CEDAR 1791.96
20 18" DBH CEDAR 1791.80
21 20" DBH CEDAR 1791.80
22 24" DBH CEDAR 1791.53
BOTANICAL TREE NAMES
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TOPOGRAPHIC MAP
FOR: KOOTENAI TRIBE OF IDAHO
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SEC.S 15 & 22, T62N, R2E, B.M.
SHEET 3 OF 7
BOUNDARY COUNTY, IDAHO
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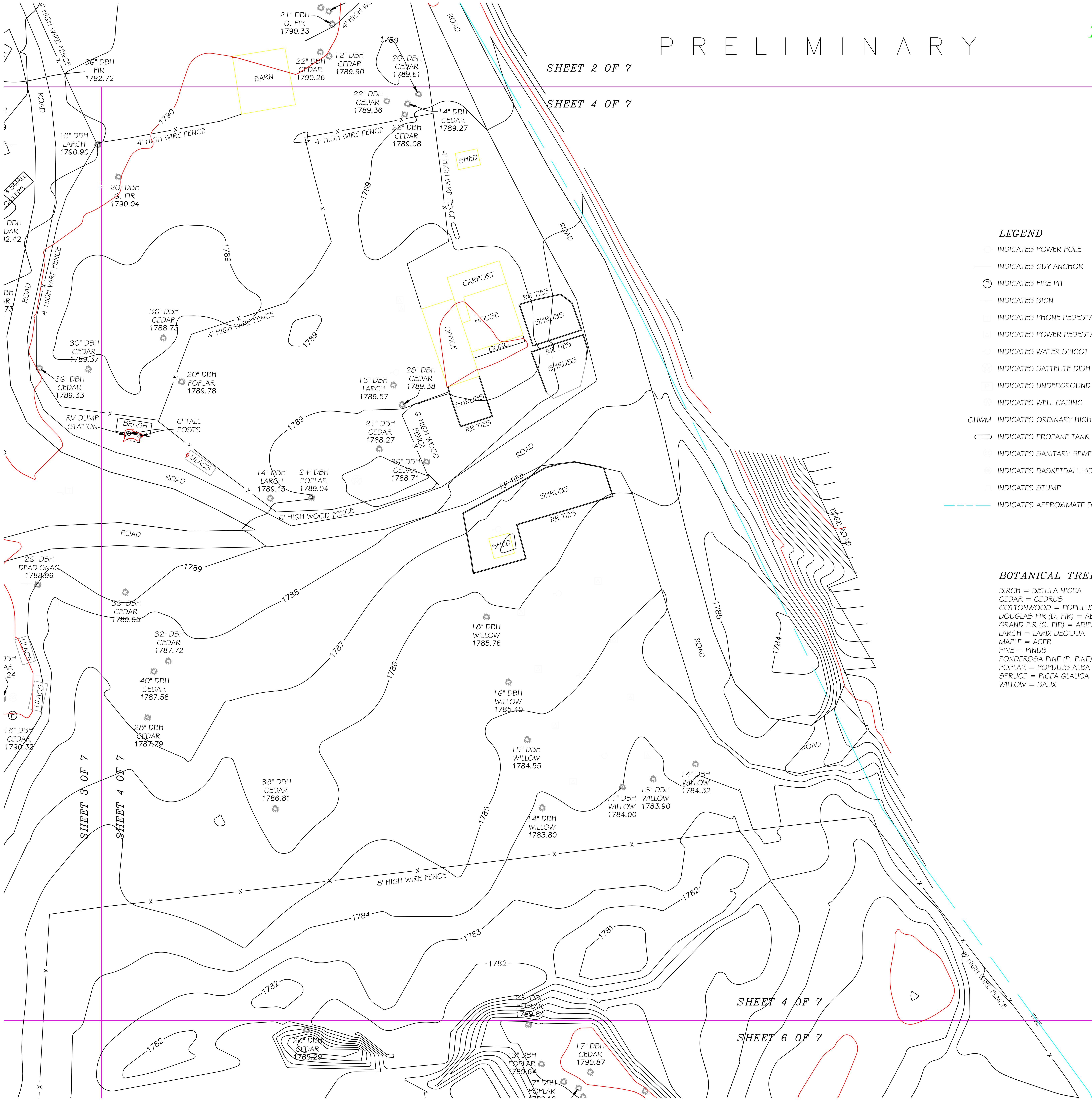

P R E L I M I N A R Y

TOPOGRAPHIC AND IMPROVEMENT MAP

OF

TWIN RIVERS RESORT

SECTIONS 15 AND 22

TOWNSHIP 62 NORTH, RANGE 2 EAST, B.M.

BOUNDARY COUNTY, IDAHO

FOR

KOOTENAI TRIBE OF IDAHO

SHEET 4 OF 7

LEGEND

- INDICATES POWER POLE
- INDICATES GUY ANCHOR
- INDICATES FIRE PIT
- INDICATES SIGN
- INDICATES PHONE PEDESTAL
- INDICATES POWER PEDESTAL/METER
- INDICATES WATER SPIGOT
- INDICATES SATTELITE DISH
- INDICATES UNDERGROUND POWER & WATER
- INDICATES WELL CASING
- OHWM INDICATES ORDINARY HIGH WATER MARK
- INDICATES PROPANE TANK
- INDICATES SANITARY SEWER CLEANOUT
- INDICATES BASKETBALL HOOP
- INDICATES STUMP
- INDICATES APPROXIMATE BOUNDARY

GEODETIC NORTH

SCALE: ONE INCH = 30 FEET
VERTICAL DATUM – NAVD88

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TOPOGRAPHIC MAP

FOR: KOOTENAI TRIBE OF IDAHO	REVISION NO. 1
DWN BY: MSS/KK	DATE: 01–15–08
SEC.S 15 & 22, T62N, R2E, B.M.	SHEET 4 OF 7
BOUNDARY COUNTY, IDAHO	JOB NO. 07–94


PRELIMINARY
TOPOGRAPHIC AND IMPROVEMENT MAP
OF
TWIN RIVERS RESORT
SECTIONS 15 AND 22
TOWNSHIP 62 NORTH, RANGE 2 EAST, B.M.
BOUNDARY COUNTY, IDAHO
FOR
KOOTENAI TRIBE OF IDAHO
SHEET 5 OF 7
GEODETIC NORTH
SCALE: ONE INCH = 30 FEET
VERTICAL DATUM - NAVD88
LEGEND
INDICATES POWER POLE
INDICATES GUY ANCHOR
INDICATES FIRE PIT
INDICATES SIGN
INDICATES PHONE PEDESTAL
INDICATES POWER PEDESTAL/METER
INDICATES WATER SPIGOT
INDICATES SATTELITE DISH
INDICATES UNDERGROUND POWER & WATER
INDICATES WELL CASING
OHWM INDICATES ORDINARY HIGH WATER MARK
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SPRUCE = PICEA GLAUCA
WILLOW = SALIX
SHEET 3 OF 7
SHEET 5 OF 7
SHEET 6 OF 7
SHEET 7 OF 7
MOYIE RIVER
POND
POND
OHWM
TOP OF BANK
BUILDING
CONC.
LILACS
RESTROOMS
CONCRETE PAD
ROAD
8' TALL WOOD POSTS
10' HIGH CHAINLINK FENCE
8' HIGH WIRE FENCE
4' HIGH WIRE FENCE
DOWNED CEDAR SNAG
BRUSH
BUSH
LILAC
24" CMP
14" DBH MAPLE 1785.11
38" DBH CEDAR 1788.96
34" DBH CEDAR 1789.23
36" DBH CEDAR 1788.71
28" DBH CEDAR 1788.33
38" DBH CEDAR 1787.35
46" DBH CEDAR 1788.80
44" DBH CEDAR 1788.26
30" DBH CEDAR 1787.01
36" DBH CEDAR 1787.30
42" DBH CEDAR 1788.68
16" DBH CEDAR 1788.32
48" DBH CEDAR 1788.12
48" DBH COTTONWOOD 1786.53
60" DBH COTTONWOOD 1785.84
60" DBH CEDAR 1786.44
70" DBH COTTONWOOD 1788.49
40" DBH CEDAR 1788.13
48" DBH CEDAR 1786.72
1-36", 1-14" DBH CEDAR 1787.55
50" DBH CEDAR 1787.36
20" DBH COTTONWOOD 1788.07
54" DBH CEDAR 1787.50
54" DBH CEDAR 1785.93
36" DBH COTTONWOOD 1785.43
30" DBH COTTONWOOD 1785.75
32" DBH COTTONWOOD 1785.44
40" DBH COTTONWOOD 1786.40
50" DBH CEDAR 1783.40
30" DBH COTTONWOOD 1784.49
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
J.R.S. SURVEYING, INC.
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TOPOGRAPHIC MAP
FOR: KOOTENAI TRIBE OF IDAHO
REVISION NO. 1
DATE: 01-15-08
SHEET 5 OF 7
JOB NO. 07-94
BOUNDARY COUNTY, IDAHO


PRELIMINARY
TOPOGRAPHIC AND IMPROVEMENT MAP
OF
TWIN RIVERS RESORT
SECTIONS 15 AND 22
TOWNSHIP 62 NORTH, RANGE 2 EAST, B.M.
BOUNDARY COUNTY, IDAHO
FOR
KOOTENAI TRIBE OF IDAHO
SHEET 6 OF 7
SHEET 4 OF 7
SHEET 6 OF 7
SHEET 5 OF 7
SHEET 6 OF 7
SHEET 6 OF 7
SHEET 7 OF 7
GEODETIC NORTH
SCALE: ONE INCH = 30 FEET
VERTICAL DATUM - NAVD88
23" DBH POPLAR 1789.84
26" DBH CEDAR 1785.29
13" DBH POPLAR 1789.64
17" DBH CEDAR 1790.87
17" DBH POPLAR 1789.10
13" DBH POPLAR 1789.35
12" DBH POPLAR 1789.10
22" DBH CEDAR 1790.68
18" DBH POPLAR 1789.06
15" DBH POPLAR 1783.92
8' HIGH WIRE FENCE
4' HIGH WIRE FENCE
5' HIGH WOOD FENCE
TOE
GATE
ELEC. TRANSFORMER
LOGS
GRAVEL AREA
LEGEND
INDICATES POWER POLE
INDICATES GUY ANCHOR
INDICATES FIRE PIT
INDICATES SIGN
INDICATES PHONE PEDESTAL
INDICATES POWER PEDESTAL/METER
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TOPOGRAPHIC AND IMPROVEMENT MAP
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TWIN RIVERS RESORT
SECTIONS 15 AND 22
TOWNSHIP 62 NORTH, RANGE 2 EAST, B.M.
BOUNDARY COUNTY, IDAHO
FOR
KOOTENAI TRIBE OF IDAHO
SHEET 7 OF 7
GEODETIC NORTH
VERTICAL DATUM = NAVD88
SHEET 5 OF 7
SHEET 7 OF 7
SHEET 6 OF 7
MOYIE RIVER
KOOTENAI RIVER
HOUSE
CONC. DRIVE
GRAVEL AREA
GRAVEL BOAT RAMP
MAN MADE EAGLES NEST
DEBRIS PILE
BRUSH AREA
METAL BOLLARDS
ELEC. TRANSFORMER
LOGS
SHED
8' HIGH WIRE FENCE
4' HIGH WIRE FENCE
5' HIGH WOOD FENCE
GATE
ROAD
TOP OF BANK
OHWM
BRUSH LINE
BRUSHY AREA
LEGEND
INDICATES POWER POLE
INDICATES GUY ANCHOR
INDICATES FIRE PIT
INDICATES SIGN
INDICATES PHONE PEDESTAL
INDICATES POWER PEDESTAL/METER
INDICATES WATER SPIGOT
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PRELIMINARY

ATTACHMENT F.
KOOTENAI TWIN RIVERS AND TRIBAL HATCHERY OUTLINE SPECIFICATION

KOOTENAI TWIN RIVERS AND TRIBAL HATCHERY
OUTLINE SPECIFICATION

DIVISION 03 – CONCRETE

033000 CAST-IN-PLACE CONCRETE

DIVISION 04 - MASONRY

042200 CONCRETE UNIT MASONRY

DIVISION 05 - METALS

052200 STRUCTURAL STEEL FRAMING
052100 STEEL JOIST FRAMING
053100 STEEL DECKING
054000 COLD-FORMED METAL FRAMING
055000 METAL FABRICATIONS
055100 METAL STAIRS
055213 PIPE AND TUBE RAILINGS
055300 METAL GRATINGS

DIVISION 06 - WOOD, PLASTICS, AND COMPOSITES

061000 ROUGH CARPENTRY
061600 SHEATHING
061753 SHOP-FABRICATED WOOD TRUSSES
062013 EXTERIOR FINISH CARPENTRY

DIVISION 07 - THERMAL AND MOISTURE PROTECTION

071113 BITUMINOUS DAMPPROOFING
071326 SELF-ADHERING SHEET WATERPROOFING
071900 WATER REPELLENTS
072100 THERMAL INSULATION
072500 WEATHER BARRIERS
074113 STANDING-SEAM METAL ROOF PANELS
074213 FORMED METAL WALL PANELS
074600 SIDING
075323 ETHYLENE-PROPYLENE-DIENE-MONOMER (EPDM) ROOFING
076200 SHEET METAL FLASHING AND TRIM
077100 ROOF SPECIALTIES
077200 ROOF ACCESSORIES
077253 SNOW GUARDS
078413 PENETRATION FIRESTOPPING
079200 JOINT SEALANTS

DIVISION 08 - OPENINGS

081113 HOLLOW METAL DOORS AND FRAMES
081416 FLUSH WOOD DOORS

DIVISION 22 - PLUMBING

DIVISION 23 – HEATING, VENTILATING AND AIR CONDITIONING

Kootenai Tribe of Idaho, August 2012

Kootenai River Native Fish Conservation Aquaculture Program Step 2 Document