

_README

This directory contains the electronic files for the document, "Water Quality Analyses and Mitigation Alternatives" (Elwha Technical Series PN-95-8) March 1997.

The drawings for appendices a and l are located in the drawings subdirectory to this directory. Drawing 1440-D-163, which shows an earlier concept for the infiltration gallery is included for information but was not used in the water quality report (95-8). The following items were not available electronically:

1. figure 1, appendix i
2. some of the cost estimate data sheets in appendix m
3. appendix n scatter graphs
4. appendix o graphs
5. appendix q material safety sheets
6. appendix s letter from Filtration Technology

ELWHA RIVER ECOSYSTEM AND
FISHERIES RESTORATION PROJECT
WASHINGTON

ELWHA TECHNICAL SERIES
PN-95-8

WATER QUALITY ANALYSIS
AND MITIGATION MEASURES

U.S. DEPARTMENT OF THE
BUREAU OF RECLAMATION
PACIFIC NORTHWEST REGION
BOISE, IDAHO



INTERIOR

MARCH 1997

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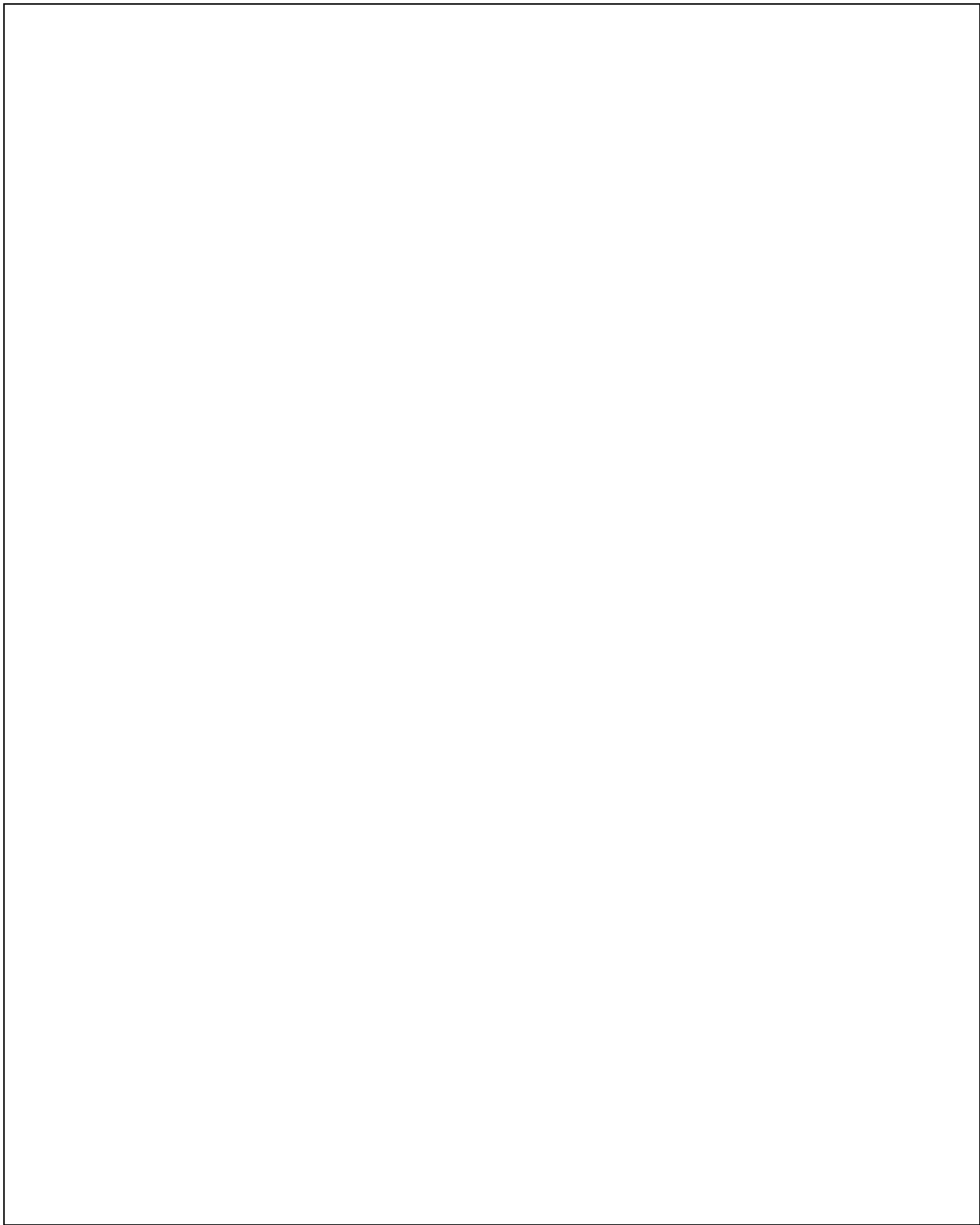


Figure I. General Location Map — Elwha River (*National Park Service, April 1996*)

*

General Location

Existing Water Related Facilities

Abbreviation and Acronyms

Act	Elwha River Ecosystem and Fisheries Restoration Act (Public Law 102-495)
cfs	Cubic feet per second
Corps	U.S. Army Corps of Engineers
Daishowa	Daishowa America Company, Limited
DCWA	Dry Creek Water Association
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPHA	Elwha Place Homeowners Association
FERC	Federal Energy Regulatory Commission
gpm	Gallons per minute
JTU	Jackson turbidity units
MCL	Maximum contaminant level (allowed)
mg/L	Milligrams per liter
mgd	Million gallons per day
µg/L	micrograms per liter
MIOX	Mixed oxidant
NTU	Nephelometric turbidity units
OM&P	Operation, maintenance, and power
pH	Acid/base indicator (negative logarithm of the hydrogen ion concentration)
ppm	Parts per million (equivalent to mg/L)
Ranney	Ranney Method Western Corporation
Reclamation	Bureau of Reclamation
RM	River mile
TDS	Total dissolved solids
THM	Trihalomethane
TSS	Total suspended solids
Tribe	Lower Elwha Klallam Tribe
USGS	United States Geological Survey
WDOE	Washington Department of Ecology
WDFW	Washington Department of Fish and Wildlife
WDH	Washington State Department of Health

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SUMMARY

This water quality appendix is one of a series of supporting documents prepared as part of efforts to restore the ecosystem and fisheries of the Elwha River, located on the Olympic Peninsula in northwest Washington State. In the early 1900's, two dams were constructed on the river, blocking salmon and steelhead access to about 93 percent of the spawning and rearing habitat. Public Law 102-495, the Elwha River Ecosystem and Fisheries Restoration Act, passed in 1992, directs the Secretary of the Interior to study ways to restore the anadromous fisheries and the ecosystem of the Elwha River and to implement a plan to accomplish that. The Act states that the Secretary is to take actions as necessary to implement:

“... protection of the existing quality and availability of water from the Elwha River for municipal and industrial uses from possible adverse impacts of dam removal.”

In 1995, the National Park Service, the lead Federal agency in this restoration effort, published a programmatic Environmental Impact Statement on alternatives for restoration of the fishery. Removal of the two existing dams was selected as the preferred alternative and led to preparation of an implementation Environmental Impact Statement which evaluated two alternatives for sediment management. The proposed alternative is the River Erosion Alternative which would allow sediment accumulated in the reservoir areas of the two dams to be eroded and move downstream through natural fluvial processes. An alternative is the Dredge and Slurry alternative which would include dredging and transporting a portion of the accumulated fine sediment by pipeline to the Strait of Juan De Fuca.

At present, water quality of the Elwha River downstream from the two dams is generally excellent except for water temperature problems. However, there are intermittent periods of high flow, usually with durations of less than 3 days, when large amounts of sediment from the upper reaches are transported downstream. Although larger sized materials (bedload) and much of the finer materials are trapped in the two reservoirs, a portion of the fine suspended solids are transported downstream past the dams to the Strait of Juan De Fuca. Water in the two reservoirs tends to absorb heat in the summer months, resulting in downstream water temperatures that are higher than would occur in the absence of the two reservoirs.

WATER QUALITY CHANGES

Removal of the two dams would allow sediment loads from upstream to move downstream to the ocean. In the short-term (a period of up to 5 years during and after removal of the dams), the largest changes in water quality would be associated directly with dam removal activities. The amounts of fine suspended material in the water downstream would be highly variable, depending on flow levels and dam removal activities. Fine sediment concentrations would generally be much higher than currently experienced, and there would be intermittent periods of 1 to 3 days when large amounts of sediment would be eroded from the reservoir areas and carried downstream. The short-term period, also referred to as the construction (dam removal) period and project operation period, would last until all easily eroded sediment in the reservoir areas is carried downstream. Water quality parameters that could be adversely affected by a significant amount include suspended and dissolved solids, including total organic carbon; turbidity; dissolved oxygen content; and temperature.

Over the long term, natural processes would be restored and sediments would move downstream to the lower reaches, particularly during high flow events. The movement of all materials to the lower reaches of the river would be, on average, greater than now occurs. During low flows, the movement of materials would be no greater than now occurs. During high flow events, the movement would be greater than at present, but peak concentrations of fine suspended sediment would be much less than during the short-term period. Water quality parameters that over the long term could be adversely affected by a significant amount include suspended and dissolved solids, including total organic carbon and turbidity. Dissolved oxygen content would not be affected and water temperatures would improve. Tables A and B summarize anticipated surface water quality changes.

Removing the two dams would affect ground-water quantity and quality in some areas. Ground-water levels now supported by the two reservoirs will drop as the reservoirs are emptied. The water in wells hydraulically connected to the river may at times become more turbid and have higher concentrations of iron and manganese as the quality of the surface water changes. The more direct the hydraulic connection, the greater the effect will be. Movement of bedload materials downstream will raise the streambed which will increase the elevation of the normal water surface, increase flood elevations, and raise ground-water levels. In the lower valley, the rising ground water will affect some septic systems.

Table A. Short Term Surface Water Quality

Factor	Units	Alternative		
		No Action	River Erosion	Dredge and Slurry
Time period	Years	—	1–5	1–5
Dissolved oxygen	percent saturation	95–110	90–100	95–105
TSS (fines only)	mg/L	1–1,500	[†] 15,000–51,000	[†] 3,900–13,000
TSS	tons/day	1.3–531	[†] 500–350,000	[†] 500–300,000
Turbidity	NTU	1–800	[†] 2,000–25,000	[†] 1,000–10,000
Total iron	µg/L	20–2,300	[†] 30,000–50,000	[†] 5,000–15,000
Total manganese	µg/L	4–210	[†] 500–10,000	[†] 50–1500
Peak temperature	°F	66	59–66	59–66
pH	none	6.7–10	5–9	6–9.5
Total organic carbon	mg/L	0–10	100–1,000	10–200

Note: These data were mostly developed from sediment modeling runs, interpolation of lakebed sediment chemical analysis, or existing STORET data (see appendix D) from the Elwha River or adjacent streams.

[†] Concentrations are expected to vary with dam removal rate and riverflow. These numbers represent maximum anticipated ranges under higher flow conditions as lakebed sediments erode.

Table B. Long Term Surface Water Quality (Natural Conditions Restored)

Factor	Units	Alternative		
		No Action	River erosion	Dredge and Slurry
Dissolved oxygen	percent saturation	95–110	95–110	95–110
TSS (fines only)	mg/L	[†] 15	[†] 69	[†] 69
Total suspended solids	tons/day	[†] 51.3	[†] 761.5	[†] 761.5
Turbidity	NTU	1–800	1–1,000	1–1,000
Total iron	µg/L	20–2,300	10–5,000	10–5,000
Total manganese	µg/L	4–210	10–700	10–700
Peak temperature	°F	66	59–63	59–63
pH	none	6.7–10	6.5–8.5	6.5–8.5
Total organic carbon	mg/L	0–10	10–200	10–200

Note: These data were mostly developed from sediment modeling runs, interpolation of lakebed sediment chemical analysis, or existing STORET data (see appendix D) from the Elwha River or adjacent streams.

[†] Average concentrations are used here to simplify the comparison

AFFECTED ENTITIES AND MITIGATION MEASURES

Water quality changes will affect all surface-water users and many ground-water users. Some individual wells will go dry and other individual wells may observe higher levels of turbidity and concentrations of iron and manganese. Domestic water supplies for the Dry Creek Water Association, the city of Port Angeles, and possibly the Elwha Place Home Owners Association will be adversely affected, mostly over the short term. The city of Port Angeles industrial water supply (surface water) — utilized by two pulp mills, Daishowa America Co. Ltd., Inc. and Rayonier, Inc., and the Washington Department of Fish and Game (WDFW) fish rearing channel — will be adversely affected over both the short and long terms. Water supplies for the Lower Elwha Klallam Tribe's fish hatchery will be affected over both the short and long terms. In the short term, the quality of the surface water supply will be unsuitable for operation of the WDFW fish rearing channel. Under the Elwha Fish Restoration Plan, this facility will be closed and rearing of Elwha stocks will be carried out in other facilities during the period of unacceptable water quality.

Subsequent to the preparation of this report, Rayonier's Port Angeles mill was closed. Efforts are currently underway to attract industry to Port Angeles to replace the jobs lost with the mill closing. Future Rayonier water measurement and monitoring activities anticipated in this report will likely be accomplished instead by the city of Port Angeles, Daishowa America, or any entities which replace Rayonier as an industrial water user. Industrial water treatment measures proposed in this report assume that local entities will be successful in recruiting new industry to the area and that this industry will utilize the same quantities of water historically used by Rayonier.

At this stage of planning, general concepts have been identified, measures selected, and costs estimated. Evaluations to date are sufficient to provide a cost ceiling, but specific measures will be reviewed and refined during the design and value engineering phases. This process, along with negotiations with affected entities, will likely result in some changes. In addition, some baseline data are still being collected and the results could affect the design of mitigation measures. Table C summarizes the entities that would be affected by water quality changes due to removal of the two dams and the measures identified for implementation to mitigate the adverse effects. A water quality monitoring program during dam removal will provide information to help make decisions on the rate of removal.

Table C. Mitigation Measures

Mitigation Measure	Impacts Mitigated	[†]Alternative
Water quality monitoring program	Changes in water quality	RE, D&S
Individual wells		
Supply temporary in-line sediment filter and bottled water to residences with wells adjacent to river upstream of Highway 101 bridge	Increased turbidity; possible increase of iron and manganese in well water	RE
Drill new wells or deepen existing wells in Indian Creek valley	Lowered ground-water level	RE, D&S
Contingency fund for unidentified wells	Impacts to unidentified wells	RE, D&S
Dry Creek Water Association		
Construct new Ranney collector [‡] , pumping plant, and pipeline	Increased turbidity; possible increase of iron and manganese in well water	RE, D&S
Install temporary filter system [‡]	Possible increase of iron and manganese	RE, D&S
Install MIOX or comparable disinfectant system	Replacement of system on current wells	RE, D&S
City of Port Angeles domestic supply		
Construct new Ranney collector [‡]	Possible decreased yield from existing Ranney collector	RE, D&S
Install temporary filter system [‡]	Possible increase of iron and manganese	RE
City of Port Angeles industrial supply		
Construct infiltration gallery and temporary pretreatment facilities.	Increased turbidity; possible increase of iron and manganese	RE, D&S
Elwha Place Homeowners Association		
Construct temporary water filter system	Increased turbidity	RE
Lower Elwha Klallam Tribe		
Modify about 10 conventional septic systems to mound systems with lift stations	Potential contamination of ground water as level rises	RE, D&S
Tribal fish hatchery		
Upgrade existing infiltration gallery, restore existing wells, construct new infiltration gallery, drill two wells, add aeration facilities	Increased turbidity of water supply	RE, D&S

[†] RE = River Erosion; D&S = Dredge and Slurry

[‡] Ranney collector and temporary filter system shared by DCWA and the city of Port Angeles

CONSTRUCTION COSTS

Construction costs are based on an April 1995 price level and include contingencies. The total construction cost includes indirect costs associated with design of facilities and construction management. The total construction cost of the measures selected to mitigate water quality changes is estimated at \$31,015,000 for the River Erosion alternative and \$27,895,000 for the Dredge and Slurry alternative.

Although the cost of the water quality monitoring program is shown in the table, the cost is not included in the total construction cost for water quality mitigation. The water quality monitoring program will provide information to adjust the rate of dam removal. Construction costs are summarized in Table D.

OPERATION, MAINTENANCE, AND POWER COSTS

Operation, maintenance, and power costs include all costs of operating project facilities during the short term (5-year period of dam removal and major erosion of sediments from the reservoir areas). Although some facilities would remain in place and continue to be operated beyond the short term, operation after the short term is not considered part of mitigation for dam removal. Because of the short operating period, replacement was not considered and no replacement costs are included. Power costs are based on current rates to users in the Port Angeles area.

The total cost for operation, maintenance, and power during the project operation period is estimated at \$3,400,000 for the River Erosion alternative and \$1,204,000 for the Dredge and Slurry alternative. Table E summarizes these costs.

Table D. Summary of Construction Costs[†]

Item	Alternative	
	River Erosion	Dredge and Slurry
Water quality monitoring program (including USGS) [‡]	\$1,000,000	\$650,000
Individuals Wells		
Temporary in-line filtration and bottled water	(see OM&P costs)	\$0
Install new wells	\$36,000	\$36,000
Contingency fund for all private wells	\$150,000	\$150,000
Dry Creek Water Association (280 gpm)		
Connect to new Ranney collector	(see Port Angeles municipal)	\$200,000
Filter plant	(see Port Angeles municipal)	
MIOX disinfection system	\$30,000	\$30,000
Port Angeles industrial supply		
Infiltration gallery & diversion modifications	\$10,768,000	\$10,768,000
Open channel pre-industrial treatment	\$5,732,000	\$5,732,000
Port Angeles municipal supply		
New Ranney well (also serves DCWA)	\$5,204,000	\$5,204,000
Filtration plant (also serves DCWA)	\$2,730,000	\$0
Elwha Place Homeowners Association (180 gpm)		
Temporary in-line treatment system (rental/yr)	\$60,000	\$0
Lower Elwha Klallam Tribe		
Mound sewage treatment system	\$162,000	\$162,000
Water supply for fish hatchery.	\$2,138,000	\$1,938,000
Field cost	\$27,010,000	\$24,220,000
Engineering design	\$1,645,000	\$1,515,000
Construction management	\$2,360,000	\$2,160,000
Total construction cost	\$31,015,000	\$27,895,000

[†] April 1995 price level

[‡] Monitoring is considered to be a separate program and not included in the field cost for water quality mitigation.

Note: Further refinement of costs during the final project design be can expected to reduce costs as design constraints are narrowed and contingencies are reduced accordingly. Application of value engineering procedures have the potential to further reduce costs at the final design stage. It is unlikely that the costs would increase due to some unforeseen element.

Table E. Total Operation, Maintenance, and Power Costs

Item	Alternative	
	River Erosion	Dredge and Slurry
Individual wells		
In-line filters, and bottled water	\$37,000	\$0
Dry Creek Water Association		
MIOX disinfection	\$30,000	\$30,000
Other (see Port Angeles municipal supply)		
Port Angeles industrial supply		
Industrial water treatment	\$2,014,000	\$927,000
Infiltration gallery pumping plant	\$237,000	\$237,000
Port Angeles municipal supply		
Increment cost for new Ranney collector [†]	\$10,000	\$10,000
Port Angeles/DCWA filter plant and DCWA booster pump	\$995,000	\$0
Elwha Place Homeowners Association	\$77,000	\$0
Lower Elwha Klallam Tribe		
Mound sewage treatment systems	\$0	\$0
Fish hatchery	([‡])	([‡])
Total operation, maintenance, and power cost	\$3,400,000	\$1,204,000

[†] Incremental OM&P costs for the new Ranney collector are relatively minor since most costs relate to water flow.

[‡] Incremental OM&P costs for new fish facilities are covered by the existing hatchery budget funded by the Bureau of Indian Affairs.

CHAPTER I.

INTRODUCTION

BACKGROUND OF STUDY

In the early 1900's, two hydroelectric dams were constructed on the Elwha River on the Olympic Peninsula in Washington State. Construction of Elwha Dam at river mile (RM) 4.9 began in 1910. Construction of Glines Canyon Dam at RM 13.4 began in 1926. Both dams were constructed without fish passage facilities and block the passage of anadromous fish that historically used the river for spawning.

In 1968, the owner and operator of the dams (Crown Zellerbach Corporation) submitted an application to the Federal Energy Regulatory Commission (FERC) to license Elwha Dam and, in 1973, applied to relicense Glines Canyon Dam. FERC proceeded with licensing activities and processed the two licenses together. Licensing the two dams became controversial for a number of reasons including a challenge in the 1980's that FERC did not have jurisdiction to relicense Glines Canyon Dam because the dam is located within Olympic National Park.

Somewhat complicating the licensing procedures was purchase of the assets of Crown Zellerbach Corporation by James River Corporation. These assets included Elwha and Glines Canyon Dams and a pulp and paper mill located in the city of Port Angeles. The mill was subsequently sold to Daishowa America Co., Ltd. (Daishowa). At present, James River Corporation owns the two dams; however, Daishowa operates the two dams and powerplants and receives the power under contract with James River Corporation. The generation supplies a portion of the power needed to operate the Daishowa mill.

To resolve issues related to the two dams, Congress passed legislation in 1992 — Public Law 102–495, the Elwha River Ecosystem and Fisheries Restoration Act (Act). The Act directs the Secretary of the Interior to study ways to fully restore the Elwha River ecosystem and native anadromous fisheries, including purchase and removal of the dams, and to submit a report to Congress. The Secretary's report, *The Elwha Report* (Interior, et al., 1994), determined that removing the dams was feasible and necessary to fully restore the fisheries and ecosystem. Environmental impacts of a full range of alternatives were discussed in the *Elwha River Ecosystem Restoration — Final Environmental Impact Statement* (National Park Service, 1995). This document is referred to as the programmatic environmental impact statement (EIS).

A final implementation environmental impact statement (National Park Service, 1996b) was prepared to give the Secretary a range of options to implement removal of both dams. Those options focus on management of sediment that has accumulated in Lake Aldwell and Lake Mills (impounded by Elwha and Glines Canyon Dams, respectively). Three alternatives are presented in the implementation EIS — the No Action alternative (the dams remain in place), the proposed action (River Erosion alternative), and a second action option (Dredge and Slurry alternative). The No Action alternative forms the basis for identifying baseline conditions used to measure the impacts of the two action alternatives. With the River Erosion alternative, most trapped sediments would be eroded by the

river and carried to the Strait of Juan de Fuca. With the Dredge and Slurry alternative, most fine (silt- and clay-sized) sediments would be dredged from the lake beds and transported by slurry pipeline to the Strait; the remainder of the fine sediment and the coarser sediment would be eroded by the river and carried downstream.

Protection of existing quality and availability of water for municipal and industrial use is required by the Act.

REPORT FOCUS AND PROBLEM ADDRESSED

This technical report is a supporting document to the implementation EIS which addresses removal of Elwha and Glines Canyon Dams. Information about issues less central to this report is provided only to the extent necessary for reader understanding. Additional information can be found in the programmatic and implementation EIS's and associated technical supporting documents.

This document summarizes findings concerning the large amounts of sediment that have accumulated within the impoundments formed by Elwha and Glines Canyon Dams. When the dams are removed, a portion of the accumulated sediment will erode through natural processes and be transported downstream to the Strait of Juan de Fuca. The amount of material and the type of sediment that would be transported downstream differs with the two action alternatives. With the River Erosion alternative, sediments would be eroded by natural processes and carried downstream at varying concentrations as the natural flow of the river changes. With the Dredge and Slurry alternative, most finer sediments would be transported by slurry pipeline, leaving some fine and all coarser materials to be eroded by natural processes.

With either alternative, the concentration of fine suspended materials in the Elwha River will increase, at times, by several hundred or a thousand fold. There is some evidence that the concentration of some dissolved minerals may increase. Although increased concentrations of suspended and dissolved solids concentrations will not present health hazards, suspended solids will present mechanical and chemical problems for industrial uses, and possibly for municipal and domestic uses. Measures are needed to reduce the concentrations to acceptable levels for each use. In addition, the transport and deposition of sediment downstream through natural processes will raise the riverbed (returning it to the predam level) and change flooding patterns and the elevation of ground water near the river. This could affect water quality, especially with respect to the flooding of wells and septic systems in those areas where the ground water is already close to the surface.

Studies were conducted to identify baseline conditions including water quality, amount of water available and used, and water users in the study area. Measures to protect water quality and the availability of water to users were identified, evaluated, and selected for implementation.

STUDY AREA AND SETTING

The Elwha River basin is the major drainage on the northern side of the Olympic Mountains, draining an area of approximately 321 square miles, 83 percent of which is located within Olympic National Park. The U-shaped glaciated valley trends north to northwest from the central Olympic Mountains to Freshwater Bay in the Strait of Juan de Fuca.

The lower river basin consists of sloping bedrock formations which are locally covered by glacial and non-glacial deposits. The Elwha River has incised these deposits, with recently-deposited alluvium partially filling the valley floor. The alluvium within the Elwha River valley consists primarily of sand and gravel and serves as the water supply aquifer for most community water systems in the area. Water levels in the aquifer and the river are generally consistent with one another, indicating that the two systems are probably hydraulically connected. The alluvial aquifer is of excellent chemical quality according to monitoring conducted by community water supply systems in the valley.

The surface-water quality of the Elwha River is rated by the Washington Department of Ecology (WDOE) as “class AA” (of exceptional quality) but is also on the water quality limited list because of elevated water temperatures. Levels of major cations, anions, metals, pesticides, volatile organic compounds, and radionuclides are below the maximums allowed, and the pH is 6.7 to 10. Most of the watershed is within the national park and is in pristine condition. The two reservoirs capture much of the sediment from upstream erosion, but store heat during late summer and early fall and cause an increase in water temperatures in the middle and lower river reaches.

The study area for this report is generally the Elwha River basin downstream from the upper end of Lake Mills at RM 16.2. However, most effects of dam removal would be downstream from the border of the Olympic National Park at RM 9.7. Ground-water studies were generally limited to the area from RM 9.7 to the mouth of the river and from the city limits of Port Angeles on the east to the edge of the drainage basin on the west. This general area encompasses the following townships, ranges, and sections:

- T31N, R7W, Sections 26, 27, 32–36;
- T30N, R7W, Sections 1–5, 8–17, 21, 22, 27–29, 32, 33;
- T29N, R7W, Sections 4, 5, 8, 9, 16, 17.

All of the population and water uses that would be affected by removal of Elwha and Glines Canyon Dams are located in the lower part of the river basin. Most of the population is located within the city of Port Angeles and on the Lower Elwha Klallam Reservation.

Table 1 shows the general location along the Elwha River of many of the facilities and features discussed in this report.

Table 1. Location of Major Features and Facilities

River Mile[†]	Feature or Facility
0.0	Mouth
0.4	Tribal fish hatchery and well field
0.6	Bluffs
1.5	Infiltration gallery for Tribal fish hatchery
1.5	Elwha Place Homeowners Association wells
2.8	City of Port Angeles Ranney collector
2.8	Return flow, Washington Department of Fish and Wildlife
2.8 to 3.2	· Washington Department of Fish and Wildlife fish rearing channel (off-stream along east side of the river) · Open channel for Port Angeles industrial diversion (parallel to above channel)
3.3	Diversion dam for city of Port Angeles industrial diversion; also supplies water to WDFW fish rearing channel
3.6	Gauging station (USGS No. 120416100) installed for the 3-week Elwha Dam drawdown during 1994.
3.7	Dry Creek Water Association wells
4.9	Elwha Dam
7.8	Mouth of Little River
8.6	McDonald Bridge gauging station (USGS No. 12045500)
9.7	Olympic National Park boundary
11.0	Elwha Campground
13.4	Glines Canyon Dam
15.3	Temporary gauging station (USGS No. 12044920) installed for 3-week Lake Mills drawdown during 1994; near downstream of exposed delta
16.2	Gauging station (USGS No. 12044900) new in 1994, just upstream of the Lake Mills delta
22.0	Mouth of Idaho Creek

[†] River miles are measured at the midpoint of a stream starting at the mouth

SUMMARY OF APPLICABLE REGULATIONS AND POLICIES

Implementation of mitigation measures would be subject to various Federal and State laws, rules, and regulations, and those requirements would be met. The major laws are summarized below.

- **Safe Drinking Water Act** — controls requirements and standards for public drinking water supplies.
- **Washington Department of Ecology and Washington Department of Health** — drinking water regulations apply to water supplies.
- **Elwha River Ecosystem and Fisheries Restoration Act** — protection of existing quality and availability of water from the Elwha River for municipal and industrial uses from possible adverse impacts of dam removal.
- **Clean Water Act** — controls discharge to navigable waterways and discharge permits
- **Washington Department of Ecology 173–201A WAC** (Washington Administrative Code) — establishes water quality standards for surface waters consistent with public health and enjoyment thereof, and the propagation and protection of fish, shellfish and wildlife including anti-degradation policy

COORDINATION

The Bureau of Reclamation (Reclamation) met early in the planning process with representatives of the Lower Elwha Klallam Tribe (Tribe), Elwha Place Homeowners Association (EPHA), Dry Creek Water Association (DCWA), Daishowa, Rayonier Inc., and the city of Port Angeles. To the extent possible, individual well owners along the Elwha River were contacted. The meetings and contacts were held to share information being developed and collected by Reclamation, to determine local concerns regarding potential water quality degradation, and to obtain local input for possible water quality mitigation measures. Individual points of contact within various Federal, State, and local agencies were established to assist communications.

Subsequent to the preparation of this report, Rayonier's Port Angeles mill was closed. Efforts are currently underway to attract industry to Port Angeles to replace the jobs lost with the mill closing. Future Rayonier water measurement and monitoring activities anticipated in this report will likely be accomplished instead by the city of Port Angeles, Daishowa, or any entities which replace Rayonier as an industrial water user. Industrial water treatment measures proposed in this report assume that local entities will be successful in recruiting new industry to the area and that this industry will utilize the same quantities of water historically used by Rayonier.

Reclamation provided presentations and technical expertise at the public workshops on the draft programmatic EIS held in Port Angeles and Seattle in December 1994. Reclamation also participated in the 1995 public workshops on the draft implementation EIS.

NOTE ON ELEVATIONS AND OTHER SURVEY DATA

Survey data on maps and drawings prepared by various agencies for the existing facilities and other features in the area of Port Angeles show sharp discrepancies. Those discrepancies are caused by various agencies using different horizontal and vertical starting points called datums. The city of Port Angeles, until recently, used local datums, and Federal agencies use a variety of other datums.

Unless otherwise noted, all elevations provided in this report are based on the North American Vertical Datum of 1988 (NAVD '88). Old city datums are about 2 feet higher than the current standards. Horizontal coordinates are based on the Washington Coordinate System, North Zone, Datum of 1983, with the 1991 adjustments.

CHAPTER II.

CURRENT CONDITIONS

GEOLOGIC SETTING

The lower Elwha River basin consists of sloping bedrock formations which are locally mantled by younger unconsolidated deposits. The bedrock formations impede the flow of ground water and define the base and the boundaries of the unconsolidated hydrogeologic system, which is the primary zone for ground water. Wells completed within the bedrock formations are typically dependent upon localized fracture zones to supply usable quantities of water, and bedrock is not generally a significant source of water supply in this area.

Bedrock exposures dominate the Elwha River basin from upper portions of the drainage to the Lake Aldwell area. Unconsolidated deposits are exposed at the surface and mantle the bedrock in most areas downstream from Lake Aldwell. Projections derived from well drilling records suggest that the bedrock is covered by about 300 feet of unconsolidated material near the Strait of Juan de Fuca. Bedrock formations include the Eocene Crescent, Aldwell, Lyre, and Twin River units.

The Crescent Formation is primarily marine basalt, occurring as massive flows with pillows, breccia, and minor sandstone. The Crescent Formation is found mainly along the middle reach of the river between Lake Mills and Lake Aldwell, but it also forms the foundation for Glines Canyon Dam. In addition, there is a small outcrop of Crescent Formation at RM 2.8 which, to some extent, controls the river channel and aquifers in the lower river.

The Aldwell Formation, primarily siltstone with minor sandstone and conglomerate, is found along the southeast side of Lake Aldwell in a small exposure. The Lyre Formation conglomerate is exposed at the bend in Lake Aldwell, at RM 6.0.

The lower member of the Twin River Formation forms the foundation for the abutments and powerhouse of Elwha Dam. The thin-bedded sandstone with minor siltstone and pebble conglomerate is exposed in the riverbed from RM 5.0 to RM 4.1 and also at RM 3.2, where a one-lane bridge crosses the river.

Bedrock formations in the lower Elwha basin were folded and faulted during the uplift events which formed the Olympic Mountains. The Hurricane Ridge fault, a major regional structure, separates the Olympic “core rocks” from the “peripheral rocks” and crosses the valley of the Elwha River at RM 14, ½ mile upstream from Glines Canyon Dam. Other smaller faults have been mapped (USGS, 1978a) across the lower Elwha drainage. Folding of the peripheral rocks created a syncline (a U-shaped fold) with an axis perpendicular to the river valley near RM 4. On the south leg of the fold, near Elwha Dam, the conglomerate beds strike approximately N 50° W and dip 15° to 20° N. On the north leg of the fold, near the one-lane bridge, the beds have a similar strike but dip about 35° S. This structure may create a thickened alluvial aquifer between RM 3.1 and 4.0. This observation agrees with the findings outlined in Harza (1992), which describes the lower Elwha ground-water system as a series of three sub-basins separated by sills.

BASIN HYDROGEOLOGY

Unconsolidated units collectively comprise the hydrogeologic system of the lower Elwha River basin. This system generally extends from the Indian Creek Valley area upstream from Lake Aldwell to the mouth of the Elwha River. The unconsolidated deposits of the lower basin include the primary ground-water supply and the materials deposited adjacent to the river.

Primary Hydrogeologic Units

A sequence of Holocene age, glacial, and non-glacial deposits comprise the unconsolidated hydrogeologic system. The older glacial and non-glacial units were deposited first, covering the bedrock surface which slopes downward toward the north. The Elwha River valley is incised into these deposits, with recently deposited alluvium partially filling the valley floor. The present topography of the lower Elwha basin reflects this geologic sequence, with glaciated uplands bounding the deeply cut channel of the Elwha River. The following descriptions include the abbreviated unit name (in parentheses) for reference to information in appendix A. Appendix A includes drawings with information on the topography, geology, hydrogeology, and well locations. Appendix B summarizes Clallam County well logs.

Recent Alluvium (Qal)

The alluvium within the Elwha River floodplain consists primarily of sand and gravel with silty zones and serves as the primary aquifer in this area. Most community supply systems — the city of Port Angeles Ranney Method Western Corporation (Ranney) collector and the wells for DCWA, EPHA, and the Tribe — draw from the alluvial aquifer. The topographic contours and geologic information presented in appendix A show that the Elwha River flows through a series of alluvium-filled sub-basins, which are separated by bedrock exposures or constrictions in the surrounding glacial deposits. The subbasins consist of:

- The Lake Aldwell subbasin near the confluence of Indian Creek, Little River, and the Elwha River;
- The upper subbasin between RM 4.0 and 3.1, which is about 60 acres and includes the DCWA wells;
- The middle subbasin between RM 3.1 and 2.8, which is about 70 acres and includes the Washington Department of Fish and Wildlife (WDFW) fish rearing channel, the industrial supply diversion, and the Port Angeles Ranney collector;
- The lower subbasin between RM 2.8 and the mouth at the Strait of Juan de Fuca, which is about 1,100 acres and includes the Tribal and EPHA wells.

The lateral extent of the river-deposited alluvium is restricted to the incised river valley bounded by the relatively steep bedrock and glacial-deposit bluffs. Drilling records indicate that the alluvium is about 55 feet thick in the middle basin and about 100 feet thick near the river mouth. Limited drilling records and inferences drawn from the bedrock structure (folding and faulting) suggest that alluvium in the upper basin is at least 70 feet thick.

Recessional Glacial Outwash (Qg₁)

Recessional glacial outwash consists of sand and gravel exposed at the surface on top of the bluffs near the mouth of the Elwha River. The deposits are relatively thin (less than 20 feet) and unsaturated in these areas. The unit does not serve as a water supply source but is used as a borrow source for several local gravel mining operations.

Glacial Till (Qg₂)

Glacial till is exposed at the ground surface over most of the upland area bounding the valley of the Elwha River. The till is composed of compacted, non-stratified sand, gravel, and cobbles in a fine-grained matrix. The unit was encountered in virtually all upland wells with typical thicknesses of 50–150 feet. An excellent exposure of this deposit exists on the west side of the Elwha River, approximately 0.5 mile from the mouth. The bluff is over 100 feet high and is nearly vertical.

Relatively few wells are completed within the till, which is not generally considered a productive aquifer. Wells that are completed in the till (at depths of 150 feet or less) yield small quantities of water when localized pockets of clean sand and gravel are encountered. Reported well yields are typically less than 20 gallons per minute (gpm) and service individual users. The available information does not identify an interval within the till capable of supporting larger water system demands.

Non-Glacial Deposits (Qn₁)

In most areas of the lower basin, drilling records identified a clayey deposit 20 to 50 feet thick. The fine-grained, gray material is likely non-glacial, perhaps originating as a marine deposit during an interglacial period. This unit does not yield appreciable quantities of ground water for supply purposes.

Older Glacial Deposits (Qg₃)

The deepest glacial unit identified from drilling records for the lower basin is an outwash sequence overlying the bedrock surface. The outwash consists primarily of sand with lesser amounts of silt and gravel. The unit was most frequently encountered in the lower portions of the basin, where maximum thicknesses of 100 to 150 feet were identified. The unit apparently becomes thinner toward the south, in the vicinity of the middle basin. Drilling records from upland-area wells in this area either went from till directly into bedrock or penetrated less than 50 feet of the older glacial material.

A number of wells are completed in these glacial deposits or in the upper portion of bedrock, which is probably hydraulically connected with the glacial deposits. The wells service individual users and generally report yields of less than 20 gpm.

Hydraulic Properties

Variability in composition and origin of the primary hydrogeologic units identified in the lower basin affects the ability of each unit to transmit ground water. In general, the alluvium and the older glacial deposits are aquifers which are relatively coarse grained, exhibit greater permeability than other aquifers, and can supply usable quantities of water. In contrast, the glacial till and the non-glacial deposits are predominantly fine-grained confining layers which do not readily transmit ground water and produce usable quantities of water only where localized sandy zones are encountered. Available information describing the hydraulic properties of these units is presented in this section; most information describes conditions within the alluvium where testing data were collected from public water supply systems.

Specific Capacity

The specific capacity of a well is its yield per unit of drawdown during pumping and is generally expressed in gallons per minute per foot of drawdown (gpm/foot). The average specific capacity of wells completed in the alluvium is much higher than reported values for wells completed in the upland areas that flank the valley. The specific capacity records for wells completed in the alluvium are typically greater than 10 gpm/foot and range to more than 100 gpm/foot. In contrast, wells completed in the upland areas generally report specific capacities of 5 gpm/foot or less.

Well Yields

Sustainable pumping rates for wells completed in the upland areas are generally less than 20 gpm. Wells completed in the alluvium have highly variable yields, but larger diameter completions have yields ranging from 100 to 1,000 gpm.

Aquifer Transmissivity

Transmissivity is the rate at which water is transmitted through an aquifer, or more specifically for well users, the amount of water that can be pumped from a well with a specific drop in water level. Pumping tests completed at several well sites within the alluvium indicate that the aquifer transmissivity, which is measured in gallons per day per foot of drawdown (gpd/foot), is high. Equivalent information has not been identified for wells completed in the uplands areas bounding the Elwha River. Sources of aquifer testing information include several ground-water studies of the potential for development of water supplies for the Tribal fish hatchery (Dames and Moore, 1989a), the WDFW rearing channel (Harza, 1992; Robinson and Knoble, 1995), and city of Port Angeles Ranney collector (Ranney, 1977 and 1994). Pumping test data were also obtained from a DCWA well-installation report.

Aquifer testing indicates that the transmissivity of the alluvium generally increases down-river. A transmissivity of 75,000 gpd/foot was estimated from DCWA data in the upper basin, whereas a higher value of 100,000 gpd/foot was calculated from data collected in the middle basin at the WDFW fish rearing channel. Studies completed at the Tribal hatchery in the lower basin estimate transmissivity of about 400,000 gpd/foot. Storativity, a technical measure of the storage capability of an aquifer, was estimated at 1.7×10^{-3} (a low capability) from the lower basin testing data (Dames and Moore, 1989a).

FLOW OF GROUND WATER

The flow of ground water in the lower Elwha River basin is from the higher elevations in the south toward the north and ultimately into the Strait of Juan de Fuca. Flow through the underlying bedrock is restricted to fractures and joints which are typically limited in extent. Therefore, the primary route of flow is through the unconsolidated hydrogeologic system. Water level information from well-drilling logs enables a qualitative assessment of flow patterns through the unconsolidated deposits.

Inferred Flow Direction

Water levels reported by drillers indicate a distinct difference in ground-water occurrence between upland areas and wells completed in the alluvium. These data are included on the cross sections shown in appendix A. Water levels measured in the upland areas are typically 100 to 200 feet higher than the hydraulic head of the alluvial aquifer (see cross sections B-B' and C-C' on drawings 3 and 4 of appendix A. The separation in water levels between these two areas appears to decrease toward the north, as shown in cross section A-A' (drawing 2) which is drawn near the Strait of Juan de Fuca shoreline. These observed water-level patterns indicate that a portion of the ground water flowing through the glacial deposits in the uplands discharges to the valley of the Elwha River, with the remainder of the flow moving toward the north to discharge to the Strait of Juan de Fuca. The difference in water-level elevation between the alluvium and the upland areas indicates that gradient reversals could not occur. Therefore, water flowing through the alluvium is not a source of recharge for the upland areas. Fluctuations in river level should not affect the ground-water level beyond the limits of the alluvium.

Within the alluvium, the general direction of flow is toward the north, paralleling the river course. Water levels in the aquifer and the river are generally consistent with each other, indicating that the two systems are in hydraulic connection. Surveyed monitoring points were established to compare hydraulic head measurements in the ground-water system with the river stage. Pumping test data indicates that the Port Angeles Ranney collector and other high-yielding community wells create localized head depressions, drawing ground-water levels below the elevation of the river, and inducing flow toward the wells.

Alluvial Aquifer Discharge

A comparison of the flow of ground water through the alluvium with the current levels of use of ground water indicates that long-term pumping is sustained by recharge from the Elwha River. Based on the aquifer properties estimated from pumping test data, ground water discharges from the middle basin to the lower basin at a rate of approximately 1 to 2 cubic feet per second (cfs). The United States Geological Survey (USGS) estimates that the discharge from the alluvium aquifer to the Strait of Juan de Fuca is about 6 cfs (USGS, 1979). The city of Port Angeles Ranney collector (located in the middle basin) has a reported operating capacity of about 11 cfs (Ranney, 1977), a quantity roughly 10 times greater than the natural flow of ground water through the middle basin.

WATER USERS

For this discussion, the valley of the Elwha River is considered in two parts, the upper and lower valleys. The upper valley extends from the park boundary at RM 9.7 downstream to RM 4.0, where the river emerges from a narrow bedrock canyon below Elwha Dam and where the alluvial floodplain widens and thickens. The lower valley begins at RM 4.0 and extends to the mouth, at the Strait of Juan de Fuca. The lower valley is considered to be composed of three subbasins, an upper subbasin (RM 4.0–3.1), a middle subbasin (RM 3.1–2.8), and a lower subbasin (RM 2.8–0.0).

Upper Elwha River Valley (RM 9.7–4.0)

There has been relatively little ground-water development in the upper valley. Most new housing construction and water wells are to the west of the river valley on a remnant glacial outwash terrace above elevations of 400 feet. The wells average less than 200 feet deep, drawing water from elevations above the level of the Elwha River and Lake Aldwell. A few homes and the Indian Creek Campground are located near the confluence of Indian Creek and the Elwha River at the upstream end of Lake Aldwell. The water levels in these wells are probably influenced by the lake level since they appear to be completed in the permeable alluvium.

Several homes are located on the east side of the Elwha River, south of the Little River tributary (at RM 7.8). The wells for these homes are shallow and the water levels reflect the fluctuating river level. These wells are not expected to be influenced by the level of Lake Aldwell since the bottom elevations of the wells are above the lake elevation. Some wellheads are apparently flooded during high river levels (personal communications with well owners).

Several domestic wells are located near the southeast side of Lake Aldwell. They appear to be completed at a higher elevation than the lake level and draw water from a perched aquifer above the bedrock.

Lower Elwha River Valley (RM 4.0 to Mouth)

Most water use in the Elwha River basin is in the lower valley, below RM 4.0. Several community water systems, industrial supplies, and fish production facilities use the Elwha River directly or use ground water for their sources of water. In addition to the water systems, discussed below, there are individual users in each subbasin. Most private wells are located in the lower subbasin on and near the Lower Elwha Klallam Reservation. Total water use by all individual users is estimated at less than 0.2 cfs.

The city of Port Angeles obtains its municipal water from a Ranney collector located adjacent to the river near RM 2.8. The lateral collecting pipes are nearly 60 feet beneath the river channel in coarse-grained alluvium. Data indicate that the collector is hydraulically connected to the river. The State of Washington generally classifies this relationship as “ground water under the influence of surface water” but has not formally made a determination for this Ranney collector.

Dry Creek Water Association

The DCWA was formed and incorporated in 1964 to serve the water needs of residents to the south and west of the city of Port Angeles. As of 1994, the Association included 392 members, of which 349 were residential connections and 43 were commercial connections. There were also 41 inactive residential connections. DCWA serves a population of about 950.

Four wells are located on the east bank of the Elwha River near RM 3.7 (in the SE ¼ of Sec. 10, T30N, R7W). Wells number 1 and 2, constructed in 1964 and 1980, respectively, are large diameter (3 to 4 feet) and about 20 feet deep. Wells number 3 and 4, drilled in 1990 to depths of 42 and 48 feet, respectively, are 12-inch-diameter wells. Well number 4 has been tested but never been put into production. Wells number 1, 2, and 3 are active and the water is chlorinated.

Current pumpage from the DCWA wells averages about 150 gpm. DCWA's original water right (for well No. 1) was obtained in 1964 for 100 gpm. Additional water rights were obtained in 1980 for a total of 280 gpm (about 0.6 cfs). In 1992, DCWA's existing water rights were amended to add additional points of withdrawal including pumpage from No. 3. A water right for well number 4 was applied for and is still pending.

The DCWA wells are located 180 to 250 feet from the left bank of the Elwha River. Due to the close proximity of the wells to the river and the shallow well depths, it is likely that at least a portion of the water comes from induced recharge from the river, rather than ground water. The average turbidity of the pumped water is in the range of 0.06 to 0.08 nephelometric turbidity units (NTU). When the river is high and turbid, turbidity in the well water is reported to increase, another indication of river water infiltration.

These structures are subject to flooding under present river conditions. The wells are located at elevation 83 feet. River flood-stage elevations for this reach are in the range of 81 to 83 feet for the 10-year frequency flood and 84 to 87 feet for the 100-year flood. The east bank of the river is being eroded and the bank edge is several feet closer to the wells now than in years past (personal communication from C. Kelly, manager of DCWA).

City of Port Angeles Industrial Supply

The city has a water right to divert 150 cfs of river flow for industrial use and owns an industrial water delivery system. Currently, this system supplies untreated water by gravity to the Daishowa and Rayonier pulp mills and to the WDFW fish rearing channel described in the next section. A rockfill diversion dam (at RM 3.3) directs flow to a diversion tunnel. At the tunnel outlet, the flow is divided to supply a maximum of 50 cfs to the WDFW fish rearing channel and a maximum of 100 cfs to an open channel that leads to a weir and screenhouse which control flow into an industrial pipeline. Excess flow is returned to the river through a wasteway to the river (about RM 2.8).

Under a contract with the city, Rayonier operates and maintains the diversion structure and distribution facilities. Although their contracts are for slightly more than 100 cfs, average usage for the two plants is about 70 cfs. Peak flows are estimated at 55 million gallons per day (mgd) (about 85 cfs) for Rayonier and 12 mgd (about 19 cfs) for Daishowa. Stripchart records of flow, maintained by Rayonier, are measured in the screen house at the downstream end of the existing open conveyance channel. Flow measurements have historically been kept at stations along the pipeline.

Some suspended material settles in the open conveyance channel. Each company treats the water at its mill site, primarily to reduce sediment and turbidity, using chemical addition, flocculation, and filtration. Since the water is diverted directly from the river, any change in surface water quality of the Elwha River affects the mills.

Washington Department of Fish and Wildlife Fish Rearing Channel

The rearing channel was constructed in 1975 pursuant to an agreement between the State of Washington Department of Fisheries¹ and Crown Zellerbach Corporation. The facility is located on the east bank of the river from about RM 2.8 to 3.2 (SE ¼ of Sec. 3, T30N, R7W). There are two parallel channels with a total width of about 80 feet and length of 1,400 feet; the total volume is 415,500 cubic feet.

Although the WDFW contract with the city of Port Angeles is for 50 cfs, the average flow to the channel is about 35 cfs. Outflow returns to the river by an open channel at RM 2.8 and is used to attract returning anadromous fish. The facility has upgrade plans to become self-supporting and independent of other WDFW hatcheries for incubation and early-rearing support. WDFW does not expect to require more water in the future than supplied under current arrangements. A ground-water study was conducted in 1992 to provide drought relief measures and provide cooler flow to the rearing channel (Harza, 1992). Two wells were drilled, one was pump-tested, and a plan for additional wells was developed. The plan, which calls for up to 12 wells spaced approximately 100 feet apart and with a discharge rate of 250 gpm each, has not been fully implemented. Three additional wells were drilled and tested in the area of the rearing channel in 1995 and are now being used. The purpose of these wells is to provide cooler, pathogen-free water for the rearing channel. Robinson and Noble (1995) described the drilling and testing project.

The elevation at the WDFW facility is just above 50 feet. A flood study of the Elwha River (FEMA, 1980) indicates that the 100-year flood level is currently about 2.4 feet below the top of the existing rearing facility.

City of Port Angeles Municipal Supply

The primary water source for the city is a Ranney collector located near RM 2.8 on the east bank of the Elwha River in the SE ¼ of Sec. 3, T30N, R7W. The city holds a water right permit for 50 cfs (about 32 mgd) for municipal purposes. In 1992, the average daily demand was 3.8 mgd and the maximum daily demand was 8.4 mgd. As of April 1994, a population of 18,030 was served within the city; 6,225 residential and 993 commercial connections. The city sells an average of 0.14 mgd to the Clallam County Public Utility District, which in 1994 served an additional 2,907 people at 1,163 residential connections. The maximum contract delivery to the Utility District is about 0.4 mgd, but not more than 8 percent of the city supply during conditions of shortage (Clallam County Planning Division, 1994).

¹ The Washington Department of Fisheries has since been folded into a combined agency, the WDFW, and the former Crown Zellerbach Corporation assets are owned by James River Corporation and Daishowa.

The Ranney collector was constructed in 1977 and consists of a large diameter vertical caisson with seven 10¾-inch outside-diameter, horizontal screen laterals projected at elevation of 9.9 feet. The 7 laterals total 528 feet in length and range from 39 to 115 feet long. Pumping facilities in the collector consist of two 600-horsepower pumps rated at 3,700 gpm each (at 530 feet total dynamic head), though the actual pump discharge is slightly greater. A nearby chlorination station treats the water before delivery to city customers.

In 1974, before construction of the collector, a thorough hydrogeological investigation of the site was completed. From the results of test pumping, the yield of one Ranney collector was estimated to be 14.4 mgd under average conditions of river stage and water temperature, decreasing to 11.7 mgd under minimum flow conditions. The results of the 1977 initial performance test of the completed Ranney collector calculated an average yield of 15.7 mgd and a minimum yield of 12.8 mgd with a pumping level elevation of 20 feet (city datum). The performance test report concluded that the collector could readily produce the required water supply of 11.0 mgd (Ranney, 1977).

In 1985, the city observed a decline in collector capacity. The water level would continue to decline with both pumps running until the low-level alarm was reached and one pump would automatically shut-off. Ranney reviewed the city data and concluded that the capacity in 1985 had declined to about 11.0 mgd compared to the initial capacity of 15.7 mgd (Ranney, 1985). The decline appeared to be due to migration of the river channel away from the collector and not due to clogging of the laterals. Ranney suggested that the city take measures to divert more river water into the side channel near the collector to increase recharge to the aquifer in that area. Although there was no evidence of clogging of the horizontal screen laterals, Ranney also suggested that a pumping test be performed to further evaluate possible clogging of the laterals.

In April 1994, the city authorized Ranney to conduct a controlled pumping test to determine the cause of continued capacity decline. An 8-inch-diameter observation well was constructed adjacent to the collector and was used to measure the water level in the aquifer during pumping of the collector. The test measured an operating efficiency of the Ranney collector of 94.9–96.0 percent, which indicates that the screen laterals were not clogged. The test further computed the effective distance to the line of infiltration and found that a significant change in the recharge conditions had occurred since the initial testing in 1977. The report to the city (Ranney, 1994) attributed the changed condition to the loss of river flow in the side channel near the collector and the increased distance to the main channel of the river. The present-day yield of the collector was calculated at 10.7 mgd (with river flow at 1,100 cfs and a temperature of 48 °F).

Elwha Place Homeowners Association

The EPHA supplies water to about 45 people (19 connections) from 2 wells located on the west side of the Elwha River near RM 1.5 (in the SW ¼ of Sec. 34, T31N, R7W). The wells are located about 750 feet from the river near an old channel. Well number 1, drilled in 1978, is completed in the alluvium and encountered bedrock at a depth of 65 feet. A 4-hour pump test revealed a specific capacity of about 67 gpm/foot. Well No. 2, drilled in 1983, was completed at the same depth as nearby No. 1. The specific capacity of this well was measured at 31.4 gpm/foot. The combined capacity of the two wells is about 186 gpm (0.4 cfs). The water is pumped to a storage tank located on the terrace above the river, at an elevation of about 175 feet, and is not treated before delivery.

The two wells are located at an elevation of 36 feet. River flood-stage elevations in this reach are approximately 31 feet for the 10-year frequency flood, 32 feet for the 200-year flood, and 33.5 feet for the 500-year flood (Corps, 1987; FEMA, 1980). The wells are above currently projected flood stage elevations.

Lower Elwha Klallam Tribe

An increasing number of households within the reservation are switching from private domestic wells to a municipal water supply. Two wells (in the NW ¼ of Sec. 35, T31N, R7W) supply water to about 200 residents. Although drilled in 1976, the wells were not put into production until early 1994. Each well is about 50 feet in depth and completed in alluvium. The well logs record a test yield of about 100 gpm from each well. In a 24-hour pumping test conducted later, each well was pumped at a rate of 55 gpm producing a drawdown of 1.4 feet (a specific capacity of about 39 gpm/foot).

Homes on the reservation in the lower delta area are served by private septic systems. Water-level readings in August 1994 measured the water table at 4 to 17 feet below ground level. Any significant rise in the river stage due to riverbed aggradation could also raise the water table slightly and cause septic system flooding.

Lower Elwha Klallam Tribe Fish Hatchery

The Tribe operates a fish hatchery on Tribal land near the mouth of the Elwha River (NE ¼ of Sec. 34, T31N, R7W). Current water demand for the hatchery is about 11.5 cfs. Expansion plans call for increasing the water use to more than 20 cfs.

An infiltration gallery, located about ½ mile upstream from the hatchery and upgraded in 1989, delivers 7 to 8 cfs of untreated river water to the hatchery by gravity flow. The infiltration gallery consists of 18-inch-inside-diameter, perforated, polyvinyl chloride pipe buried about 10 feet in the riverbed. Increased sedimentation could cause increased river migration from the perforated pipe and adversely affect the capacity of the infiltration gallery.

River water is mixed with approximately 4.5 cfs of ground water supplied by two wells. The east production well, completed in 1977, was initially tested at 2,000 gpm with 28 feet of drawdown; a specific capacity of 71.4 gpm/foot. A performance test conducted in 1989 measured a specific capacity of 58 gpm/foot (Dames and Moore, 1989a). Mineral encrustation of the well screen was thought to have lowered well capacity. The west production well, drilled in 1989, was tested at 1,000 gpm with 17.3 feet of drawdown; a specific capacity of 57.8 gpm/foot. A third well drilled in 1976 (tested in 1989 at a specific capacity of 34 gpm/foot) supplies water to the egg incubation and office facilities. Aquifer testing indicates that a steady-state yield of 8.0 cfs from a well field in this area is possible without risk of salt water intrusion (Dames and Moore, 1989a).

More detailed information may be found in *Report of Hydrogeological Services, Water Supply Feasibility Study, Lower Elwha S'Klallam Tribal Fish Culture Facility* (GeoEngineers, 1994), an appendix to FishPro (1994).

Minimum Instream Flows

The instream flow necessary for fish and wildlife and recreational use has not been quantified. Instream flows and recharge from the river to the underlying aquifer are necessary to maintain a level of ground water that prevents salt water from intruding into wells located near the shoreline.

Summary of Water Users and Water Use

Figure 1 shows the maximum, average, and minimum flows of the Elwha River as recorded at the McDonald Bridge gauging station. The average flow is 1,500 cfs. Prior to operation of the dams as run-of-the-river facilities, storage control of Lake Mills affected daily flow but had little effect on peak flood flows. Extremely low flows, including a minimum discharge of 10 cfs, reflect flow control at Glines Canyon Dam in the 1930's and 1940's and no longer occur. The minimum flow recorded at the McDonald Bridge gauging station between 1974 and 1986 was 372 cfs.

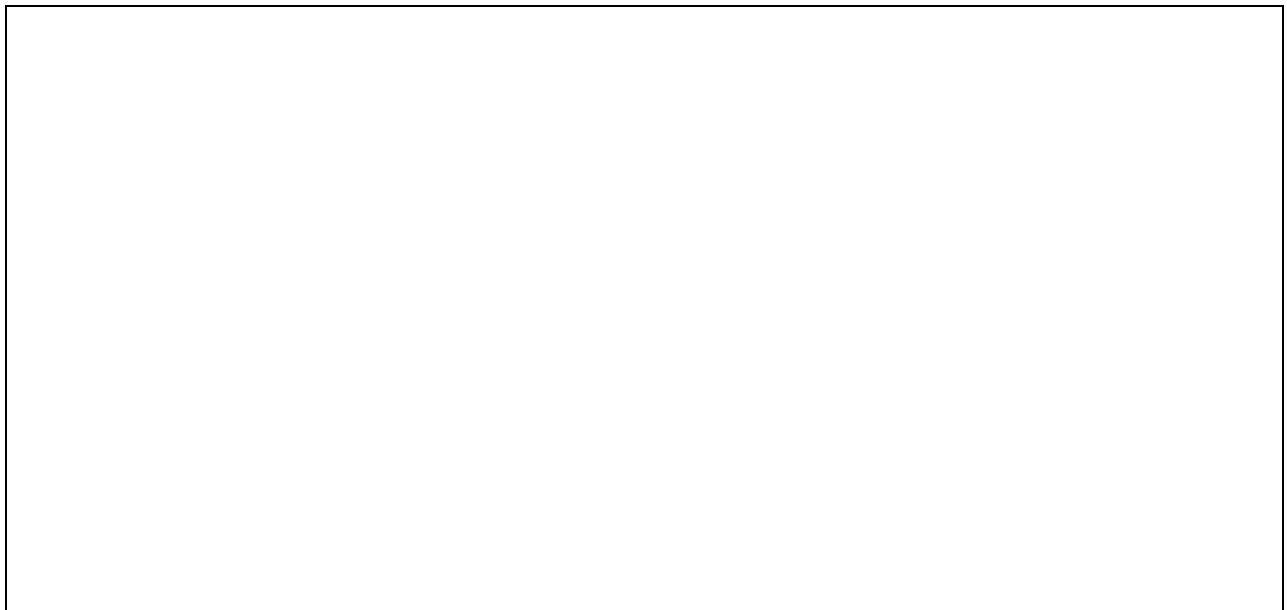


Table 2 provides information as reported in the WDOE water rights data base and the available well log records on water permits. Also included are estimated usage of individual users who are exempt from the permitting process. It was assumed that individual homes average less than 3.5 gpm, the upper threshold for exemption from further permitting.

Based on these assumptions, the estimated water use in the lower Elwha River valley is about 125 cfs although there are permits for 210 cfs. The lowest average flow for any 7 consecutive days has a 50 percent probability of being less than 377 cfs (USGS, 1979).

Table 2. Current Water Permits and Use

Location	User	Permit	Use
Upper valley	Scattered wells (ground water)	(†)	(†)
Lower valley			
Upper subbasin (RM 3.1–4.0)	Dry Creek Water Association (ground water)	0.6 cfs	0.3 cfs
	Other users (ground water)	0.0 cfs	<0.05 cfs
Middle subbasin (RM 2.8–3.1)	WDFW rearing channel and industrial diversions (surface water)	150.0 cfs	150.0 cfs
	City of Port Angeles (ground water) [‡]	50.0 cfs	6.3 cfs
	Other users (ground water)	0.0 cfs	<0.05 cfs
Lower subbasin (RM 0–2.8)	Lower Elwha Klallam Tribe (ground water)	0.3 cfs	0.3 cfs
	Lower Elwha Hatchery (ground water)	4.5 cfs	4.5 cfs
	Lower Elwha Hatchery (surface water)	7.0 cfs	7.0 cfs
	Elwha Place Homeowners Association (ground water)	0.4 cfs	0.4 cfs
	Other users (ground water)	0.0 cfs	<0.1 cfs
Total		≈210 cfs	≈170 cfs

[†] Not estimated, some are above the elevation of the Elwha River

[‡] Ground water possibly under the influence of surface water

WATER QUALITY

Overview

Due to the hydraulic connection between the Elwha River and the alluvium aquifer, the quality of the surface water and the quality of ground water are similar. The surface water has excellent quality; the concentrations of many chemicals are below detection limits and all are less than the maximums allowed by the Washington State Drinking Water regulations. Water testing conducted in 1977 as part of the USGS (1979) study of water resources of the Tribal reservation indicated the ground water to be of excellent chemical quality. The watershed is protected by National Park status in the upper reaches. Most of the remaining basin is rural in character and there are no landfills or industrial discharges. Non-point sources of pollution, such as agricultural and urban run-off, have a very minor influence due to the small number of farm operations and limited development within the river basin.

Available information on the quality of ground water is limited to monitoring conducted by community water systems in the basin. "Group A" public water systems (those with more than 15 connections or more than 25 people) are regulated by the Washington State Department of Health (WDH).

State testing requirements for Group A water systems vary according to the water source and the size of the system. All must test for coliform bacteria at least once per month. Ground-water systems must have a complete inorganic chemical analysis performed every three years; surface-water systems analyze for inorganic chemicals each year. Group A surface-water systems are required to monitor turbidity every day. Testing requirements for trihalomethane (THM), volatile organic compounds, and pesticides vary according to many criteria, including water source, population served, and level of chlorine treatment.

Three Group A systems are located in the basin: city of Port Angeles, DCWA, and EPHA. Data indicates that the Port Angeles Ranney collector is a ground-water source under the influence of surface water. While it has not been officially designated as such, the city follows the testing regulations required for surface-water users.

Although not regulated by the State, approximately 200 people use a community water source in the lower valley on the reservation. Two community wells have replaced several private domestic wells. The wells have been sampled for inorganic, synthetic, and volatile organic chemicals.

Appendix C includes the water quality analyses of the four major community water systems. The samples were collected at the source before any treatment. No volatile organic compounds have been detected during the sampling and testing of any community water system.

All homes in the lower basin rely on private septic systems for on-site sewage disposal. At high ground-water levels and tidal conditions, the buried perforated drain lines of some systems at the lower end of the valley may be in contact with the water table. The coarse-grained alluvium does not provide much filtration of the waste water that enters the aquifer, and a failed system could be a source of ground-water contamination.

To assess potential salt water intrusion, 12 water samples were tested in August 1994 to determine chloride levels in wells located near the river mouth. Eight samples were taken from wells on or near the reservation; the remaining four samples were from wells on lower Place Road, west of the Elwha River along Freshwater Bay. The maximum chloride concentration tested at 8 milligrams per liter (mg/L), the minimum was less than 1 mg/L, and the mean was about 2 mg/L. These low levels of chloride concentration indicate that, to date, there has been no salt water intrusion into the shallow alluvium aquifer near the shoreline.

Data Sources and Findings

Data sources and the information collected by specific entities are summarized in this section. The levels of major surface-water quality factors are also summarized in tables in chapter III.

United States Geological Survey

Data on water quality collected by the USGS for the period of 1974–86 at the McDonald Bridge station (USGS Gauge No. 12045500) are stored in the Environmental Protection Agency (EPA) STORET database and are summarized in appendix D. This station is located at RM 8.6 and the STORET information is considered final and not subject to revision. Subsequent data are considered provisional (subject to revision).

The data presented in appendix D indicate that the surface-water quality upstream is excellent. The only exception is a maximum recorded temperature of 14.4 degrees Celsius (°C), which could be stressful to anadromous fish.

The USGS collected water and sediment samples during a test to evaluate the effects of drawdown of Lake Mills on water quality. Water samples were collected on three dates in April 1994 at each of four locations.² In addition to standard water quality parameters (temperature, pH, hardness, etc.), the concentration of metals, pesticides, volatile organic compounds, and radionuclides were measured. These data are summarized in appendix E.

Based on the data, the water quality is excellent at the monitoring station at RM 16.2. Toxic or hazardous chemicals, if present, are generally below detectable limits, and in no instance were present above the limits established by regulation. The data from the delta site indicates the presence of notable amounts of iron and manganese minerals, apparently re-suspended during drawdown induced erosion. Iron and manganese are generally only nuisance constituents affecting aesthetic water quality.

Two sediment samples taken from the bottom of Lake Mills during the drawdown were analyzed for metals, pesticides, and radionuclides. No hazardous materials were detected. Iron and manganese concentration in the sediment were higher than found in the upstream water samples.

² These locations include a new (1994) station just upstream of the Lake Mills delta at RM 16.2 (USGS 12044900); a temporary station (12044920) about RM 15.3, installed for the 3-week drawdown and removed afterward; the permanent station (12045500) at McDonald Bridge (RM 8.6); and a temporary station (12046100) at RM 3.6, about 1 mile downstream from Elwha Dam.

The USGS No. 12044900 gauging station (RM 16.2) established in 1994 provides information on flow, temperature, and turbidity of the Elwha River upstream from the two existing reservoirs. Flow and temperature data collected during 3 months of 1994 are summarized in appendix F. Data collected to date indicate that the natural temperature profile at this station peaks in late July or early August.

Industry

Daishowa and Rayonier collect daily data on flow and turbidity. Measuring the turbidity of incoming water is a step in adjusting the water treatment at each mill to achieve a target water quality for the industrial processes. Appendix G summarizes Daishowa data for the period of 1983–93. The daily average turbidity over this period was 8.4 NTU.

City of Port Angeles

Since April 1994, the city has collected daily data on temperature, pH, and turbidity of water from its Ranney collector located at RM 2.8 and water from the Elwha River adjacent to the collector. Data collected from April 1994 through September 1995 are summarized in appendix H.

These data show that the turbidity and the pH of collector water remains within fairly narrow limits except during periods when river water turbidity increases by a large amount. Large increases in turbidity accompany large increases in flow. Turbidity of the Elwha River and collector water increased during mid-April 1994, in response to the April 1994 drawdown of Lake Mills. The temperature of the collector water tends to increase and decrease in an annual pattern with the river water temperature, but lags behind reflecting the specific heat capacity of the alluvium above the collector.

Turbidity in water from the Ranney collector has infrequently exceeded the maximum allowable level of 1.0 NTU. These higher levels may be the result of increased amounts of colloidal-size particles suspended in the river water under high flow conditions or may represent flow of river water vertically around the caisson during high flows. A comparison of river flow at high levels with turbidity in the Ranney collector does not show a clear correlation (figure 2).

Ranney has collected and studied turbidity data from other Ranney collector sites in the Pacific Northwest and found no correlation between river turbidity and collector turbidity at any site with river turbidity levels that range from 0.9 to 34 NTU (Ranney, 1991). Turbidity levels as high as 2,800 Jackson Turbidity Units (JTU)³ and suspended sediment levels as high as 4,500 mg/L have not adversely affected the Ranney collectors located on the Russian River north of Santa Rosa, California. These collectors supply water to all of Sonoma County and part of Marin County (Ranney, 1995). These data suggest that limited increases in river turbidity should not adversely affect a Ranney collector's natural filtering capability or increase the turbidity levels of water in the Ranney collector.

³ There is no direct relationship between JTU and NTU.

Turbidity data from the USGS gauging station upstream of Lake Aldwell (RM 16.2) is compared with city of Port Angeles data on turbidity of the Elwha River near the city's Ranney collector (RM 2.8) in appendix I. This comparison shows that peaks of turbidity that occur at RM 16.2 are considerably attenuated by RM 2.8.



Elwha Place Homeowners Association

There appears to be no connection between turbidity levels observed in the river and in the EPHA wells (personal communication with EPHA manager). The maximum turbidity measured in the delivered water is approximately 0.4 NTU.

Lower Elwha Klallam Tribe

The Tribe collected water flow and water and air temperature data for 3 years (1987–89) at the Tribal fish hatchery and collected water temperature data at three sites on the Elwha River from August 1992 to June 1994. These sites included an upper site at Idaho Creek (about RM 22); a middle site at

McDonald Bridge (RM 8.6); and a lower site below the bluffs about RM 1, near the fish hatchery. Summaries of data collected by the Tribe are in appendix J.

Water temperatures in the lower river regularly exceed 18.5 °C during summer months. These high temperatures have been associated with major fish kills in the lower river and probably limit the diversity and population of aquatic invertebrates. Water temperatures higher than 14–15 °C (57–59 °F) tend to exacerbate skin diseases and increase mortality of cold-water fish (including the native anadromous fish).

Lake Mills Sediment

The results of chemical and geotechnical testing of fine sediment collected from Lake Mills in March 1995 are shown in appendix K. Iron and manganese are the major metals found in the sediment.

Ground Water and Geology

Interpretation of hydrogeologic conditions in the lower Elwha River basin was developed from published reports, State agency file information, and a limited field reconnaissance. The primary sources of information consisted of:

- *Geologic Map of the Olympic Peninsula (Map I-994)* (USGS, 1978a), including unpublished refinements presented in the report *Port Angeles Regional Watershed* (Clallam County, 1994);
- A total of 236 water well logs on file with the WDOE for the study area;
- Responses to a “Water Use Inventory” developed for this project and mailed in June 1994 to all landowners in the study area within 2 miles of the river, including those on Lower Elwha Klallam Tribal lands;
- A 3-day field reconnaissance which included water level monitoring in 32 wells and the measurement of chloride levels in 12 wells located near the mouth of the river.

As discussed in chapter II, “Basin Hydrogeology” section, Appendix A includes a series of drawings developed from the USGS and Clallam County reports to aid understanding of the hydrogeological conditions in the Elwha River basin. These drawings include a map showing the surficial distribution of geologic units and generalized cross sections showing the vertical distribution of these units. The surficial map also shows locations of wells identified in the WDOE files and the water use inventory. Two cross sections run parallel to the river (one on either side) and four sections intersect the river at RM 0.3, RM 3, RM 5, and RM 8.8. Each cross section is 5 to 6 miles in length.

Appendix B summarizes the well-log data in the WDOE files and data gathered from the water use inventory.

CHAPTER III.

FUTURE CONDITIONS

METHODOLOGIES FOR ANALYZING IMPACTS

The potential effects of water quality changes on water users were determined through identification of critical impact indicators, or water quality parameters, that must remain within certain limits to avoid adverse effects on aquatic life and water users. The most critical of these are total dissolved solids (TDS) and TSS.

A study of the hydrogeology of the Elwha River watershed identified the area of potential impact as being restricted to the alluvial river valley. All available well logs were reviewed for location, well completion details, and wellhead elevations. Current elevations were compared to the 100-year flood level projected after removal of the dams to determine if facilities would be subject to increased flooding (Corps, 1995).

Wells on the Lower Elwha Klallam Reservation in the lower river valley were monitored for 1 year to evaluate river influence on the level of ground water and to determine the gradient. Several wells were monitored monthly and one was monitored with a continuous recorder. The estimated changes in ground-water levels that would follow removal of the dams were based on projected levels of riverbed aggradation and present river stage to ground-water level relationships.

Sedimentation analysis (Reclamation, 1996) provides the major information for predicting impacts of dam removal on water quality. For this analysis the effects of dam removal were separated into short-term effects and long-term effects. Short term effects are those associated with the period when sediments accumulated in Lake Mills and Lake Aldwell are redistributed downstream. Computer modeling assumes that this period of sediment redistribution would occur over a period of 3 years and 4 months. However, the actual length of this period could be shorter or longer depending on rainfall, rate of runoff, and other factors. For this water quality analysis, the period of short-term effects was assumed to begin during dam removal and to continue for up to 5 years after dam removal. Long-term effects are those associated with the period that would follow redistribution of lakebed sediment. For this analysis the period of long-term effects is assumed to be 50 years.

Information on current conditions collected by operators of various systems was compared with information on predicted conditions to identify potential impacts.

OVERVIEW

No Action

Future water quality conditions with the No Action alternative are dependent on processes that have been ongoing for many years and would be expected to continue.

The two dams form pools of water that (1) slow water flow over the streambed and allow suspended solids to settle and some dissolved solids to be trapped (decreases turbidity during peak flows), (2) elevate the ground-water level for some well users; and (3) decrease the ground-water level in the lower valley.

At present, the downstream TDS and TSS are low, in part because the two reservoirs trap all of the coarse sediment and a percentage of the fine sediment entering the reservoirs. This trapping eliminates sediment recruitment (transport) to the middle and lower reaches of the lower valley. However, natural processes downstream from Elwha Dam continue to move deposited sands and fine sediments from the river to the sea, resulting in the lowering of the elevation of the river bottom. Therefore, the water surface was lowered, the rate of channel migration was decreased, flood levels were decreased, and the riverbed was left armored with coarse cobbles and gravel. Loss of sands and fine sediments has increased the hydraulic connection between the river and the underlying aquifer and slightly increased the yield of some wells.

Yield from the Port Angeles Ranney collector is diminishing and will continue to diminish further as long as the river continues to migrate toward the west bank and away from the collector laterals. The Ranney collector and other high-yield wells depend on induced recharge from the river to maintain high yields.

The quality of water from the DCWA wells, which have a very close hydraulic connection to the river, is often reduced during periods of high river turbidity. This would continue to occur.

The dams would continue to trap sediments and maintain current conditions with regard to river migration, erosion, and flooding.

Action Alternatives (Dam Removal)

Removal of the dams would allow the Elwha River to erode a portion of the sediment deposited behind the dams and transport that sediment downstream. In addition, the natural sediment loading from above Lake Mills would be transported downstream. Downstream TDS and TSS would increase and bedload would move downstream raising the elevation of the river bottom. The impact, compared to the No Action alternative, is the sum of the natural load entering Lake Mills plus the additional load due to erosion of lakebed sediment minus the load historically passing the reservoirs. The impact can be measured both in terms of quantity and quality of the additional loading of dissolved and solid materials.

Potential effects over the short term (during the period of greatest erosion of sediment from the two reservoir areas) include higher turbidity, higher water temperatures, and lower dissolved oxygen concentration, resulting in increased mortality of aquatic life, fouling of existing water treatment

systems and plumbing, and water becoming generally unfit for the current beneficial uses. Increased quantities of suspended and dissolved solids in the short term would increase the costs of water treatment to remove the additional solids. Over the long term (after the greatest period of erosion of sediments from the reservoir areas), water temperature should be lower during part of the year, dissolved oxygen concentration higher, and average TDS and TSS higher than with the No Action alternative.

Changes in surface-water quality would affect instream uses and water users that use river water or ground water with a close hydraulic connection to the river. These users include Rayonier, Daishowa, and the WDFW fish rearing channel (divert water directly from the river), the Tribal fish hatchery (uses an infiltration gallery), and individuals with wells in direct contact with surface water.

With either action alternative to manage the sediment, there would be major physical changes in the river system. Some of those changes would be most intense during and immediately after dam removal and would be similar for both alternatives but would be more intense for the River Erosion alternative. Over the long term (50 years), the impacts of both action alternatives would be nearly identical. Table 3 summarizes long-term and short-term physical changes.

Table 3. Categories of Physical Change With Dam Removal

Physical Change	Time Period[†]
Possible increased iron and manganese concentrations	Short term — immediate
Increased river turbidity, suspended solids	Short term — immediate Long term — slight increase
Lowered water table in areas now supported by reservoir operations (Indian Creek delta)	Long term — immediate
Increased river aggradation (riverbed is raised) in lower valley leading to: · Raised water table · Increased flood levels in areas where aggradation occurs · Increased channel migration	Long term — build up to equilibrium

[†]Short-term is up to 5 years during and immediately following dam removal

The impact of increased TSS and TDS will depend on the method and timing of sediment releases during dam removal. Levels of suspended sediment are projected to exceed 50,000 mg/L for short periods during dam removal (Reclamation 1996). This could possibly reduce yield and degrade the water quality in the city's Ranney collector and the DCWA wells.

Fine sediments, especially during high flows and during dam removal may infiltrate the well screens of near-river wells. The increase of sediments carried downstream would promote the natural process of channel movement which may also impact near-river wells.

In the Indian Creek valley, the water table in the alluvial aquifer would be lowered when Lake Aldwell is drained. The major effect for water users will be water levels that decline below the pump settings in some wells or even below the well completion depth.

River aggradation would lead to increased flooding potential which is a water quality concern because of possible contamination of wells or other water systems and contamination of the ground water from failed septic systems. In the upper valley, from Glines Canyon Dam downstream to Highway 101, there would be increased potential for flooding and overtopping of wells located near the river. Downstream from Elwha Dam, there would be increased potential for flooding of some wellheads. In the lower delta area, the level of ground water is expected to rise due to a higher river stage as sediments are deposited raising the riverbed (aggradation) and this would increase flooding potential of individual wells. Wellhead elevations of several wells located on the flood plain are below the current 100-year flood level. Ground-water levels are already high in some areas and an increase may adversely affect septic systems and lead to contamination of the ground water.

Impacts of riverbed aggradation and flooding are generally covered in *Sediment Analysis and Modeling of the River Erosion Alternative* (Reclamation, 1996d) and *Elwha River Restoration Study: Flooding Impacts Associated with Removal of the Elwha and Glines Canyons Dams* (Corps, 1995). Discussion of these effects in this report are limited to the effect on septic systems and contamination of the ground water. Water quality effects on fish and other aquatic life are addressed in the Elwha Fish Restoration Plan and not further addressed in this report.

PHYSICAL CHANGES

Surface Water Quality

Critical impact indicators for surface water quality have been identified. Current values for these indicators have been measured and are projected to remain unchanged with the No Action alternative. However, some values of some indicators, especially those related to fine suspended solids (TSS, turbidity, total iron, and total manganese), do not remain at a constant value and vary markedly with riverflows. Concentrations tend to be low for long periods and very high for short periods of high riverflow. This condition of high peak concentrations in response to riverflow, generally with a duration of 1–3 days, will continue into the future with, or without, dam removal. Peak concentrations will increase markedly for both action alternatives but will be greater for the River Erosion alternative. Under the No Action Alternative, fine sediment concentrations are typically less than 50 mg/L, but can exceed 1,000 mg/L during floodflows.

Table 4 lists the critical impact factors and summarizes the range of values that are expected with the No Action alternative and the two action alternatives for the short term (during and immediately after dam removal). A range of peak values for some factors is shown and those peaks could be expected to last for 1–3 days. The values between peaks would be much higher than with the No Action alternative. For example, fine suspended sediments, could be greater than 200 mg/L much of the time and more than 1,000 mg/L for many days in a row depending on the stage of dam removal. Table 5 summarizes the values of critical impact factors expected with the No Action alternative and the two action alternatives for the long term (after most sediments in Lake Mills and Lake Aldwell have eroded).

Table 4. Critical Impact Indicators of Water Quality (Short Term)

Factor	Units	Alternative		
		No Action	River Erosion	Dredge and Slurry
Time period	Years	—	1–5	1–5
Dissolved oxygen	Percent saturation	95–110	90–100	95–105
TSS (fines only)	mg/L	1–1,500	[†] 15,000–51,000	[†] 3,900–13,000
TSS	Tons/day	1.3–531	[†] 500–350,000	[†] 500–300,000
Turbidity	NTU	1–800	[†] 2,000–25,000	[†] 1,000–10,000
Total iron	µg/L	20–2,300	[†] 30,000–50,000	[†] 5,000–15,000
Total manganese	µg/L	4–210	[†] 500–10,000	[†] 50–1500
Peak temperature	°F	66	59–66	59–66
pH	None	6.7–10	5–9	6–9.5
Total organic carbon	mg/L	0–10	100–1,000	10–200

Note: These data were mostly developed from sediment modeling runs, interpolation of lakebed sediment chemical analysis, or existing STORET data (see appendix D) from the Elwha River or adjacent streams.

[†] Concentrations are expected to vary with dam removal rate and river flow. These numbers represent maximum anticipated ranges under high flow conditions as lakebed sediments erode.

Table 5. Critical Impact Indicators of Water Quality (Long Term, Natural Ambient Conditions Restored)

Factor	Units	Alternative		
		No Action	River Erosion	Dredge and Slurry
Dissolved oxygen	Percent saturation	95–110	95–110	95–110
TSS (fines only)	mg/L	[†] 15	[†] 69	[†] 69
TSS	Tons/day	[†] 51.3	[†] 761.5	[†] 761.5
Turbidity	NTU	1–800	1–1,000	1–1,000
Total iron	µg/L	20–2,300	10–5,000	10–5,000
Total manganese	µg/L	4–210	10–700	10–700
Peak temperature	°F	66	59–63	59–63
pH	none	6.7–10	6.5–8.5	6.5–8.5
Total organic carbon	mg/L	0–10	10–200	10–200

Note: These data were mostly developed from sediment modeling runs, interpolation of lakebed sediment chemical analysis, or existing STORET data (see appendix D) from the Elwha River or adjacent streams.

[†] Average concentrations are used here to simplify the comparison

With the two action alternatives, the primary impact to surface water quality would be increases in TSS and TDS as solids and dissolved minerals are released from the reservoirs by erosion and dissolution. TSS concentrations downstream will be affected by the size of the notches cut in Glines Canyon Dam, the timing of releases through the notches with respect to seasonal hydrology or natural discharge, and the erodability of the sediments. Mineralogy, grain size, and chemical content are characteristics of the sediments that will determine the overall impact to quality of the surface water. A study of lakebed sediments has provided information on the chemical composition and state of these materials (see appendix K).

There are an estimated 9.2 million cubic yards of fine sediments contained in the two reservoirs including 2.4 million cubic yards in the deltas of the reservoirs. Under the Dredge and Slurry alternative, up to 5 million cubic yards of fine lakebed sediment would be dredged from the two reservoirs and transported to the Strait through a slurry pipeline. Due to old logs and tree stumps on the reservoir bottoms and other factors, only 50–80 percent of the lakebed sediment could be dredged and none of the sediment in the deltas of the reservoirs would be dredged. Although the magnitude of impacts with the Dredge and Slurry alternative would be much less than with the River Erosion alternative, the impact would be large. Any coincident combination of weather, hydrology, and the rate of dam removal could produce brief peak turbidities of up to 51,000 mg/L with the River Erosion alternative and up to 25,000 mg/L with the Dredge and Slurry alternative. Table 6 summarizes fine sediment concentrations over the short term.

Table 6. Short Term Sediment Concentrations (Dam Removal) (mg/L)

Dam Removal Phase	River Erosion Alternative	Dredge and Slurry Alternative
Begin removal	6,700–43,000 >10,000 (0–26 days)	1,700–11,000 >5,000 (0–2 days)
Stop (during winter floods)	< 200 (20–85 days)	<200 (20–120 days)
Continue removal	5,600–11,000 >5,000 (13–33 days)	1,400–2,700 >1,000 (21–38 days)
Stop (during spring runoff)	<200 (80–100 days)	<200 (100 days)
Finish removal	15,000–51,000 >10,000 (4–25 days)	3,900–13,000 >5,000 (0–9 days)
Winter floods after removal	21,000–38,000 >10,000 (3 days)	5,300–9,400 >5,000 (1 day)

There is some evidence that the concentrations of dissolved iron and manganese could increase with the two action alternatives. Pore water in samples of fine sediments from Lake Mills was found to contain high concentrations of iron (an average of 27.5 mg/L for three samples) and manganese (an average of 4.67 mg/L for three samples). It is possible that the iron and manganese concentrations could remain elevated with additional leaching from the sediment during transport and deposition and could cause iron fouling of water delivery systems and mineral staining of fixtures and clothing.

A more likely possibility is that the iron and manganese have dissolved in the pore water as result of an oxygen poor or reducing environment. Released downstream, the dissolved iron and manganese are likely to form insoluble compounds in an oxygen environment and precipitate, adding to the TSS. Many variables, including the oxygen content of the water and the distribution and reactivity of organic matter, would control the amount of oxidation.

Ground-Water Quality

The primary impact to wells would be due to increased turbidity of the river in the short-term and the long-term. Fine sediment may settle out in the interstices of the coarse riverbed material and decrease the rate of infiltration from the river to the alluvial aquifer. This could decrease the yield of the city's Ranney collector and wells near the river. Some of the finest-sized sediment (rock flour) could be carried into the collector. Under current conditions, water samples from the Ranney collector have infrequently exceeded the 1.0 NTU maximum contaminant level (MCL), although this may be due to turbid water traveling down the outside of the collector caisson during high flow events.

During dam removal or at other times of high turbidity, the DCWA wells would probably exceed regulated turbidity levels with either action alternative.

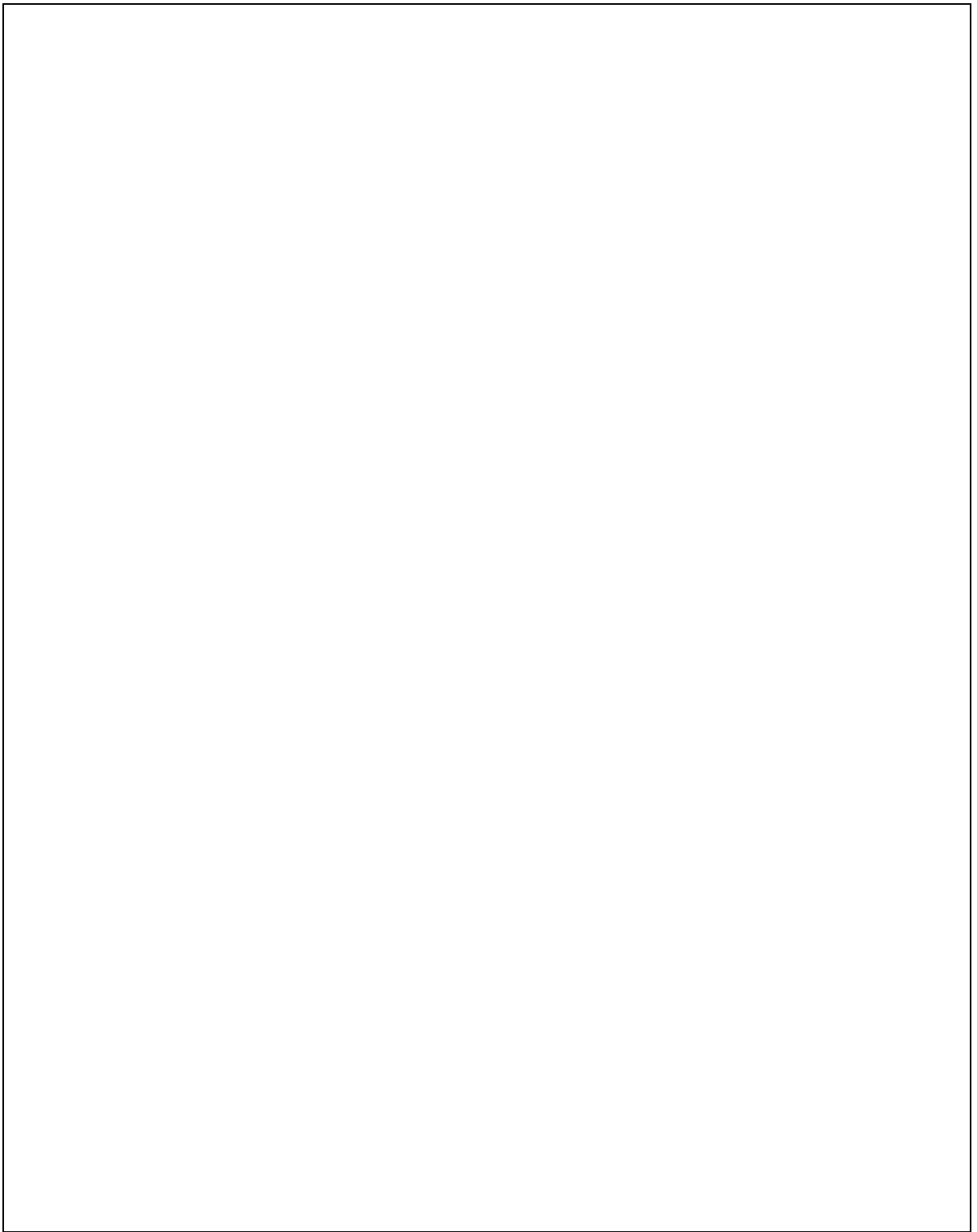
Some domestic wells located south of Highway 101 along Olympic Hot Springs Road may be subject to degraded water quality due to their close proximity to the river and shallow depths. Responses in the water-use inventory indicated that the water from these wells does not get "cloudy" during periods of high river turbidity. With the high concentration of TSS projected for the two action alternatives during dam removal, it is possible that water in these wells would begin to show some turbidity in response to river turbidity.

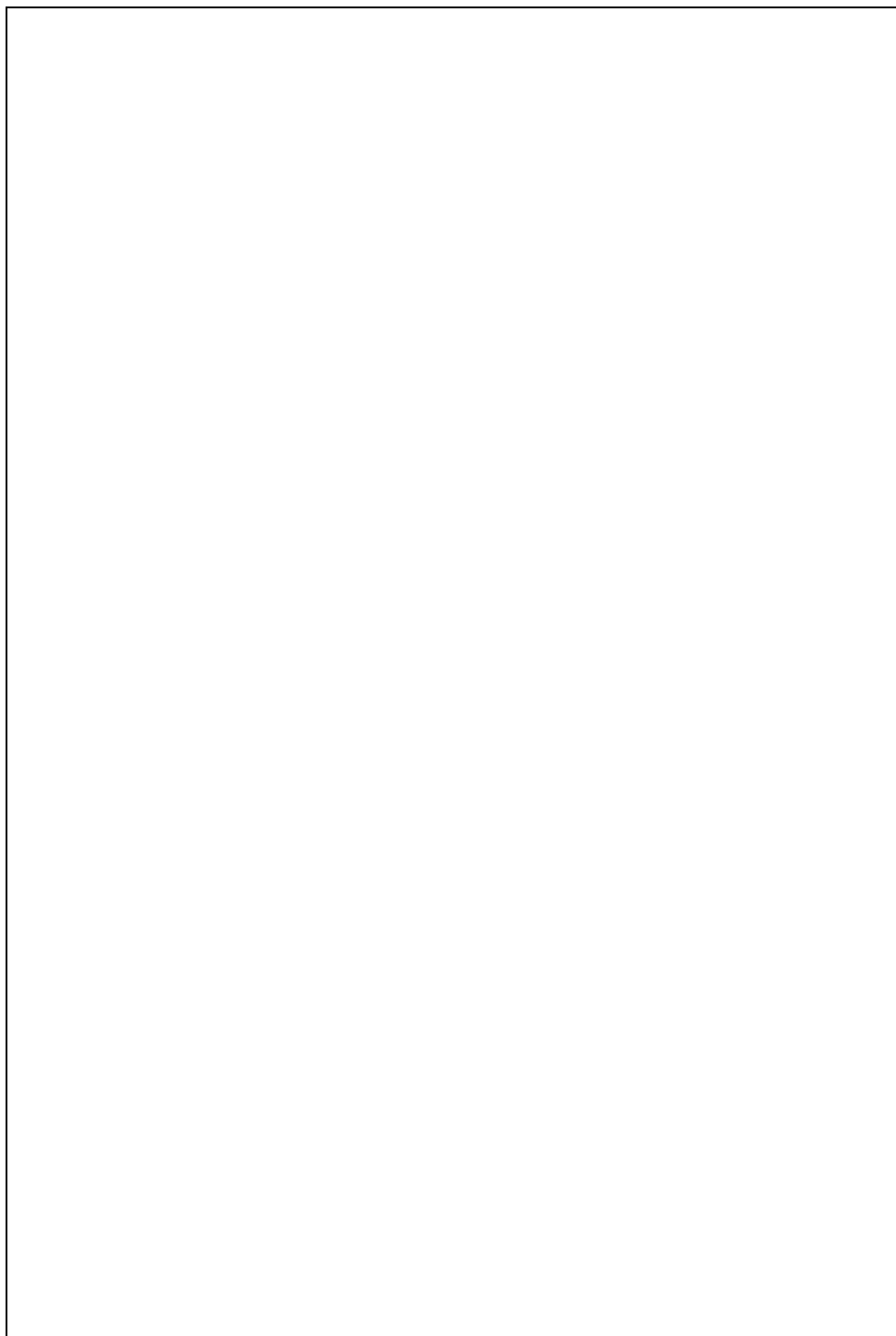
Upstream Ground-Water Elevation Decrease

Lake Aldwell supports an artificial constant head (ground-water elevation) at the east end of Indian Creek valley, near the mouth of Indian Creek. If Elwha Dam is removed and Lake Aldwell is drained, the head gradient in the valley aquifer would steepen and ground-water elevations will decline.

Downstream Riverbed Aggradation

With either action alternative, redistribution and deposition of sediment now trapped in the two reservoirs would cause the riverbed to aggrade (rise) in areas of slower streamflow. The water elevation in the lower valley would rise by 1 to 5 feet (average of 2.5 feet) over the next 50 years. Since the lower Elwha River reach loses water to the aquifer, the ground-water table would be expected to also rise. Figure 3 shows the general contour of ground water in the lower river reach at present. The elevation of ground water varies with river stage at a ratio of about 1:0.3. A 1-foot rise in river stage causes a 0.3-foot rise in the water table at the "Bosco" well, located about 1,500 feet from the river (see figure 4). A higher river stage would cause an increase in water table elevation which would affect septic systems along the lower reach.





Based on an average river stage increase of 2.5 feet, the water table would be expected to rise about 1-foot higher in the lower delta area during floods than occurs as present. As shown in figure 3, the water table is currently less than 4 feet below the ground surface in some areas. All residences in the lower delta area use on-site septic systems for sewage disposal. Clallam County requires at least a 3-foot separation between the septic system drain line and the water table. During seasonal high water levels and high tidal conditions, some conventional septic systems are probably in contact with the water table and do not meet the county separation requirement.

IMPACTS TO SPECIFIC SITES AND USERS

The impacts described in this section are those that would occur without any mitigation measures. With the mitigation measures described in the next chapter there would be no significant water quality impacts for water users.

The No Action alternative would have no impacts. Water quality, quantity, and flooding potential would remain unchanged from current conditions.

Impacts under the two action alternatives would be identical over the long term. For the short term (during and immediately after dam removal), impacts would be more intense under the River Erosion alternative.

Upper Valley Well Users

Some wells located near the river between Glines Canyon Dam and Highway 101 may experience unacceptable levels of suspended solids. Several wells near the river could be overtopped and contaminated during flood events as the riverbed rises. This includes at least 10 private domestic wells and a well at the Elwha Campground (near RM 11).

In the Indian Creek valley, some wells may experience lower water levels. At least two wells located in this area could be affected and would need to be replaced.

Dry Creek Water Association

During periods of increased turbidity, water from the DCWA wells could be expected to exceed the MCL for suspended solids. It is also possible that the yield would decrease.

City of Port Angeles Industrial Diversion

In the short term, this direct diversion from the Elwha River will undergo the large increase in TSS and total iron and manganese anticipated for the Elwha River as shown in table 4. Over the long term, the TSS would vary widely but average higher than with the No Action alternative.

The amount of suspended solids needed to be removed to meet the required water quality for the industrial processes would be so large under the River Erosion alternative as to be not achievable with current facilities. The amount of removed solids (sediments) that may be discharged from the mill

treatment plants into the environment would exceed the individual discharge permits by a large amount.

WDFW Fish Rearing Channel

The quality of surface water during and immediately after dam removal, with either action alternative, would be unacceptable for the intended use. Under the Elwha Fish Restoration Plan, the rearing channel would be closed during the period of unacceptable water quality (1–5 years with either action alternative). Other fish rearing facilities would be used for Elwha stocks during this period. The fish restoration plan assumes reactivating the channel after the river water quality returns to acceptable conditions.

City of Port Angeles (Ranney Collector)

Water quality may exceed the MCL for TSS and TDS. The action alternatives would be expected to increase deposition of sediment in the lower Elwha River and could increase the rate of channel migration near the Ranney collector.

Elwha Place Homeowners Association

If the river begins to migrate more frequently and further, the river could eventually move closer to these wells and affect the water quality.

Lower Valley and Lower Elwha Klallam Tribe

The lower valley and the Tribe will be affected by a higher ground-water table which could inundate septic systems in the lowest delta area and septic systems for a few homes on the west side of the river.

Lower Elwha Klallam Tribe Fish Hatchery Ground-Water Supply

An increase in suspended sediments in the river along with aggradation of the riverbed over the hatchery infiltration gallery is anticipated to decrease the capacity of the gallery and increase the turbidity of water delivered. The increased turbidity of the water delivered from the gallery would be unacceptable for fish hatchery requirements.

CUMULATIVE IMPACTS

There is a potential that natural erosion or landslide events upstream of Lake Mills or forest fires within the watershed could increase suspended solids and add to the effects of dam removal. These emergency situations could exceed the capability of mitigation measures.

CHAPTER IV.

MITIGATION

OVERVIEW

Mitigation measures for the two action alternatives were developed on the basis of anticipated changes in water quality and the requirements of various Federal, State, and local regulations. The Act requires protection of existing water quality and availability for municipal and industrial users and specifically mentions the city of Port Angeles, Dry Creek Water Association, and industrial users of the Elwha River. The goal of the mitigation measures is to eliminate the impacts of dam removal on water quality and availability for these and other water users.

Most impacts that result from river aggradation, such as the overtopping and contamination of wells during floods, and associated mitigation are included in a flood report (see Corps, 1995).

Expansion and renovation of the Lower Elwha Klallam Tribe's fish hatchery are described in FishPro, 1994. The water supply action and the associated costs are considered mitigation for water quality impacts.

The WDFW fish rearing channel as indicated in the previous chapter would be inactive during the greatest change in water quality. No method was identified for providing the required water quality for rearing fish at the facility during and immediately following dam removal. The use of other facilities for fish rearing is part of the Elwha River Fish Restoration Plan (National Park Service, 1996).

Potential mitigation measures were identified and evaluated. Final selection was based on cost, effectiveness, and acceptability. Measures that were not selected are briefly described in Chapter V. At this stage of planning, general concepts have been identified, measures selected, and costs estimated. Evaluations to date are sufficient to provide a cost ceiling, but specific measures will be reviewed and refined during the design and value engineering phases. This process, along with negotiations with affected entities, will likely result in some changes. In addition, some baseline data are still being collected and the results could affect the design of mitigation measures.

ACCOMPLISHMENT

The set of mitigation measures selected for implementation would meet the goal of the Act; that is, water quality and availability for users would not be diminished and could exceed current conditions. To achieve this, some mitigation measures would be permanent while others would be temporary until sediment has eroded from the reservoirs. Most measures for the two action alternatives are identical and would have identical capital costs; however, use of facilities and costs for operation, maintenance, and power (OM&P) would be less for the Dredge and Slurry alternative. Some measures, particularly those that address possible increased iron and manganese concentrations apply only to the River Erosion alternative. With the mitigation measures implemented, water users should suffer no project-related, adverse water-quality effects, and there would be no significant impact.

DESCRIPTION

Mitigation measures include a water quality monitoring program and actions to address potential adverse effects to individual wells, the DCWA supply, the city of Port Angeles industrial diversion and municipal supply, the EPHA supply, the Tribal fish hatchery supply, and rural sewage systems. Facilities associated with temporary mitigation measures are intended to mitigate short-term effects and then be declared surplus and removed for salvaged. However, served entities would be given first right to purchase and may wish to retain the facilities on a permanent basis. Mitigation measures are summarized in table 7.

Water Quality Monitoring

A water quality monitoring plan, administered by the National Park Service, would be established to measure water quality parameters for several years under either action alternative. Sampling sites would include a USGS station to be located at Goblin's Gate (about RM 15.8) just downstream from the confluence of the Elwha River and Long Creek, the historic McDonald Bridge station (RM 8.6), and a new site to be located downstream from Elwha Dam and upstream of the new infiltration gallery for the industrial diversion. Sampling frequency and selection of parameters to measure would be determined by regulatory requirements and to insure adequate data coverage prior to, during, and after dam removal.

Comparisons would be made with historic data from the McDonald Bridge station to adjust monitoring activities and between monitoring stations to determine when natural conditions have been established and the monitoring program is no longer needed. The monitoring program with the Dredge and Slurry alternative would be less extensive because most fine sediments would be removed and transported to the Strait by slurry pipeline.

Individual Wells

Point-of-entry sediment filter units would be installed at 10 residential wells. A total of 15 replacement filters with a filter limit of 10 microns would be provided for each well. In addition, each residence would be provided with a water cooler and 30 gallons (six 5-gallon bottles) of bottled water per month for drinking and cooking, if needed.

The well and water use inventory conducted during the summer of 1994, had a response rate of about 40 percent, so there may be additional well users who would be affected by dam removal. One Elwha River water user did not draw water from a well but filled containers from the river for home use. In addition, several respondents noted plans to drill a well within 1–2 years. To account for possible additional impacts, a contingency fund is included to mitigate impacts that may be identified in the future.

New Wells

At least two new wells in the Indian Creek valley would be provided to replace wells that go dry as the level of the ground water drops in the area above Lake Aldwell. The new wells would be 6 inches in diameter, probably 200 feet deep, and include a submersible pump and the necessary piping, valves, and electrical equipment.

Table 7. Mitigation Measures

Mitigation Measure	Impacts Mitigated	Alternative [†]
Water quality monitoring program	Changes in water quality	RE, D&S
Individual wells		
Supply temporary in-line sediment filter and bottled water to residences with wells adjacent to river upstream of Highway 101 bridge	Increased turbidity; possible increase of iron and manganese in well water	RE
Drill new wells or deepen existing wells in Indian Creek valley	Lowered ground-water level	RE, D&S
Contingency fund for unidentified wells	Impacts to unidentified wells	RE, D&S
Dry Creek Water Association		
Construct new Ranney collector [‡] , pumping plant, and pipeline	Increased turbidity; possible increase of iron and manganese in well water	RE, D&S
Install temporary filter system [‡]	Possible increase of iron and manganese	RE, D&S
Install MIOX or comparable disinfectant system	Replacement of system on current wells	RE, D&S
City of Port Angeles domestic supply		
Construct new Ranney collector [‡]	Possible decreased yield from existing Ranney collector	RE, D&S
Install temporary filter system [‡]	Possible increase of iron and manganese	RE
City of Port Angeles industrial supply		
Construct infiltration gallery and temporary pretreatment facilities.	Increased turbidity; possible increase of iron and manganese	RE, D&S
Elwha Place Homeowners Association		
Construct temporary water filter system	Increased turbidity	RE
Lower Elwha Klallam Tribe		
Modify about 10 conventional septic systems to mound systems with lift stations	Potential contamination of ground water as level rises	RE, D&S
Tribal fish hatchery		
Upgrade existing infiltration gallery, restore existing wells, construct new infiltration gallery, drill two wells, add aeration facilities	Increased turbidity of water supply	RE, D&S

[†] RE = River Erosion; D&S = Dredge and Slurry

[‡] Ranney collector and temporary filter system shared by DCWA and the city of Port Angeles

DCWA Water Supply

The existing wells of the DCWA would be abandoned, and water would be supplied to the DCWA distribution system from the new Ranney collector. A pipeline and pumping system would be constructed from the temporary filtration plant to terminate near the existing DCWA well field. A mixed oxidant (MIOX) or comparable disinfection system for treatment of water would be provided and connected at the DCWA end of the supply pipe.

City of Port Angeles Municipal Supply System

A Ranney collector would be constructed on the west bank of the river, slightly upstream from the existing diversion dam. (The site is shown on drawing 1440-D-164 in appendix L.) The new collector would be constructed with the same capacity as the existing collector (10 mgd) and would be positioned so that possible future changes in the river course would not simultaneously impact both collectors. The discharge line from the new collector would be joined to the discharge line of the existing collector and lead to a new temporary filtration plant. Water for the city would be disinfected using the existing chlorination facility after it leaves the proposed filter plant.

A building would be constructed, and a package in-line filtration plant meeting the requirements of the State of Washington and EPA's Surface Water Treatment Rule would be installed. The treatment plant would eliminate objectionable taste, appearance, and precipitation problems associated with possible sediment, iron, and manganese concentrations. Filtration would also meet EPA standards for the *cryptosporidium* and *giardia lamblia* in the public water supply. Used filters would be disposed of at a local landfill site.

DCWA and the city of Port Angeles would hold joint ownership, subject to negotiations, of the new Ranney collector. DCWA would transfer its existing water rights and the city would transfer a portion of its water rights to the new point of withdrawal.

City of Port Angeles Industrial Diversion

The most costly and extensive mitigation measures modify the existing industrial diversion to reduce suspended solids concentrations to current levels. These include a new infiltration gallery to replace the existing surface water diversion, and temporary facilities to precipitate suspended solids and move the accumulated sediments to the river (see the series of drawings in appendix L).

The infiltration gallery would be composed of a lateral pipe system, a concrete carrier pipe, a pumping plant, a concrete discharge pipe, and a vertical riser structure that connects to the existing supply tunnel. The treatment facilities would consist of a series of sequential chambers for rapid mix of chemicals, flocculation of the mixture, settling the coagulated particles, and collecting and flushing the accumulated sediment to the river. Accessory facilities would include a building for chemical storage and pumps, piping, and related equipment to measure flow and add chemicals.

Lateral Pipe Infiltration Gallery

The infiltration gallery design provides a capacity of 300 cfs (twice the diversion right) with pumping to provide a safety factor in the event that infiltration rates are reduced during operation due to clogging from sediment deposition. It would be located in the riverbed upstream from the existing diversion dam. The system includes eight “L” shaped laterals of solid pipe buried in the riverbed and connected to a concrete carrier pipe that parallels the river on the left bank. The long leg of each lateral, which would vary from 8 inches in diameter at the upstream end to 32 inches in diameter at the downstream end, would be parallel to river flow. Arrayed perpendicular to the lateral, 16 on each side, would be 32 collector pipes, each 35 feet long. The perforated pipes are designed for free, or near-free flow, to maximize the hydraulic head and minimize the length of perforated pipe required.

Risers (vertical pipes extending above the ground) with blind flanges would be provided for backflushing each lateral collection system. Each lateral would have a sediment trap for removal of heavier sediments that may enter during periods of high sediment concentration in the river. A butterfly valve with a manual actuator would be provided between the sediment trap and the vertical riser to isolate the lateral for backflushing. A butterfly valve downstream from the sediment trap would have a motorized actuator to control flow in the lateral. Sediment traps at the end of each lateral would provide operators with information on sand passage through each lateral. If final designs include a single large sediment trap instead of eight smaller ones, the opportunity to identify problems in specific laterals would be lost.

An option that could be added to the system is placement of saddle meters in each lateral pipe and a control system installed at the pumping plant that would read the meters and adjust the control valves in the laterals to maintain a uniform water surface in the pump sump. This option is not included in the cost estimates.

Concrete Carrier Pipe

A concrete carrier pipe to collect water from the eight infiltration gallery laterals would be buried along the left bank of the river from the upper lateral and terminate at the intake to the pumping plant. The size of the carrier pipe would increase from 36 inches in diameter at the upper end to 72 inches in diameter near the end of the lateral collection system.

Pumping Plant

A pumping plant with four 30-cfs pumps and two 15-cfs pumps (total capacity of 150 cfs) would be constructed at the downstream end of the infiltration gallery carrier pipe. An additional pump for backup and maintenance periods would not be included as the full 150 cfs is seldom diverted and there are sufficient periods when pump maintenance can be performed without interruption of service. Failure of any single pump would not be expected to interrupt service while awaiting repairs or replacement.

The discharge line from each pump would be equipped with a check valve to eliminate backflow when the unit shuts down, and each discharge line would be equipped with a guard valve to isolate its pump. The current design locates the motors within the pumping plant on a slab at elevation 60 feet because the desirable location of the pump discharge valves and manifolding is below the required water

surface elevation at the tunnel inlet. Placing the pump motors in this position, rather than on the top slab of the structure at elevation 80 feet, is more aesthetically pleasing and should decrease vandalism at this remote location. Equipment would be protected from 100-year flood events.

The 30-cfs pumps would have 75 horsepower motors and the 15-cfs pumps would have 40 horsepower motors operating on 460 volts. Electrical service would be provided by the 12.5 kilovolt power line which crosses the Elwha River near the pumping plant site. A switchyard and transformer for the pumping plant would be located near the connection to the power line and would also service the proposed Ranney collector pumps. An engine generator with a capacity of about 450 kilowatts, placed in the switch yard, could supply power to the pumping plant and the Ranney collector pumps during power outages.

An option described in chapter V under “Infiltration Gallery Design” is to provide a by-pass to the pumping plant and increase the size of the discharge pipe. With this option, gravity flow would be sufficient to meet the water supply needs of the two mills after the water treatment facilities are removed. The cost of this option is not included in the project cost estimates.

Concrete Discharge Pipe

A 54-inch-diameter concrete discharge pipeline that passes under the Elwha River would convey water from the pumping plant to a vertical riser structure on the opposite side of the river. The top of the pipeline would be a minimum of 5 feet below the surface of the riverbed.

Vertical Riser Structure

A vertical riser structure would be constructed at the downstream end of the concrete discharge pipe to connect to the existing tunnel entrance.

Access Road

An access road would be constructed from the existing road, between the one-lane bridge and a house near the river, to the pumping plant and the sediment traps. About 1,000 feet of the new road, leading from the existing road to the pumping plant, would be elevated to provide access during floods; construction would include culverts to pass flows through existing flood channels. The remaining 1,500 feet of new road, leading to the sediment traps and backflushing system, would be constructed at the existing ground surface level. About 1,000 feet of the existing connector road would be improved.

Temporary Pump Stations

Two temporary pump stations would be required to maintain deliveries to the mills during construction of the treatment facility and the infiltration gallery. The first site would be used for 13 months during construction of the treatment facility, and the second site would be used for eight months during subsequent construction of the infiltration gallery. The temporary pump station would consist of a lined sump excavated in the river, a platform, three 30-cfs pumps and one 15-cfs pump (all would eventually be installed in the permanent pumping plant). A screening system would be placed on all sides of the platform to keep fish out of the pumps and to protect the pumps from trash. About 600 feet of corrugated metal pipe (30-inch diameter for the larger pumps and 21-inch diameter

for the small pump) would be used as discharge lines between the pump station and the mill diversion. Temporary power lines would be constructed from the newly constructed switchyard adjacent to the new infiltration gallery.

Treatment Facilities (General)

The treatment facilities would be constructed in the general location of the existing 1,900-foot-long open channel between the upwell structure and the industrial pipeline inlet and would consist of parallel chambers to provide 100 percent redundancy. As soon as one side is constructed and tested, it could be placed in operation. The design provides a maximum flow of about 100 cfs (65 mgd) and unattended operation. Redundant treatment units would provide sufficient capacity to allow regular maintenance and emergency repair without jeopardizing the water quality or quantity delivered to the mills. Grated walkways and handrails for equipment access and safety would be provided along the water basins.

Storage Building

A building for chemical storage and feed equipment would be constructed near the existing residences at the WDFW fish rearing channel and provide on-site storage of at least a 30-day supply of chemicals. Piping for injection of chemicals would be buried and lead from this building to the rapid-mix unit. This building may also include space to house offices, a laboratory, and data collection/process control.

Rapid-mix Units

An ultrasonic flow meter would be located at the existing upwell structure to measure the flow rate using a constant-head orifice system.

Two rapid-mix units (one active and one spare) would be constructed next to and connected to the existing upwell structure. Each unit would be square with reinforced concrete sides 35 feet long and a total volume about 6,000 cubic feet to provide a water detention time of at least 1 minute.

Flocculation Units

Two flocculation basins sharing a common wall would be constructed just downstream from the rapid mix units. Each basin would be about 5 feet high, 45 feet wide, and 535 feet long with a total capacity of 120,000 cubic feet. The basins would provide a minimum water retention time of 20 minutes and have a flow-through velocity of less than 1 foot per minute.

Sedimentation Basins

Two parallel sedimentation basins, with a 20-foot-wide access road between the two basins, would be constructed just downstream from the flocculation basins. Each sedimentation basin would be 5 feet high and about 1,330 feet long and lined with high-density polyethylene on compacted soil. Each channel would have a trapezoidal cross section with side slopes of 3:1, a bottom width of 10 feet, and a water-surface width of about 52 feet. The water detention time would be about 35 minutes. Tube settlers would direct sediment deposition to the center of each channel, and a pumping system would

move the accumulated sediment to the river. At the end of each sedimentation channel, a concrete trough would route the treated water to the existing channel upstream of the screenhouse.

An option is to replace the synthetic liner with a layer of clay, if an abundant source is available locally and provides an acceptable seepage rate. Another option is to construct the sediment basins of concrete and use vertical walls.

Flow of Water

From the existing upwell structure, water would enter a rapid-mix basin through an 8- by 5-foot gate. Flow would leave the basin by passing over a 35-foot-long weir. Water velocity into the rapid-mix units would be 2.5 feet per second.

After passing over the weir, the water would flow through an 8- by 5-foot concrete trough 15 feet long and leading to an 8- by 5-foot flocculation basin entrance gate. The trough would also contain an 8- by 5-foot slide gate to direct flow to either flocculation basin. Inside, the flocculation basin flow would slow to 0.5–1.5 feet per second. Water flow out of the flocculation basin would be controlled by a 14- by 5-foot gate, set to control the outlet velocity at 1.5 feet per second.

From the flocculation basin, water would flow through a 10-foot-wide, 7-foot-high, 55-foot-long trough under the road and through the entrance gate (10 feet wide by 7 feet high) for the sedimentation basin. Flow through the sedimentation tank would slow to 0.5 feet per second. At the end of the sedimentation basin, water would be skimmed from the surface into sixteen 100-foot-long troughs. Each trough would be two sided and contain V-notched weirs for a total of about 3,200 feet of overflow weir. The plastic effluent troughs would discharge into the existing channel which would be widened to receive flow from the sedimentation basins.

EPHA Wells

The wellheads and pump house would be modified and a temporary in-line filter system for sediment and iron and manganese would be installed.

Lower Elwha Klallam Tribe Septic Systems

Ten conventional septic systems were identified that would fail to meet county requirements for separation between septic drain lines and the water table as the result of a water table rise associated with dam removal. Each of these 10 conventional septic systems would be replaced with a mounded disposal system and lift station.

Lower Klallam Tribe Fish Hatchery

The fish hatchery would be modified and expanded as generally discussed by FishPro (1994). Water supply facilities include upgrading the two existing hatchery wells, providing two new wells, and upgrading and extending the existing infiltration gallery. Water aeration facilities would be included, and meters, valves, and pipelines would be replaced as needed. Each existing well would be video inspected and re-developed to restore the original specific capacity. Pumps would be tested to

determine wear and the need for replacement. The two new wells would be located west of the levee in the river flood plain between RM 0.5 and 1.0.

During dam removal, the wells would supply dilution water (when needed) and cool, pathogen-free water to the incubation ponds and intermediate rearing units of the expanded hatchery. At times, the water supply could consist of 10 parts ground water to 1 part of surface water to provide a concentration of fines of less than 500 mg/L, an acceptable level for fish for short periods of time. The maximum rate of water use for the expanded plant is a flow of 3,775 gpm from ground water and a flow of 8,000 gpm from surface water, a total of nearly 12,000 gpm. Currently, about 2,000 gpm are pumped from ground water and 4,000 gpm are supplied from the existing infiltration gallery, a total of 6,000 gpm.

There are concerns that the expanded use of ground water could lead to over pumping of the aquifer and intrusion of salt water. Several ground-water investigation reports describe the local aquifer conditions and limitations (USGS, 1977; Dames and Moore, 1989; GeoEngineers, 1994). To prevent saltwater intrusion and ensure a sustainable supply, Dames and Moore concluded that 3,600 gpm can be safely pumped or up to 4,500 gpm can be pumped for short periods (durations of 60 days or less, once a year) from the entire lower valley. This compares with the proposed rate of 5,835 gpm for all uses including individual homes, two community wells, and the new fish hatchery usage and exceeds the safe yield from the aquifer. However, the Dames and Moore flow rates do not take into account additional recharge from the river. Hydraulic continuity with the river and induced recharge to the aquifer by pumping from near-river wells would help to prevent saltwater intrusion and interference with existing wells in the area.

GeoEngineers proposed to locate the new production wells near the river and to complete them within a deep (more than 75 to 100 feet) “semi-confined” unit to limit continuity with the river. They suggest that continuity with the river be limited so that the pumped ground water remains at the optimum temperature and pathogen-free for use in the incubation ponds.

The confining layer described by Dames and Moore and referred to by GeoEngineers does not appear to be laterally continuous throughout the area. A test well drilled at the hatchery in 1976, during the USGS study, is “unconfined” and is located within a few hundred feet of a “semi-confined” well. The lower river valley is composed of sediment of deltaic origin. Delta deposits usually vary in composition and character due to the variable energy levels of the depositional environment. Many wells in the lower river valley report thin layers of clay interspersed throughout the alluvial sand and gravel. Locally, the clay layers can create semi-confining conditions where they inhibit the vertical movement of water. However, the confining beds do not appear to be laterally continuous or extensive throughout the lower valley. The new production wells may not encounter a confining bed to prevent hydraulic connection to the river.

GeoEngineers recommended that an 8-inch test well and one or two small-diameter observation wells be drilled initially on the flood plain. The wells would be tested to determine the percentage of the pumping rate that is contributed by the river and the effect of the pumping on nearby wells. A ground-water sample would be taken after several hours of pumping and analyzed to determine if the desired temperature and water quality parameters would be maintained.

CONSTRUCTION OF FACILITIES

Facilities for individual wells and mounded septic systems would be completed in less than 1 year. The municipal, industrial, and fish hatchery facilities would be completed over a 3-year period and be in operation prior to dam removal.

City of Port Angeles Industrial Facilities

The first activity would be construction of a temporary pumping plant to ensure a continuous water supply.

Construction of the treatment facilities would begin at the downstream end of the facilities, by the sedimentation basin. This would allow installation of the effluent troughs, weirs, and tube settlers while the rapid-mix and flocculation basins with associated troughs and gates are also being constructed. As soon as one side is fully tested, the temporary pumps and corrugated metal pipe can be relocated and the second pretreatment side can be constructed.

Construction of the gallery piping would require installing a sheet-pile cofferdam and dewatering system around the entire eight-lateral piping system. Because of the short time frame of low river flow (4 to 4½ months), the entire construction area would be dewatered to maximize the efficiency of construction activities. As soon as the area is dewatered, construction activities would include removing and stockpiling the coarse armored layer of the riverbed, excavating for the infiltration gallery piping; installing the graded gravel, piping, valves, and sediment traps; backfilling; replacing the armored layer; and removing the dewatering system and the sheet pile cofferdam. Special care would be needed to avoid disturbing the riffle area downstream from the gallery during construction. Construction of the pumping plant would require dewatering, as would construction of the discharge line and vertical riser structure. The discharge line would need to be constructed in two phases, as the entire river cannot be blocked. Because of the short construction period, the portion of the discharge line that passes under the river and the vertical riser structure must be constructed concurrently with the infiltration gallery pipe.

The temporary pump station at site 1 would be in place and operational before the tunnel diversion is shut down for construction of the treatment facility (see drawing 1440-D-164 in appendix L).

The treatment facilities would be operational before the temporary pump station at site 2 (see drawing 1440-D-164) is put into operation to allow removal of the existing rock diversion dam and construction of the lower end of the discharge line and the vertical riser structure. When all construction is complete and the infiltration gallery is ready to go into service, water can be supplied to the mills from both the temporary pumping station and the permanent pumping plant. This would be accomplished by moving the pumps in sequence from the temporary pumping station to the permanent pumping plant.

The sump and the H-pile supports for the platform of the permanent pumping plant would be constructed during the low flow period.

All facilities would be constructed under one contract. The rationale is that one contractor would be responsible for all equipment, for coordination between the various segments, and for the overall schedule.

City of Port Angeles Municipal Diversion and DCWA Facilities

The new Ranney collector and the temporary filter plant could be constructed at any time of the year. The Ranney collector discharge line would be constructed concurrently with the industrial supply infiltration gallery discharge line to minimize in-river construction. It is possible that the construction of the Ranney collector, filter plant, pumps, and supply line for DCWA could be included in a single contract.

Lower Elwha Klallam Tribe Fish Hatchery

Water supply facilities for the fish hatchery would be completed as described by FishPro (1994).

OPERATION, MAINTENANCE, AND POWER

Some facilities would immediately become the property of the owners while other facilities would be maintained and operated as project facilities during the period when TSS and TDS due to dam removal are high — 1 to 5 years for both action alternatives. Operation as project facilities means that OM&P costs (with some exceptions) would be absorbed by the Federal Government as mitigation during the period when TSS and TDS are high due to dam removal.

New Wells and Septic Systems

New wells and the new mounded sewage treatment systems would become the property of the landowners who would be responsible for operation and maintenance.

Well Filters and Bottled Water

Filters for individual wells and the EPHA wells and bottled water for individual well owners would be provided only with the River Erosion alternative. These could be maintained by individual owners or by a contractor. Bottled water deliveries would be provided by a contractor. These mitigation measures would be continued during the 1- to 5-year period of need caused by higher levels of TDS and TSS. At the conclusion of this period, expendable supplies would no longer be provided and arrangements would be made to return systems to their original conditions or possibly leave the filters in place if desired by the individual well owners.

DCWA

The MIOX disinfection system, the water supply pipeline, and the DCWA interest in the Ranney collector would be maintained and operated as a project facility. It is anticipated that training would be supplied to DCWA personnel who would operate the MIOX system as a project facility. Power for operation of the booster pumps for the water supply line would be a project cost, but costs to operate the new Ranney collector would be a responsibility of DCWA and the city (see city municipal diversion below for operation of other facilities). At the conclusion of the project operation period,

the MIOX disinfection system would be considered surplus. DCWA would have first right to purchase.

City of Port Angeles Industrial Diversion

The infiltration gallery and water treatment facilities would be operated and maintained by a contractor as a project facility. At the end of the operating period, the title to the infiltration gallery would be transferred to the city of Port Angeles and the water treatment facilities would be declared surplus and removed.

City of Port Angeles Municipal Diversion

The new Ranney collector and the temporary filtration plant would be operated as project facilities, and project power would be supplied to operate the temporary filtration plant. Actual operation of the new Ranney collector would be contracted to the city. Operation of the temporary filter plant and the DCWA booster pumps would be by contract; possibly with the city. The filter plant is not included in the Dredge and Slurry alternative. Additional negotiation will be required to determine relationships and rights of the city and DCWA.

Fish Hatchery

The new water supply facilities for the fish hatchery would be operated by the Tribe.

COSTS

Construction Costs

Construction cost estimates in this report are based on an April 1995 price level and include contingencies and indirect costs. Also included in the total construction cost are design of facilities and construction management.

The total construction cost of the measures selected to mitigate water quality is estimated at \$31,015,000 for the River Erosion alternative and \$27,895,000 for the Dredge and Slurry alternative. Not included in this total is the cost for water quality monitoring. The amount of the monitoring program that can be attributed to water quality is \$1,000,000 for the River Erosion alternative and \$650,000 for the Dredge and Slurry alternative. Construction costs are summarized in table 8 and detailed cost sheets are provided in appendix M.

Table 8. Summary of Construction Costs[†]

Item	Alternative	
	River Erosion	Slurry Pipeline
Water quality monitoring program (including USGS) [‡]	\$1,000,000	\$650,000
Individuals Wells		
Temporary in-line filtration and bottled water	(see OM&P costs)	\$0
Install new wells	\$36,000	\$36,000
Contingency fund for all private wells	\$150,000	\$150,000
Dry Creek Water Association (280 gpm)		
Connect to new Ranney collector	(see Port Angeles M&I)	\$200,000
Filter plant	(see Port Angeles M&I)	
MIOX disinfection system	\$30,000	\$30,000
Port Angeles industrial supply		
Infiltration gallery & diversion modifications	\$10,768,000	\$10,768,000
Open channel pre-industrial treatment	\$5,732,000	\$5,732,000
Port Angeles municipal supply		
New Ranney well (also serves DCWA)	\$5,204,000	\$5,204,000
Filtration plant (also serves DCWA)	\$2,730,000	\$0
Elwha Place Homeowners Association (180 gpm)		
Temporary in-line treatment system (rental/year)	\$60,000	\$0
Lower Elwha Klallam Tribe		
Mound sewage treatment system	\$162,000	\$162,000
Water supply for fish hatchery	\$2,138,000	\$1,938,000
Field cost	\$27,010,000	\$24,220,000
Engineering design	\$1,645,000	\$1,515,000
Construction management	\$2,360,000	\$2,160,000
Total construction cost	\$31,015,000	\$27,895,000

[†] April 1995 price level

[‡] Monitoring is considered to be a separate program and not included in the field cost for water quality mitigation.

Note: Further refinement of costs during the final design process can be expected to reduce costs as design constraints are narrowed and contingencies are reduced accordingly. Application of value engineering procedures have the potential to further reduce costs. It is unlikely that costs would increase due to some unforeseen element.

OM&P Costs

OM&P costs include all costs to operate project facilities during the project operation period of 1 to 5 years for either action alternative. Because of the short operating period, replacement was not considered and no replacement costs were included. Power costs are based on current rates to users. The total cost for OM&P during the project operation period is estimated at \$3,400,000 for the River Erosion alternative and \$1,204,000 for the Dredge and Slurry alternative. These are summarized in table 9 and additional detail is provided in appendix M.

Table 9. Total Operation, Maintenance, and Power Costs

Item	Alternative	
	River Erosion	Dredge and Slurry
Individual Wells		
In-line filters, and bottled water	\$37,000	\$0
Dry Creek Water Association		
MIOX disinfection	\$30,000	\$30,000
Other (see Port Angeles municipal supply)		
Port Angeles industrial supply		
Industrial water treatment	\$2,014,000	\$927,000
Infiltration gallery pumping plant	\$237,000	\$237,000
Port Angeles municipal supply		
Increment cost for new Ranney collector [†]	\$10,000	\$10,000
Port Angeles/DCWA filter plant and DCWA booster pump	\$995,000	\$0
Elwha Place Homeowners Association	\$77,000	\$0
Lower Elwha Klallam Tribe		
Mound sewage treatment systems	\$0	\$0
Fish hatchery	([‡])	([‡])
Total operation, maintenance, and power cost	\$3,400,000	\$1,204,000

[†] Incremental OM&P costs for the new Ranney collector are relatively minor since most costs relate to water flow.

[‡] Incremental OM&P costs for new fish facilities are covered by the existing hatchery budget funded by the Bureau of Indian Affairs.

ENVIRONMENTAL IMPACTS

Implementation of the following mitigation measures would have environmental impacts ranging from below detectable levels to minor. These are the water quality monitoring program, well filters and bottled water for individual well owners, and temporary in-line treatment system for the EPA. The major impact would be a slight increase in road traffic due to installation and maintenance of

facilities. Environmental impacts for drilling new wells would be slight and limited to the construction period.

Environmental effects of the new Ranney collector and associated facilities to connect to the Port Angeles municipal supply and the DCWA would be slight and limited primarily to the construction period. If constructed at the same time as new facilities for the industrial water supply, the incremental construction impacts would be minor.

Impacts for construction of a new water supply for the Tribal fish hatchery would be minor and limited to the construction period but would require instream work and careful timing to limit potential construction impacts to aquatic organisms. Noise and increased traffic at the site would be of limited duration.

The major impacts of mitigation measures is associated with construction and operation of facilities for the industrial water supply to the Daishowa and Rayonier mills.

Impacts on the main roads approaching the site would be significant. The increased construction traffic, both in terms of type and volume, would necessitate working with County and local planning entities to ensure roads and highways are safe and maintained in good condition throughout the construction period. The paved road leading to the WDFW fish rearing channel and the river would require improvements for safety during construction and for permanent use after the project.

Noise and visual impacts would be limited primarily to construction traffic and the construction site during the construction period. After the construction is completed there would be negligible impacts.

The sediment model indicates that there would be about 825 days of clear water (historic levels of TSS) and 394 days of elevated levels of TSS in the 3 year and 4 month-period modeled for the action alternatives. Treatment of the water would involve adding polymer suspensions that include petroleum distillates. Sediments that are generated would include those chemicals along with the natural fine sediments suspended in the water. For the River Erosion alternative, treatment of 65 mgd at the industrial diversion would generate an estimated 550,000 cubic yards of sediments with 20-percent solids (see appendix R). This assumes that the infiltration gallery would reduce water turbidity by 77 percent.⁴ The weight of fines and added water-treatment chemicals in the sediments would be about 102,000 tons dry and would occupy about 551,000 cubic yards (at 20 percent solids and a specific gravity of the solids of 1.1). This amounts to about 450 cubic yards per day over a 3.3-year period at a pumping rate of 20 gpm. The Dredge and Slurry alternative would result in about 20 percent of the sediments produced with the River Erosion alternative.

In actual operation, the rate of sediment accumulation would vary with the concentration of suspended solids in the river water which would be expected to increase with flow rate. As a result, the rate of sediment removal would also increase with river flow and the amount of suspended solids carried by the river. The sediments would be pumped from the bottom of the sedimentation basins to a holding area and then pumped about 300 feet to a point near the middle of the river cross section.

⁴ Whatman number 40 filter paper, a laboratory standard for estimating the effect of a slow sand filter, was found to reduce the turbidity of a 30,000 parts per million suspension of lake sediment by 75 percent.

River flow in the reach where the sediments would be added is estimated to be a minimum of 500 cfs (224,400 gpm). At a sediment flow of about 20 gpm, the dilution rate would be so great that addition of sediments would not significantly change the water quality of the river and, in most cases, would not be measurable. As river flows increase and suspended sediment concentration increases, the rate of pumping of accumulated sediment could increase with no measurable affect on water quality. At the dilutions envisioned, it is anticipated that the chemicals added in the treatment process would have little if any significant or measurable affect on water quality or aquatic organisms.

CHAPTER V.

MITIGATION CONSIDERATIONS

FORMULATION STEPS

The first step in identifying potential mitigation measures is to identify the specific water quality factors that would be affected. Major changes with either action alternative in the short term were identified as increased concentrations of suspended and dissolved solids including inorganic and organic compounds. There would also be some change in the pH, temperature, and concentration of dissolved oxygen. Physical and chemical analyses of sediments from Lake Mills (see appendix K) indicate that a large percentage of the sediments are clay- and silt-sized and that dissolved iron and manganese exist in high concentrations in the pore water of lakebed sediment.

Although extensive modeling has been accomplished, it is difficult to predict the exact pattern of sediment release as it would be directly related to the timing of dam-removal activities, precipitation/river flow, and erodability of lakebed sediment. Sediment release during dam removal would be monitored and demolition activities could be adjusted to limit riverbed aggradation and possibly TSS levels.

Suspended solids are expected to be the primary problem for industrial water users. The smaller particles would be colloidal rock flour and a portion could be expected to enter infiltration galleries. These particles could also enter some wells located near the river, but probably at a much lower rate than at infiltration galleries.

Iron and manganese may adversely affect some downstream water users. Adverse effects include bad taste, colored water, stains from iron and/or manganese, and accumulation of minerals in water supply facilities. High concentrations could interfere with some chemical reactions in industrial processes. Actual concentrations of iron and manganese in waters released during dam removal would be a function of flows and other factors.

The rise in the water table that will accompany aggradation of the lower river reaches may also have an effect on water quality.

The second step in identifying potential mitigation is to determine the level of water quality to be met. The goal of the Act is that the quality of the delivered water remain unchanged from that with the dams operating. Since the historic levels of TSS and TDS have varied widely and operations are expected to be costly, some type of accounting system is needed.

The third step is to identify and evaluate measures that would meet the goal in an effective and acceptable manner and at the least cost. Identifying and evaluating measures for individual well owners and septic systems in the lower valley was generally straightforward. Potential flooding effects related to river aggradation have been generally addressed in other technical documents. In addition, the Elwha Fish Restoration Plan (National Park Service, 1996) addresses expansion and renovation of the Tribal fish hatchery, rearing fish at other facilities, and closure of the WDFW fish

rearing channel for the short term. As a result, most of the identification and evaluation phase focused on the city of Port Angeles industrial water supply and the municipal supplies for the city and the DCWA.

Identification and selection of mitigation methods were based on project research, experience, engineering judgement, laboratory tests, and comparisons of cost effectiveness. Best case to worst case estimates of effects were developed and various increments and combinations of measures were developed to provide a range of options.

Mitigation measures not selected for implementation were dropped for one or more of the following reasons: (1) another option was equally effective and less costly; (2) the option was considered infeasible for some physical reason, (3) the option was found not to be needed; or (4) the option was likely unacceptable because of local concerns.

TREATED WATER OBJECTIVE

Prior to the design of water treatment facilities, the baseline conditions and desired level of treatment were established. These standards are vital to minimizing treatment costs and to avoiding possible claims of degraded water quality. The general decision for formulation purposes was that treated water during the short term should be of the same quality as in the past. For domestic use this poses little problem as the quality of water obtained from most wells has remained fairly constant.

For the industrial diversion, the major difficulty is that the concentration of suspended solids varies widely over time. Both Rayonier and Daishowa have filter plants which use chemical addition (alum and polymer), flocculation, and filtration to remove undesirable sediment and turbidity. These existing facilities provide a low level of TSS (less than 5 mg/L) for the pulping process. The level of treatment is adjusted as necessary to achieve the required water quality.

Achieving water quality mitigation with a zero balance — no adverse effect and no benefit to the user compared with the historic water quality — is difficult, but two methods were identified. The method selected requires an accounting system to deliver the historic average water quality to the mills. The second method requires estimating natural turbidity levels based on streamflow to deliver the water quality that would have resulted in the absence of dam removal.

Historic Average Turbidity

The selected approach consists of accounting yearly turbidity values using a baseline of 11 years. The objective with this approach is to provide water to the mills with a turbidity statistically equivalent to the prior 11-year average. If this method is implemented, concurrence from the WDOE, the city of Port Angeles, and the two mills would be obtained prior to dam removal.

Turbidity readings from the new gauge at RM 16.2 (time delayed for travel) would be used to set the target turbidity level to be reached by treatment for daily and hourly operation. Real-time gauging station measurements, telemetry, and landline data communication to the automated controls at the pre-treatment site would be employed, and the data communications and process control responses would be remotely monitored. The actual target turbidity for treated water would be turbidity

measured at the upstream gauge minus the historic reductions attributable to operation of Lake Mills and Lake Aldwell. The historic reduction is calculated by comparing the measurements from the gauge with equivalent mill and city river turbidity measurements for the period of record prior to initiation of dam removal. A turbidimeter would record the turbidity of the effluent from the treatment plant and would be used as a check on the measured mill turbidities.

The operating goal would be to deliver treated water that has an average turbidity between the highest annual average and the lowest annual average of a 10-year baseline. Average turbidity of delivered water over semi-annual periods would be calculated. If this calculation indicates that the treated water is outside the goal, the level of treatment during the next period would be adjusted to move the average turbidity back toward the center. After the second semi-annual period, a running average would be maintained.

Turbidity-Flow Equations

An alternate approach is to define the mathematical relationship between turbidity and riverflow and use that relationship for treatment of water. This approach is not recommended at present because the relationship cannot be fully described. If this approach were to be selected, additional research would be needed to develop equations for high flow events that follow in close sequence, to account for other factors such as precipitation, wildfire, and landslides, and to develop algorithms for water treatment.

Scatter graphs of flow and turbidity at the mill diversion were prepared and are included as appendix N. Values above 50 NTU and 10,000 cfs, although valid, were omitted from the graphs to use a scale that better shows relationships.

This analysis indicates that there is a fairly predictable relationship between flow and turbidity when flows are 2,000 cfs or less. At higher flows, turbidity tends to increase with flows but fluctuates widely. Three of many discrete high-flow events were graphed for analysis and are included as appendix O. During these high-flow events, flow increases but turbidity lags, flow peaks and begins to decline but turbidity continues to increase, and, as flow continues to decrease, turbidity decreases. In these events, the flow peaks rapidly but subsides at a much lower rate.

When the river flow is neither rapidly rising nor falling, much of the data can be reasonably accommodated by the following equation:

$$T = 0.7 - (5.31 \times 10^{-5}Q) + (2.19 \times 10^{-6}Q^2)$$

where:

T is turbidity in NTU

Q is river flow in cfs.

During changing flows, a two-part equation defining the relationship between Elwha River flow and turbidity was found. During a rising flow event the equation is:

$$T = 0.7 - (5.09 \times 10^{-5} Q) + (4.13 \times 10^{-7}Q^2)$$

and during a falling flow, immediately preceded by a fairly steady flow, the equation is:

$$T = 0.7 - (1.48 \times 10^{-7} Q) + (5.49 \times 10^{-6} Q^2)$$

INFILTRATION GALLERY DESIGN

An infiltration gallery for the industrial diversion was selected on the basis that this measure would eliminate fish passage problems at the existing diversion dam and would greatly decrease sediment concentrations in the diverted water. In the short term, this decrease would reduce the cost for chemical treatment during the project operation period and in the long term would eliminate the need for chemical treatment to achieve current levels of suspended sediment.

The Elwha River sub-base material basically consists of clean sands and gravel below the present armored layer, so it is possible to replace the existing diversion structure with an infiltration gallery. The infiltration gallery must deliver a diversion of at least 100 cfs during the dam removal period and 150 cfs afterwards, with sufficient head to meet the required water surface elevation of 62.0 feet at the existing intake to the 72-inch-diameter industrial supply pipeline. A critical element in the design of the infiltration gallery is the head loss anticipated with treatment facilities. This head loss was estimated at 3.7 feet for treating a water delivery of 100 cfs to the industrial mills.

Preliminary Design

A preliminary design used three perforated pipes, each about 1,800 feet long, buried in the river bed with a spacing of 25 feet and parallel to the river centerline. Cleaning accumulated sediments from the long pipelines would be difficult and possibly impractical. Failure of a pipeline would result in a loss of one-third of the capacity. This design was dropped in favor of the design discussed in chapter IV which includes eight laterals and provisions to isolate and clean each lateral in case of blockage.

Gravity Flow Potential

The infiltration gallery design selected for implementation provides a 100 percent safety factor (delivery capacity twice that of maximum demand) based on pumping to meet the required flow of 100 cfs with temporary treatment facilities in place and 150 cfs after the temporary treatment facilities are removed. A pumping design, which does not allow for gravity flow, was selected because gravity flow operation with the treatment facilities in place appeared unlikely based on the physical constraints of the site.

After removal of the treatment facilities, operation with gravity flow is possible. Modification of the current design to allow gravity flow at that time may be desirable to eliminate OM&P costs associated with the pumping plant. Construction of a bypass around the pumps would allow a maximum discharge by gravity flow of about 79 cfs when using all 8 laterals; not enough to meet the demand.

An option would be to replace the 54-inch-diameter discharge pipeline with a 72-inch-diameter pipeline and construct a 72-inch-diameter pipeline to bypass the pumping plant. The bypass pipeline would include two 72-inch-diameter butterfly valves with motor operators. This option could provide a flow of 164 cfs when using all 8 laterals. This would provide virtually no safety factor for the total diversion requirement of 150 cfs with the WDFW fish rearing channel in operation and abandonment of the pumping plant at that time would be unacceptable from a design viewpoint. However, if operation of the WDFW fish rearing channel is discontinued in the future, the safety

factor would be 64 percent for a demand of 100 cfs. This safety factor with gravity flow is less than the current pumping design of 100 percent but may be acceptable.

Table 10 summarizes hydraulic data and table 11 summarizes the incremental cost for modification to allow gravity flow.

Table 10. Port Angeles Industrial Supply Infiltration Gallery Flow

Number of laterals	Hydraulic Head		Maximum Discharge Potential
	First Lateral	Last Lateral	
Current design — 54-inch-diameter pipe discharge pipe			
4	1.9 feet	1.3 feet	27.3 cfs
8	2.6 feet	2.0 feet	78.6 cfs
Modification — 72-inch-diameter discharge pipe and bypass around pumping plant			
4	4.4 feet	3.8 feet	70.1 cfs
8	5.1	4.5 feet	164.0 cfs

Table 11. Incremental Field Costs to Modify Infiltration Gallery for Gravity Flow

Item	Cost
Increase pipe from 54-inch to 72-inch diameter	\$71,500
Earthwork for increased pipeline size	\$22,500
Bypass pipe (72-inch diameter)	\$40,000
Earthwork for bypass pipe	\$24,000
Steel “Y” (2 in bypass)	\$15,000
Butterfly valves (2) (72-inch diameter with motor operators)	\$80,000
Mobilization	\$12,700
Unlisted items (10 percent)	\$26,300
Contingencies (20 percent)	58,000
Field cost	\$350,000

WATER TREATMENT

The only viable means of treating large volumes of water to remove fine sediment, especially colloidal-size particles, is with chemicals that cause coagulation and precipitation. The effectiveness of various chemicals was evaluated by jar tests in a laboratory. These tests used a 30,000 parts per

million (ppm) suspension of sediment obtained from Lake Mills and various flocculants. A target turbidity for treated water was set at 11 NTU.

The tests found that alum or lime treatment alone would be ineffective and that treatment with a polymer at a concentration of 15 to 20 ppm, or at a lower concentration with alum or lime, is effective. Flocculated material settled relatively rapidly (3 to 30 minutes) as would be required for use in an industrial water diversion. A polymer alone would be effective in reducing the water turbidity anticipated during and immediately following dam removal to historic levels. Results of specific jar tests are included in appendix P.

The flocculant used in the jar testing equipment, Cytec Magnifloc® 1906N (CAS 064742-47-8)⁵ is a nonionic polyacrylamide in water-in-oil emulsion using a petroleum distillate of hydrotreated light kerosene. If alum (CAS 10043-01-3) is utilized in the water treatment system, even under low river flow conditions, the small amounts of alum or polymer in the sediments is not expected to impact the river water quality to a harmful degree. River water quality downstream from the sediments outfall would be monitored for dissolved oxygen, nitrates, nitrites, sulfates, total and dissolved aluminum, alkalinity, pH, and bacteria to verify these predictions.

Alternate coagulants that have been considered to date are Nalco Nalclean® 8181, and Betz Polymer 2651 and Polymer 2189. Additional information on these is included in appendix Q.

Appendix R includes information on anticipated sediment concentrations and approximate dosages of alum and polymer. Suspended sediment concentrations are based on conditions found during June 1989 to September 1992, a period of high sediment concentration. Reclamation staff estimate average dosages of 5 mg/L of alum and 7 mg/L of polymer (a total of 12 mg/L of chemicals) would be needed to meet the water quality requirements of the mills. The amounts of chemical needed and costs in appendix R are based on the River Erosion alternative. The total amount of chemical used with the Dredge and Slurry alternative would be about 20 percent of that used for the River Erosion alternative.

Design and Operation of Facilities

Where applicable, all treatment units are designed to meet the rules and regulations of the WDH. Facilities have been designed to minimize impacts to the surrounding area.

Complete (100 percent) redundancy of all units is provided. Standard water treatment criteria adopted by most states were used in the designs for velocity control, and baffle plates were included in the rapid-mix and flocculation tanks to assure flow distribution across the cross-sectional area.

Ultrasonic flow meters were chosen because they do not require long lengths of pipe to achieve accurate results as do some propeller-type meters, and magnetic meters do not perform well at the anticipated high concentrations of colloids.

It was assumed that Elwha and Glines Canyon Dams would be removed in a manner which minimizes significant and sudden increases in turbidity and that the rate at which sediment leaves each reservoir area would be a function of streamflow, erodability, and the pace and timing of dam lowering. A

⁵ Chemical abstract system number of the Environmental Protection Agency

sedimentation model was used to predict potential levels of sediment in the river. This model assumed a period of 3 years and 4 months (1,219 days) and used river flows for the water years 1989–92.

Disposal of sediments by pumping to the river was selected because there is no land available for disposal near the treatment site, and off-site disposal would be costly and have an adverse impact on the community. Flocculated colloidal material would be removed from the sedimentation basins and returned to the Elwha River on a continuous basis over a period of 3 to 4 years following removal of the dams. The rate of discharge of sediments to the river would vary directly with river flow and the concentration of suspended sediments in the diverted water.

Treatment Facility Hydraulic Losses

Determining hydraulic losses of the treatment facility is necessary to assure that the water supply facilities have sufficient design capacity. The total head loss estimated for the treatment facility is 3.7 feet for a flow of 100 cfs. Incremental head losses of the treatment facility are discussed below.

Three existing slide gates, just downstream of the tunnel outlet, can be used in conjunction with the rapid-mix basin entrance gate, to form a constant head orifice measuring system. For design purposes it is assumed that the constant head orifice would be set for a head loss of 0.3 feet.

Water would pass into one of the two rapid-mix basins through an 8-foot by 5-foot slide gate (with a 0.2-foot head loss). The water then would move through the basin, flow over an adjustable weir (with a 0.9-foot head loss), and pass through an 8-foot-wide trough (with a 0.1-foot head loss) to one of the flocculation basins. The adjustable weir may be designed to be lowered to reduce head loss when the pretreatment facilities are not in use. Total head loss for the rapid-mix basin is estimated at 1.2 feet.

Water would enter the flocculation basin through an 8-foot by 5-foot gate, with a 0.2-foot head loss. At an average velocity of 0.5 feet per second, there would be no friction loss through the flocculation basins. The water would leave the flocculation basin through a 14-foot by 5-foot gate, with a 0.07-foot head loss, into a 14-foot wide trough, with a 0.03-foot head loss, which would move the water to one of two sedimentation basins. Total head loss for the flocculation basin is estimated at 0.3 feet.

Flow through the sedimentation basins would be so slow that there would be no friction loss. Water would enter the basins through a 10-foot by 7-foot gate, with a 0.07-foot head loss. At the end of the sedimentation basins, water would be skimmed from the surface into sixteen, 100-foot-long troughs. At the end of the troughs, the water would free-fall into the pool immediately upstream of the industrial diversion screen house, with a 1.8-foot head loss. Total head loss for the sedimentation basins is approximately 1.9 feet.

OPTIONS NOT SELECTED

Individual Wells

An option to providing filters at some wells and bottled water to well owners is to more extensively modify some wells to avoid the infiltration of fine solids and water with potentially high manganese and iron concentration. This measure was dropped as being too costly.

DCWA Water Supply

An alternative to connecting the DCWA system to the city of Port Angeles Ranney system is to abandon the two shallowest wells (No. 1 and No. 2); drill a new well further from the river; equip the new well and Well No. 4 with pumps and ancillary equipment; and construct a new chlorine station and filtration treatment system.

This option was eliminated as land easements and physical space for the new well and treatment system are problems that would be difficult to address and the option is not cost effective.

Industrial Water Supply

Temporary Settling Basin

This measure was identified as a possible add-on to the measures selected for implementation. The WDFW fish rearing channel would be lined with an impermeable geotextile and modified to create a large settling basin. Treated water would be diverted into a stilling well at one end, with clarified water pumped from the other end back to the open channel at the existing screen house. The additional holding time would allow chemically flocculated sediment to settle out. Settled solids would be removed and discharged along with material collected from the open channel treatment facilities.

This measure was dropped from consideration on the basis that the selected treatment measures would be effective. If additional treatment of water is needed, this measure could be implemented at an added cost.

Temporary Sand Filters

This measure is an add-on that would be an alternative to the Temporary Settling Basin. The WDFW fish rearing channel would be lined with an impermeable membrane and filled with sand and gravel. Chemically treated water from the open channel would be diverted to the modified rearing channel for treated water to percolate through the filter materials, physically removing solid particles from the water. The clarified water would be returned to the open-channel system and filtered sediment would be slurried with the open-channel material back to the river along with some of the filter sand and gravels. Periodic cleaning (backflushing) and replacement of filter materials would be required.

This option was dropped as unnecessary.

Three-day Storage

This measure would provide clear water for 3 days of operation (126 million gallons) for use during high turbidity periods as an alternative to treating water with a very high TSS concentration. A steel storage tank would be constructed to store clarified river water from the open-channel, pre-industrial treatment system. During periods of large increases in turbidity, stored water could be diverted into the delivery pipeline or blended with processed water to achieve an acceptable level of suspended solids. Water to fill the storage tank would be supplied by the excess capacity of the open-channel, pre-industrial treatment system during periods of lower TSS concentration.

This option was dropped from further consideration as ineffective. The sediment management investigation team estimated that the periods of high sediment concentration could last for weeks or months.

Permanent Treatment Plant

This measure is an alternative to the open channel, pre-industrial treatment measure selected for implementation. It includes dual-media gravity filters for rapid filtration and a clear well with low-head pumps. The dual media rapid filtration cells would be constructed downstream from the gravity settling basin. Water partially clarified in the settling basin would flow through the dual-media filters for mechanical removal of additional solids, and then move to a clear well for pumping into the industrial delivery pipeline. The gravity filters would be automatically backwashed as they become loaded with sediment. Backwash water would be returned with the settled solids to the Elwha River downstream from the existing Ranney collector. This filtration system would be remotely monitored and controlled through telemetry to minimize on-site operations. The plant would be sized for anticipated peak loads during the dam removal period. Afterwards, it would be underutilized. A permanent, all-weather access road would be needed.

This option was eliminated as too costly.

Pipeline from Upstream of Lake Mills

A pipeline would be constructed to convey water from upstream of Lake Mills to the industrial diversion. Although the water would contain much lower TSS and TDS than river water downstream, treatment facilities and treatment would still be required to meet current water quality levels.

This measure was eliminated from further consideration on the basis of high costs for installation and later removal, unacceptability of intrusion into the National Park, and potential operation and maintenance problems.

New Diversion Structure With Fish Passage

This measure is an optional diversion facility for the industrial diversion. A permanent diversion structure with fish passage and protection facilities would be constructed to continue to allow diversion of water and up and downstream movement of anadromous fish. The diversion structure could be constructed of concrete or other materials and include a movable crest to create the necessary

water surface elevation to meet industrial diversion flow requirements during low flow periods. Current criteria for fish passage and protective facilities would be used.

This measure was eliminated from further consideration as the water treatment costs would be much higher than for the selected alternative.

Well Field

A well field was considered as an alternative to the infiltration gallery. With this measure, a series of closely spaced wells would be developed along the right riverbank in the same river reach as selected for the infiltration gallery. These wells would be shallow and completed in the river alluvium to ensure a direct hydraulic connection to riverflow. The well field would include several backup wells for emergency operations and well maintenance. Water would be pumped into a common header for distribution similar to the infiltration gallery approach. Other features such as access roads, turbidity control, electrical supply, piping, and emergency generation would be similar to the infiltration gallery approach. This alternative was rejected because the costs for operation, maintenance, and power for pumping appeared greater than the selected alternative.

City of Port Angeles Municipal Water Supply

Three-Day Storage

This option would provide 21 million gallons of clear water (enough water for at least 3 days)⁶ for use during very high turbidity periods. This is an alternative to treating water with a very high concentration of TSS.

A steel tank for water storage would be constructed and used to store water. During periods of high turbidity, the stored water would be diverted to the delivery pipeline at a blending rate suitable to reach an acceptable level of turbidity.

This option was dropped from further consideration as ineffective when the sediment management investigation team estimated that periods of high sediment concentration could last for weeks or months.

Permanent Treatment Plant

This measure is an option to the iron treatment-bacteria filtration measure selected for implementation. It was formulated to address concern that fine sediments and iron and manganese would plug the zone of infiltration for Ranney collectors.

⁶ Assumes that the demand is somewhat less than the maximum daily demand. In 1992, the average daily demand was 3.8 mgd and the maximum daily demand was 8.4 mgd.

The conventional water treatment plant with a design life of 25 to 35 years would be constructed to process surface water to provide acceptable water quality for residential use. It is likely the plant would be needed for only 1 to 5 years, when the city could resume the use of the existing municipal water supply system. During operation of the water treatment plant the Ranney collector would remain idle.

This option was dropped from further consideration because plugging of the infiltration area for the Ranney collector is unlikely, the measure is not cost effective, and a site for the plant is not readily available.

Elwha Place Homeowners Association

Connection of the EPHA system to the new Ranney collector proposed for the city of Port Angeles and DCWA was considered. This option was dropped because it is more expensive than the selected alternative.

Tribal Fish Hatchery

Providing a water supply using sand filters was briefly identified as a potential. Additional treatment would still be needed to reduce suspended solids to meet hatchery requirements. The only means of treating the large amounts of water required is with chemical flocculants. However, the fish may not be able to tolerate the treated water. As a result these measures were found to be unacceptable.

Summary of Options Not Selected

Field costs of the options not selected are summarized in table 12.

Table 12. Field Costs of Mitigation Measures Not Selected
(April 1995 Price Level)

Mitigation Action or Item	Alternative	
	River Erosion	Dredge and Slurry
Individual wells		
Modify existing wells	\$70,000	\$70,000
Dry Creek Water Association (280 gpm)		
Install new wells	\$240,000	\$240,000
Permanent new treatment system	\$115,000	\$115,000
City of Port Angeles industrial supply		
Temporary settling basin	\$3,000,000	
Temporary sand filters	\$3,750,000	
Three days of water storage	\$7,000,000	
Permanent water treatment plant	\$11,250,000	
Pipeline to Elwha River above Lake Mills	\$7,100,000	
New diversion and dam and fish passage modifications	\$5,000,000	\$5,000,000
City of Port Angeles municipal supply		
Three days of water storage	\$1,000,000	
Permanent water treatment plant	\$10,500,000	
Elwha Place Homeowners Association (180 gpm)		
Connect to new Ranney well	\$300,000	\$300,000
Flood proof existing wells	\$35,000	\$35,000
Lower Elwha Klallam Tribe fish hatchery		
Sand filters	\$700,000	
Chemical flocculation and sand filter	\$850,000	
Attraction flow measures	\$700,000	

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The studies documented in this report were conducted by the *ad hoc* Water Quality Review Team consisting of Steve Bowser, team leader, Kayti Didricksen, T. R. Haider, Bob Jurenka, and Dennis Gathard. All, except Dennis Gathard, a consultant for the Lower Elwha Klallam Tribe, are Reclamation employees. All of the Reclamation team members, except Kayti Didricksen, are stationed at the Technical Service Center in Denver; Kayti Didricksen is stationed in the Pacific Northwest Region. Primary subject responsibilities are summarized in the table below.

Subject	Team Member
General ground water description and impacts to ground water	Kayti Didricksen
General surface water description and impacts to surface water	Steve Bowser
Overview of mitigation and coordination	Steve Bowser
Mitigation at the industrial diversion	Bob Jurenka and T. R. Haider
Mitigation at the municipal water system	Steve Bowser and Kayti Didricksen
Mitigation at Lower Elwha Klallam Tribe Fish Hatchery	Dennis Gathard

Reclamation Peer Reviewer: I have reviewed the document and believe it to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Reviewer: _____ Date: _____

Reclamation Team Members: I have discussed the above document and review requirements with the Peer Reviewer and believe that this review is completed, and that the document will meet the requirements of the project.

Team Member _____ Date: _____
(Steve Bowser, team leader)

Team Member _____ Date: _____
(Kayti Didricksen)

Team Member _____ Date: _____
(T. R. Haider)

Team Member _____ Date: _____
(Bob Jurenka)

