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Managing Water in the West

Dam Removal Experiences - Elwha River Restoration Project, Washington

Northwest Hydro Operators Forum
2012 Fall Program – Session 1



Thomas E. Hepler, P.E.
U.S. Department of the Interior
Bureau of Reclamation



Overview

- **Project Background**
- **Procurement Process**
- **Elwha Dam Removal**
- **Glines Canyon Dam Removal**
- **Transmission Line Removal**
- **Project Costs and Schedule**

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Project Background

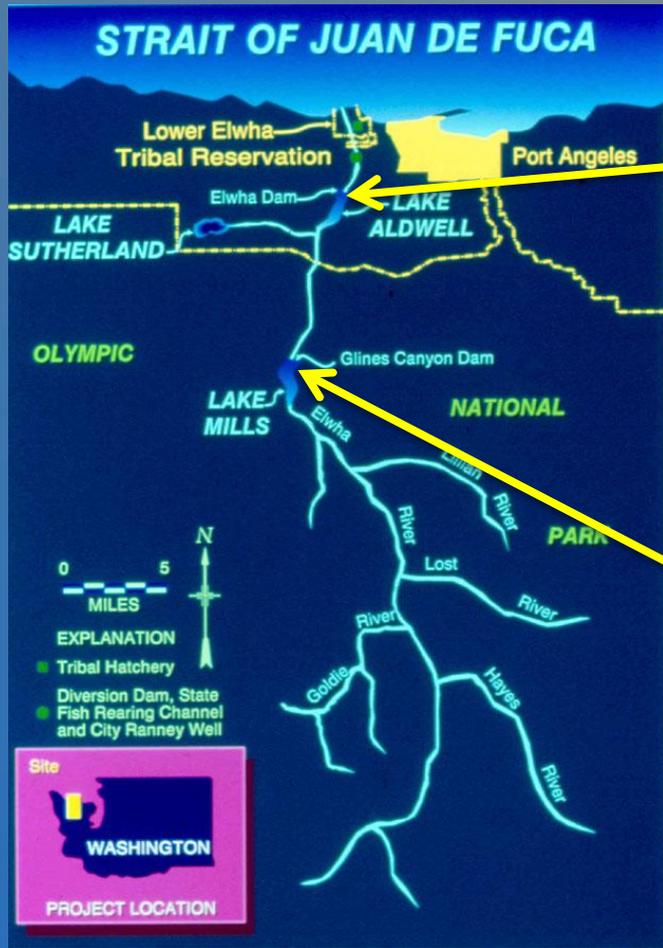
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Elwha Project Highlights

- Largest dam removal and river restoration project in U.S. history
- Removal of Elwha Dam (108 feet high) and Glines Canyon Dam (210 feet high)
- Opens up 70 miles of the Elwha River in northwestern Washington for fish passage
- Pacific salmon populations estimated to climb from 3,000 to 400,000 within 25 years

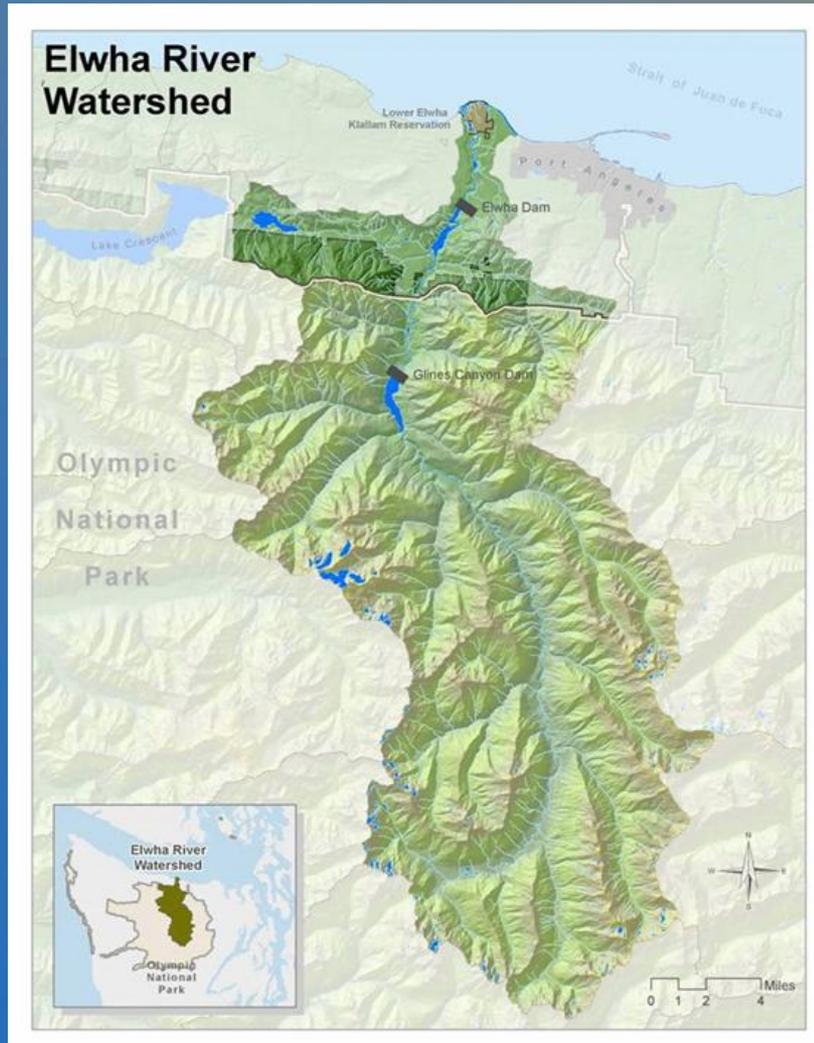
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Elwha River Location and Sites



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Elwha River Watershed



Area = 325 sq miles

River Flow

$$Q_m = 1,500 \text{ ft}^3/\text{s}$$

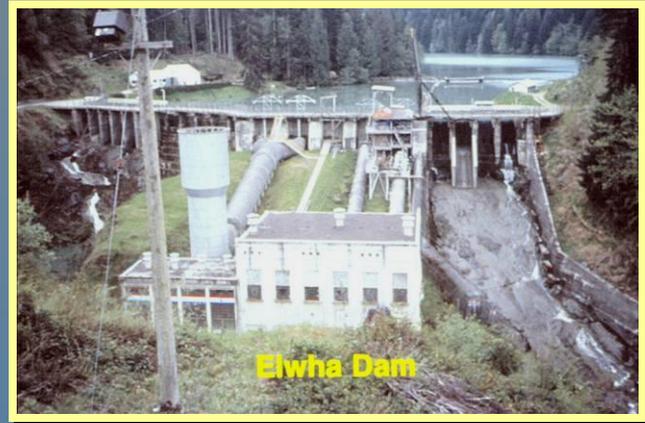
$$Q_2 = 13,000 \text{ ft}^3/\text{s}$$

$$Q_{100} = 45,000 \text{ ft}^3/\text{s}$$

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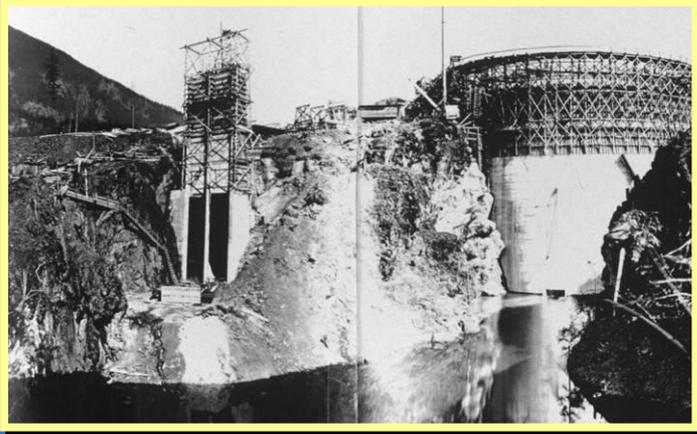
Elwha Dam

- Built 1913 at RM 4.9
- Concrete gravity dam
- 108 feet high
- Two gated spillways
- Four plugged outlets
- Stabilizing fill upstream
- Three high penstocks
- 12 MW plant (four units)
- Run-of-river operation
- 8,600 a-f storage
(Lake Aldwell)

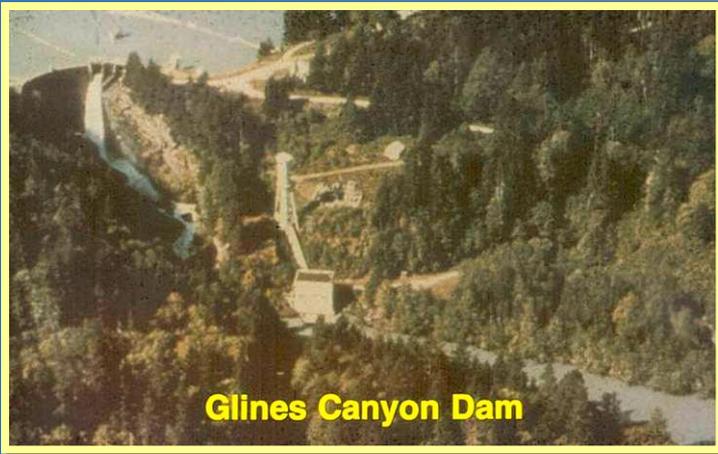


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Glines Canyon Dam



- Built 1927 at RM 13.4
- Concrete thin arch dam
- 210 feet high
- One gated spillway
- One abandoned outlet
- One mid-level penstock
- 16 MW plant (one unit)
- Run-of-river operation
- 25,800 a-f storage
(Lake Mills)



Elwha Project Issues

FERC Licensing Issues:

- Glines Canyon Dam FERC license expired in 1977
- Elwha Dam was never licensed by FERC

Endangered Species Act (ESA) Issues:

- Fish passage blocked for listed species for 100 years

Native American trust responsibilities:

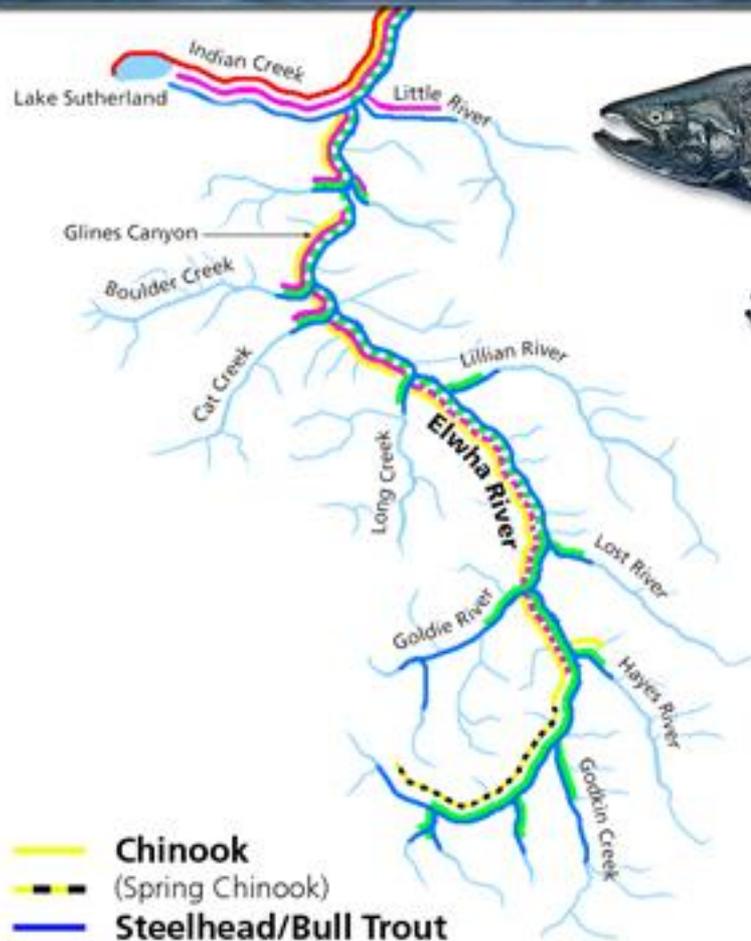
- Fishing rights granted under Treaty with U.S.
- Cultural sites for Lower Elwha Klallam Tribe flooded
- Tribe first moved for removal of both dams in 1986

Dams blocked natural sediment transport to Ediz Hook

Glines Canyon Dam is within Olympic National Park

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Potential Range Map for the Seven Elwha Salmonids



Chinook



Steelhead



Chum



Coho



Sockeye



Bull Trout



Pink

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Elwha Project Legislation - 1992

Elwha River Ecosystem and Fisheries Restoration Act:

- Bi-partisan legislation with widespread support
- Suspended FERC relicensing issues
- Required Federal (DOI) studies to fully restore ecosystem and anadromous fisheries to Elwha River
- Provided for project acquisition by U.S. Government at a fixed price (\$29.5 million) from the private owner (James River paper mill in Port Angeles)
- Ensured affected parties would remain whole:
 - Maintain quantity and quality of water supplies
 - Maintain flood protection
 - Protect cultural resources

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Elwha Project – Removal Decision

NPS assigned lead responsibility to prepare EIS:

- Programmatic EIS (1995) – Evaluated alternatives and supported removal of both dams
- Implementation EIS (1996) – Evaluated specific removal methods and supported sediment erosion
- Supplemental EIS (2005) – Updated EIS details

Record of Decision (ROD) – Set Project Components:

- Removal of Elwha and Glines Canyon Dams
- Natural erosion of reservoir sediments
- Water quality protection (new treatment plants)
- Flood protection (raised flood control levees)

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Reservoir Sediment Issues



**Lake Aldwell
(Elwha Dam)**



Deltas

**Lake Mills
(Glines Canyon Dam)**

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2010 Reservoir Sediment Volumes

24 million yd³ ± 4 million yd³

Lake Aldwell – 4 mcy

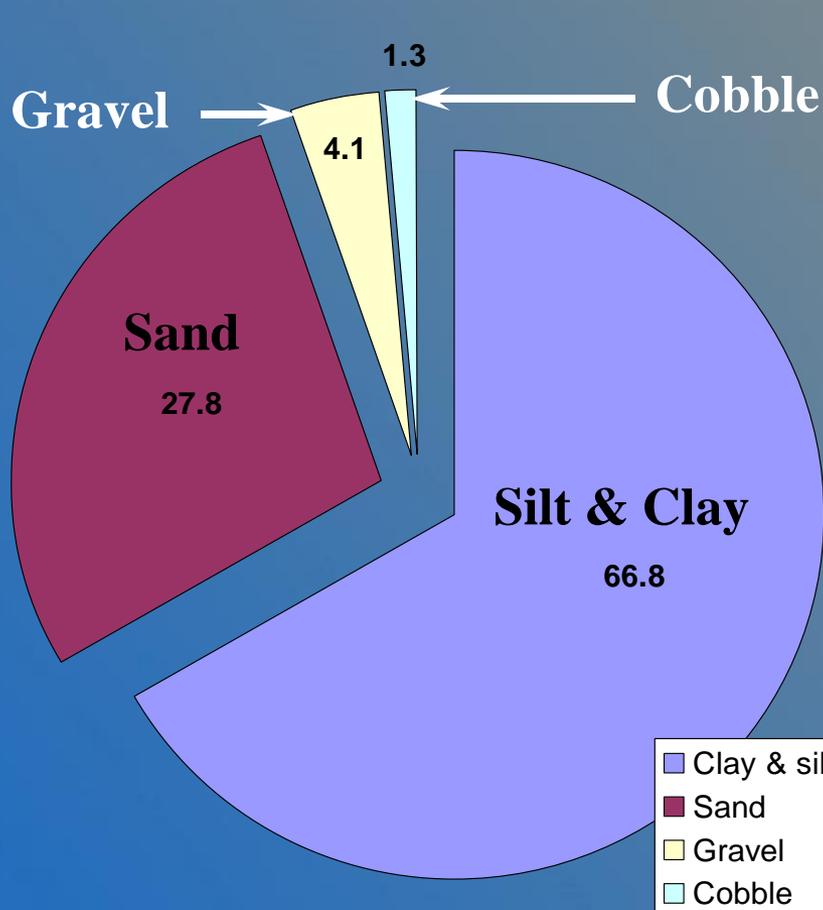
Lake Mills – 20 mcy



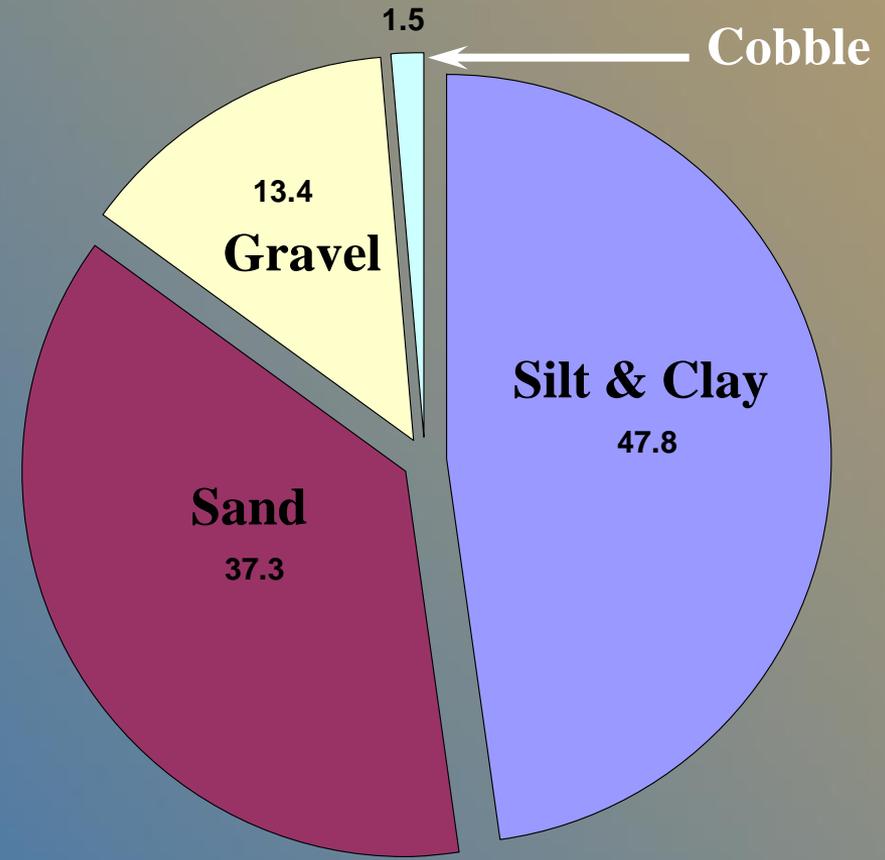
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Sediment Grain Size Distributions

Lake Aldwell



Lake Mills

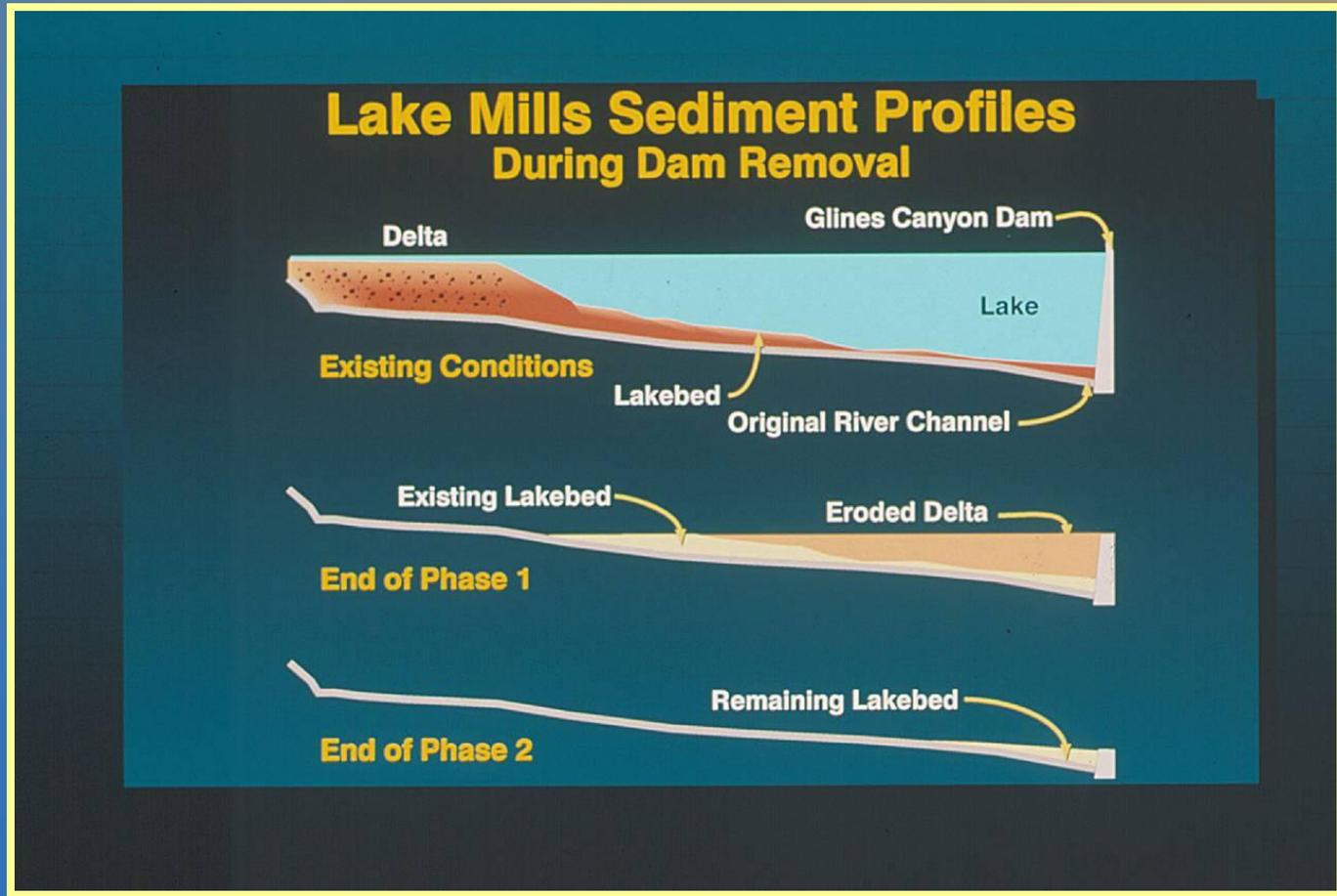


Sediment Management Plan

- Remove Elwha and Glines Canyon Dams concurrently, in controlled increments, over a 2 to 3 year period
- Limit reservoir drawdown rate to 1.5 or 2 feet per day for reservoir slope stability and for sediment erosion
- Provide reservoir hold periods (no drawdown) at 10 – 20 foot intervals for up to 14 days
- No reservoir drawdown and sediment release during critical migration periods for fish: May – June, August – September 15, and November – December (5.5 months)
- Limit downstream turbidity to 40,000 ppm at d/s intake

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Staged Drawdown – Lake Mills



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Sediment Impact Predictions

- 1994 Lake Mills Drawdown Experiment (18 ft)
- 1994 and 2010 Reservoir bathymetric surveys
- Reservoir sediment erosion models:
 - Numerical models
 - Physical (hydraulic) models
- Adaptive management – real time monitoring
 - Channel incision and widening in deltas
 - Downstream delta advancement
 - Sediment terrace stability

Lake Mills Sediment Redistribution

Hydraulic Modeling: (St. Anthony Falls Lab)

- Staged drawdown
- Pilot channel tests
- Redistribution of delta deposits



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Environmental Mitigation Measures

Flood Protection - due to coarse sediment deposition

- Raise existing levees and roads up to 3 feet
- Replace existing wells and septic systems

Water Quality Protection - from increased turbidity

- Construct new surface diversion intake on river
- Construct new water treatment plants for city and industrial users – Port Angeles and Nippon Paper Mill
- Maintain water supply to State and Tribal hatcheries

Fish Hatchery Improvements – to protect broodstock

- Improvements to State fish-rearing facility
- Replacement of Tribal fish hatchery

Replacement Power – from Bonneville Power Admin

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Fish Ramp and Diversion Weir (River Mile 3)



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Elwha Water Treatment Plant



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Elwha Westside Levee



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New Tribal Hatchery and Rearing Pens



Photo by Keith Thorpe, Peninsula Daily News

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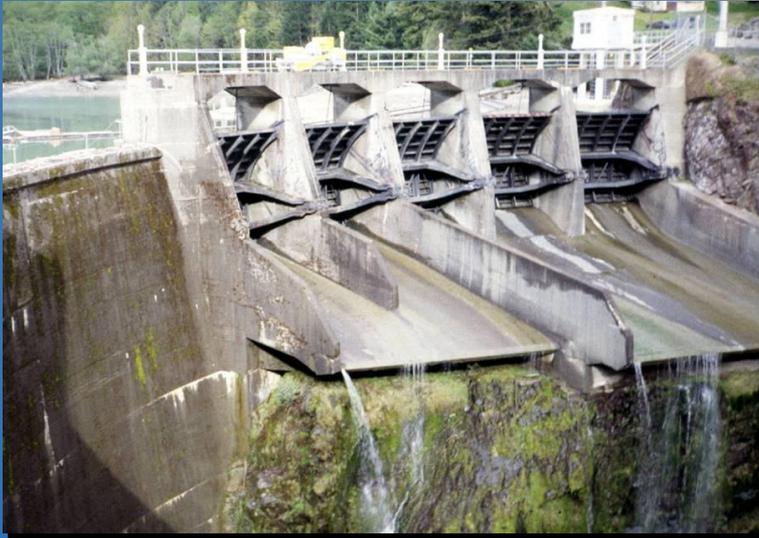
Dam Removal Project Objectives

- Safely remove Elwha and Glines Canyon Dams to provide a free-flowing river at both sites
- Pass river flows throughout dam removal
- Facilitate sediment management through controlled releases and construction work schedules
- Minimize downstream impacts to fisheries
- Restore Elwha Dam site to near pre-dam conditions
- Retain certain structures for historical preservation and public viewing at Glines Canyon Dam site
- Achieve reasonable removal and restoration costs

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Glines Canyon Remaining Features

Gated Spillway



Thrust Block



Modifications for Public Access Required on Both Abutments

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Reservoir Revegetation



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Procurement Process

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Dam Removal Steps

- **Step One – Acquisition by DOI (February 2000)**
 - Obtained property and water rights
 - Responsible for O&M, Dam Safety (BOR)
- **Step Two – Designs and Specifications (BOR)**
 - Data collection, removal limits, sequencing
 - Schedule constraints (seasonal, environmental)
 - Cost estimates based on assumed methods
- **Step Three – Permitting (BOR)**
 - Clean Water Act (401- WDOE, 404 - USACE)
 - Hydraulic Project Approval (WDFW)
- **Step Four – Mitigation and Removal Activities**
 - Dam Removal Solicitation issued March 2010

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Specifications and Drawings

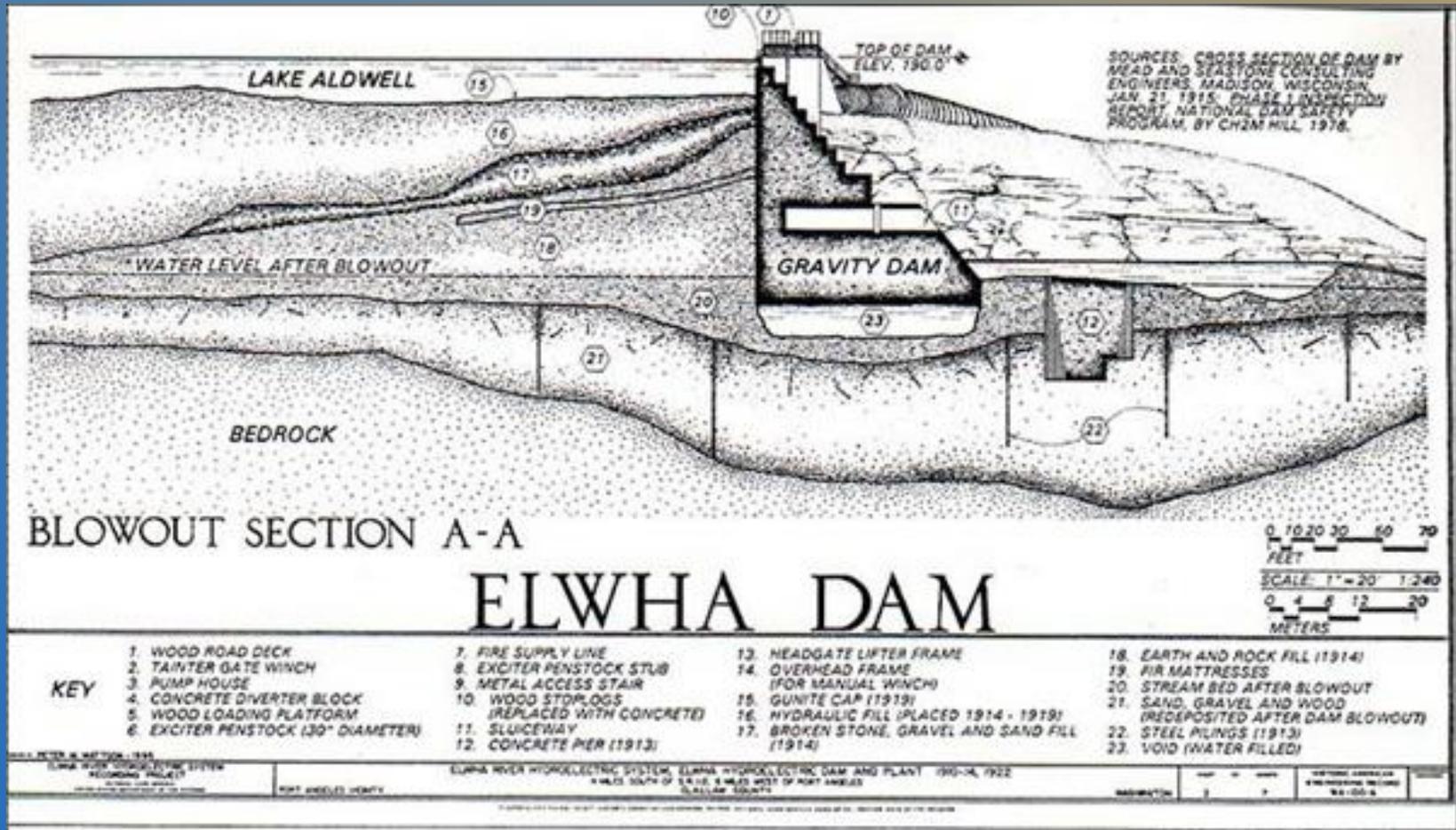
- Specifications describe Govt assumptions for removal of both dams (not binding) and constraints
- Project drawings portray existing site conditions and minimum structure removal limits, new construction and earth embankments
- Original design drawings included for informational purposes (in original project datum)
- Includes appended and referenced reports for additional information pertinent to the project

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Geologic Investigations & Records

- Geologic data specific to needs included in the specifications, with additional reports available
- Elwha Dam site geology includes drill hole explorations in 1994 and 2002 for potential diversion channel and cofferdam
 - Surface mapping, cross-sections, bedrock contours, logs
- Glines Canyon Dam site geology based on available information, without new explorations for removal
 - Bathymetry, some pre-construction data

1912 Blowout at Elwha Dam



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Contracting Method

Request for Proposals (Negotiated Procurement)

- **Technical Proposal**

- Proposed channel alignment(s) at Elwha Dam
- Proposed notching methods for Glines
- Proposed concrete demolition methods
- Waste removal methods (cranes, cableway)
- Proposed construction schedule

- **Cost Proposal**

Awarded to Barnard Construction based on technical and cost factors providing “best value” to Govt.

Construction management contract to URS Corp.

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Permissible Work Periods

- Weekdays, weekends, and holidays - 7:00 am to 7:00 pm
- Activities that generate excessive noise limited to period from 2 hours after sunrise to 2 hours before sunset from April 1 to September 15 each year
- Below Elwha Dam – in-water work in the Elwha River limited to period from July 1 to October 1
- Reservoir drawdown rates and hold periods specified
- Activities that result in reservoir drawdown limited to:
 - January through April
 - July
 - September 15 through October
 - Total 6.5 months/year

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Project Conditions

Both powerhouses to be decommissioned by Govt prior to commencement of dam removal activities (target start date February 3, 2011):

- Elwha penstock gates to be permanently closed
- **Glines Canyon turbine runner vanes to be removed for operation as a low-level outlet using wicket gates (with station service power) for reservoir drawdown**
- Hydraulic fluids and batteries to be removed
- Electrical systems to be de-energized
- Overhead cranes to be made non-operational

Large logs must be passed through both sites

Submittal Requirements

Key Submittals – Division 1

- **Construction Schedule** (cost and resource-loaded)
- Accident Prevention Plan
- **Waste Management Plan**
- Quality Control Plan
- Storm Water Pollution Prevention Plan (SWPPP)
- Road Improvement Plan
- Material Safety Data Sheets
- Other submittals as required by specifications

Submittal Requirements

Key Action Submittals:

- **Elwha Demolition Plans**
- **Glines Canyon Demolition Plans**
- Transmission Line Removal Plans
- Hazard Abatement Plans
- **Diversion and Care Plans**
- Fish Recovery Plans
- Conceptual Blasting Plan
- Other submittals as required by specifications

Waste Management and Disposal

- Waste disposal in landfills to be minimized
(50% recycling per NPS environmental goals)
- Elwha Dam requires much more excavation from forebay than required for embankments on site; but concrete rubble may be buried on site
- Glines Canyon Dam waste materials must be removed from the Park; no on-site burial allowed
- All mechanical, electrical, misc metalwork, timber, and steel to be removed for disposal per specs

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Environmental Site Assessments

- **Federal Occupational Health, 2008**
 - Elwha Dam
 - Glines Canyon Dam
- **Ecology and Environment, Inc, 1999**
 - Elwha Dam
 - Glines Canyon Dam
 - Power transmission corridor
- **Limited subsurface investigations for soil contaminants (heavy metals and oil)**
- **Powerplants certified “PCB-free” by owner**

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Removal and Disposal of Haz/Mat

- Lead, asbestos, some PCBs, and oil found at sites
- Specifications include removal and disposal of:
 - Contaminated soil
 - Asbestos containing materials
 - Coatings containing hazardous materials
 - Equipment with coatings containing haz/mat
 - Polychlorinated biphenyls (PCBs)
- Contract Line Items include costs for characterizing, transporting, and disposal of hazardous materials, and for removal and backfill of contaminated soil

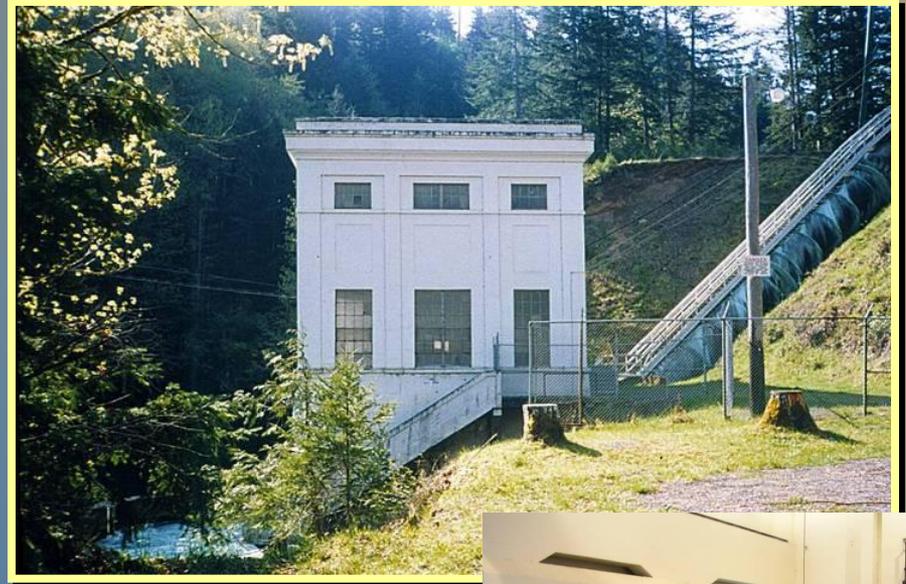
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Bid Options – Glines Canyon Dam

Option A – Modification of Powerhouse and Penstock

Option B – Removal of Powerhouse and Penstock

Powerhouse and penstock cheaper to remove than to modify!



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Early Contract Modifications

- **Glines Canyon Dam – Dam demolition without low-level power penstock releases**
 - Cheaper to notch dam at higher levels than to modify turbine runner for low-level releases
 - Barge-mounted excavator working in wet anyway
 - Powerhouse and penstock could be removed early
- **Elwha Dam – Payment for all earthwork under Lump Sum rather than by volume**
 - Avoids volume computations for payment and problem with eroded materials, for same bid price

Reservoir Operations

- **Spillway gates at both sites secured by Govt in fully raised position prior to start of work:**
 - Elwha Dam, spillway crest EI 179.2
 - Glines Canyon Dam, spillway crest EI 570.3
- **Reservoir levels for start of work would be dependent upon hydrologic conditions:**
 - Lake Aldwell expected around EI 182
 - Lake Mills expected around EI 575

Elwha Dam Removal

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Use of Premises and Site Access

- Elwha Dam accessible by steep and narrow paved Lower Dam Road from Hwy 112 to right abutment
- Some improvements necessary for construction hauling equipment (within 60 foot ROW)
- Access to left abutment via bridge on dam crest (bridge approach required repairs if used)
- Three Contractor Use Areas defined in specs – one on each abutment, and one at d/s pole yard (~1.5 acre);
- Additional land was obtained by Contractor from County at Hwy 112 for office trailers and stockpiles

Contract Line Items – Elwha Dam

Contract Line Item Title	Quantity	Unit of Measure
Demolition of gravity dam structures		Lump sum
Demolition of powerhouse		Lump sum
Demolition of misc. structures		Lump sum
Site excavation	200,000	Cubic yards
Embankment for left abutment	51,000	Cubic yards
Rockfill for left abutment	4,000	Cubic yards
Placing topsoil	10,000	Square yards
Seeding	2	Acres
Roadway guardrail	120	Lineal feet

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Plant Shutdown June 1, 2011



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Drawdown Capacity



- Nine 13.75-foot-wide by 19-foot-high spillway gates available (123.75' crest length)
- Penstocks ineffective – intakes too high
- Original diversion outlets plugged, buried
- **Diversion channels**

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Streamflow Diversion

Reservoir operations below El 182 dependent on Contractor's diversion and care plans

- **El 182 to El 142:**
 - 3-foot increments at average 1.5 feet per day
 - 14 day hold periods at El 167, El 152, and El 142
- **El 142 to El 112: (dam removal to El 100)**
 - Max average drawdown rate of 2 feet per day
 - 14 day hold periods at El 127 and El 112

Visual monitoring of forebay landslide first 24 hours of each drawdown increment for evidence of instability

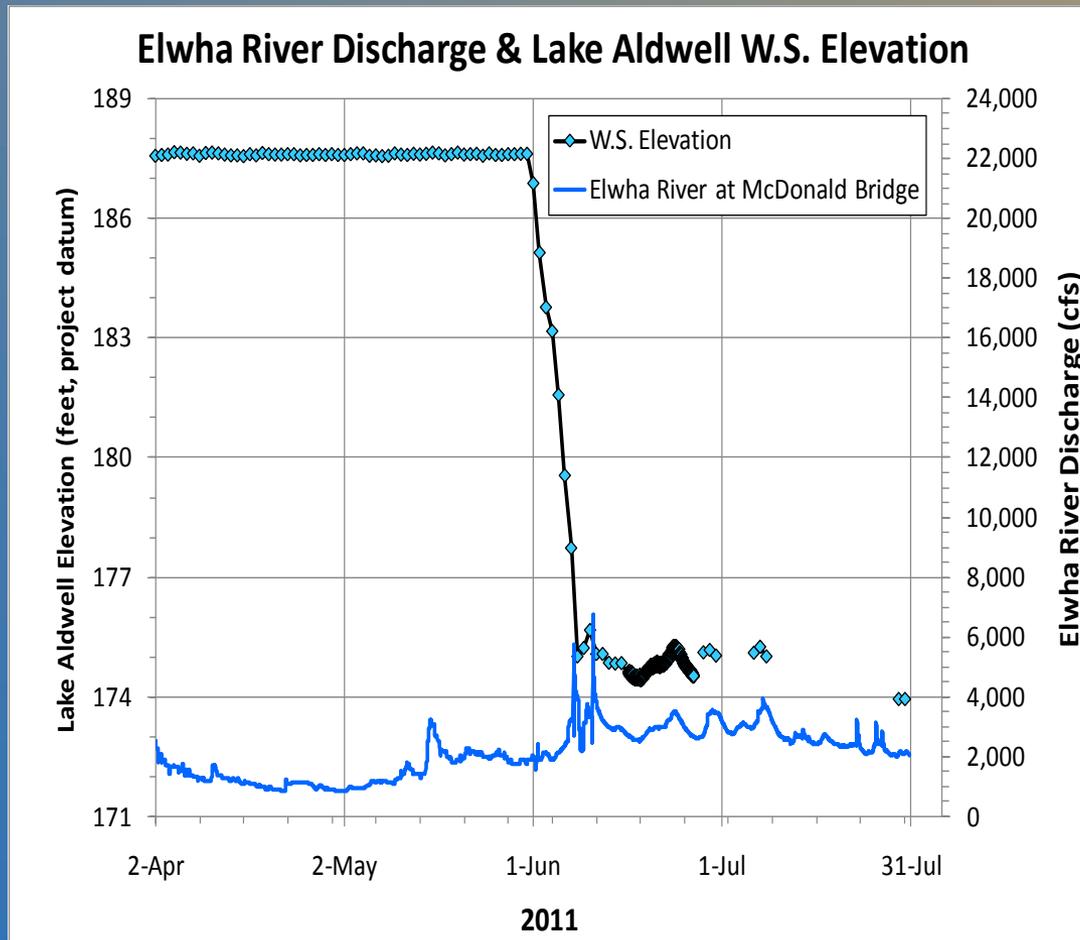
Contractor to furnish RWS monitoring equipment and data

Lake Aldwell Initial Drawdown



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Lake Aldwell Drawdown Rate



Elwha Dam Unwatered Forebay



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Groundbreaking Ceremony



September 17, 2011



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Initial Demolition – Right Spillway



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Post-Tensioned Tendons

Installed in 1980
and 1986

43 installations,
about 60' lengths

1/2-inch-dia, 270 ksi
strands (7 or 12 ea)

Fully grouted with
neat cement

No signs of
corrosion in anchor
heads and tendons



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First Diversion to Right Side



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Bridge Access to Left Side



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Aerial View of Diversion



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Diversion to Left Side



Flood Peak – Nov 23, 2011

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Elwha Powerhouse Demolition



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Elwha Surge Tank Toppled

Before



After



Diversion Back to Right Side



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Final Diversion to Left Side



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Final Dam Excavation to El 100



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Diversion in March 2012



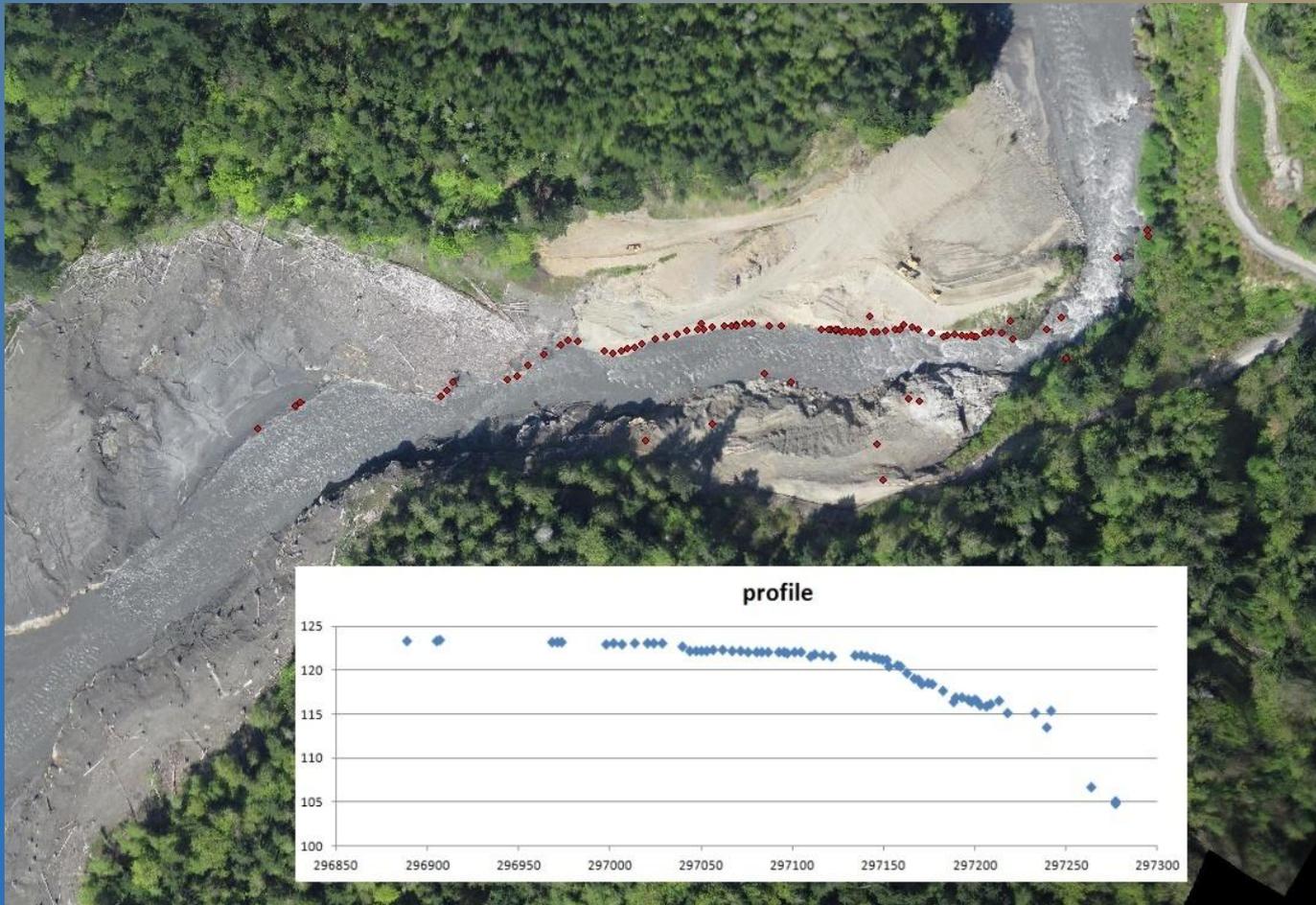
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Rock Drop Structure, Right Side



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Elwha Channel Plan, Profile



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Elwha Channel Comparisons



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Current View – Elwha Site



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Current View – Reservoir Area

Sep 23 12 15:45:25



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Glines Canyon Dam Removal

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Use of Premises and Site Access

- Glines Canyon Dam accessible by paved Olympic Hot Springs Road from Hwy 101 to left abutment, and by unpaved Whiskey Trail Road to right abutment
- Powerhouse accessible by unpaved road
- Some improvements necessary for construction hauling equipment on all access roads – plans to be approved in advance by Olympic National Park
- All trees to be preserved unless otherwise approved
- Three Contractor Use Areas defined in specs – one on each abutment and one near powerhouse (~2 acres)

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Contract Line Items – Glines Canyon

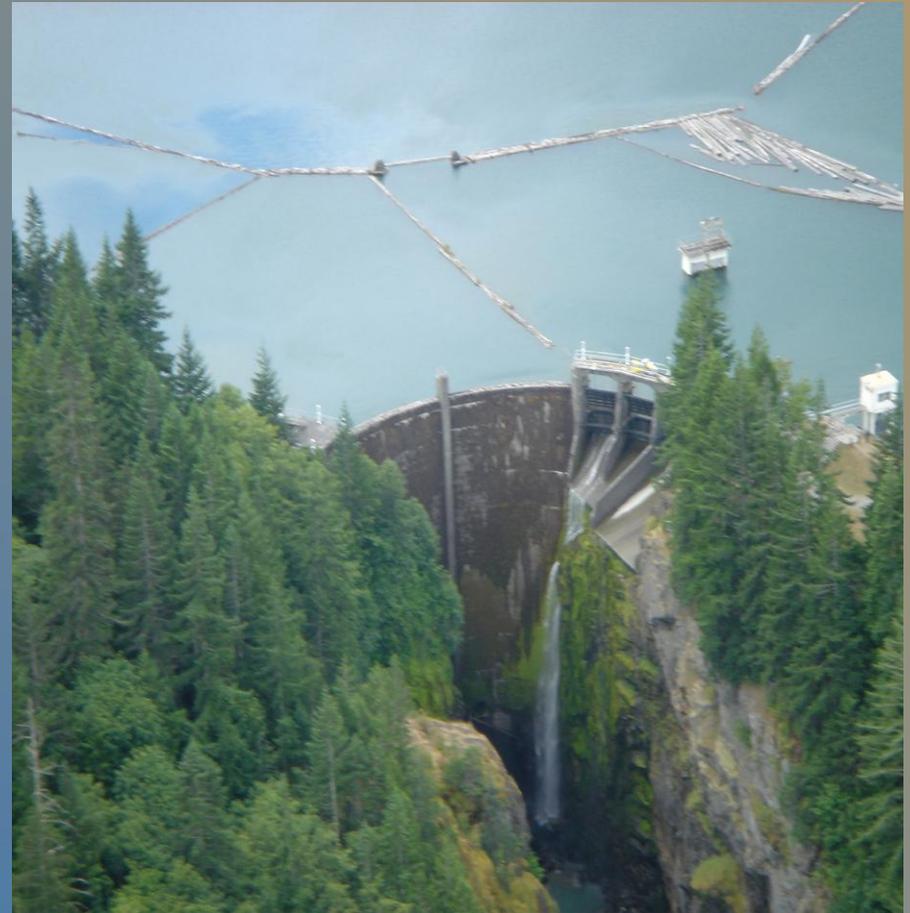
Contract Line Item Title	Quantity	Unit of Measure
Demolition of arch dam structures		Lump sum
Demolition of surge tank		Lump sum
Demolition of misc. structures		Lump sum
Visitor improvements		Lump sum
Site excavation	3,000	Cubic yards
Embankments	900	Cubic yards



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Drawdown Capacity

- Five 20-foot-wide by 20-foot-high spillway gates available (100' crest length)
- Mid-level penstock would require turbine runner modification (no bypass provided)
- Low-level sluiceway assumed not available
- **Diversion notches**



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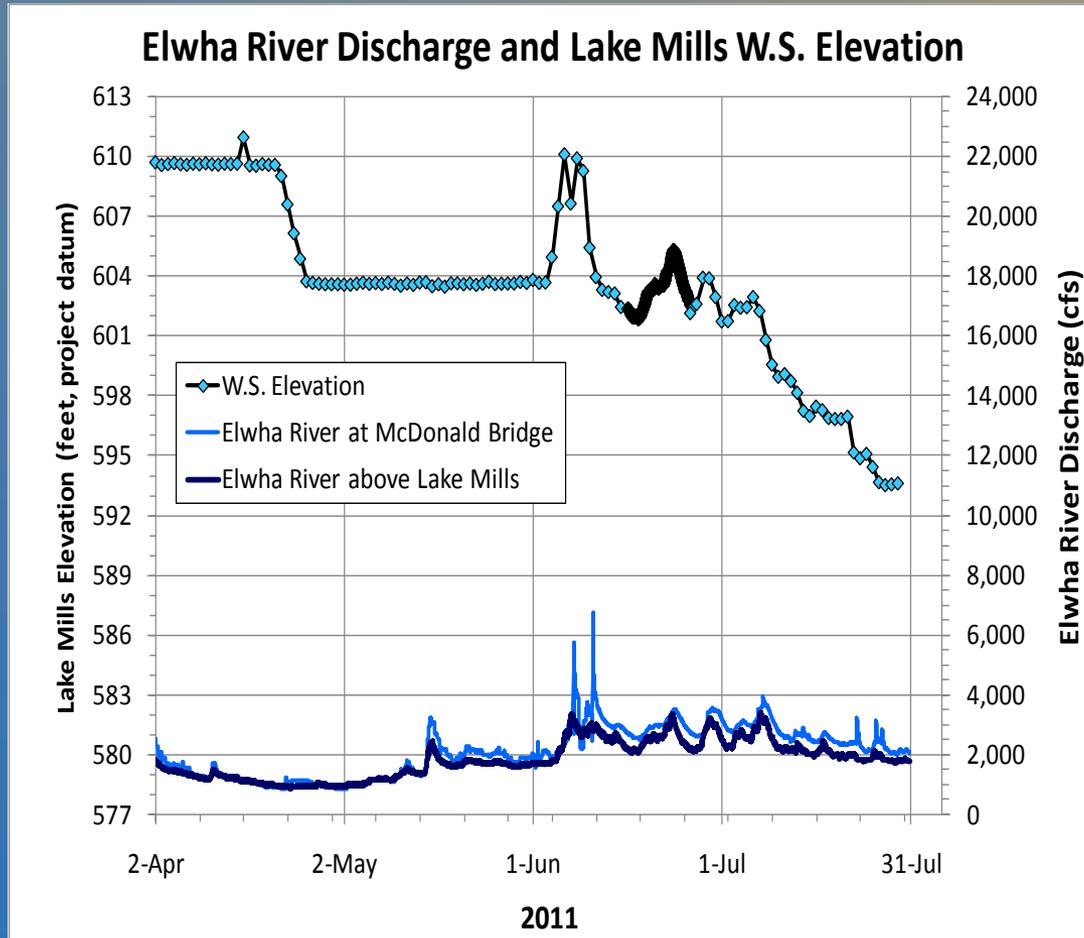
Streamflow Diversion

Reservoir operations below El 575 dependent on Contractor's diversion and care plans

- **El 575 to El 470:**
 - 3-foot increments at average 1.5 feet per day
 - 14 day hold periods at El 575, El 560, El 545, El 530, El 515, El 500, El 485, and El 470 (15-foot intervals)
- **El 470 to El 410: (dam removal to El 400)**
 - 5- to 10-foot increments at average 2 feet per day
 - 7 day hold periods at El 450 and El 430 (20-foot intervals)

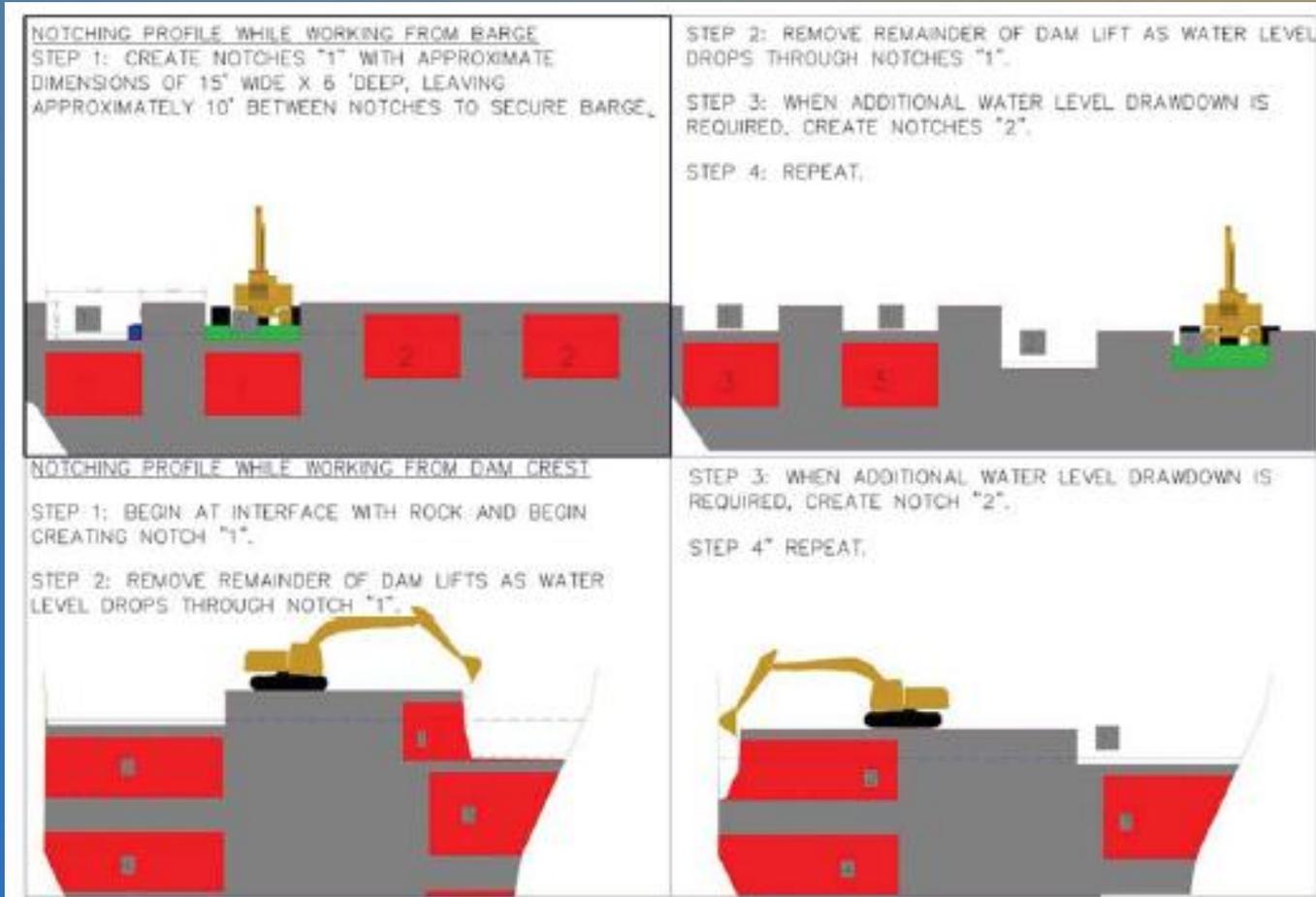
Contractor to furnish RWS monitoring equipment and data

Lake Mills Initial Drawdown Rate



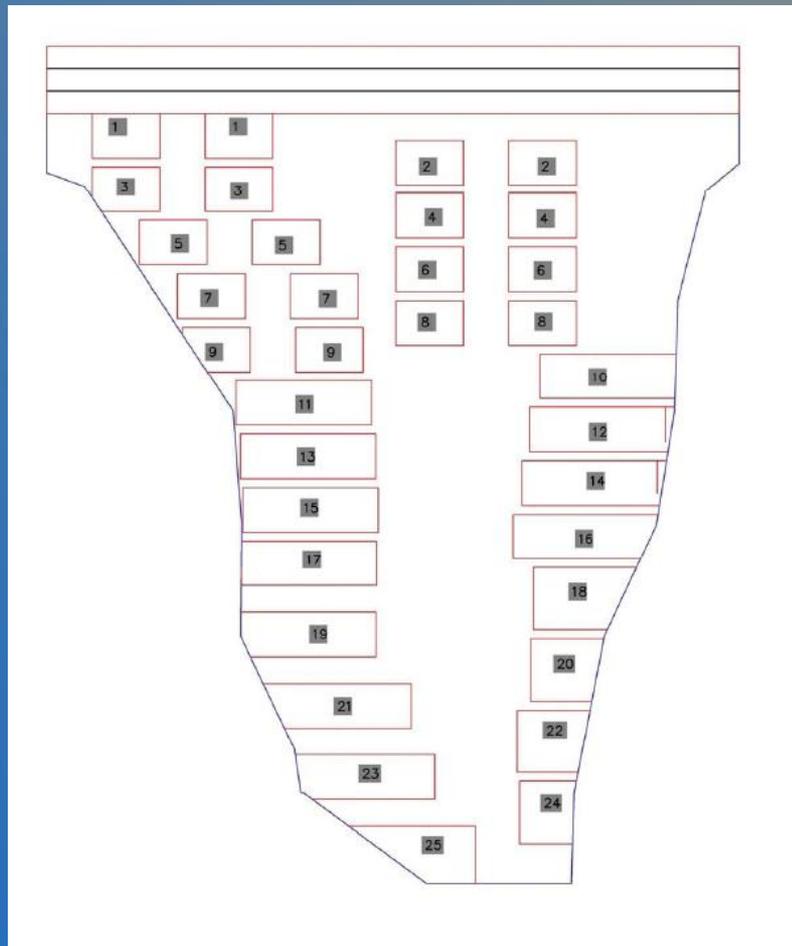
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Glines Canyon Dam Demolition



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Glines Canyon Notching Sequence



- Nine lifts proposed from barge
- Sixteen lifts proposed from dam crest
- Maximum depth of each notch limited to 15 feet (per spec)

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Demolition Began Sept 15, 2011



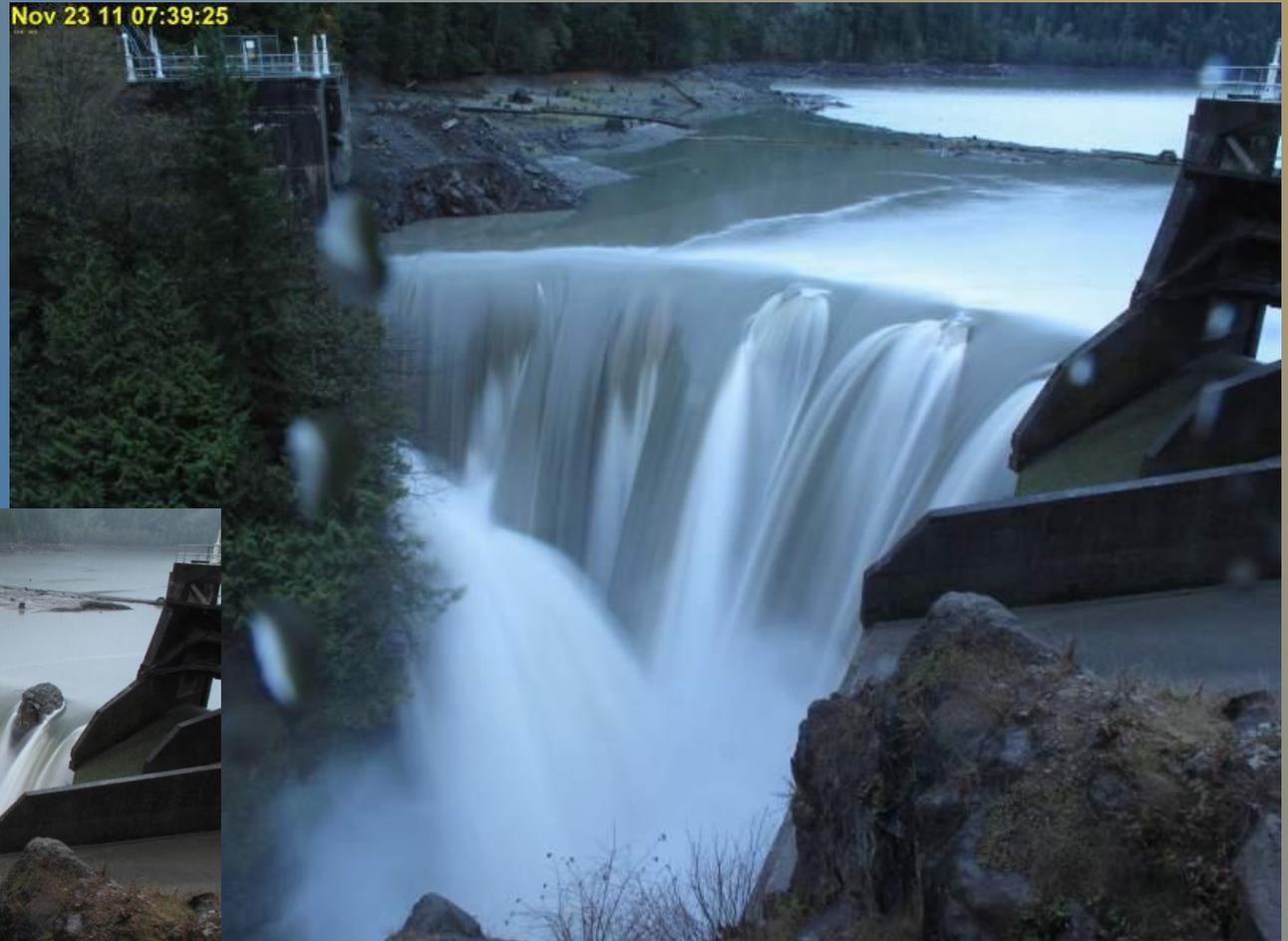
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Initial Notch – Oct 4, 2011



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Flood Peak – Nov 23, 2011



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Crane Modification

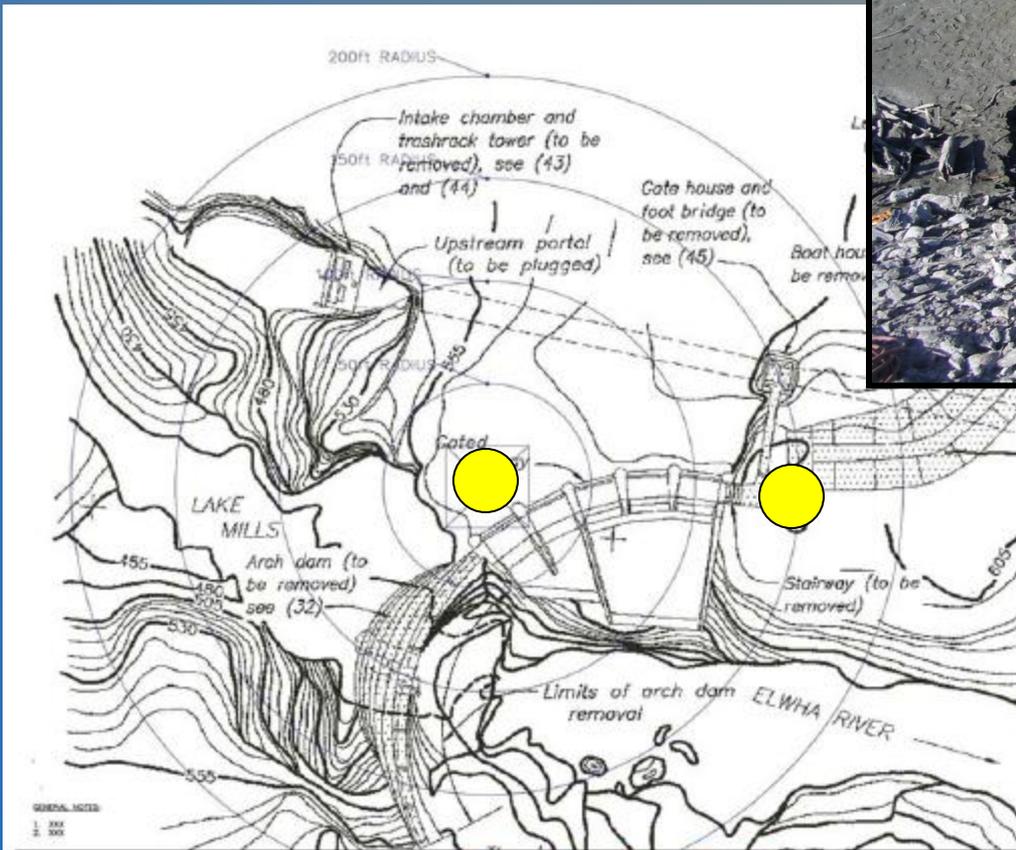


Figure 2 – Crane Pad 2

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Ringer Crane Mobilization



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First Notch Blast – July 2, 2012



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Drilling for Blasting – July 12



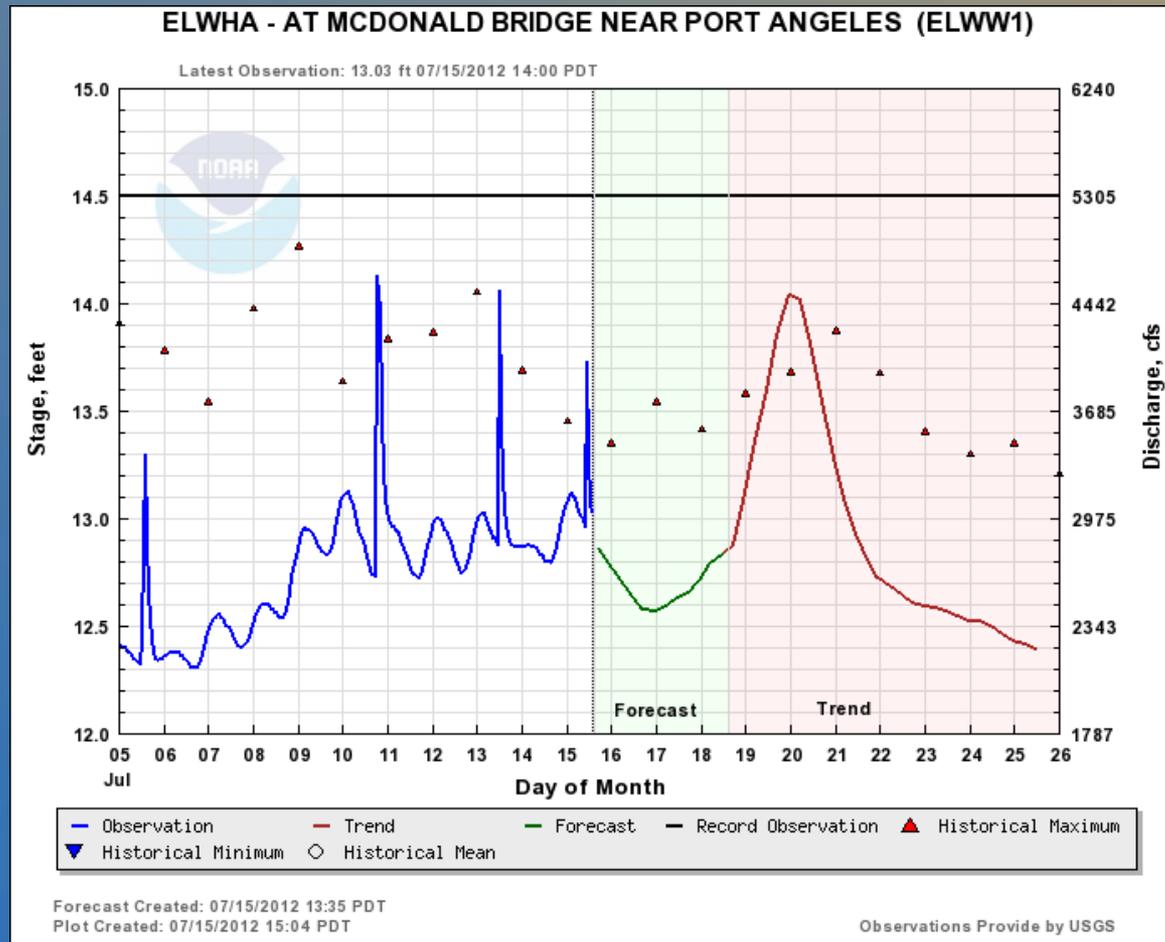
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Lift Lines in Concrete Arch



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Notch Blast Peak Flows - July



Notch Blasting at Lower Levels

(Debris Confinement)



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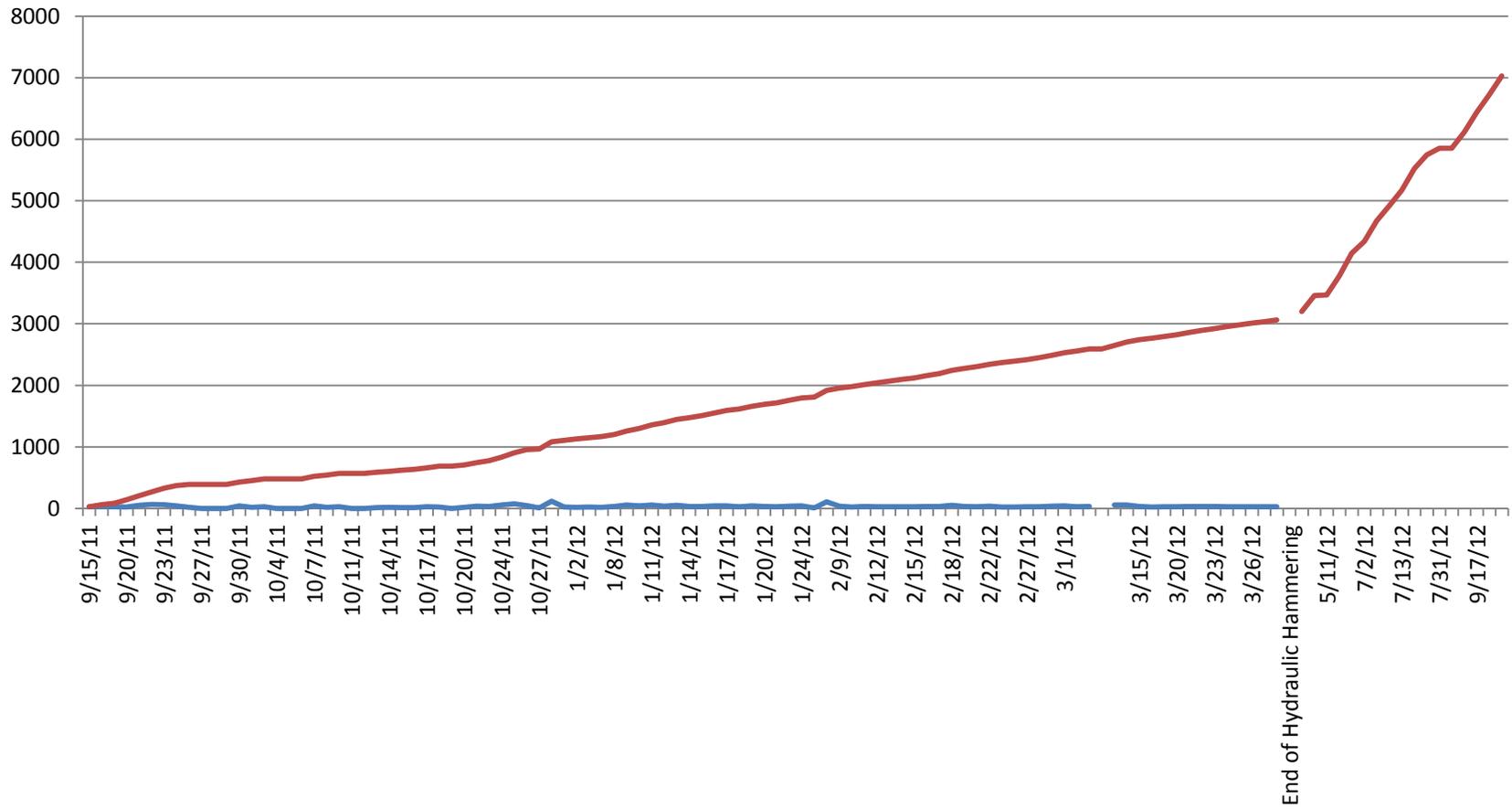
Mechanical Debris Removal



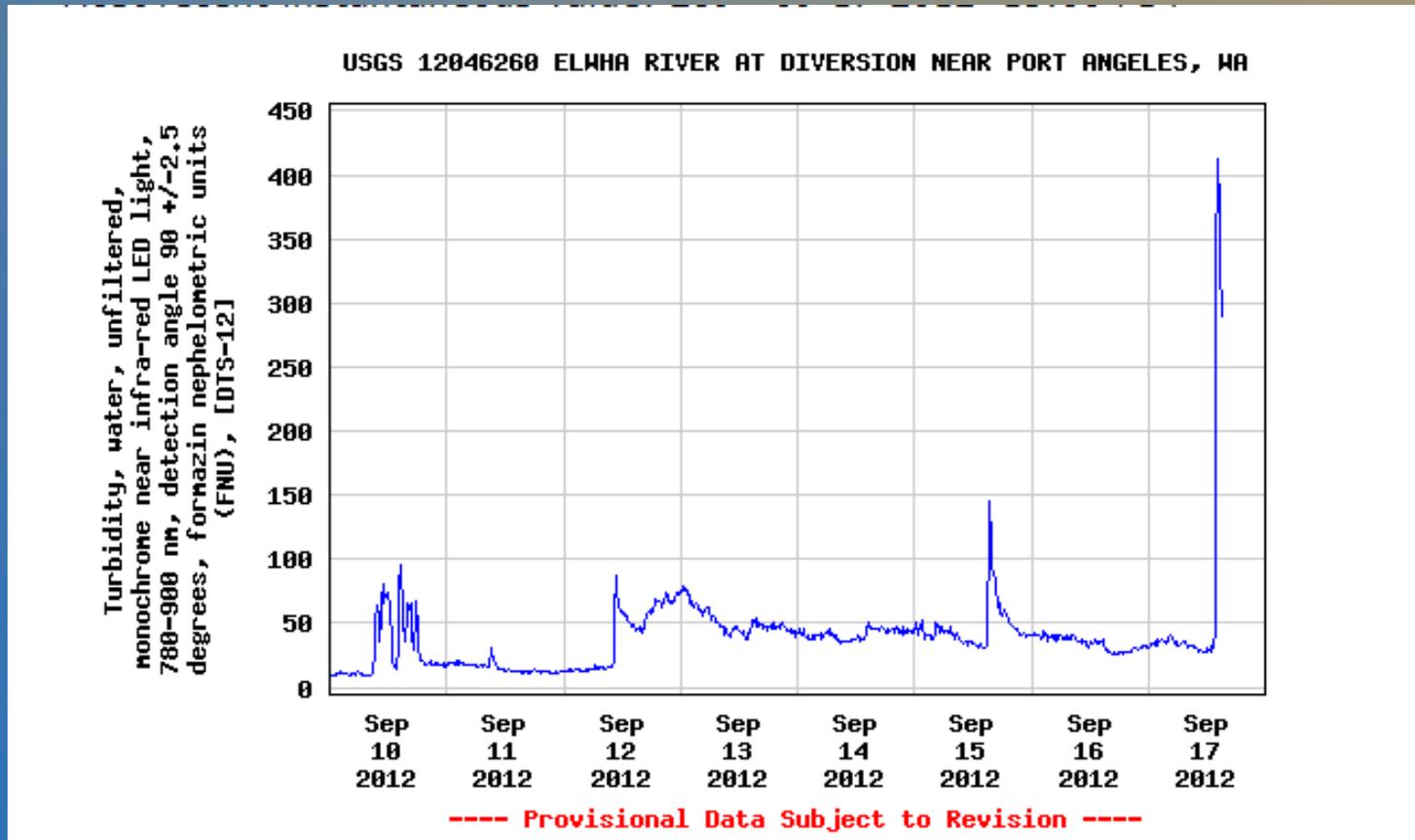
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Glines Production Rates

(15,000 yd3 total volume in dam)



Turbidity Readings in River



Powerhouse Demolition



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Toppling Glines Surge Tank



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Glines Transformer Yard Site

Contaminated soil
(mineral oil)
removed to 4,000
mg/kg, then capped
with 15 feet of soil
(required 460 kg/mg
without soil cover)



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Intake Tower and Gate Shaft



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Visitor Improvements



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Right Abutment Parking Area

Before



After

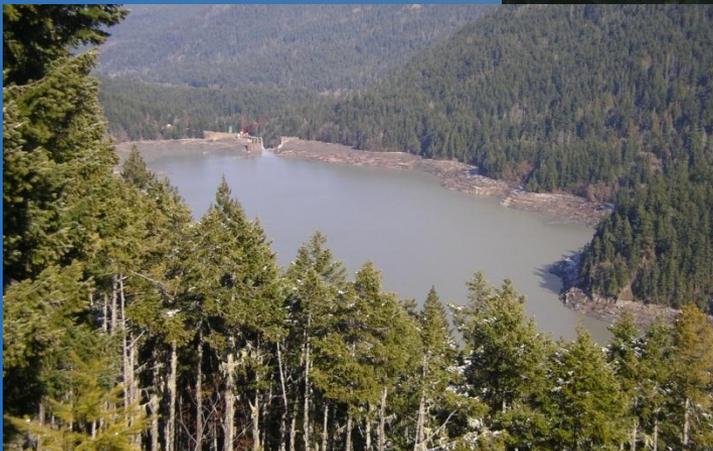
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River Channel Obstructions



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Dwindling Lake Mills



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Transmission Line Removal

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69 kV Transmission Line #3

Elwha Powerhouse to Glines Canyon Transformer Yard:

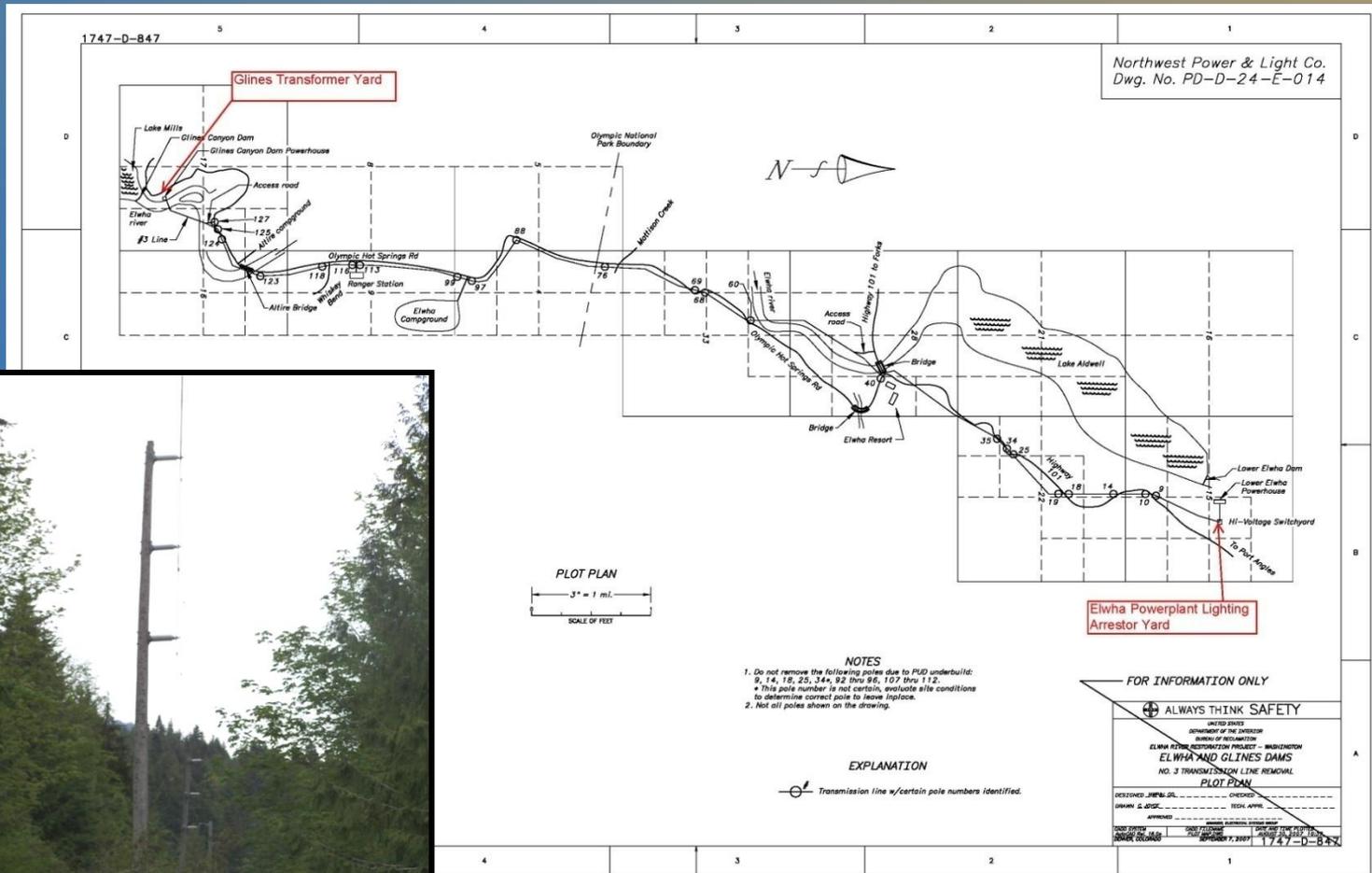
- Total length approximately 7.25 miles
- Poles numbered 1-134 (poles 54, 55, 113, and 134 missing)
 - 19 poles underhung w/ PUD domestic supply lines
 - Poles 92-96 underhung with active Qwest communications line
- Wood Poles – various lengths and diameters
- Insulators – multi-variations of ceramic and aluminum
- Conductor –1/0 copper



Must de-energize existing PUD lines first!

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69 kV Transmission Line #3



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69 kV Transmission Line #3

Line Access and Crossings:

- Majority of line accessible from paved roads - Hwy 101 and Olympic Hot Springs Rd
- Primarily on Hwy 101 right-of-way, Olympic Hot Springs Rd right-of-way, or on federal lands
- Crosses less than 12 private parcels on dedicated O&M easements
- Crosses Hwy 101 seven times, Olympic Hot Springs Rd three times
- Crosses the Elwha River at five points:
 - Hwy 101 (Pole 44)
 - McDonald Gage Station (Pole 60)
 - Altair Bridge (Pole 123)
 - Bottom of Whiskey Bend (Pole 129)
 - Top of Whiskey Bend (Pole 133) to Glines Transformer Yard

Removed by subcontractor within 10 weeks, Fall 2011

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Project Costs and Schedule

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Elwha Project – Overall Costs

- Project Acquisition - \$29.9 million
 - **Dam Removals – \$26.9 million (award)**
 - Elwha Dam Removal
 - Glines Canyon Dam Removal
 - Transmission Line Removal
 - Water Quality Protection -
 - Port Angeles Water Treatment Plant, \$27.6 million (complete)
 - Elwha Water Treatment Plant, \$79 million (complete)
 - Flood Protection (Levees) - \$23.3 million
 - Tribal Fish Hatchery - \$16.4 million (award)
 - Ecosystem Restoration - \$15.9 million
 - Numerous related contracts and non-contract costs
- TOTAL PROJECT BUDGET - \$325 million**

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Elwha Project – Overall Schedule

Water Quality Protection:

- Port Angeles Treatment Plant Oct 2007 – Oct 2009
- Industrial Treatment Plant Dec 2007 – Nov 2010

Tribal Fish Hatchery: Feb 2010 – Mar 2011

Flood Control Levees: Jun 2010 – Mar 2011

Dam Removals:

- Decommission Powerplants Mar 2011 – Sep 2011
- **Dam Removal contract Mar 2011 – Sep 2014**
 - Elwha Dam Removal substantially complete by Sep 2012
 - Glines Canyon Dam Removal complete by July 2013?

Salmon above Elwha Dam Site!

(One year after dam demolition began)



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For More Information:

Web Cameras:

<http://www.video-monitoring.com/construction/olympic/js.htm>

Project Web Site:

<http://www.nps.gov/olym/naturescience/elwha-ecosystem-restoration.htm>

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