Report, Volume I of II

Spokane River and Long Lake Reservoir Use Attainability Analysis

Prepared for

Spokane River UAA Sponsoring Committee

December 2004

Prepared by

CH2MHILL

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Report

Part 1: Transmittal Letter and Executive Summary

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Transmittal Letter

Spokane River and Long Lake Reservoir Use Attainability Analysis

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December 23, 2004

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Re: (a) Spokane River Use Attainability Analysis
(b) Comments to Draft Dissolved Oxygen TMDL

Dear Ms. Hoffman and Gentlemen:

The Sponsors of the Spokane River and Long Lake Reservoir Use Attainability Analysis (Spokane River UAA) are pleased to provide Ecology with the enclosed final UAA, as well as the Sponsors' collective comments to the proposed dissolved oxygen Total Maximum Daily Load ("DO TMDL"). The Spokane River UAA has incorporated many of Ecology's comments, including adding an economic analysis section. We submit the Spokane River UAA and the proposed DO TMDL comments to you and request that Ecology (1) defer finalizing the DO TMDL; (2) adopt the Spokane River UAA by rulemaking; and (3) incorporate the Spokane River UAA's data, subcategory uses and associated criteria, and recommendations into the DO TMDL.

The Spokane River UAA contains three key components:

(a) A biological assessment of the Spokane River from the outlet of Lake Coeur d'Alene to Long Lake Dam with recommended subcategories of use for the Spokane River.

(b) A recommended implementation plan to reduce point source phosphorus discharges to the Spokane River by 95 percent and mitigation measures to achieve downstream water quality standards.

(c) An economic assessment of the affordability of the TMDL implementation plan and the affordability of the Spokane River UAA implementation plan.

Appendixes are provided that contain reference documents and supporting information. The recommendations are specific to the Spokane River within Washington State.

The biological assessment establishes that use subcategories are appropriate and will protect existing and attainable uses. The implementation plan provides a strategy to comprehensively reduce total phosphorus loading to the river through both point and nonpoint source controls and to enhance downstream surface water quality through lake aeration. Further reductions in total phosphorus loading to the Spokane River are expected through conservation and re-use measures that the Sponsors have committed to implement.

The economic assessment demonstrates that the alternatives contemplated in the pending TMDL exceed accepted standards of affordability. While the Spokane River UAA implementation plan places onerous financial requirements on the Sponsors, it falls within accepted standards of affordability. The Spokane River UAA implementation plan will improve surface water quality in the Spokane River reach from the Washington and Idaho Stateline to Long Lake Dam as well as improving downstream surface water quality.

The Sponsors prepared this Spokane River UAA in response to Ecology's development of a proposed TMDL that is based on water quality standards that were not derived from a designated use analysis as provided for under 40 CFR 131(g); Use Attainability Analysis. While Ecology has adopted use-based standards (pending approval by the U.S. Environmental Protection Agency), those standards are not, in themselves, based on designated uses specific to the Spokane River and Long Lake Reservoir. The Spokane River UAA recommends designated uses and criteria specific to the Spokane River and Long Lake Reservoir, which protects both existing and attainable uses.

We are prepared to assist Ecology in its review of this Spokane River UAA and supporting documents and the rulemaking petition that will follow. We believe that it is critical to move forward with this approach, which implements actions that are affordable, protective of existing and attainable uses and downstream surface water quality, and capable of being implemented.

If you should have any questions, please contact John Spencer, CH2M HILL, at 425-453-5000 or Jspence1@ch2m.com.

Sincerely,

Submitted on Behalf of
The Sponsors of the Spokane River UAA

By:

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c: Sponsors of the Spokane River UAA

Report

Executive Summary

Spokane River and Long Lake Reservoir Use Attainability Analysis

Prepared for

Spokane River UAA Sponsoring Committee

December 2004

Prepared by

CH2MHILL

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Abbreviations and Acronyms

°C	degrees Celsius
Avista	Avista Utilities
CFR	Code of Federal Regulations
City	City of Spokane
County	Spokane County
DO	dissolved oxygen
Ecology	Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
LTI	Limno-Tech, Inc.
mg/L	milligrams per liter
MHI	median household income
NLoT+25 percent NPS BMPs	next level of treatment combined with reasonable control of nonpoint source loads through implementation of best management practices
RM	River Mile
RO	reverse osmosis
SOD	sediment oxygen demand
Spokane River UAA	Spokane River and Long Lake Reservoir Use Attainability Analysis
Spokane Tribe	Spokane Tribe of Indians
Stateline	Washington and Idaho Stateline
TMDL	total maximum daily load
TP	total phosphorus
UAA	use attainability analysis
WDFW	Washington Department of Fish and Wildlife

1. Background

This Spokane River and Long Lake Reservoir Use Attainability Analysis (Spokane River UAA) has been prepared to define the existing and attainable uses for the Spokane River from the Washington and Idaho Stateline (Stateline; River Mile [RM] 96) to Long Lake Dam (RM 34). Federal regulations (40 Code of Federal Regulations [CFR] 131.3[g]) define a use attainability analysis (UAA) as a structured scientific assessment of the factors affecting the attainment of the use on a river-reach basis. This assessment may include physical, chemical, biological, and economic factors, as described in Section 131.10(g). Section 131.10(g) provides that a UAA is justified if the state can demonstrate that attaining the *currently designated use is not feasible* (emphasis added) because of any one of six specific factors. A designated use is non-attainable if one or more of the following conditions (as adapted from 40 CFR 131.10[g]) are satisfied:

1. Naturally occurring pollutant concentrations prevent the attainment of the use; or
2. Natural, ephemeral, intermittent, or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met; or
3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or
4. Dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or
5. Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or
6. Controls more stringent than those required by Sections 301(b) and 306 of the Clean Water Act would result in substantial and widespread economic and social impact.

The Spokane River UAA defines the existing and attainable uses for the Spokane River from the Stateline to Long Lake Dam based on factors 4 and 5 above, either of which is sufficient to result in modifying the use.

Currently designated uses for the Spokane River are based on a statewide system of categorizing rivers and lakes under a class-based system that does not include a specific assessment of the existing and attainable uses for the Spokane River.

The Clean Water Act also requires the state to prepare a total maximum daily load (TMDL) analysis and implementation plan to regulate the discharge of pollutants to meet established surface water quality standards. TMDLs are to be prepared for rivers and lakes that do not meet surface water quality standards.

If a TMDL is prepared without specifically defining existing and attainable uses for a water body, the TMDL might use inappropriate surface water quality standards and, thus, develop inappropriate pollutant loading allocations for that water body. This approach could have serious economic implications, without any corresponding environmental benefit.

2. Purpose of the Spokane River UAA

A consortium of stakeholders came together to sponsor the Spokane River UAA. The purpose of the Spokane River UAA is to evaluate surface water quality standards that are appropriate and necessary to protect existing and attainable uses of the Spokane River based on the UAA factors referred to in Section 1. The goal of the Spokane River UAA sponsors is to assure the protection of the Spokane River by achieving surface water quality standards that are both attainable and protective of existing and attainable uses.

The Spokane River UAA evaluates the biological and ecological basis for the designation of existing and attainable uses and recommends use designations and criteria appropriate to the Spokane River and Long Lake Reservoir. An in-depth assessment of information obtained from almost 300 documents was used to develop the Spokane River UAA. The document sources include state and federal environmental agencies, the Spokane Tribe of Indians (Spokane Tribe), local agencies, universities in Idaho and Washington, and Avista Utilities (Avista). (See Appendix C for a list of sources.) The source documents span studies from 1933 to 2004. Fisheries specialists, ecologists, and water resources and modeling experts evaluated this information and developed the recommendations contained in this report. (See Appendix G for the resumes of contributing authors.)

The Spokane River UAA sponsors include representatives from the following industries and municipalities in both Washington and Idaho:

- City of Spokane
- City of Spokane Valley
- Spokane County
- City of Coeur d'Alene
- City of Post Falls
- Hayden Regional Sewer District
- Liberty Lake Sewer and Water District
- Kaiser Aluminum Corporation
- Inland Empire Paper Company

3. Designated Uses, Surface Water Quality Standards, Spokane River UAA, and the TMDL

Designated uses of the river form the fundamental basis for surface water quality standards. The criteria contained in surface water quality standards are set to protect designated uses. They become the "target" standards for establishing regulatory limits on pollutant discharges (loading) to the river through the establishment of a TMDL and an implementation plan.

The Washington Department of Ecology (Ecology) is currently developing a dissolved oxygen (DO) TMDL plan for the Spokane River downstream of the Stateline Bridge (RM 96) to Long Lake Dam (RM 34; Ecology, 2004e). The TMDL will establish regulatory limits on the discharge of pollutants that contribute to the drop in DO levels below surface water quality standards. In the case of the Spokane River, the primary oxygen-consuming pollutant is phosphorus.

In the absence of specific current guidance, the Spokane River UAA has drawn from existing regulations, the Chesapeake Bay UAA, and numerous other UAAs, either adopted or underway.

The Spokane River UAA has three major elements:

- Biological Assessment and Recommendation of Designated Uses and Criteria (Part 2)
- Implementation Plan (Part 3)
- Economic Assessment (Part 4)

4. Biological Assessment and Recommendation of Designated Uses and Criteria (Part 2)

For purposes of the biological assessment, the Spokane River, beginning at the outlet of Coeur d'Alene Lake in Idaho, was divided into riverine (RM 112 to RM 58) and reservoir (RM 58 to RM 34) segments. The recommendations cover the Spokane River from the Stateline (RM 96) to Long Lake Dam (RM 34).

4.1 Spokane River (RM 112 to RM 58)

The free-flowing reach of the Spokane River between Post Falls Dam and the Stateline provides a variety of habitat types (pool, riffle, run) that support rainbow trout spawning from early April through late May or June. During this spawning period, water temperature conditions are conducive to spawning. However, spawning does not occur during the summer when elevated water temperatures preclude this use. (Since the early 1970s, elevated water temperatures [mean monthly summer temperatures greater than 20 degrees Celsius (°C) with maximum temperatures of greater than 24°C] have been recorded consistently.)

For this same reach, DO levels during the winter and spring spawning period are typically greater than 9.5 milligrams per liter (mg/L). Minimum DO levels at the Stateline during the summer low-flow months have typically ranged between 7.5 mg/L and 8.0 mg/L since the 1960s. Between Upriver Dam and Nine Mile Dam, current water temperatures reflect the influence of cooling groundwater recharge. It is likely that the higher DO levels observed in this reach relative to the Stateline area are because much of this reach is free-flowing, with increasing flows in the downstream direction.

Dams and other human activities have altered the existing uses. Reasonably foreseeable actions will not change the existence or attainability of uses in this water body. The existing uses, including those present since November 28, 1975 (the cut-off date for existing uses established by law), are the same as the attainable uses. (Uses present since November 28, 1975, even if not present today, are defined as existing uses.) Physical conditions and water temperature will continue to determine the attainable uses.

4.2 Long Lake Reservoir (RM 58 to RM 34)

Long Lake Reservoir was formed by the completion of the Long Lake Dam in 1915. The reservoir impounds water received from the Spokane River drainage basin. Based on summer volume, 69 percent of the total volume of the reservoir consists of relatively shallow water (above and including a depth of 15 meters [49 feet]). The other 31 percent of the volume contains water below depths of 15 meters (49 feet). Substrate data indicate that gravel needed to support rainbow trout spawning is quite limited (less than 1 percent) within the reservoir.

Long Lake Reservoir typically becomes thermally stratified by June, with fully developed stratification completed by mid-July. By mid-September, fall turnover typically occurs so that the reservoir becomes well mixed again for the start of the next water year.

The epilimnion in Long Lake Reservoir is the upper warm layer of water that is typically well mixed, well illuminated, and generally isothermal. The metalimnion contains the thermocline (a layer of water in which temperature declines rapidly with depth, typically defined as -1°C per meter of depth). It is the middle layer associated with the interflow that restricts the mixing of the upper and lower layers of the reservoir. The hypolimnion in Long Lake Reservoir is the bottom layer of cold water that is isolated from the upper layers.

Historical and current temperature data indicate that surface water temperatures commonly exceed the current Washington State surface water quality criterion of 20°C during the summer. During the warmest summer period, 65 percent of the reservoir maintains temperatures below 20°C. In August, during summer stratification, low DO levels (less than 5.0 mg/L) are consistently observed at depths below 22 meters (72 feet).

Long Lake Reservoir has had 89 years to form the existing flora and fauna. These biota have been subjected to changing land-use and management conditions that have affected the current biological conditions. Given the existing conditions within Long Lake Reservoir, the water quality appears to have stabilized to a mesotrophic status.

Similar to many aquatic systems, the fish abundance and health are a reflection of the reservoir's productivity and stability. The fisheries within Long Lake Reservoir have changed through time with water quality and habitat modifications and the introduction of non-native species. Long Lake Reservoir is currently managed by the Washington Department of Fish and Wildlife (WDFW) as a mixed fishery. In particular, the reservoir is managed for naturally reproducing populations of cool- and warm-water fishes as an inherited (that is, not stocked) tournament and recreational bass fishery.

Suitable conditions required by rainbow trout within Long Lake Reservoir are defined as temperatures of less than 20°C and DO levels greater than 5.0 mg/L. These suitable conditions are present within 48 percent of the volume of the reservoir during August. In comparison, 35 percent of the volume of the reservoir (within the surface epilimnion) is warmer than what most cool- and cold-water fishes prefer. The remaining 17 percent of the volume of the reservoir is more oxygen-deficient than what most fishes prefer.

Because trout spawning is unlikely, and rearing is limited in Long Lake Reservoir, WDFW stocking eliminates these from being critical life stages for the supplemented trout population. It appears very unlikely that trout would preferentially seek, or even rely on, deep water in the lower hypolimnion that is seasonally hypoxic.

4.3 Recommended Designated Uses and DO Criteria

Goals similar to those used to develop the Chesapeake Bay program (EPA, 2003b) were followed in developing recommended designated uses and DO criteria for the Spokane River and Long Lake Reservoir.

4.3.1 Spokane River (RM 96 to RM 58)

A new subcategory of use, referred to as "Spokane River Cold- and Cool-Water Mixed Fishery," should be established in Washington's surface water quality standards. This subcategory provides for:

- The protection of indigenous and non-indigenous cold- and cool-water fish species and other associated aquatic life
- Limited spawning, rearing, and migration of rainbow trout
- A more site-specific temporal application of biologically based criteria

Table ES-1 provides a summary of recommended DO criteria for the riverine reach (RM 96 to RM 58).

TABLE ES-1
Spokane River Cold- and Cool-Water Mixed Fishery (RM 96 to RM 58): Summary of Recommended DO Criteria

Geographic Area	April to May	June to September	October to March
Entire River			
1-Day Minimum Value	9.5 mg/L	6.0 mg/L	8.0 mg/L
30-DADMin Value	11.0 mg/L	8.0 mg/L	- -

DADMin = day average of the daily minimum

4.3.2 Long Lake Reservoir (RM 58 to RM 34)

A new subcategory of use, referred to as "Long Lake Reservoir Mixed Fishery," should be established in Washington's surface water quality standards. This subcategory provides for:

- The protection of indigenous and non-indigenous fish species and other associated aquatic life
- Trout rearing, which exists within this reach
- A more site-specific temporal and geographic application of biologically based criteria

This subcategory relies on a seasonal and reservoir zone application of DO criteria, which protects the most sensitive life stages of salmonids (notably, rainbow trout) when and where those life stages occur.

Similar to the Chesapeake Bay system (EPA, 2003b), recommended uses and DO criteria for Long Lake Reservoir vary depending on the location in the reservoir where different life stages and activities need to be supported.

Table ES-2 summarizes the recommended DO criteria for the Long Lake Reservoir reach (RM 58 to RM 34).

TABLE ES-2
Long Lake Reservoir Mixed Fishery (RM 58 to RM 34): Summary of Recommended DO Criteria

Geographic Area	July to September [1]	October to June
Riverine		
1-Day Minimum Value	6.0 mg/L	8.0 mg/L
30-DADMin Value	8.0 mg/L	- -
Transitional		
1-Day Minimum Value	6.0 mg/L	8.0 mg/L
30-DADMin Value	8.0 mg/L	- -
Lacustrine – Epilimnion		
1-Day Minimum Value	6.0 mg/L	8.0 mg/L
30-DADMin Value	8.0 mg/L	- -
Lacustrine – Metalimnion		
1-Day Minimum Value	6.0 mg/L	8.0 mg/L
30-DADMin Value	8.0 mg/L	- -
Lacustrine – Hypolimnion (Upper)		
1-Day Minimum Value	5.0 mg/L	8.0 mg/L
30-DADMin Value	- -	- -
Lacustrine – Hypolimnion (Lower)		
1-Day Minimum Value	Narrative [2]	8.0 mg/L
30-DADMin Value	- -	- -

[1] To protect early brown trout spawners, the recommended winter DO reservoir criterion (8.0 mg/L applied as a 1-day minimum) should also be applied within the riverine reach from mid-September (September 15) through the end of September (September 30). (The winter criterion already applies beginning on October 1.)

[2] The narrative criterion for the lower hypolimnion (expected to be less than 12 percent of the reservoir volume during August when the warmest temperatures and lowest DO levels are observed) requires sources to maximize the "suitable volume" (defined as water with temperatures below 20°C and DO levels above 5.0 mg/L). The narrative criterion also includes a long-term goal to achieve a 1-day minimum DO value of 4.0 mg/L on a spatially averaged basis. This narrative criterion will be implemented via the TMDL process, since it requires that point and nonpoint sources continue to implement controls that minimize the volume of water that falls below 5.0 mg/L. Given that low DO values have been consistently observed since the 1970s, continued improvements to benthic conditions will ensure that existing uses within the lower hypolimnion will continue to be protected.

DADMin = day average of the daily minimum

4.4 Dissolved Oxygen Saturation Considerations

The above recommendations for DO criteria do not take into account the fact that DO concentrations are a function of water temperature and elevation, in addition to the other factors already discussed at length in this Spokane River UAA report. As a result, the DO criteria shown in Tables ES-1 and ES-2 should be applicable unless barometric pressure, altitude, and water temperature conditions preclude attainment of these criteria, in which case DO levels should not be less than 90 percent saturation. A percent saturation qualifier is included in both the Idaho and Oregon surface water quality standards. Ecology has recognized the importance of this in another recent process on the Chehalis River (Ecology, 2004g).

4.5 Deficit Criterion of 0.2 mg/L Dissolved Oxygen

State surface water quality standards contain a criterion allowing for no more than a 0.2 mg/L deficit in DO from "natural or background" water quality where natural or background water quality is less than the established standard.

The outcome related to the Draft TMDL (Ecology, 2004e) is almost totally driven by Ecology's conclusion that there is no assimilative capacity in the system for point sources. Ecology reaches this conclusion because of its application of the 0.2 mg/L DO deficit criterion to Long Lake Reservoir. This Spokane River UAA report provides analyses that explain why the 0.2 mg/L DO deficit criterion should not be applied to the reservoir, which is not a natural system, and recommends that this criterion not apply to the reservoir and that Washington's surface water quality standards be amended to reflect this recommendation.

4.6 Attainable Surface Water Quality Standards

The Spokane River UAA biological assessment has shown that Ecology's current surface water quality criteria (9.5 mg/L absolute DO level and 0.2 mg/L differential DO level) cannot be met a high percentage of the time, regardless of treatment scenario, including removing the point source loads entirely from the Spokane River. On the other hand, the criteria proposed in this Spokane River UAA (protective of existing and attainable uses) can be met under most conditions, even recognizing the severity of 2001 low flows as the basis for the evaluation.

5. Implementation Plan (Part 3)

Parallel to this Spokane River UAA process, local stakeholders have been engaged in the TMDL process and have developed potential implementation strategies. For example, Spokane County and the City of Spokane jointly sponsored a one-day workshop on August 23, 2004, to evaluate advanced wastewater treatment technologies (CH2M HILL, 2004; Appendix F of the Spokane River UAA). The main objective of this workshop was to identify all proven and emerging technologies and to estimate what ranges of effluent phosphorus concentrations could be consistently and reliably achieved utilizing those technologies.

The Spokane River UAA recommends a comprehensive implementation plan to control both point and nonpoint sources of pollutants to the Spokane River. The Spokane River UAA sponsors are committed to following this implementation plan as part of a long-term program to protect existing and attainable uses and achieve downstream surface water quality standards. The heart of the plan is a commitment to implement technologies to achieve a 95 percent reduction in the point source phosphorus load to the Spokane River.

5.1 Implementation Plan Elements

Elements of the recommended Implementation Plan include the following items:

- **95 percent reduction in point source loading of phosphorus.** The Rock Creek treatment facility on the Tualatin River in Oregon (owned and operated by Clean Water Services) has been used as a representation of the best proven large-scale treatment process technology. Results from the Rock Creek treatment facility were used to estimate phosphorus removal from point sources. This removal efficiency is defined as the "next level of treatment technology." While each point source on the Spokane River might choose different treatment technologies, this reference plant has been used to set a median effluent phosphorus concentration at 0.05 mg/L. This technology typically provides a treatment efficiency of greater than 99 percent. The Spokane River UAA sponsors have proposed to implement final effluent filtration to achieve this effluent phosphorus concentration in recognition of the fact that, during much of the time, the plants will operate significantly below this concentration. (This is documented with the Clean Water Services plant on the Tualatin River and with the Upper Occoquan plant in Northern Virginia, which achieves 0.01 mg/L effluent phosphorus about 40 percent of the time.) Because some phosphorus is currently being removed by secondary treatment, the reduction in load to the river due to final effluent filtration will be about 95 percent.

- **Best proven technology**. The next level of treatment represents the best currently available, proven technology for point sources that will have any net environmental benefit on the Spokane River and Long Lake Reservoir. Improvements beyond this scenario reflect human-caused conditions that cannot be remedied. This is consistent with the conclusion from a very similar UAA process for the Chesapeake Bay (EPA, 2003b).

- **Water conservation and reuse.** The Spokane River UAA sponsors have proposed the implementation of water conservation and reuse programs that will reduce hydraulic flow and further reduce the pounds of phosphorus discharged directly to the Spokane River.
- **Contributing to the control of nonpoint sources**. The Spokane River UAA sponsors have proposed to contribute to the control of nonpoint sources, which Ecology recognizes to be the major contributor to Long Lake Reservoir DO sags (Ecology, 2004a).
- **Adaptive management strategy.** The federal Clean Water Act requires that all feasible steps be taken to achieve the highest quality water attainable. However, in watersheds where nonpoint sources are a major contributor to pollution, feasible steps may be difficult to identify and implement. This situation is particularly applicable to the bottom (lower hypolimnion) of Long Lake Reservoir. The recommendation in this Spokane River UAA requires that sources maximize the volume of water in the lower hypolimnion to DO levels above 4.0 mg/L. The extent to which this volume can be maximized depends not only on the feasible control of point and nonpoint loads to the reservoir, but also on potential changes in sediment oxygen demand (SOD) as phosphorus loads decrease.
- **On-the-ground implementation.** The concept of adaptive management as it applies to TMDL implementation allows for on-the-ground implementation to proceed where uncertainty exists about how and when reduction targets will be met.
- **Continuation of monitoring to ascertain water quality improvements**. The Spokane River UAA sponsors have proposed to continue collecting samples and analyzing the results of water quality monitoring methods.
- **Reservoir aeration.** The Spokane River UAA sponsors have conducted an initial investigation of aeration of Long Lake Reservoir. Based on this initial investigation, it appears that reservoir aeration would provide significant benefit to DO levels in the reservoir and downstream water quality. In addition, very preliminary estimates of potential costs associated with reservoir aeration suggest that it appears to be a feasible technology. Therefore, the Spokane River UAA sponsors believe that reservoir aeration should be further investigated.
- **Work with Avista**. The Spokane River UAA sponsors propose to work with Avista to incorporate Federal Energy Regulatory Commission (FERC) considerations and concerns and to implement a comprehensive workable solution.

5.2 Downstream Surface Water Quality

Currently, state and Spokane Tribe surface water quality standards for temperature and DO are not consistently being met downstream of Long Lake Reservoir (see Section 3.4 of Part 2 of the Spokane River UAA). It is important to note here that reservoir modeling by both Ecology and Limno-Tech, Inc. (LTI) has shown that Ecology's Draft TMDL (2004e) would not meet Ecology's or the Spokane Tribe's downstream DO surface water quality standards.

Amending Washington’s surface water quality standards to designate uses and criteria for Long Lake Reservoir consistent with the criteria recommended in this Spokane River UAA would not exacerbate those downstream problems. Modeling by LTI indicates that the next level of treatment combined with reasonable control of nonpoint sources (Scenario 3, the next level of treatment plus 25 percent reduction in nonpoint source loads through implementation of best management practices [NLoT+25 percent NPS BMPs] scenario) should increase DO levels in the vicinity of the Long Lake Reservoir. This improvement represents the highest attainable conditions based on feasible control of pollutant sources. If other direct improvements in Long Lake Reservoir DO levels were implemented (for example, aeration), it is likely that downstream criteria would be met. As noted above, the Spokane River UAA sponsors have conducted an initial investigation of reservoir aeration. This investigation has shown that aeration appears to be feasible and should be further evaluated.

6. Economic Assessment (Part 4)

An economic assessment was completed related to treatment alternatives proposed by the implementation plan contained in Ecology's Draft TMDL (2004e) and treatment alternatives recommended in the Implementation Plan of the Spokane River UAA (Part 3). Using order-of-magnitude cost estimates, this assessment is an initial determination of the affordability of three treatment alternatives. Costs are presented in this assessment only for upgrades to the City of Spokane (City) plant and for the costs to build the new Spokane County (County) regional treatment plant. References to total phosphorus (TP) removed are for all point source discharges to the river.

The marginal costs of phosphorus removal and DO improvement for each alternative were assessed. The sensitivity of the City's and the County's residential sewer rates to the capital cost of each alternative was also assessed. Other factors such as unemployment rates, local government financial capacity, and budget strength were also assessed.

The alternatives evaluated were:

- Implementation of final filtration for point source phosphorus reduction to achieve a 95 percent reduction in total point source loading to the Spokane River
- Land application of municipal wastewater in an agricultural operation
- Implementation of reverse osmosis (RO) technology to achieve 99 percent reduction in municipal phosphorus loads

The capital costs are shown in Table ES-3.

TABLE ES-3
Capital Cost Estimates for Proposed Facilities for the City of Spokane and Spokane County (2004$)

	City of Spokane			Spokane County[4,5]		
Costs	**Final Filtration**[1]	**Land Application**[2]	**Reverse Osmosis**[3]	**Final Filtration**	**Land Application**	**Reverse Osmosis**
Capital	$57.0 million	$404.7 million	$558.7 million	$108.1 million	$161.6 million	$190.9 million

Capital costs represent estimated expenditures by the City and County. They are not adjusted for the allocation of costs between the City and County for that portion of the City Reclamation Plant that Spokane County will pay.

Footnotes:

[1] CH2M HILL, 2004c (Appendix E3).
[2] CH2M HILL, 2004a (Appendix E1).
[3] CH2M HILL, 2004b (Appendix E2).
[4] HDR Engineering, Inc., 2004 (Appendix E4).
[5] Capital costs provided by Bruce Rawls, Spokane County Utilities Director. These capital costs are for an 8 million gallons per day (MGD) plant and include, for the land application and RO alternatives, costs for a facility plan amendment and an environmental assessment.

6.1 Household Cost Impact

The first level of measurement analyzed a household's ability to pay. This is measured by the annual household's sewer cost as a percentage of median household income (MHI) and is referred to as the residential indicator. Other measures included an examination of unemployment rates, poverty levels, and the financial capacity of the City and the County.

Residential indicators were calculated for the City and the County for each of the treatment alternatives. Under EPA guidelines, a residential indicator of:

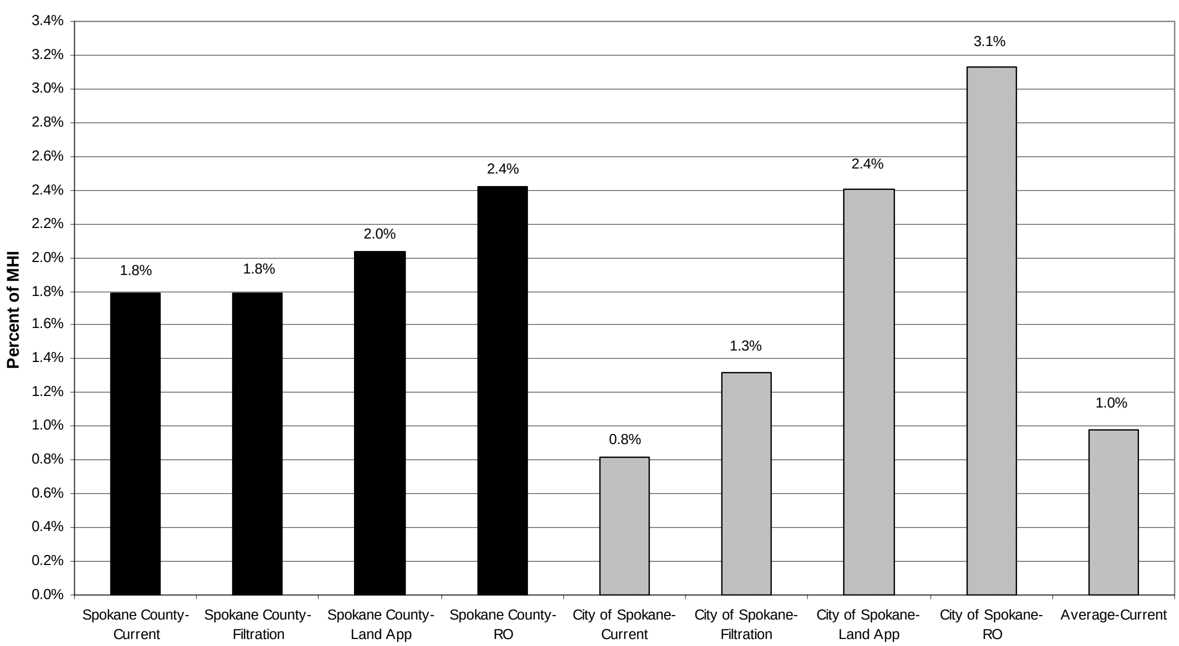
- Less than 1.0 percent of MHI is considered a low financial impact
- Between 1.0 and 2.0 percent of MHI is considered a mid-range financial impact
- Greater than 2 percent of MHI is considered a high financial impact

Ecology, by comparison, defines financial hardship as when the financial indicator for an individual community is greater than 1.5 percent of MHI (Ecology, 2004i).

Currently, the City and the County have residential indicators of 0.8 percent and 1.8 percent, respectively. At their current levels, the existing sewer rates for the City are considered to be within the affordable range. Under Ecology's guideline (2004i), the County would currently meet the criterion for financial hardship based on its residential indicator.

Implementation of the alternatives results in the following household cost impact based on the residential indictor (Figure ES-1).

FIGURE ES-1
Annual Average Sewer Bill as a Percent of MHI (Residential Indicator) after Implementation of Proposed Alternatives



The City's residential indicator increases from 0.8 percent under current conditions to 2.4 percent under the land application alternative and 3.1 percent under the RO alternative. The County's residential indicator increases from 1.8 percent under current conditions to 2.0 percent under the land application alternative and 2.4 percent under the RO alternative.

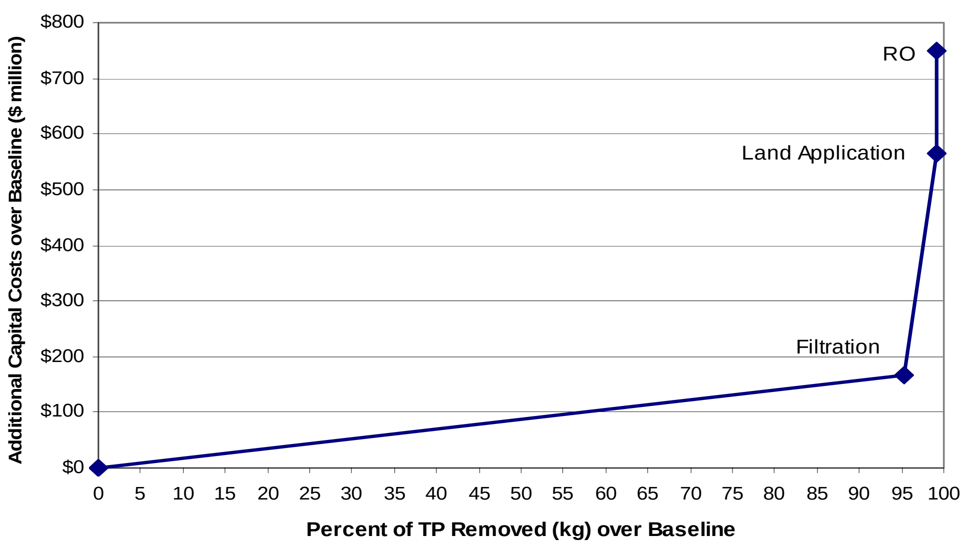
In other words, based on the residential indicator, neither the City nor the County can affordably implement either the land application alternative or the RO alternative. Further refinement of this assessment would not appear to produce any different outcomes.

6.2 Efficiency of the Treatment Alternatives

The economic assessment evaluated the efficiency of the alternatives based on the cost of removing additional amounts of phosphorus for each treatment alternative. Filtration is expected to remove approximately 95 percent of the TP at a capital cost of $165 million. Land application and RO would have capital costs of $566 million and $750 million, respectively, and would remove 99 percent of TP from the Spokane River.

Figure ES-2 illustrates the decreasing efficiency in reducing TP beyond the 95 percent removal level.

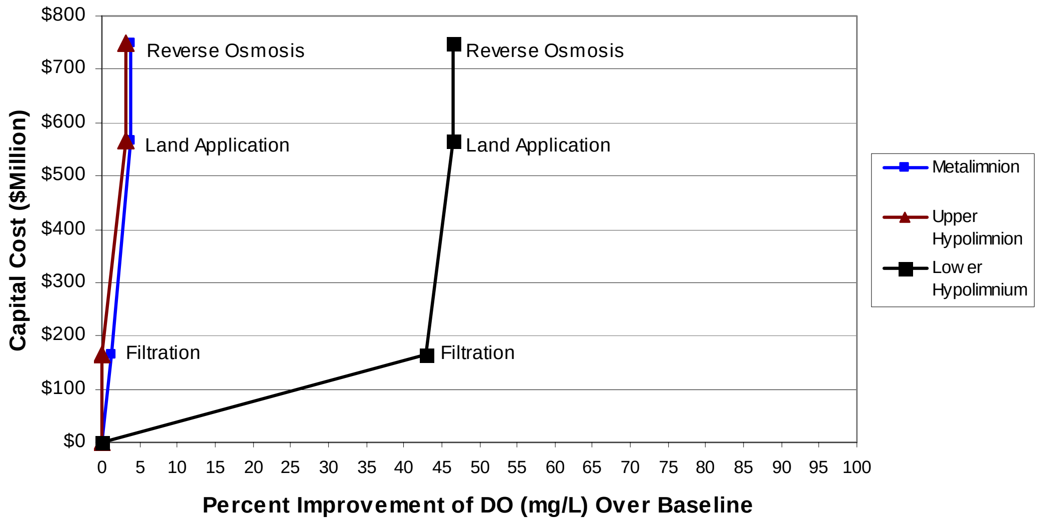
FIGURE ES-2
Percent of Total Phosphorus Removed from the Spokane River over Baseline Conditions



Note: The capital cost of the land application alternative could range from $566 million to $688 million, depending on whether leaching of salts would be permitted. This assessment has used the lower range of these estimates to demonstrate the impact of these capital costs on sewer rates and median household income.

A similar assessment was performed for increasing levels of DO achieved for each treatment alternative (see Figure ES-3). The percent improvement of DO over baseline for each alternative was evaluated. The capital cost for each alternative was included to indicate the efficiency of each alternative. For example, the metalimnion zone in Long Lake Reservoir experienced improved levels of DO under the filtration and land application/RO alternatives of 1 percent and 4 percent, respectively.

FIGURE ES-3
Percent Improvement of Dissolved Oxygen over Baseline by Alternative



Note: The capital cost of the land application alternative could range from $566 to $688 million, depending on whether leaching of salts would be permitted. This assessment has used the lower range of these estimates to demonstrate the impact of these capital costs on sewer rates and median household income.

The assessment of DO improvements shows that point source reductions beyond 95 percent removal of TP do not significantly increase DO levels in the reservoir. Nonpoint, internal recirculation, and natural sources of TP are the dominating factors related to existing DO levels. Even if 100 percent of TP removal was achieved via any of the proposed alternatives, the DO levels in the reservoir would still not meet the Washington surface water quality standard of 8.0 mg/L proposed by Ecology (2004e). In addition, neither the land application alternative nor the RO alternative would significantly improve the DO levels beyond filtration technologies.

It would be an inefficient use of public resources to require the City and the County to spend the additional hundreds of millions of dollars to implement land application or RO facilities while not achieving significant marginal benefits over the least-cost alternative. In addition, land application of effluent would likely cause a decrease in summer river flows and could potentially reduce the DO levels in the reservoir.

6.3 Economic Assessment Conclusions

The following conclusions can be derived from the economic assessment:

- The final filtration, land application, and RO alternatives achieve nearly the same results in DO improvement in Long Lake Reservoir, indicating that other sources (including nonpoint and natural sources) are significant contributors to current levels of DO.

- The land application and RO alternatives cost considerably more than the final filtration alternative and place a high financial burden on the ratepayers of the City, the County, and other dischargers, exceeding accepted measures of affordability.
- The land application alternative is not significantly more effective in mitigating DO, yet it is far more expensive than final filtration.
- Implementing either the land application alternative or the RO alternative would not be an effective or efficient use of resources.

7. Spokane River UAA Conclusions

The Spokane River UAA demonstrates that establishing subcategories of uses and criteria specific to the Spokane River, which are protective of existing and attainable uses, can be achieved with the next level of treatment and reasonable levels of nonpoint source control. Therefore, the Spokane River uses subcategories and criteria associated with those uses should be designated through amendment of Washington's surface water quality standards set forth at WAC 173-201A-600, Table 600 and WAC 172-201A-602, Table 602.

The Spokane River UAA implementation plan is an affordable plan and achieves appropriate levels of protection of existing and affordable uses, even under the severe 2001 year low-flow conditions.

The Spokane River UAA implementation plan provides for the improvement of water quality downstream. Initial investigations of aeration in the reservoir suggest that aeration, when used in conjunction with filtration, could provide significant benefits to the DO levels in the reservoir and should be investigated further.

Report

Part 2: Biological Assessment and Recommendations

Spokane River and Long Lake Reservoir Use Attainability Analysis

Prepared for

Spokane River UAA Sponsoring Committee

December 2004

Prepared by

CH2MHILL

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Abbreviations and Acronyms

°C	degrees Celsius
µg/L	micrograms per liter
Advisory Committee	Spokane River UAA Advisory Committee
aMW	average megawatts
Avista	Avista Utilities
Baseline	Refers to CE-QUAL-W2 model run—LTI's Scenario 1 and Ecology's CURRENT run
BMP	best management practice
BOD	biochemical oxygen demand
BOD5	biochemical oxygen demand after five days
CBOD	carbonaceous biochemical oxygen demand
CE-QUAL-W2	Spokane River CE-QUAL-W2 water quality modeling application
CFR	Code of Federal Regulations
cfs	cubic feet per second
CIP	Capital Improvement Program
CSO	Combined Sewer Overflow
CURRENT	Ecology's baseline CE-QUAL-W2 model scenario reflecting calibration for 2001 drought conditions
CWB	Cold water biota
DADMax	day average of the daily maximum
DADMin	day average of the daily minimum
DEQ	Department of Environmental Quality
DO	dissolved oxygen
Draft TMDL	Draft Total Maximum Daily Load to Restore and Maintain Dissolved Oxygen in the Spokane River and Lake Spokane (Long Lake) (Ecology, 2004e)
Ecology	Washington Department of Ecology

Effluent Treatment	Ecology's CURRENT CE-QUAL-W2 model scenario except that effluent quality was improved for all dischargers so that total phosphorus was 0.020 mg/L, ammonia was 0.1 mg/L, and CBOD was 2.0 mg/L
EPA	U.S. Environmental Protection Agency
ESP	Earth Systems and Parametrix
FERC	Federal Energy Regulatory Commission
Flow Augmentation	Ecology's CURRENT CE-QUAL-W2 model scenario with minimum flow altered so that it never dropped below 745 cfs through September at the Post Falls gage
FPA	Federal Power Act
HDI	Hardin-Davis Inc.
HDR	HDR Engineering
HED	hydroelectric development
IBI	Index of Biotic Integrity
IDAPA	Idaho Administrative Procedures Act
IDEQ	Idaho Department of Environmental Quality
IDFG	Idaho Department of Fish and Game
km	kilometer
km^2	square kilometer
LTI	Limno-Tech, Inc.
mg/kg	milligrams per /kilogram
mg/L	milligrams per liter
mgd	million gallons per day
mm	millimeters
MOD	Modified cold or warm water biota
MW	megawatts
NAS	National Academy of Sciences
New Scen 4	LTI CE-QUAL-W2 model Scenario 4, but with City of Spokane effluent flows set to zero
NHC	Northwest Hydraulic Consultants, Inc.
NLoT	Next level of treatment (LTI's CE-QUAL-W2 model Scenario 2)

NLoT+25 percent NPS BMPs	Next level of treatment plus 25 percent reduction in nonpoint source loads through implementation of best management practices (LTI's CE-QUAL-W2 model Scenario 3)
NMFS	National Marine Fisheries Service
NO-POINT	Ecology's CURRENT CE-QUAL-W2 model scenario without point source loads (flows retained and concentrations set to groundwater levels)
NO-POINT WA&ID	Ecology's CE-QUAL-W2 model scenario where Idaho point source loads were also removed using the uncalibrated Idaho model and point source flows were retained in the run
NO-SOURCE	Ecology's CURRENT CE-QUAL-W2 model scenario without point source loads (flows retained and concentrations set to groundwater levels), tributaries, and upstream boundary conditions set at background conditions
NPDES	National Pollutant Discharge Elimination System
OAR	Oregon Administrative Rule
ODEQ	Oregon Department of Environmental Quality
pers. comm.	personal communication
PM&Es	protection, mitigation, and enhancement measures
PERMIT	Ecology's CURRENT CE-QUAL-W2 model scenario with point source loads increased to current permit limit levels
Pollutant Loading Assessment	Spokane River and Lake Spokane (Long Lake) Pollutant Loading Assessment for Protecting Dissolved Oxygen (2004a)
PS = 0 Concentration	Point source pollutant concentrations set to zero (LTI's CE-QUAL-W2 model Scenario 4)
PSSA	Priority Sewer Service Area
RI/FS	Remedial Investigation and Feasibility Study
RM	River Mile
RMS	root mean square
RPWRF	Riverside Park Water Reclamation Facility
SAWTP	City of Spokane's Advanced Wastewater Treatment Plant
Scen 1	Scenario 1
Scen 2	Scenario 2
Scen 3	Scenario 3

Scenario 1	LTI's CE-QUAL-W2 model Baseline scenario
Scenario 2	LTI's CE-QUAL-W2 model next level of treatment (NLoT) scenario
Scenario 3	LTI's CE-QUAL-W2 model next level of treatment plus 25 percent reduction in nonpoint source loads through implementation of best management practices (NLoT+25 percent NPS BMPs) scenario
Scenario 4	LTI's CE-QUAL-W2 model point source pollutant concentrations set to zero (PS = 0 Concentration) scenario
SCWB	Seasonal cold water biota
Sediment Oxygen Demand (SOD)	Ecology's CURRENT CE-QUAL-W2 model scenario without point source loads (flows retained and concentrations set to groundwater levels), tributaries and upstream boundary conditions set at background conditions, and SOD set at oligotrophic levels
SOD	sediment oxygen demand
Spokane River UAA	Spokane River and Long Lake Reservoir UAA
SR-HC TMDL	Snake River-Hells Canyon TMDL (including Brownlee Reservoir)
SS	Salmonid spawning
Stateline	Washington and Idaho Stateline
TMDL	total maximum daily load
TP	total phosphorus
UAA	Use Attainability Analysis
ug/L	micrograms per liter
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WCAC	Washington Citizens Advisory Committee
WDFW	Washington Department of Fish and Wildlife
WWB	Warm water biota

1. Background

Surface water quality standards include designated beneficial uses (for example, aquatic life, recreation, water supply, etc.) and water quality criteria to protect those uses (for example, numeric threshold concentration values for parameters such as dissolved oxygen [DO], water temperature, and many others).

The Washington Department of Ecology (Ecology) is currently developing a DO total maximum daily load (TMDL) for the Spokane River downstream of the Washington and Idaho Stateline (Stateline) Bridge to Long Lake Dam (Ecology, 2004e). This stretch of the river (River Mile [RM] 96 at the Stateline to RM 34 at Long Lake Dam) has been designated by Ecology as an impaired water for DO. Section 303(d) of the federal Clean Water Act mandates that the state of Washington establish TMDLs for impaired waters. The TMDLs for the Spokane River and Long Lake Reservoir are the subject of the Draft Total Maximum Daily Load to Restore and Maintain Dissolved Oxygen in the Spokane River and Lake Spokane (Long Lake) (Draft TMDL) (Ecology, 2004e) and subsequent implementation of a plan to limit point sources of pollution that are contributing to the impairment.

The designated beneficial uses of a water body form the basis for water quality criteria. The water quality criteria are established to protect the designated beneficial uses. TMDL waste load allocations are designed to achieve compliance with water quality criteria associated with designated beneficial uses. Because the ultimate goal of a TMDL is to meet water quality criteria and the designated beneficial uses associated with those criteria, the water quality criteria should be based on existing and attainable beneficial uses.

A Use Attainability Analysis (UAA) is conducted to define, on a river-reach basis, existing and attainable uses and to modify or change surface water quality standards. The U.S. Environmental Protection Agency (EPA) and the Clean Water Act federal regulations explicitly authorize a UAA when designated beneficial uses either do not exist today or have not existed since November 28, 1975, or are not attainable (EPA, 1983). A UAA may also be used to define site-specific criteria for the protection of designated beneficial uses, provided the site-specific criteria are consistent with the purpose and intent of the state surface water quality standards. In either case (removal of a designated use or setting site-specific criteria), a proposed modification to surface water quality standards must be protective of downstream surface water quality standards.

Both the UAA and Site Specific Criteria processes are set forth in federal regulations (40 Code of Federal Regulations [CFR] 131.10 and 30 CFR 131.11), as well as in Ecology's recently revised surface water quality standards (Washington Administrative Code [WAC] 173-201A-430-440).[1] The UAA process, which determines existing and attainable uses, should precede the setting of TMDLs. If existing and attainable uses were determined first, it would be less likely that the waste load and load allocations adopted in a TMDL would be geared toward achieving non-existing or non-attainable uses.

[1] Washington's revised surface water quality standards are currently pending before EPA for approval.

The Spokane River and Long Lake Reservoir UAA (Spokane River UAA) has been developed:

- To evaluate the biological and ecological basis for the designation of existing and attainable uses
- To determine if site-specific criteria are appropriate to protect those uses

The geographic scope of the Spokane River UAA extends from the outlet of Coeur d'Alene Lake (RM 112) in Idaho to Long Lake Dam (RM 34) in Washington (Figure 1-1).[2]

Broadly, the study area has been divided into two reaches:

- **Spokane River (RM 112 to RM 58)—Outlet of Coeur d'Alene Lake to Nine Mile Dam.** This overall reach is characterized by a combination of two free-flowing reaches containing riverine (lotic) habitats and five reaches impounded by dams that form pools that are relatively shallow and narrow. The impounded reaches do not thermally stratify.
- **Long Lake Reservoir (also referred to as Lake Spokane by some authors; created by Long Lake Dam; RM 58 to RM 34).** This reach extends from the outlet of Nine Mile Dam to Long Lake Dam. The reservoir has an upstream-most portion that is shallow and narrow (more riverine) and a portion that is deep and more lake-like (lacustrine), with a portion in between that is transitional between a riverine and lacustrine environment. The transitional and lacustrine portions of the reservoir thermally stratify.

The attributes and characteristics of these two reaches are discussed in detail in Section 3.

1.1 Report Organization

This document presents a UAA for the Spokane River and Long Lake Reservoir, documents the process used in developing this UAA, provides recommended criteria based on existing and attainable uses, and analyzes the economic impacts and implementation of these criteria. As such, the report is organized to present the following information:

Volume I

- **Part 1: Front Matter**
  - **Transmittal Letter.** A letter to Ecology from the sponsors of the Spokane River UAA.
  - **Executive Summary.** This section provides a high-level overview of the results of the Spokane River UAA.
- **Part 2: Biological Assessment and Recommendations**
  - **Section 1: Background.** This section introduces the Spokane River UAA; discusses the goals and rationale for a UAA; describes how water quality in the Spokane River has improved over the last 26 years; provides information about related studies and activities; and discusses the public involvement process.

[2] Management activities upstream of Coeur d'Alene Lake have already been addressed as part of the Idaho TMDL process.

- **Section 2: Regulatory Framework.** This section discusses requirements for UAAs, state responsibilities and frameworks, and UAA guidance and case studies.
- **Section 3: Existing Water Body Assessment.** This section summarizes the data used; discusses the physical, chemical, and biological conditions in the Spokane River, Long Lake Reservoir, and downstream from the reservoir; and presents information about existing uses within the Spokane River and Long Lake Reservoir.
- **Section 4: Attainable Beneficial Uses.** This section describes in detail the attainable physical, chemical, and biological conditions in the Spokane River; the attainable physical, chemical, and biological conditions in Long Lake Reservoir; and other Washington case studies related to the recovery of lake and reservoir systems following control of anthropogenic influences. It then summarizes and discusses attainable uses for the Spokane River and Long Lake Reservoir.
- **Section 5: Recommendations.** After providing recommendations on spawning-emergence, summer rearing, and winter uses for the Spokane River, this section recommends DO criteria for this more riverine-like reach subcategory. Similarly, after providing recommendations on cold-water summer rearing; brown trout spawning; cool-and warm-water spawning and summer rearing; cold-water summer foraging, and winter uses, this section recommends DO criteria for this reservoir reach subcategory. The final part of the section discusses the attainability of the proposed DO criteria.
- **Section 6: References.** This section provides bibliographic information about the sources cited in the Spokane River UAA.

- **Part 3: Implementation Plan**

  This section presents information related to the application of recommended criteria as they relate to temporal issues, spatial issues, and a consideration of natural conditions. The process for implementing the Draft TMDL and its link with this Spokane River UAA are also discussed. In addition, information about the protectiveness of downstream uses is provided.

- **Part 4: Economic Assessment**

  The economic assessment evaluates the impacts of treatment alternatives to achieving the TMDL total phosphorous (TP) loading and the recommended treatment alternatives presented in the Spokane River UAA Implementation Plan (Part 3).

Volume II

- **Part 5: Appendixes**
  - **A: Comments related to Spokane River UAA.** This appendix includes the following parts:
    - **A1**: Summary of and Responses to Comments Received on Draft Spokane River UAA (Issued June 2004)

  - **A2**: Summary of and Responses to Comments Received on Revised Advisory Committee Draft Spokane River UAA (Issued August 2004)
  - **A3**: Letter from Washington Department of Ecology (July 8, 1998)
- **B: Checklist of UAA Elements.**
- **C: Summary of Data Sources Used to Support Spokane River UAA.**
- **D: Results of Applying the Spokane River CE-QUAL-W2 Model in Support of Use Attainability Analyses.** This appendix includes the following parts:
  - **D1**: Results of Applying the Spokane River CE-QUAL-W2 Model in Support of Use Attainability Analyses Report
  - **D2**: TMDL Model Parameters for Updated Next Level of Treatment Table
  - **D3**: Additional Charts of LTI CE-QUAL-W2 Modeling Results for Year 2001
- **E: Economic Assessment Background Materials.** This appendix includes the following parts:
  - **E1**: Land Application of Reclaimed Water
  - **E2:** Conceptual Design and Cost Estimate of Reverse Osmosis System for Phosphorus Removal from Secondary Effluent
  - **E3:** Spokane Phosphorus Removal Costs
  - **E4:** Spokane County Preliminary Evaluation of Land Application
- **F: Advanced Wastewater Treatment Technology Evaluation Workshop (August 24, 2004).**
- **G: Resumes of Spokane River UAA Project Team.**

1.2 Introduction

1.2.1 What Are the Goals of the Sponsoring Group?

A consortium of stakeholders involved in the TMDL-setting process believes that the UAA process should precede the setting of a TMDL. That way, existing and attainable uses could be determined before assimilative capacity was calculated or pollutant loading allocations were developed.

The UAA process is necessary to establish a sound regulatory and scientific basis for defensible allocations under a TMDL. When a use is “designated” in a regulation, but does not exist and cannot be attained, a TMDL should not be based on that use.

Attaining surface water quality standards in the Spokane River will require considerable investment by the people who live and work in the region. The stakeholder group believes that citizens in northern Idaho and eastern Washington should not be forced to expend resources to try to attain a use that, under the federal regulations, is not attainable.

Fortunately, the federal Clean Water Act allows the UAA and the TMDL to be used together, first to revise the surface water quality standards to reflect existing and attainable uses, and then to adopt a TMDL that fully protects those uses.

The specific goals of this stakeholder group are:

- To protect beneficial uses that currently exist or that could be attained with additional treatment of point and nonpoint discharges
- To ensure that the TMDL model reflects the best available information so that informed cleanup decisions can be made
- To directly address the growth pressures on the Spokane River by achieving a net reduction in the discharge of phosphorus and other pollutants that contribute to the DO impairment of the river
- To be financial stewards of public monies such that these resources are spent on effective and achievable cleanup objectives

The sponsors of this Spokane River UAA include representatives from the following industries and municipalities in both Washington and Idaho:

- City of Spokane
- City of Spokane Valley
- Spokane County
- City of Coeur d'Alene
- City of Post Falls
- Hayden Regional Sewer District
- Liberty Lake Sewer and Water District
- Kaiser Aluminum Corporation
- Inland Empire Paper Company

The Spokane River UAA is a scientific and technical examination of the human and natural factors influencing the river's water quality and watershed health. The Spokane River UAA determines the river's existing and attainable uses and proposes criteria for protecting those uses. The Spokane River UAA has relied on physical, chemical, and biological data to determine what the highest attainable uses are for the Spokane River and Long Lake Reservoir.

1.2.2 Why is a UAA an Appropriate Tool for the Spokane River?

One of the main reasons to consider a UAA, not only for the Spokane River but also elsewhere in Washington, is that Ecology has recently changed from a class-based to a use-based system for setting surface water quality standards. In doing so, Ecology was not able to evaluate on a site-specific basis whether or not the carry-over of the class-based suite of uses was appropriate for specific water bodies. One inherent weakness of the class-based system is that the suite of uses is linked to the class, regardless of whether or not the suite of uses is applicable to a specific water body. For example, the class-based carry-over resulted in the designation of Long Lake Reservoir for salmonid spawning and core rearing (with criteria associated with those uses). The surface water quality standards did not differentiate uses or criteria for different locations or depths within the reservoir. Ecology has recognized that natural lakes are often very different from man-made reservoirs. However, it did not have the time or resources to develop separate surface water quality standards for reservoirs in the latest rule-making effort (Ecology, 2003).

In addition, Washington and Idaho surface water quality standards are set to protect a wide range of conditions in these states. Because of the broad geographic nature of these regulations, it is appropriate that the statewide criteria be conservative and provide protection for a variety of stream and lake/reservoir conditions. In the absence of more localized information, it is also appropriate that Ecology and the Idaho Department of Environmental Quality (IDEQ) rely on these conservative criteria to protect the most sensitive aquatic species and their susceptible life stages. The UAA process acknowledges the possibility that surface water quality standards may need to be revised because presumed uses are neither existing nor attainable.

In the case of the Spokane River and Long Lake Reservoir, water quality criteria have been set (and are used as TMDL targets) to protect cold-water salmonid spawning and rearing and other aquatic life uses, throughout the system. As discussed in detail in Section 3, the Spokane River system currently has limited ability to support cold-water salmonids because, in part, water temperatures are elevated and physical habitat is limited. (Physical habitat has either not existed since the construction of the hydropower facilities or it has been sufficiently altered so that the use of the physical habitat to support cold-water salmonids has been limited or precluded). The physical limitations of water temperature and habitat influence the determination of attainable beneficial uses.

As noted above, the Spokane River does not currently support a robust cold-water fishery. This does not mean that cold-water fishes such as rainbow trout and mountain whitefish are not present. Rather, the macroinvertebrate community reflects a cool- to warm-thermal regime that supports a community of cool- and cold-water fishes that are tolerant of, or have adapted behavior to, seasonally warm water temperatures. Where existing cold-water species spawn and rear, the Spokane River UAA provides for the continued protection of those uses. Where existing cold-water species do not spawn, the Spokane River UAA recognizes that protection of rearing uses must continue or be improved at appropriate levels given the site-specific constraints of the Spokane River.

1.2.3 How Has Spokane River Water Quality Improved Over the Last 26 Years?

As early as the 1950s and 1960s, nutrient concentrations in the Spokane River were identified as water quality concerns (Washington State, 1961). By 1969, it was recognized that low DO concentrations were present in Long Lake Reservoir, and monitoring was conducted to better characterize the extent of the situation (Washington State, 1969).

In 1978, the City of Spokane's Advanced Wastewater Treatment Plant (SAWTP) came on-line.[3] Phosphorus discharges and loading to Long Lake Reservoir decreased, with corresponding decreases in chlorophyll *a* concentrations, primary productivity, orthophosphate concentrations, and hypolimnetic anoxia (Soltero, et al., 1979 through 1985, cited in Ecology, 2004a). Figure 1-2 shows the marked decrease in low DO (less than

[3] In April 2004, the name of this facility was officially changed to Riverside Park Water Reclamation Facility (RPWRF).

5 milligrams per liter [mg/L]) and anoxic (less than 1 mg/L) conditions within Long Lake Reservoir since 1978.

Figure 1-3 shows the reduction in phosphorus loading from major dischargers to the Spokane River between 1986 and 2002. This is particularly relevant given the high population growth (16 percent) during the same time period. Major dischargers to the Spokane River have spent millions of dollars over this time period reducing discharges to the river and improving water quality while balancing increasing growth pressures.

1.3 Related Studies and Activities

The following studies and activities ongoing in the Spokane River watershed are interrelated with the Draft TMDL (Ecology, 2004e) and the Spokane River UAA.

1.3.1 Middle Spokane River Watershed Planning—Little/Middle Spokane River Watershed Resource Inventory Areas 55 and 57

Purpose/Objective: The Middle Spokane River Watershed Planning Unit began work in the fall of 1998 to address major issues in the Little and Middle Spokane River watersheds. These issues included water supply to meet a growing population over the Spokane Valley/Rathdrum Prairie sole source aquifer, flows in the Spokane River, and coordination with Idaho water interests and governments. The Middle Spokane River Watershed Planning Unit is also working to coordinate instream flow assessment efforts with the Federal Energy Regulatory Commission (FERC) relicensing for Avista Utilities' (Avista's) five hydropower projects on the Spokane River.

1.3.2 Avista Relicensing of Spokane River Hydroelectric Projects

Purpose/Objective: The Federal Power Act (FPA) of 1920 provides FERC exclusive authority to license all nonfederal hydroelectric projects that are located on navigable waterways or federal lands. New licenses are normally issued for a period of 30 to 50 years. In pursuit of relicensing Spokane River hydroelectric projects, Avista's FERC relicensing committee is directing extensive planning. This includes ongoing environmental studies, consultation with resource agencies to reach consensus, and public involvement programs. Avista's FERC relicensing committee is considering the non-generating benefits of the natural resource (for example, fish, wildlife, aesthetics, water quality, land use, and recreational resources) along with the benefit of power production. The following stakeholder work groups have been formed: cultural; fisheries; plenary; recreation, land use and aesthetics; terrestrial; and water resources.

1.3.3 The Northwest Power and Conservation Council Intermountain Province Subbasin Planning, Spokane Subbasin Work Team

Purpose/Objective: Congress created the Northwest Power and Conservation Council in 1980 to give the states of Idaho, Montana, Oregon, and Washington a voice in how the region plans for its energy needs, while at the same time mitigating the effects of the hydropower system on fish and wildlife in the Columbia River Basin. Six subbasin work teams have been formed, including a Spokane Subbasin Work Team. This work team will create a local Spokane subbasin management plan to help guide Bonneville Power Administration's project funding.

1.3.4 City of Spokane Combined Sewer Overflow Reduction Program

Purpose/Objective: The City of Spokane's aging sewer system was designed to overflow when it rains, spilling storm water combined with untreated sewage into waterways, including the Spokane River. The combined sewer system carries sanitary and storm water runoff in the same pipes. The intent of the Combined Sewer Overflow (CSO) Reduction program is to ensure that untreated overflows to the Spokane River from the combined sewer system are reduced. This is accomplished through implementation of capital projects directed at reducing the number of overflows. These projects are designed to achieve Ecology's criterion of one overflow per year and to meet surface water quality standards.

1.3.5 Bi-State Aquifer Study

Purpose/Objective: Northern Idaho and eastern Washington officials are working to create a more cohesive approach to water management in the Spokane Valley/Rathdrum Prairie Aquifer. Federal funds have recently been allocated to this bi-state study.

1.3.6 Washington Citizens Advisory Committee on Cleanup of Heavy Metals Contamination in the Spokane/Coeur d'Alene River Basin

Purpose/Objective: The Washington Citizens Advisory Committee's (WCAC's) primary purpose is to serve citizens in eastern Washington by providing an organization to track, review, and comment on studies and cleanup strategies for the Spokane River/Coeur d'Alene Basin and Bunker Hill Mining and Metallurgical Complex Remedial Investigation and Feasibility Study (RI/FS) The WCAC helps ensure that impacts to the Spokane River are considered and addressed.

1.3.7 Spokane Aquifer Joint Board

Purpose/Objective: The Spokane Aquifer Joint Board consists of 22 water purveyors throughout the Spokane Valley, including the City of Spokane and the Town of Millwood. It is dedicated to providing safe, clean drinking water to more than 300,000 customers in the Spokane area.

1.3.8 Little Spokane River Watershed Management Plan

Purpose/Objective: The Spokane Conservation District received a Centennial Clean Water Fund Grant from Ecology to develop a management plan for the Little Spokane River watershed. A planning committee is being formed to help evaluate current issues and watershed needs. A work plan is being developed for information and education in the watershed.

1.3.9 Watershed Planning in Hangman (Latah) Creek

Purpose/Objective: The Spokane Conservation District facilitates the watershed planning process in the Hangman (Latah) Creek watershed. This process is designed to allow local citizens and governments to join with other stakeholders to form a central "Planning Unit" in an effort to address the water resources issues in Hangman Creek. The Planning Unit's primary focus is on water quantity in the basin. However, they are also addressing water quality, instream flows, habitat, and storage. The collection of information on water rights, uses, and future water needs continues. The Planning Unit has contracted instream flow work to Hardin-Davis Inc. (HDI) of Corvallis, Oregon. HDI has completed data collection, modeling, and analysis on flows, hydrology, water temperature, and riparian mapping. The Planning Unit is pursuing an additional application to study water quality in more detail.

1.3.10 Spokane County Septic Tank Elimination Program

Purpose/Objective: The goal of the Spokane County Septic Tank Elimination Program is to provide sewer service to all houses and businesses located within the Priority Sewer Service Area (PSSA). The PSSA relates to protection of the Spokane Valley/Rathdrum Prairie Aquifer and the associated aquifer protection areas, consistent with local growth management requirements. The PSSA is organized into priority areas. These priority areas serve as the foundation for development of the Capital Improvement Program (CIP) and financing strategies to construct new sewer lines and provide sewer service to properties within the PSSA. Ongoing implementation of this program requires adequate wastewater treatment capacity.

1.4 Public Involvement

Public involvement for the Spokane River UAA involves four key components:

- Consultation with key stakeholders (Tribal governments, resource agencies, Avista, local government)
- Consultation with public interest groups and civic organizations (fisheries, environmental, chambers of commerce)
- Spokane River UAA Advisory Committee (Advisory Committee) meetings
- Public workshops

In addition to these formal components:

- A Draft Spokane River UAA report was circulated in June 2004. A summary of comments received regarding the Draft report, and responses to those comments, is provided in Appendix A1. These comments were posted on August 12, 2004, on the Spokane River Uses web site (http://www.spokaneriveruses.net/documents/Spokane_UAA_AppA.pdf).
- The revised Draft Spokane River UAA report was circulated in August 2004. A summary of comments received regarding the revised Draft report, and responses to those comments, is provided in Appendix A2.
- Public involvement and comments have been welcome throughout the draft stages of this project (see http://www.spokaneriveruses.net/links.htm).

1.4.1 Consultation with Key Stakeholders

Consultation on a Government-to-Government basis with Tribal Governments

The Spokane River UAA study is responsive to the government interests of the Spokane Tribe of Indians (Spokane Tribe) and the Coeur d'Alene Tribe. One of the key concerns for the Spokane Tribe is compliance with surface water quality standards that have been established by the Spokane Tribe downstream of the study area. Consultation with the Spokane Tribal government has included meetings between Spokane River UAA consultant team members and Spokane Tribal Fisheries Management staff on August 5, 2003; between the City of Spokane and the Spokane Tribal Fisheries Management staff on August 5, 2004; and the involvement of Spokane Tribal Fisheries Management staff on the Advisory Committee. The City of Spokane (one of the Spokane River UAA sponsors) has requested another meeting with Spokane Tribal government officials and the Coeur d'Alene Tribe and expects that this will happen after the Spokane River UAA is completed. The Spokane Tribe and the Coeur d'Alene Tribe want to review the completed Spokane River UAA, which proposes a plan that achieves common water quality objectives of protecting the Spokane River uses and provides a basis for those discussions.

Consultation with Resource Agencies

Consultation with resource agencies has been coordinated through the Washington Department of Fish and Wildlife (WDFW). In addition to multiple meetings and telephone conversations, WDFW publications have been reviewed to understand the fishery management goals and requirements for the Spokane River.

Consultation with Avista

Spokane River UAA staff has consulted with Avista on their studies and model output on the Spokane River and Coeur d'Alene Lake. Avista studies are currently underway and only a limited number of final reports are available. An Avista representative participates on the Advisory Committee, and provided information that is discussed in the dam section of the Spokane River UAA (Section 4.1).

Consultation with Local Government

Consultation with local government has been accomplished through representatives of municipal and industrial wastewater facilities from Washington and Idaho that discharge or plan to discharge to the Spokane River under National Pollutant Discharge Elimination System (NPDES) permits. The Sponsors' Committee consists of the following:

- City of Coeur d'Alene
- Hayden Regional Sewer District
- City of Post Falls
- Liberty Lake Sewer and Water District
- City of Spokane Valley Public Works
- Spokane County
- City of Spokane Wastewater Management
- Kaiser Aluminum Corporation
- Inland Empire Paper Company

Spokane River UAA staff has worked with the Sponsors' Committee to manage the scope, schedule, and budget for the Spokane River UAA report and to coordinate the gathering of information regarding utility facility plans.

1.4.2 Consultation with Spokane River Public Interest Groups and Civic Organizations

A revised Draft Spokane River UAA report was circulated in August 2004 to all interested parties. Meetings were scheduled in September and October with public interest groups and civic organizations.

The goals of these meetings were:

- To provide an overview and update on the findings and preliminary conclusions and recommendations of the Spokane River UAA study
- To receive direct input on the substance of the report regarding any proposed changes in designated uses on the river

Meetings were held for groups and organizations as follows:

- **September 16, 2004.** Environmental Groups (Sierra Club, Center for Justice, Lands Council). Subsequent to the meeting, a list of questions from Environmental Groups was provided to the sponsors of the Spokane River UAA to address. These questions and responses are included in Appendix A2.
- **September 27, 2004.** Fisheries Groups (Spokane Fly Fishers, Trout Unlimited, the Blue Dun, Spokane Canoe and Kayak Club).
- **October 6, 2004.** Spokane Valley Chamber of Commerce, Builders, Realtors.
- **October 12, 2004.** Spokane Regional Chamber of Commerce.
- **October 22, 2004.** Kootenai Environmental Alliance.

1.4.3 Spokane River UAA Advisory Committee Meetings

The Advisory Committee consists of all of the Spokane River UAA Sponsors and includes other key stakeholders (some discussed previously) as follows:

- Idaho Department of Environmental Quality
- Lake Spokane Protection Association
- Spokane Tribe of Indians
- Stevens County Commissioners
- Washington State Department of Fish & Wildlife
- Spokane Conservation District
- Washington Department of Ecology
- Avista
- Sierra Club
- Lands Council
- EPA—Office of Water

- Spokane Regional Chamber of Commerce
- State Parks Commission

Advisory Committee meetings provide a forum for discussions between the Spokane River UAA Sponsors, other key stakeholders (representatives of a cross-section of public agencies and citizen interest groups), and the study team. The Advisory Committee provides advice and guidance on the process and methods for public involvement. In addition, the Advisory Committee provides direct input and perspectives on the findings and recommendations of the Spokane River UAA study report.

To date, there have been four Advisory Committee meetings: December 10, 2003, February 11, 2004, June 15, 2004, and August 17, 2004. The purpose of the last meeting was to review the second draft of the Spokane River UAA study report so that it could be completed.

1.4.4 Public Workshops and Meetings

One public workshop was held February 26, 2004, to provide the public with an overview of the purpose and scope of the study and to present an initial biological assessment of the Spokane River and Long Lake Reservoir. Additional public workshops may be planned, pending advice from the Advisory Committee and input from public interest groups and civic organizations.

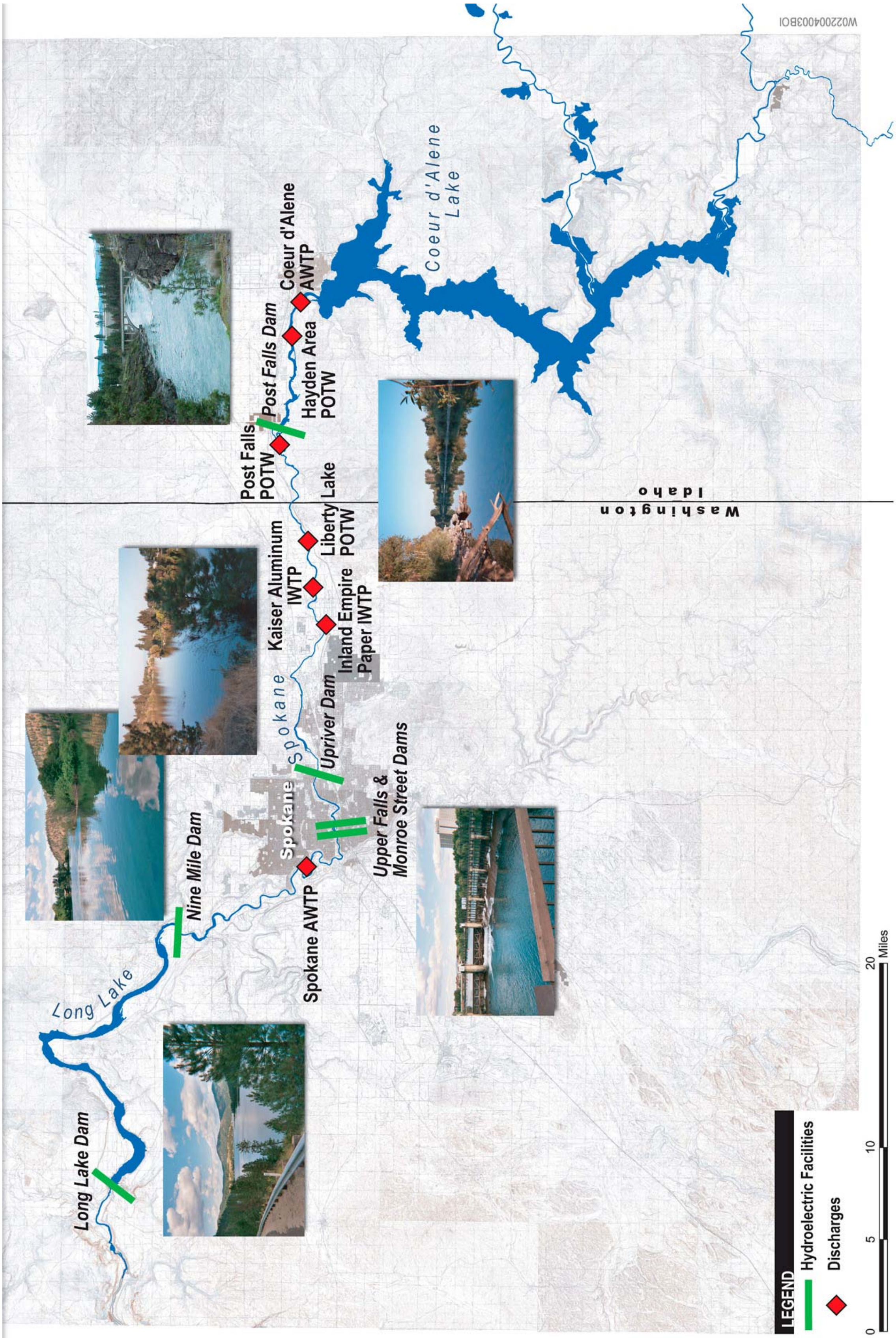

Figure 1-1. Study Area.

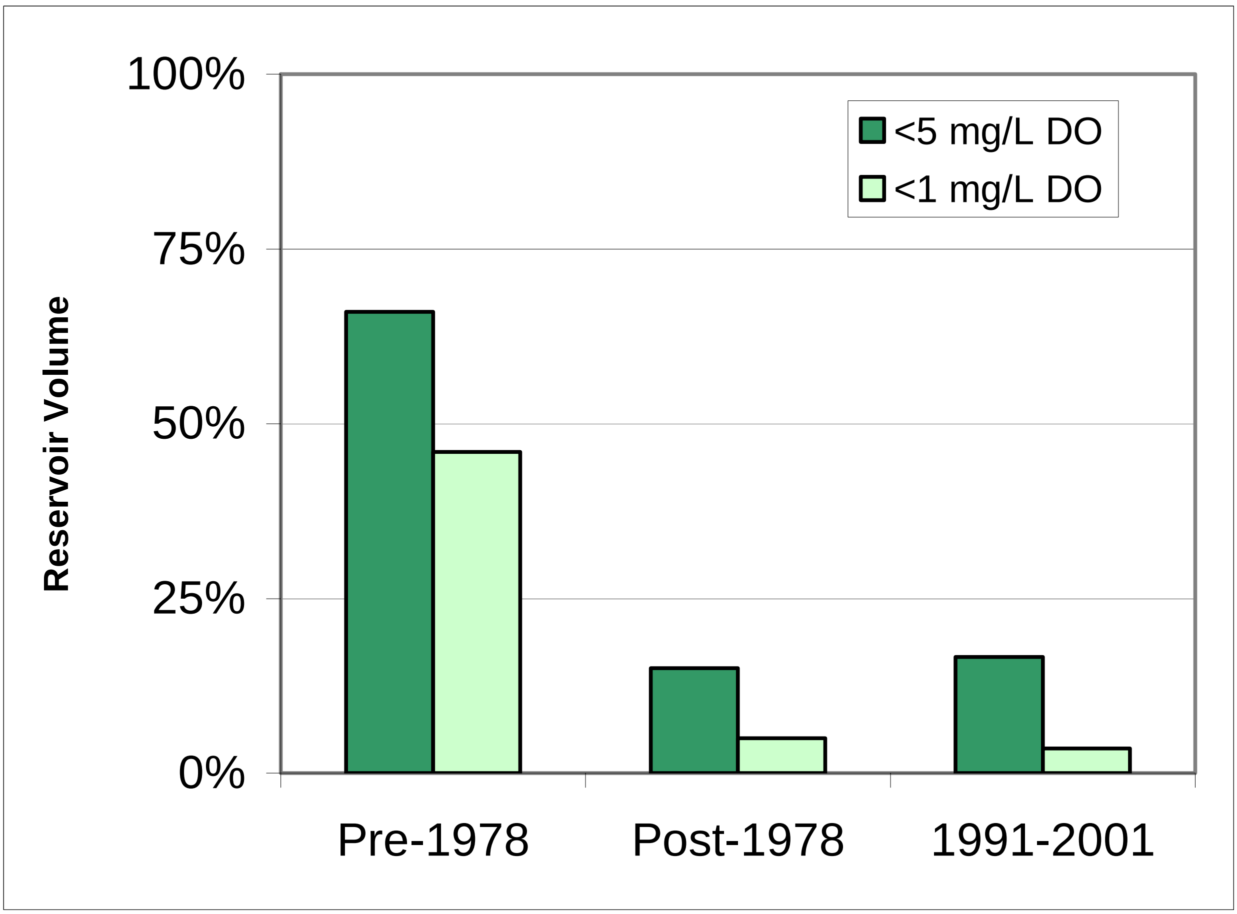

Figure 1-2. Decrease in Low DO and Anoxic Conditions within Long Lake Reservoir.

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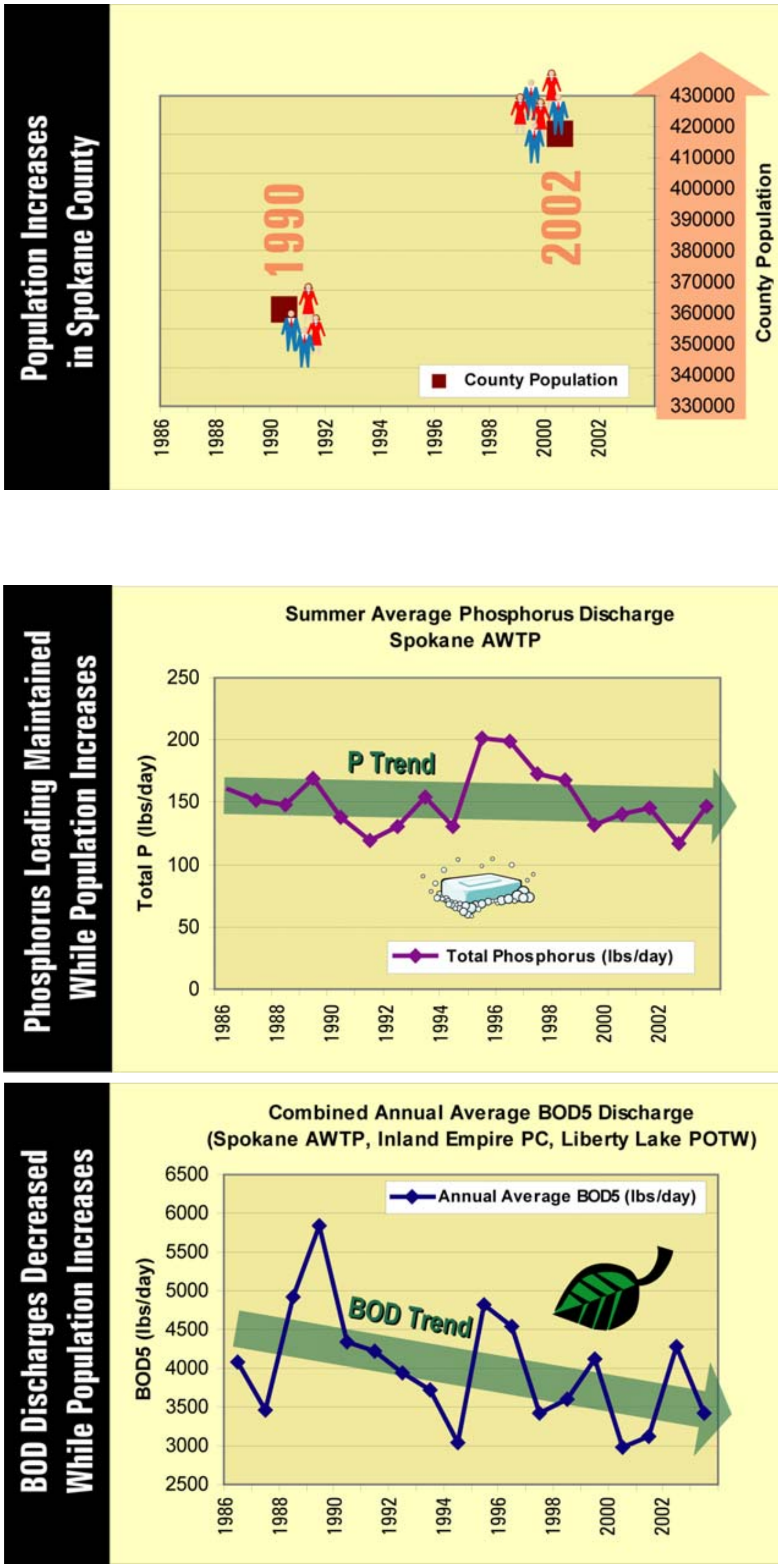

Figure 1-3. Reduction in Phosphorus Loading to the Spokane River.

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2. Regulatory Framework

2.1 UAA Requirements

In discussing surface water quality standards and associated beneficial uses and criteria, it is important to distinguish between designated, existing, and attainable uses.

- Designated uses are those that have been established through the formal rule-making process
- Existing beneficial uses are those uses that exist or have existed in a given water body any time after November 28, 1975, whether or not the use is formally designated for the water body (EPA, 1983)
- Attainable uses are those uses that would be expected to be present if, at a minimum, point sources had required technology-based controls in place (for example, secondary treatment for municipal treatment facilities) and nonpoint sources applied cost-effective and reasonable best management practices (BMPs)

While a designated use can be modified to a use requiring less stringent criteria, an existing use can only be upgraded to a use requiring more stringent criteria (EPA, 1994). Furthermore, designated uses can be removed only if they are neither existing nor attainable, due to at least one of the 40 CFR 131.10(g) conditions. That is, designated uses may not be removed if the uses could be attained, at a minimum, by implementing technology-based effluent limits for point sources and by implementing BMPs for nonpoint sources. When designated uses are different than attainable uses, standards can be revised through a UAA to reflect uses that are being, or can be, attained.

These distinctions are critical because a UAA is often misunderstood and mischaracterized as a process that allows surface water quality standards to be lowered if they are not being met. Instead, UAAs provide for the designation of appropriate surface water quality standards that protect beneficial uses that exist or are attainable. Existing and attainable beneficial uses are the correct basis for setting appropriate criteria.

A designated use is non-attainable if one or more of the following conditions (as adapted from 40 CFR 131.10[g]) are satisfied:

1. Naturally occurring pollutant concentrations prevent the attainment of the use; or
2. Natural, ephemeral, intermittent, or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met; or
3. Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or

4. Dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or
5. Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or
6. Controls more stringent than those required by Sections 301(b) and 306 of the Clean Water Act would result in substantial and widespread economic and social impact.

Only one of these conditions must be met in order to determine that a designated use is not attainable. Washington's UAA guidance (Ecology, 2004b) has interpreted the federal requirements to mean that where human activities (for example, pollution, dams, mining, etc.) contribute to a limitation of what uses are attainable, economic and social factors associated with restoring uses must be examined in determining what is attainable. This guidance is discussed further in Section 2.3.

2.2 State and Spokane Tribal Responsibilities and Frameworks

The IDEQ is responsible for implementing the water quality standards provisions of the Clean Water Act in Idaho. It has promulgated state water quality rules to meet this responsibility in IDAPA 58.01.02–*Water Quality Standards and Wastewater Treatment Requirements*. These rules establish both designated uses and appropriate criteria; designated uses are those beneficial uses specified for given water bodies and criteria are conditions presumed to support or protect the designated uses. In Washington, Ecology holds a similar responsibility under Chapter 173-201A WAC—Water Quality Standards For Surface Waters of the State of Washington. The Spokane Tribe has also promulgated surface water quality standards that have been approved by EPA. State and Spokane Tribe standards are described in detail below.

Figure 2-1 provides a summary of currently designated uses and DO criteria that are discussed in more detail below.

2.2.1 Idaho Framework

According to Idaho Administrative Procedures Act (IDAPA) 58.01.02, Idaho surface water use designations include:

- Aquatic life:
  - Cold water biota (CWB)
  - Salmonid spawning (SS)
  - Seasonal cold water biota (SCWB)
  - Warm water biota (WWB)
  - Modified cold or warm water biota (MOD)

The aquatic life category is used to protect and maintain a viable aquatic life community of cold or warm water species, as appropriate. Table 2-1 arrays the Idaho aquatic life criteria for each of the aquatic life categories (except for the WWB that would not apply to the Spokane River system).

TABLE 2-1
Comparison of Selected Water Quality Criteria for Some Idaho Aquatic Life Categories

Parameter	CWB	SS	SCWB	MOD[1]
Water temperature (°C)				
Daily maximum	22	13	26	—
Daily average	19	9	23	—
DO[2]				
mg/L (minimum)	6.0	6.0[3]	6.0	—
Intergravel (mg/L)	—	5.0, 7-day mean of 6.0	—	—
pH	6.5 to 9.0	6.5 to 9.0	6.5 to 9.0	—

Notes:
[1] Water quality criteria for MOD are developed on a site-specific basis.
[2] DO criteria do not apply to waters of the hypolimnion in stratified lakes and reservoirs.
[3] 1-day minimum DO value of 6.0 mg/L or 90 percent saturation, whichever is greater.

°C = degrees Celsius
CWB = cold water biota
mg/L = milligrams per liter
MOD = modified cold or warm water biota
SCWB = seasonal cold water biota
SS = salmonid spawning

SS conditions apply to waters that provide for active, self-propagating populations of salmonid fishes. CWB criteria are appropriate for the protection and maintenance of a viable aquatic life community of cold-water species. SCWB criteria are appropriate for the "protection and maintenance of a viable aquatic life community of cool and cold water species, where cold water aquatic life may be absent during, or tolerant of, seasonally warm temperatures." SCWB criteria only apply between June 21 and September 21 of each year. The CWB criteria apply during the remaining months.

Finally, MOD uses may be appropriate when the aquatic community is limited due to one or more of the factors specified in 40 CFR 131.10(g). These factors preclude attainment of reference stream conditions. Therefore, attainable site-specific MOD criteria that are protective of the modified community must be established and incorporated into the rule-making process. In addition, site-specific criteria can be developed independently from a MOD beneficial use for any water body through site-specific analyses that effectively protect designated and existing beneficial uses (IDAPA 58.01.02.275).

IDEQ has identified the study area within Idaho as providing cold-water aquatic life and salmonid spawning. This means that the applicable DO criteria are 6.0 mg/L as a daily minimum, or 90 percent of DO saturation, whichever is greater. Intergravel DO criteria also apply.

2.2.2 Washington Framework

Ecology administers the state's surface water quality standards regulations (Chapter 173-201A WAC). These regulations establish minimum requirements for the quality of water that must be maintained in lakes, rivers, streams, and marine waters. These minimum requirements ensure that all beneficial uses associated with these water bodies are protected.

Prior Standards

Prior to July 2003, Washington's surface water quality standards classified all fresh waters in the state by broad categories that were protected at different levels. The standards contained three minimum DO criterion levels:

- Class AA—9.5 mg/L
- Class A—8.0 mg/L
- Class B—6.5 mg/L

As of 1998, Ecology did not have supporting information on the technical basis of these numbers (Hicks, 1998, personal communication [pers. comm.]; Appendix A3). Ecology standards personnel examined available Ecology files to document the basis for various water quality criteria, including DO. Ecology noted that:

> "The existing dissolved oxygen thresholds have existed in the state standards as far back as 1967… the criteria have never been expressed as other than an absolute threshold value, even though other criteria have been and continue to include averaging periods." (Hicks, 1998, pers. comm.; Appendix A3)

Class AA and Class A standards provided two different levels of protection for the same set of beneficial uses and were intended to protect salmonid spawning, rearing, and migration. Class AA waters were predominantly established within forested upland areas, but Class A waters were found broadly throughout the state. Class B waters were designed only to protect salmonid rearing and migration, and were not intended to apply to waters used for spawning.

With each class, the criteria were applied as the lowest single daily minimum measurement of DO occurring in the water body. The former rule also had a Lake Class, which did not apply numeric DO criteria but required that lakes be maintained at natural levels. Table 2-2 provides a summary of class-based criteria applicable to the Spokane River system.

TABLE 2-2
Former Class-Based Surface Water Quality Standards for Spokane River and Long Lake Reservoir

Water Body	Former Classification	Dissolved Oxygen Criteria
Spokane River (Nine Mile Bridge upstream to the Stateline)	Class A	Dissolved oxygen shall exceed 8.0 mg/L, unless natural conditions are less than the criteria. Then, the natural conditions shall constitute the criteria.
Long Lake Reservoir (from Long Lake Dam upstream to Nine Mile Bridge)	Lake Class	No measurable decrease from natural conditions.

In addition, the Spokane River from Nine Mile Bridge (RM 58) to the Stateline (RM 96) also had the following site-specific water quality criteria (Chapter 173-201A WAC):

- Temperature shall not exceed 20 degrees Celsius (°C) due to human activities.
- When natural conditions exceed 20°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t=34/(T+9)[4].

Long Lake Reservoir from Long Lake Dam (RM 34) to Nine Mile Bridge (RM 58) had the following site-specific water quality criteria (Chapter 173-201A WAC):

- The average euphotic zone concentration of total phosphorus (as TP) shall not exceed 25 micrograms per liter (μg/L) during the period of June 1 to October 31.
- Temperature shall not exceed 20°C due to human activities. When natural conditions exceed 20°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t=34/(T+9).

Another provision is the definition of a reservoir as a water body with a mean detention time of more than 15 days (WAC 173-201A-020). This definition then links with water temperature and DO criteria (WAC 173-201A-200) and with applicable mixing zones (WAC 173-201A-400). No specific criteria related to stratified systems are explicitly specified.[5]

Current Standards

In July 2003, Ecology revised Washington's surface water quality standards. EPA has not yet approved Washington's revised standards. For the purposes of this Spokane River UAA, the revised standards contain the following key revisions:

- Moving from a "class-based" system to a "use-based" system for designating beneficial uses of fresh waters (although the suite of uses for each class was simply rolled over into

[4] In this equation, "t" represents the maximum permissible temperature increase measured at a mixing zone boundary. "T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge.

[5] The lack of zone-dependent criteria continues to apply in current standards that provide for lake-specific nutrient criteria (WAC 173-201A-230).

the use-based system without any site-specific consideration of the appropriateness of those uses for any water body)

- New language on how to prevent degradation of existing water quality
- New language on use attainability analyses
- New language on site-specific criteria, variances, and water quality offsets
- New water temperature and DO criteria

Ecology's new standards apply criteria for DO to protect salmonids and other aquatic species by relying on a 1-day minimum DO value. Table 2-3 provides a summary of current (July 2003) DO criteria for the Spokane River.

TABLE 2-3
July 2003 Use-Based Surface Water Quality Standards for Spokane River and Long Lake Reservoir

Water Body	Aquatic Life Use Designation	Dissolved Oxygen Criteria
Spokane River (Nine Mile Bridge upstream to the Stateline)	Salmon and Trout Spawning, Non-core Rearing, and Migration	Dissolved oxygen shall exceed 8.0 mg/L, unless natural conditions are less than the criteria. Then, the natural conditions shall constitute the criteria with no measurable decrease from natural conditions (0.2 mg/L).
Long Lake Reservoir (from Long Lake Dam upstream to Nine Mile Bridge)	Salmon and Trout Spawning, Core Rearing, and Migration	Dissolved oxygen shall exceed 9.5 mg/L, unless natural conditions are less than the criteria. Then, the natural conditions shall constitute the criteria with no measurable decrease from natural conditions (0.2 mg/L).

Specific definitions regarding what constitutes core versus non-core rearing are not provided in the current Ecology standards. Given Ecology's transfer of class-based designations to use-based designations, "core rearing" presumably applies to headwater systems that support extraordinary salmonid migration, rearing, spawning, and harvesting conditions (such as those found in relatively pristine headwater streams that were previously classified as extraordinary Class AA waters). Thus, "non-core rearing" presumably applies to excellent salmonid migration, rearing, spawning, and harvesting conditions (such as those found in higher order streams downstream from pristine headwater streams that were previously classified as excellent Class A waters). Ecology has indicated that additional future guidance to determine what waters would be considered core versus non-core might be based on consideration of the frequency and times of spawning, the extent and quality of rearing and spawning habitat, and the salmonid population density and diversity of the water bodies (Ecology, 2003).

In the interim, as part of EPA's regional water temperature criteria development (EPA, 2003a), EPA defines core rearing to mean "moderate to high density salmon and trout juvenile rearing during the period of maximum summer temperatures." In Oregon's approved temperature standards, core cold-water habitat is defined as "waters that are expected to maintain temperatures within the range generally considered optimal for salmon and steelhead rearing… during the summer" (Oregon Administrative Rule [OAR] 340-041-0002[13]). EPA defined non-core rearing as "moderate to low density salmon and trout juvenile rearing during the period of summer maximum temperatures." Because density values vary widely across the region, no specific numeric density definitions are provided.

Evolution of Current Criteria

Ecology has acknowledged that it does not have any record of the scientific basis for its current DO criteria (Hicks, 1998, pers. comm.; see Appendix A3). Ecology later undertook a detailed investigation into appropriate DO levels that would "…maintain healthy and productive populations of the state's aquatic species…" (Ecology, 2002a).

Ecology's comprehensive literature summary recommended criteria to protect salmonid species and associated macroinvertebrates (Figure 2-2). This information formed the basis for the proposed criteria changes, also shown in Figure 2-2 (Applicable Proposed Ecology DO Criteria).

Ecology's recommended standards were released for public comment. Ecology received significant concerns related to the proposed DO criteria (Ecology, 2003). Therefore, Ecology elected to withdraw the portion of the rule that changed the DO criteria and continue to use the former criteria applied to classes. This final decision, in relation to the literature summary of appropriate DO values and the proposed criteria, is also shown in Figure 2-2 (Applicable Current Ecology DO Criteria).

As part of this process, lakes/reservoirs were removed from the former "Lake Class" and placed into the various fish-related uses that have numeric criteria for both water temperature and DO, with the caveat of not exceeding "natural conditions." Ecology interprets "natural conditions" in two ways (see comment from Melissa Gildersleeve/ Ecology; Appendix A1):

1. To **implement** surface water quality standards (such as the TMDL or permitting issues), Ecology considers "natural conditions to be the lake (as formed by the dam) without anthropogenic pollution sources."
2. To promulgate **rule revision**s (for instance a use change or a variance in the context of removing designated uses), Ecology considers natural conditions "to be the condition of the waterbody without human influences – including dams or other hydrologic modifications." Ecology considers this interpretation to be "necessary to remain in compliance with the federal UAA regulations at 40 CFR 131.10(g)(4)."

The application of these interpretations is discussed in more detail in Sections 4 and 5.

Ecology recognizes that the "natural condition" (plus the small 0.2 mg/L incremental allowance for human degradation) does not completely address stratified conditions such as those commonly found in lakes and reservoirs (Ecology, 2003). For example, revised criteria are based largely on targets developed for sensitive species that rely on riverine and stream systems for critical life stages such as spawning. Ecology expects that additional guidance will be developed to address situations specific to lakes and reservoirs, particularly in those that stratify (Ecology, 2003).

Concurrent with the Spokane River UAA process, Ecology has provided additional rationale for the current DO criteria (Ecology 2002b; Ecology, 2003). Specifically, Ecology believes these criteria reflect DO concentrations that "could be depended upon to generally provide full protection for the more sensitive life stage of spawning which tends to occur in the fall through spring when oxygen concentrations are naturally higher" (Ecology, 2002b).

While this may be appropriate on a statewide basis, the Spokane River does not support any native fall spawners (native rainbow trout spawn from April through May), as discussed in more detail in Section 3. There are limited numbers of brown trout in the system, which are fall spawners. However, this species of trout is not native to Washington and is more tolerant of higher water temperatures and lower DO than other trout species (Wydoski and Whitney, 2003; Simpson and Wallace, 1982; Scott and Crossman, 1973). See Section 3 for a more detailed discussion of fisheries resources.

Designated Uses and Criteria for the Spokane River Downstream of Long Lake Dam

As noted earlier, the outcome of a UAA process must be protective of downstream surface water quality standards.

Washington State Surface Water Quality Standards.

The Spokane River from its mouth upstream to Long Lake Dam has the same Ecology-assigned use designations and criteria under the current standards as the riverine segment from the Nine Mile Bridge to the Stateline (that is, Salmon and Trout Spawning, Non-core Rearing, and Migration). This translates into a minimum DO criterion of 8.0 mg/L (unless natural conditions constitute the criterion with no measurable decrease from natural conditions [0.2 mg/L]).

Spokane Tribe Surface Water Quality Standards.

The Spokane Tribe has established its own water quality standards for surface waters on lands within the constitutional jurisdiction of the Spokane Tribe, and EPA Region 10 has approved these standards. Within its reservation border, the Spokane Tribe has identified the Spokane River as a Class A water body. Class A includes the following designated uses applicable to fish and shellfish:

- Salmonid migration, rearing, spawning, and harvesting
- Other fish migration, rearing, spawning, and harvesting
- Mollusks, crustaceans, and other shellfish rearing, spawning, and harvesting

The Spokane Tribe has set a DO criterion for Class A waters of not less than 8.0 mg/L.

Comparison of Current Ecology Criteria to Other Region 10 Developments

A comparison of current Washington criteria to approved criteria and TMDL approaches in other Region 10 states is applicable to the extent that certain technical rationales extend beyond state-specific situations. For example, differential treatment of lakes versus reservoirs is a topic that has been raised other states such as Oregon, Idaho and others.

A TMDL addressing Brownlee Reservoir (on the Snake River on the Oregon-Idaho border, encompassed by the overall Snake River-Hells Canyon [SR-HC] TMDL) was developed recently by both state water quality agencies (IDEQ and Oregon Department of Environmental Quality [ODEQ], 2004). EPA approved the SR-HC TMDL in 2004. Although

Brownlee Reservoir supports a mixed fishery dominated by cool- and warm-water species (similar to Long Lake Reservoir), rainbow trout and mountain whitefish (with a limited upstream sturgeon population) are also present. The TMDL for Brownlee Reservoir concluded that the 30-day average cool-water DO criterion of 6.5 mg/L would be the target, applicable to the upper layers of the reservoir only (IDEQ and ODEQ, 2004). The lower layers of the reservoir were assigned narrative criteria and a target of 3.0 mg/L to prevent lethality. These targets were specifically excluded from driving any upstream load allocations for total phosphorus and chlorophyll *a*. Instead, IDEQ and ODEQ (2004) elected to require the Idaho Power Company to implement additional improvements in DO by:

1. Contributing to equivalent reductions in total phosphorus or organic matter upstream,
2. Direct oxygenation of the metalimnetic and transition zone waters, or
3. Other appropriate mechanisms that can be shown to result in the required improvement.

This case study is discussed in more detail in the Lower Hypolimnion subsection of Section 5.2.4.

Other recent court cases and rulemaking processes in Oregon and Washington have further raised EPA Region 10's awareness related to the importance of maintaining oxygen-rich waters. Recent approved rules in Oregon (prompted by litigation and approved by EPA) include a geographic and seasonal designation of salmonid life stage uses for the entire state. Oregon's standards include applicability of uses and criteria when and where they occur.[6]

Additionally, proposed changes to Oregon's toxic standards address an important reservoir implementation issue (ODEQ, 2004). Proposed rules were developed including agency consultation with EPA Region 10, U.S. Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries), and Tribal representatives (ODEQ, 2004). These rules recognize that some Oregon reservoirs stratify and that when this stratification occurs, it may prevent the water body from meeting standards throughout the entire water column. For example, a stratified water body may violate the temperature criterion at or near the surface but be in compliance at depth. Similarly, the water body may violate the DO criterion in a bottom layer but be in compliance above.

The proposed rule clarifies ODEQ's intent to consider the water body as not impaired if the sole reason for exceedance is its stratified condition, so long as three observable layers (epilimnion, metalimnion, and hypolimnion) are documented. OAR 340-041-0061 is proposed to clarify that stratified waters will not be considered impaired for temperature, DO, or pH so long as they comply with water quality criteria in at least one of the strata in order to protect beneficial uses. While the proposed rule recognizes these physical and chemical realities, it also makes clear that sources must maximize the volume of layers that are capable of meeting the applicable criteria and supporting designated beneficial uses.

This approach is consistent with Idaho's rules for DO criteria in waters discharged from dams, reservoirs, and hydroelectric facilities (IDAPA 58.01.02.276). These waters are subject

[6] Oregon's standards also continue to recognize that reservoirs have less stringent chlorophyll *a* targets than natural lakes that thermally stratify.

to specific downstream DO requirements of 3.5 mg/L as an instantaneous minimum coupled with a 7-day average of the daily minimum (DADMin) of 4.7 mg/L and a 30-Day Mean of 6.0 mg/L.

Idaho has also adopted a rule (that has been awaiting EPA action for several years) that includes a "seasonal cold water" fishery use. This seasonal use is intended to provide for the "protection and maintenance of a viable aquatic life community of cool and cold water species, where cold water aquatic life may be absent during, or tolerant of, seasonally warm temperatures" (IDAPA 58.02.01). These criteria only apply between June 21 and September 21 of each year. The cold water biota criteria apply the remaining 9 months. Idaho's existing rules also preclude the application of a DO criterion to the hypolimnion of a stratified water body.

2.3 UAA Guidance and Case Studies

Compared to other regions nationwide, very few UAAs have been completed and approved in Region 10 (encompassing Washington, Idaho, Oregon, and Alaska). EPA is in the process of developing a federal Designated Use Plan to improve national consistency in the review of UAAs and to provide clearer direction concerning the information that should be included in a UAA. This plan is being developed as a follow-up to EPA's 2003 National Water Quality Standards Strategy, which identified designated uses as a top priority (EPA, 2003c).

One of the priority items in the National Water Quality Standards Strategy includes providing "technical support, outreach, training and workshops to assist states and Tribes with designated uses, including use attainability analyses and tiered aquatic life uses." This priority is consistent with the National Academy of Sciences' (NAS) recommendation that designated use evaluations be conducted prior to developing TMDLs in order to provide for the application of appropriate targets (NAS, 2001).

EPA expects to hold internal workshops in each region between September 2004 and spring 2006. EPA is actively soliciting input from states, Tribes, and stakeholders on high priority issues such as:

- Determining how attainability is defined
- Identifying when relying on human-caused conditions (40 CFR 131.10[g][3]) is appropriate
- Clarifying when substantial and widespread economic and social impacts (40 CFR 131.10[g][6]) are applicable
- Evaluating mechanisms for short-term goals other than use removal

Recent Draft UAA guidance developed by Ecology (2004b) recognizes that "in cases where a UAA supports the development of a totally new, intermediate use category, the state will consider a new and more applicable use category in the water quality standards." This is based on the demonstration that the new use category represents the highest attainable condition. A checklist of required items as outlined in Ecology's Draft UAA Guidance is provided in Appendix B.

Recognition of subcategories that are defined geographically and/or spatially and seasonally is consistent with the recently issued use refinements promulgated by EPA in Chesapeake Bay (EPA, 2003b). Refined subcategories (for example, migratory fish spawning and nursery, open-water fish and shellfish, deep-water seasonal fish and shellfish, and deep-channel seasonal refuge) of the current broad aquatic life designated uses were derived to address spatially and seasonally distinct habitats and living resource communities with widely varying DO requirements (Figure 2-3; EPA, 2003b).

Other Region 10 UAA activities include an EPA-assisted ODEQ project that focuses on developing UAA guidance specifically for dam and reservoir situations (expected to be completed by December 2004). IDEQ and ODEQ are in the process of developing UAA guidance.

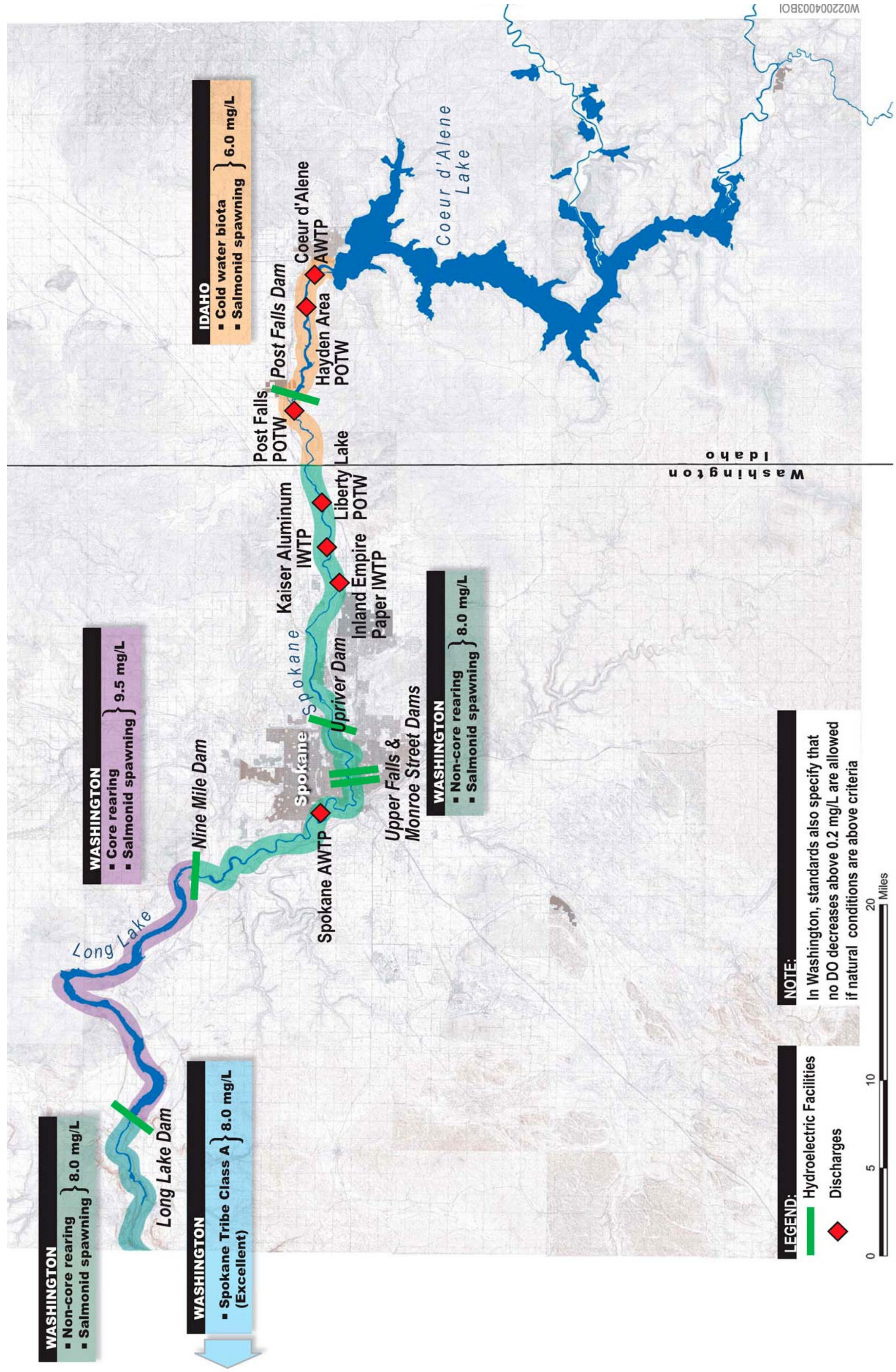


Figure 2-1. Summary of Currently Designated Uses and DO Criteria.

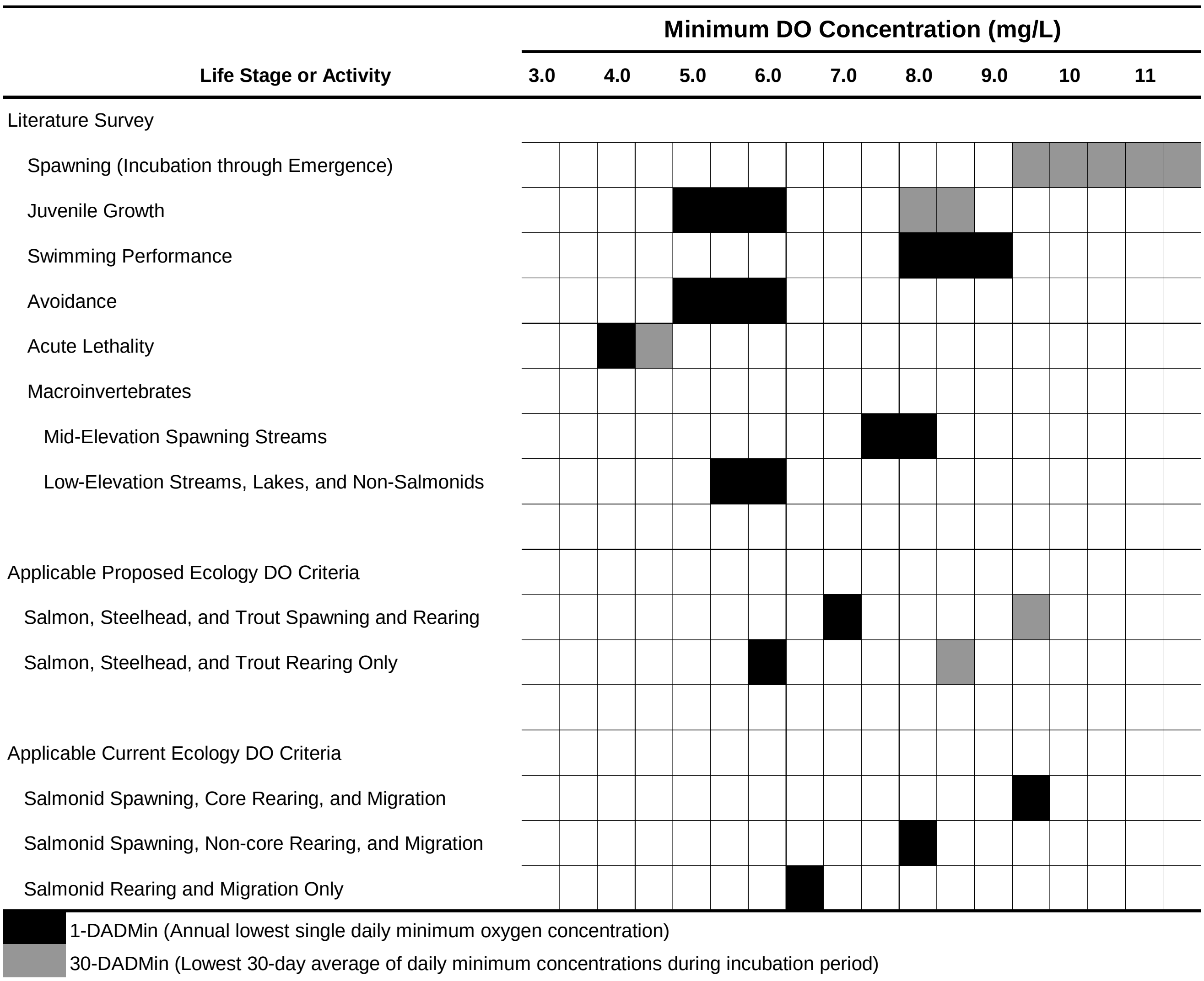
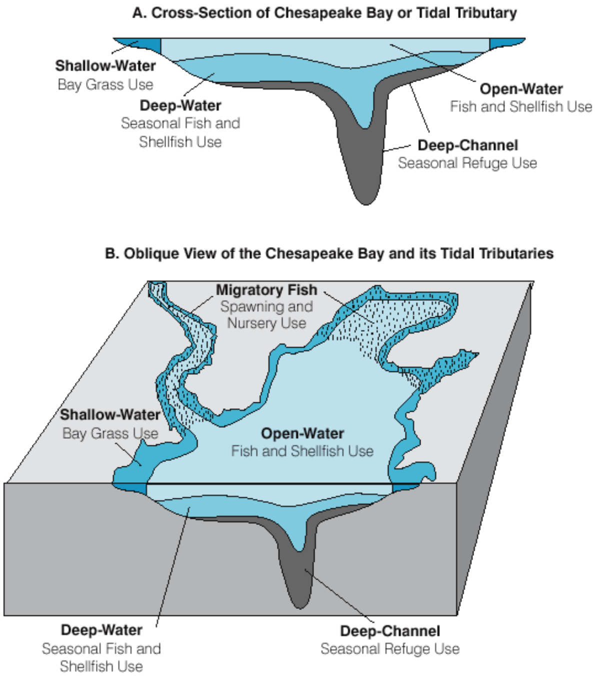


Figure 2-2. Literature Survey and Proposed and Current Ecology DO Criteria.



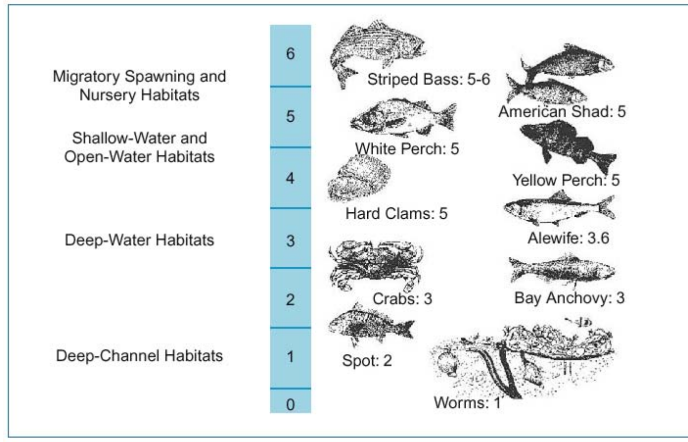


Table 1. Chesapeake Bay dissolved oxygen criteria.

Designated Use	Criteria Concentration/Duration	Protection Provided	Temporal Application
Migratory fish spawning and nursery use	7-day mean ≥ 6 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Survival/growth of larval/juvenile tidal-fresh resident fish; protective of threatened/endangered species.	February 1 - May 31
	Instantaneous minimum ≥ 5 mg liter^{-1}	Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species.	
	Open-water fish and shellfish designated use criteria apply		June 1 - January 31
Shallow-water bay grass use	Open-water fish and shellfish designated use criteria apply		Year-round
Open-water fish and shellfish use	30-day mean ≥ 5.5 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species.	Year-round
	30-day mean ≥ 5 mg liter^{-1} (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile and adult fish and shellfish; protective of threatened/endangered species.	
	7-day mean ≥ 4 mg liter^{-1}	Survi al of open-water fish larvae.	
	Instantaneous minimum ≥ 3.2 mg liter^{-1}	Survival of threatened/endangered sturgeon species."	
Deep-water seasonal fish and shellfish use	30-day mean ≥ 3 mg liter^{-1}	Survival and recruitment of bay anchovy eggs and larvae.	June 1 - September 30
	1-day mean ≥ 2.3 mg liter^{-1}	Survival of open-water juvenile and adult fish.	
	Instantaneous minimum ≥ 1.7 mg liter^{-1}	Survival of bay anchovy eggs and larvae.	
	Open-water fish and shellfish designated-use criteria apply		October 1 - May 31
Deep-channel seasonal refuge use	Instantaneous minimum ≥ 1 mg liter^{-1}	Survival of bottom-dwelling worms and clams.	June 1 - September 30
	Open-water fish and shellfish designated use criteria apply		October 1 - May 31

[1] At temperatures considered stressful to shortnose sturgeon (>29_C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg liter^{-1} will protect survival of this listed sturgeon species.

Figure 2-3. Example from Chesapeake Bay as a Case Study for Subcategories of Uses that Are Spatially and Temporally Defined.
From EPA, 2003b.

3. Existing Water Body Assessment

3.1 Summary of Data Used

As specified by EPA (1994) and Ecology (2004b), water quality is composed of three interrelated conditions: physical, chemical, and biological. Federal and state agencies, as well as private entities and universities, have collected data on these conditions for both the Spokane River (RM 112 to RM 58) and Long Lake Reservoir (RM 58 to RM 34) from before the 1970s to the present. A summary table of data used in the Spokane River UAA is provided in Appendix C, and references are cited when discussing specific data.

The period from the 1970s through the current period was selected for this analysis because the Clean Water Act defines existing uses as those that have occurred anytime since November 28, 1975. This includes any partial uses that may be negatively impacted by current conditions, but are still present in the water body (Ecology, 2004b).

No critical data gaps were identified and it was not necessary to collect additional field data specifically to support the Spokane River UAA because extensive information is currently available for this reach of the Spokane River (RM 112 to RM 58) and for Long Lake Reservoir (RM 58 to RM 34).

Consistent with discussions in Section 1, the water body assessment breaks the study area into two major reaches:

- Spokane River (RM 112 to RM 58): Outlet of Coeur d'Alene Lake to Nine Mile Dam
- Long Lake Reservoir (RM 58 to RM 34): Outlet of Nine Mile Reservoir to Long Lake Dam

Both of these reaches are discussed in the following sections.

3.2 Spokane River (RM 112 to RM 58)

The Spokane River and Lake Spokane (Long Lake) Pollutant Loading Assessment for Protecting Dissolved Oxygen (Pollutant Loading Assessment; Ecology, 2004a) provides an overview of the riverine portion of the study area (see Figure 1-1). This reach contains five hydroelectric facilities, seven NPDES-permitted point sources, and two major tributaries (Table 3-1).

TABLE 3-1
Summary of Major Elements of the Spokane River System between RM 112 and RM 58 (adapted from Ecology, 2004a) (Hydroelectric Facilities, Point Source Discharges, and Major Tributaries)

Element	RM	Comments
Coeur d'Alene Lake Outlet	112	
Coeur d'Alene AWTP	110	
Hayden Area POTW	108.7	
Post Falls Dam	102.0	Constructed in 1906.
Post Falls POTW	100.5	
Liberty Lake POTW	92.7	
Kaiser Aluminum IWTP	86.0	
Inland Empire Paper IWTP	82.6	
Upriver Dam	80.2	Constructed in 1936.
Upper Falls Dam	74.2	Constructed in 1922.
Monroe Street Dam	74.0	Constructed in 1890, replaced in 1974.
Hangman (Latah) Creek	72.4	Adds average annual flow 243 cubic feet per second (cfs; 4 percent of mainstem flow measured at U.S. Geological Survey [USGS] Gage 12422500). Cities of Cheney, Spangle, Rockford, Tekoa, and Fairfield all have small seasonal POTW discharges to creeks in the Hangman watershed.
City of Spokane SAWTP	67.4	
Deep/Coulee Creek	59.2	Occasionally intermittent stream with minimal or no flow during summer. Excellent trout stream with discharging/recharging reaches. City of Medical Lake discharges to Deep Creek.
Nine Mile Dam	58.0	Constructed in 1910.

NOTE: Adapted from Ecology, 2004a and Avista, anticipated public release 2005
cfs = cubic feet per second
USGS = U.S. Geological Survey

In addition to these elements, other sources of nutrients in this reach include the Spokane Aquifer (Patmont et al., 1985) and nonpoint sources along the length of the river system and its major tributaries.

Because this reach can be broken down further in terms of varying sub-reaches that support different aquatic life, a summary of physical, chemical, and biological conditions are described for each sub-reach.

Throughout this report, 2001 conditions are presented to represent potentially worst-case conditions. The year 2001 was a relatively low-flow year with extreme water temperature and DO levels.

3.2.1 Physical Conditions

Coeur d'Alene Lake Outlet (RM 112) to Upriver Dam (RM 80)

This reach contains two dams (Post Falls Dam [RM 102.1] and Upriver Dam [RM 80.2]). The basin is generally composed of highly porous, poorly sorted glacial deposits (Bailey and Saltes, 1982). Between the Coeur d'Alene Lake outlet and Post Falls Dam, the Spokane River functions as a river at high-flow periods, even within reservoirs, and as a mixture of riverine and lacustrine environments at low-flow periods (Falter and Mitchell, 1982). During low-flow periods, although lacustrine tendencies increase downstream with increased water depth, patterns of vertical stratification are not readily evident.

During certain times of the year, the Post Falls Dam can control Spokane River flows and Coeur d'Alene Lake water levels (Avista, 2000a). At other times (late January through spring runoff), the Post Falls Dam either cannot influence river flows or is operated as a run-of-river system, where the natural restriction in the lake outlet channel controls releases. (This is similar to what would have occurred prior to the construction of the Post Falls Dam in 1906.)

The free-flowing reach of the Spokane River between Post Falls Dam and the Stateline provides a variety of habitat types (for example, pool, riffle, run). It has a gradient of approximately 9.5 feet per mile at low flow, with substrates containing large cobbles, and some exposed bedrock in scour pools (Bennett and Underwood, 1992). With the exception of the area between RM 90.4 and RM 84.7, which contains many mid-channel boulders, the substrate between Stateline and Upriver Dam (RM 80.2) is typically composed of granitic cobbles. Gravel and sand are found in low-energy pockets behind boulders or on inside corners of river bends (Bailey and Saltes, 1982). The river does not exhibit a typical riffle-pool morphology, since most of the river between riffles is shallow at low flows, with only moderate velocity (about 1 foot per second; Bailey and Saltes, 1982).

Instream flow and fish habitat surveys conducted on behalf of Avista (Parametrix, 2003) indicate that spawning habitat in this reach tends to be shallow and spread out laterally in the river channel. This spawning habitat occurs primarily at relatively large and shallow gravel bars. Between RM 101.7 and RM 84.0, 13.6 redds per mile were counted during the spawning period in 2003. Northwest Hydraulic Consultants, Inc. (NHC) and HDI (2004) echo consistent recommendations that flows should be managed during spawning and incubation (approximately April 1 to May 31) so that eggs and pre-emergent fry in the redds remain wetted. This issue is being evaluated as part of the Avista FERC re-licensing process (see Section 1.3.2).

This reach is free flowing until it reaches the backwater of Upriver Dam (Patmont et al., 1985). The portion of the river upstream of RM 88 loses flow to the underlying aquifer at a rate of approximately 144 cubic feet per second (cfs) during the summer (Patmont et al., 1985). Downstream of RM 88, the river gains flow from the aquifer, except in the vicinity of the dam that alters the localized raising of the river level (Patmont et al., 1985; Whalen, 2000).

To better understand the relative effects from point sources on river flows in this reach, Figure 3-1 shows the relative contribution of dischargers to Spokane River flows within Washington. This figure is based on August 2001 effluent concentrations presented in the

Pollutant Loading Assessment (Ecology, 2004a) with the monthly mean streamflow for August of that year (U.S. Geological Survey [USGS], 2003b). Together, these data provide a conservative view of the relative proportion of effluent to river flows because 2001 was a drought year and August data reflect the smallest monthly flows. Even under these worst-case conditions, the largest point source in this reach (Kaiser Aluminum) contributes only 6 percent to the mainstem river flow. (Using August flows for the entire period of record brings the highest contributions of the largest point source down to 2 percent of the river flow [USGS, 2003b].)

Upriver Dam (RM 80) to Nine Mile Dam (RM 58)

This reach of the Spokane River contains three hydroelectric dams (Upper Falls [RM 76.2], Monroe Street [RM 74.2], and Nine Mile [RM 58.1]) that form impoundments. These facilities are operated as run-of-river reservoirs. However, pools have been created above each of these facilities. The free-flowing sections in-between impoundments are characterized by sequences of riffles, runs, and pools (Kleist, 1987), with mixes of cobbles and boulders. The river channel in the quasi-free-flowing reach below Upriver Dam (RM 80.2) to Monroe Street Dam has more of an urban influence, with hardening of the banks. The influence of the Monroe Street Dam causes the Spokane River velocity to slow, forming the reservoir. The substrates above the dam change from cobble- and boulder-dominated substrates within the free-flowing reaches, to sands, silts, and organic detritus within the reservoir (Kleist, 1987).

The free-flowing reach below Monroe Street Dam (RM 74.2) to Nine Mile reservoir (RM 63) is similar to the upper free-flowing reach in that salmonid spawning has been documented. Suitable spawning habitat in this reach consists of small patches of suitable substrates located primarily among vegetation along the banks of the river (Parametrix, 2003). Brush and larger vegetation heavily influence habitat characteristics in this reach. The substrate in the uppermost end of the Nine Mile reservoir consists predominantly of boulders, and then transitions to silts, loams, and sands immediately upstream from the dam.

The largest input of aquifer water into the Spokane River is in the section of river below the Upriver Dam (RM 80.2). There, the average input is typically near 580 cfs over a 2.9-kilometer (km; 1.8 mile) distance. This equates to approximately 40 percent of the flow of the river. This is significant in that, during the summer when water temperatures typically rise, this area of the river becomes a cool-water refugia for salmonids and native cold-water fish species. As shown in Figure 3-1, the SAWTP (RM 67.4) contributed approximately 7 percent to the mainstem river flow during August 2001. (Using August flows for the entire period of record brings the contributions of the SAWTP down to 3 percent of the river flow [USGS, 2003b]).

3.2.2 Chemical Conditions

Coeur d’Alene Outlet (RM 112) to Upriver Dam (RM 80)

Between 1973 and 1978, mean monthly summer water temperatures of 22°C were observed at Post Falls during August (Yake, 1979). In the late 1970s and early 1980s, EPA and USGS collected additional data in the reach of the Spokane River between the Coeur d’Alene Lake outlet (RM 112) and Post Falls Dam (RM 102.1; Yearsley, 1980; Sietz and Jones, 1981). During the summer period, average August temperatures in this reach were consistently between

18 and 22°C, with maximum temperatures recorded between 24 and 25°C. More recent data support this trend, with IDEQ (University of Idaho, 1992) and USGS (2003b) monitoring activities recording average August water temperatures between 22 and 24°C, with maximum temperatures greater than 24°C.

The warm temperatures are due to surface water with elevated temperatures released from Coeur d'Alene Lake into this reach. Modeling conducted by Avista predicts that current conditions generally promote slightly high water temperatures compared to a natural condition (Golder and HDR Engineering [HDR], 2004). Current operations result in slightly lower epilimnion temperatures during early summer (late May to August), when the lake elevation can be controlled. In late August to early September, the epilimnion temperature is predicted to be higher (generally within 1.5°C) than that predicted under the natural scenario. Because outflows from Coeur d'Alene Lake originate from the epilimnion, releases to the downstream Spokane River reach are also likely warmer now than would naturally occur during the late summer low flow period (Golder and HDR, 2004; Avista, 2002). The extent to which these elevated water temperatures persist downstream is currently being evaluated by Avista (Golder and HDR, 2004).

EPA and USGS studies also reported historical average August DO concentrations in this reach in the 6.0 to 8.5 mg/L range. (Minimum DO concentrations ranged from less than 1.0 to 7.0 mg/L in the deeper, lower reaches of the reservoir reach; Yearsley, 1980; Sietz and Jones, 1981). Typical for many reservoirs, low DO levels were attributed to long residence times and high water temperatures. More recent data support this trend, with IDEQ (University of Idaho, 1992) monitoring activities recording average August DO levels of 5.5 to 8.0 mg/L. All of these data confirm that "stratification and oxygen depletion are only found in the Spokane River under very low flow regimes, in the deepest locations, and for a short period" (IDEQ, 1994).

By the time the Spokane River enters Washington State (RM 96), temperature and DO conditions improve compared to the impounded reach between the outlet of Coeur d'Alene Lake and Post Falls Dam. Figure 3-2 shows the monthly ranges of water temperature and DO at Stateline (RM 96; data collected from 1990 through 2002), as reported in the Pollutant Loading Assessment (Ecology, 2004a). Warm summer water temperatures of over 23°C were recorded in 1959 (Washington State, 1961), and maximum July-August temperatures of 22 °C were observed between 1957 and 1977 at the Stateline (Yake, 1979).

Downstream from RM 85, inflows from groundwater reduce temperature in the river (Golder and HDR, 2004). This makes this recharged reach valuable as a cold-water refugia.

Minimum DO levels at Stateline during the summer low-flow months typically range between 7.5 mg/L and 8.0 mg/L. These conditions are similar to those observed in 1959 and 1960 (July through September), with DO levels in the 7.7 to 9.0 mg/L range (Washington State, 1961). Yake (1979) recorded mean monthly summer DO levels at Stateline of 8.0 mg/L between 1959 and 1977.

Upriver Dam (RM 80) to Nine Mile Dam (RM 58)

Similar to the upstream reach, this reach has also undergone water quality studies dating back for decades. Between 1972 and 1978, mean monthly water temperatures of 17°C (July) and 18°C (August) were observed at Riverside State Park (RM 66; Yake, 1979). In 1989, EPA collected intensive data at Riverside State Park during August (Yearsley, 1982). These data show average water temperature ranges around 16°C (downstream from groundwater inputs), with maximum temperatures around 17°C. Average DO levels during this same time period were between 8.0 and 9.0 mg/L, with minimum values of 6.0 mg/L (Yearsley, 1982).

Figure 3-3 shows the monthly ranges of water temperature and DO at Riverside State Park (data collected from 1990 through 2002), as reported in the Pollutant Loading Assessment (Ecology, 2004a). Water temperatures reflect the influence of cooling groundwater recharge and are typically below Washington's water temperature standard of 20°C for the Spokane River. These water temperatures are improved from conditions observed at the Stateline, where typical average summer temperatures (July through September) range between 15 and 17°C, with typical maximum temperatures of 18 to 20°C.

DO conditions in this reach are somewhat better than those observed at the Stateline. Table 3-2 provides a summary of DO data presented in the Pollutant Loading Assessment (Ecology, 2004a) showing this comparison.

TABLE 3-2
Summary of DO Data Comparing Stateline (RM 96) and Riverside (RM 66) Monitoring Stations

Station	Average DO Levels (mg/L)	Minimum DO Levels (mg/L)
Stateline (RM 96)		
Oct-Jun	11.3	8.3
Jul-Sept	8.1	7.4
Riverside (RM 66)		
Oct-Jun	12.0	9.0
Jul-Sept	9.7	8.3

Note: Data from the Pollutant Loading Assessment (Ecology, 2004a).

This trend seems somewhat counterintuitive because of the number of dischargers that are located in-between these two stations and the substantial groundwater recharge (which typically has lower DO levels than surface water [Ecology, 2004a]) within this reach. However, higher DO levels downstream are likely because much of this reach is free flowing, with increasing flows in the downstream direction.

Another summary of available DO data for other stations in the river was determined using Ecology monitoring data collected between 1990 and 2002 at additional stations (Ecology, 2004c). Specific to spawning periods for rainbow trout in this reach (April through May), DO levels for the river have a daily average concentration of 11.8 mg/L (median 11.9 mg/L), with an absolute minimum of 8.7 mg/L (n=96) (Ecology, 2004c). Diurnal fluctuations for these stations and spawning period are not available, so available diurnal data for August were used to determine a surrogate ratio between average daily values and minimum daily values.[7] This application is conservative because summer diurnal swings are larger than spring diurnal swings. This causes the estimated spring minimum values to be lower than likely measured values.

During the July through September period, when the only native salmonid life stages that occur are rearing and migration, the average DO in the river is 9.1 mg/L (median also 9.1 mg/L), with an absolute minimum of 6.9 mg/L (n=295). Factoring in available diurnal information (collected from August), the average minimum daily DO in the river is 8.5 mg/L (median also 8.5 mg/L), with an absolute minimum of 6.6 mg/L (n=295).

3.2.3 Biological Conditions

Fisheries and benthic invertebrate assemblages are used to describe the aquatic conditions of the Spokane River, as these are important in assessing existing aquatic life uses. These characteristics include species composition and attribute classifications, such as a species' tolerance to water pollution and its water temperature preference, as well as fish habitat suitability for certain species life stage functions. Descriptions of the fisheries and benthic invertebrate assemblages within the project area are presented in the following sections.

Periphyton and Macroinvertebrates

USGS (2003a) conducted a survey of six sites within the Spokane River between Post Falls Dam and the Little Spokane River. This study included periphyton and macroinvertebrate surveys. The results concluded that chlorophyll *a* levels were below the levels suggestive of nuisance algal conditions. However, levels of chlorophyll *a* at the lowermost site, below the Seven Mile Bridge (RM 63), were approaching the nuisance level (USGS, 2003a).

The total abundance of macroinvertebrates collected at the six sites exceeded that expected at undisturbed (least impacted) sites. However, the number of key taxa (that is, mayflies, stoneflies, and caddisflies) was two to three times lower than at undisturbed reference sites. Further, substrates appeared adequate to support a biologically diverse array of macroinvertebrates and did not indicate physical habitat degradation. However, the low numbers of key taxa indicate water quality impairment related to metals, PCBs, or elevated stream temperatures (USGS, 2003a).

Kleist (1987) conducted macroinvertebrate studies at nine sites within the Spokane River reach that included two within the Nine Mile Reservoir. The river sites increased in species abundance moving downstream. However, the lower two sites were located below the Spokane wastewater treatment facility. It is likely that this contributed to the increase in macroinvertebrate abundance. Two additional macroinvertebrate sites were located within Nine Mile Reservoir. Researchers found a "highly reduced diversity of organisms" dominated by oligocheates and chironomids, with fewer total numbers of the taxa down-reservoir compared to up-reservoir (Kleist, 1987). The findings within the reservoir were similar to those of Pfeiffer (1985) and are consistent with the lack of taxa diversity found within a sediment-dominated substrate (Johnson et al., 1993). Finally, Kleist (1987) observed low zooplankton numbers within the reservoir and postulated that zooplankton are a minor component in providing food for fishes within the run-of-river system. Mayhew (1977, cited

[7] The time of day was also factored into this analysis. If the data were collected before 9:00 a.m., the diurnal correction factor (from average values to minimum values) was not applied because the early morning values represent the lowest DO values of the diurnal fluctuation.

in May et al., 1988) found that hydraulic residence time plays an important role in zooplankton abundance, supporting Kleist's (1987) observation.

Macroinvertebrate riffle data are summarized from surveys conducted from 1983 and from 1999. These macroinvertebrate data are categorized into associated thermal categories, as described in IDEQ (2002; Table 3-3). These data describe previous and recently collected macroinvertebrates as being dominated by species having a wide range of thermal tolerances, with a preference (that is, highest densities) for warm summer water temperatures, followed by those with a preference for cooler temperatures. These data suggest that the recently collected (USGS, 1999) macroinvertebrates have a tendency toward eurythermal (that is, wide temperature tolerances) warm summer conditions, with small numbers of eurythermal cool (that is, most abundant in cooler conditions), few eurythermal hot, and few stenothermal (that is, narrow range of temperatures) cold taxa present. Historical community data from 1982 show the same community structure tendency toward eurythermal warm summer, with small numbers of eurythermal cool and eurythermal hot, and rarely stenothermal cold, taxa present (Funk et al., 1983). Thus, the macroinvertebrate community is reflective of a cool- to warm- (predominantly warm) thermal regime, even though the reach certainly contains a community of cool- and cold-water fishes (in addition to warm-water fishes) that are tolerant of, or have adapted behavior to, seasonally warm temperatures. The community structures may be reflective of the upstream reservoir management, natural riverine sections and their influences, and the constructed lacustrine habitats (that is, backwater areas).

TABLE 3-3
Current and Historical Riverine Macroinvertebrate Community Characterization

Macroinvertebrate Communities[1]	Riffle Habitats (1999)[2]	Qualitative Multiple Habitats (1999)[2]	Multiple Habitats (1982)[3]
Eurythermal hot summer	8%	0%	5-25%
Eurythermal warm summer	83-93%	77-90%	75-100%
Eurythermal cool summer	6-17%	10-17%	10-15%
Stenothermal cold summer	0%	6%	

NOTE: All survey sites were located between RM 72 and RM111
[1]Adapted from IDEQ, 2002
[2]USGS, 1999
[3]Funk et al., 1983
Eurythermal Hot Summer = Tolerates wide range, most abundant in hot summer water temperatures
Eurythermal Warm Summer = Tolerates wide range, most abundant in warm summer water temperatures
Eurythermal Cool Summer = Tolerates wide range, most abundant in cool summer water temperatures
Stenothermal Cold Summer = Tolerates narrow range, most abundant in cold summer water temperatures

In addition, the Index of Biotic Integrity (IBI) scores indicated poor biotic integrity that is based on fish community structure in the Spokane River between Post Falls and the Little Spokane River. Contaminants were also measured from tissues of caddisflies (USGS, 2003a). The results from the tissue samples indicated that lead and zinc levels were five times higher than those from tissue samples at non-impacted sites. These high lead and zinc levels support results of other studies on contaminants within fish tissues for this reach of river. USGS (2003a) suggested that the contaminant levels are likely from historical mining practices and recent industrial and urban influences and that additional studies could verify the sources and levels of contamination.

Fisheries

Figure 3-4 provides a summary of the predominant fish communities and salmonid spawning uses that are discussed in more detail below.

Table 3-4 describes the fishes that have been found within the Spokane River, upstream of Nine Mile Dam (RM 58).

> *NOTE: Table 3-4 describes the entire fish community found within Spokane River reaches from various surveys. This table does not provide an indication of relative abundance, which is an important factor in determining existing uses. Relative abundance is discussed further under each sub-reach.*

Table 3-4 also describes the pollution tolerance and water temperature preferences of the Spokane River fishes, as described within Zaroban et al. (1999). Zaroban et al. (1999) defined pollution “tolerant” species as “fishes that tend to increase in abundance with human disturbances, particularly in relation to increased siltation, turbidity, and water temperature, and lowered concentrations of DO.” They defined species with an “intermediate” pollution tolerance as being “neither tolerant nor sensitive to increased siltation, turbidity, temperature, or lowered DO, but are typically replaced by tolerant species in those situations.” Zaroban et al. (1999) reported that “sensitive” fish species “tend to either disappear or are greatly reduced in association with other human disturbances” and are “typically intolerant of siltation, turbidity, increased water temperature, and lowered DO, and tend to be replaced by intermediate and tolerant species.”

TABLE 3-4
Fishes within the Spokane River between RM 58 and RM 112 (tolerances and preferences from Zaroban et al., 1999)

Common Name[1]	Scientific Name	Native Status	PT	TP
Family: Salmonidae (Trout)				
Redband trout[2,6a]	*Oncorhynchus mykiss gairdneri*	Native	SENS	COLD
Rainbow trout*[6a,b]	*Oncorhynchus mykiss*	Native and non-native strains	SENS	COLD
Westslope cutthroat trout*[6a]	*Oncorhynchus clarki lewisi*	Native	SENS	COLD
Bull trout[2]	*Salvelinus confluentus*	Native	SENS	COLD
Mountain whitefish[6b]	*Prosopium williamsoni*	Native	INT	COLD
Kokanee salmon	*Oncorhynchus nerka*	Non-native	SENS	COLD
Chinook salmon[2,6a]	*Oncorhynchus tshawytscha*	Non-native	SENS	COLD
Lake Superior whitefish[5]	*Coregonis clupeaformis*	Non-native	INT	COLD
Brown trout[6a]	*Salmo trutta*	Non-native	INT	COLD
Brook trout	*Salvelinus fontinalis*	Non-native	INT	COLD
Family: Acipenseridae (Sturgeon)				
White sturgeon[2]	*Acipenser transmontanus*	Native	SENS	COLD
Family: Esocidae (Pike)				
Northern pike	*Esox lucius*	Non-native	INT	COOL
Family: Cyprinidae (Minnow)				
Northern pikeminnow [6a,b]	*Ptychocheilus oregonensis*	Native	TOL	COOL
Peamouth	*Mylocheilus caurinus*	Native	INT	COOL
Longnose dace[6a,b]	*Rhinichthys cataractae*	Native	INT	COOL

TABLE 3-4
Fishes within the Spokane River between RM 58 and RM 112 (tolerances and preferences from Zaroban et al., 1999)

Common Name[1]	Scientific Name	Native Status	PT	TP
Speckled dace[6a]	*Rhinichthys osculus*	Native	INT	COOL
Redside shiner[6a,b]	*Richardsonius balteatus*	Native	INT	COOL
Chiselmouth[2]	*Acrocheilus alutaceus*	Native	INT	COOL
Carp[4]	*Cyprinus carpio*	Non-native	TOL	WARM
Tench	*Tinca tinca*	Non-native	INT	WARM
Family: Catostomidae (Sucker)				
Bridgelip sucker*[6b]	*Catostomus columbianus*	Native	TOL	COOL
Largescale sucker *[6a,b]	*Catostomus macrocheilus*	Native	TOL	COOL
Longnose sucker	*Catostomus catostomus*	Native	INT	COLD
Family: Ictaluridae (Catfish)				
Black bullhead	*Ictalurus melas*	Non-native	TOL	WARM
Yellow bullhead[6a]	*Ictalurus natalis*	Non-native	TOL	WARM
Brown bullhead[6a]	*Ictalurus nebulosus*	Non-native	TOL	WARM
Family: Centrarchidae (Sunfish)				
Pumpkinseed[6a]	*Lepomis gibbosus*	Non-native	TOL	COOL
Largemouth bass[6a]	*Micropterus salmoides*	Non-native	TOL	WARM
Smallmouth bass[3, 6a]	*Micropterus dolomieu*	Non-native	INT	COOL
Black crappie[4, 6a]	*Pomoxis nigromaculatus*	Non-native	TOL	WARM
White crappie[4]	*Pomoxis annularius*	Non-native	TOL	WARM
Family: Percidae (Perch)				
Yellow perch	*Perca flavescens*	Non-native	INT	COOL
Family: Cottidae (Sculpin)				
Shorthead sculpin	*Cottus confusus*	Native	SENS	COLD
Torrent sculpin[6a]	*Cottus rhotheus*	Native	INT	COLD

[1] Species found in Falter and Mitchell (1980), unless denoted otherwise
[2] Whalen (2000)
[3] Osborne et al. (2003)
[4] Bennett and Hatch (1991)
[5] Avista (2000a)
[6a] Upper Spokane – USGS (2003a)
[6b] Lower Spokane – USGS (2003a)
* Hybrids as well

PT = Pollution Tolerance
SENS = Sensitive
INT = Intermediate Tolerance
TOL = Tolerant
TP = Temperature Preference

Other Notes: Some species have had very rare recent sightings (that is, white sturgeon, bull trout, westslope cutthroat trout, and kokanee; Whalen, 2000). White sturgeon accounts stem from one individual record and populations of bull trout are assumed to be historically weak in density through this segment (Whalen, 2000). Various strains of rainbow trout have been introduced into the Spokane River system but the degree of genetic introgression with respect to the native redband strain is unknown (Whalen, 2000). Kokanee are present within the Chain Lake section of the Little Spokane River (thought to be potentially native) but their numbers have been declining since the 1990s and numbers within the mainstem Spokane River are severely depressed (Whalen, 2000).

More than 35 species of fishes and hybrids have been found within the Spokane River segment (Table 3-4). Of these species, 17 are native to the Spokane River subbasin and the other 18 species were introduced. Of the native fishes, six species (four salmonids, white sturgeon, and shorthead sculpin) are considered sensitive to human disturbances and three species (northern pikeminnow and bridgelip and largescale suckers) are considered tolerant of human disturbances. None of the native fishes are considered warm-water fishes, while all native minnows and two of the three suckers are considered intermediate-temperature (cool-water) tolerant.

The WDFW has set specific goals for the management of fishes within the Spokane River subbasin under the Wild Salmonid Policy. The goals include the protection, restoration, and enhancement of wild salmonid productivity, production, and diversity of native populations and their ecosystems within the subbasin (Whalen, 2000).

The historic fish assemblage in the Spokane River subbasin included resident and anadromous salmonids. Below Spokane Falls, the fish assemblages were dominated by anadromous chinook salmon and steelhead *O. mykiss* (Scholz et al., 1985, cited in Whalen, 2000). Hydroelectric projects were constructed within the Columbia River and the Spokane River system that lacked adult passage facilities. This resulted in the extirpation of these stocks. The upper Spokane River system was dominated by resident salmonids that included westslope cutthroat trout, bull trout, redband rainbow trout, and mountain whitefish (Whalen, 2000). Currently, the lower Spokane River fish assemblage consists of an array of non-native species that includes largemouth bass, yellow perch, tench, brown trout, and other species well adapted to warm-water conditions. Historic stocks of native species that continue to inhabit the Spokane River below Spokane Falls include largescale sucker, redside shiner, northern pikeminnow, and chiselmouth.

Native chinook and steelhead runs are no longer found within the Spokane River subbasin. Isolated populations of, perhaps, residualized chinook can be found within segments of the Spokane River system, and it is anticipated that these fish were outmigrants of stocked populations from Coeur d’Alene Lake (Donley, 2003, pers. comm.). Kokanee have been found within Long Lake Reservoir during recent surveys, although in small numbers (Osborne, et al). Kokanee are native to isolated portions of the Little Spokane River system and the population of these fish appears to be at severely depressed levels and restricted to the Chain Lake portion of the Little Spokane River system (Whalen, 2000). Non-native kokanee were introduced into Coeur d’Alene Lake by Idaho Department of Fish and Game in 1937, and have been actively stocked within the lake since that time (Peters et al., 1998). Anderson and Soltero (1984, cited in Osborne et al., 2003) suggest that the kokanee found within Long Lake Reservoir are likely migrants of the stocked fish that have moved down the Spokane River from Coeur d’Alene Lake and are not reproducing within the reservoir.

In addition, mountain whitefish are distributed across eastern Washington and can be found in lesser numbers within most streams and reservoirs within the main Spokane River. Mountain whitefish are also found in Long Lake Reservoir (Osborne et al., 2003) and were once more abundant and more widely distributed throughout the Spokane River system, prior to dam construction (Wydoski and Whitney, 2003).

The limited distribution and abundances of the remaining native salmonids and the extirpation of native anadromous fishes within the Spokane River system suggest a need to select cold-water species that can serve as indicators for aquatic conditions within the Spokane River system. Redband rainbow trout (O. mykiss gairdneri) is a native subspecies of rainbow trout (O. mykiss; Behnke, 1992) and are distributed east of the Cascades within tributaries to the Columbia River (Wydoski and Whitney, 2003). WDFW (2003) examined the genetic structure of several populations of rainbow trout within the Little Spokane River and suggest that isolated populations of resident native fishes are still found within the Little Spokane River system. Given the difficulties in differentiating the native strain from those stocked within the system and the similarities in life history and habitat requirements (Behnke, 1992), rainbow trout will serve as a good cold-water indicator of the fisheries within the main Spokane River.

The following sections describe fisheries associated with the Spokane River by river segments.

Coeur d'Alene Outlet (RM 112) to Upriver Dam (RM 80)

Most of the studies in this reach have focused on rainbow trout, recognizing that this species is one of the few native cold-water species that remains in the subbasin, as well as its popularity among fisheries. Rainbow trout populations in Washington and Idaho are very similar, including the population estimates, the percentage of trout in each age group, and the mean lengths in each age group (Davis, 1991). Downstream from Post Falls, there are three primary areas that support rainbow trout spawning in this section of the river (the Island Complex, Starr Road Bar, and Harvard Road [Avista, 2000a]). However, there are 18 locations known to support spawning at lesser degrees (Whalen, 2000). These areas support a population of naturally reproducing rainbow trout (Donley, 2003, pers. comm.; Avista, 2002; Avista, 2000a; Whalen, 2000; Underwood and Bennett, 1992; Bennett and Underwood, 1988).

WDFW records do not show that this section of the river was ever stocked with rainbow trout (Whalen, 2000). This suggests that this population has the ability to withstand concentrations of metals such as zinc present in the water and may not be influenced by WDFW stocking. However, records describe that Idaho Department of Fish and Game (IDFG) has stocked this reach within Idaho with a variety of salmonids (IDFG, 2004). The WDFW manages this portion of the river as catch-and-release in part because of Washington Department of Health concerns over contamination in fish (Donley, 2003, pers. comm.). In addition, westslope cutthroat trout are relatively abundant in the Spokane River upstream of Post Falls and are also collected within this and lower reaches (Kadlec, 2000; Whalen, 2000; Kleist, 1987; Bailey and Saltes, 1982).

From early April through early June, rainbow trout spawning, incubation, and emergence typically occur downstream of Post Falls (Avista, 2000a). It is believed that this population of rainbow trout appears to be adapting to spawning earlier than is typical for most populations of rainbow trout. This can result in increased survival of fry because of more favorable flow and water temperature conditions (Avista, 2000a). In addition, rainbow trout in this reach of the river appear to be genetically unique and adapted to specific habitats found in the reach (Avista, 2002). These trout can withstand elevated water temperatures during the summer and heightened contaminant concentrations such as zinc (Whalen, 2000; Kadlec, 2000).

Spawning and fry emergence is, to a large extent, dependent upon water temperatures and flow (Avista, 2000a). In this section of the river, water temperatures of 3.8 to 5°C initiate spawning. Emergence of fry from the redds in this area of the Spokane River occurs as water temperatures reach 13°C, typically by late May or early June (Avista, 2000a).

Fry recruitment has also been coupled to Spokane River flows (Avista, 2002; Avista, 2000a; Underwood and Bennett, 1992; Bennett and Underwood, 1988). Flows above 6,000 cfs have been shown to increase emergence and fry survival (Avista, 2002; Avista, 2000a). Flows below 6,000 cfs can dewater redds prior to emergence and decrease fry recruitment (NHC and HDI, 2004; Avista, 2000a), which can destabilize age class structure. Avista can begin to control river flows around June and therefore potentially influence rainbow trout age 0+ survival and recruitment by maintaining flows of 6,000 cfs or more. A WDFW goal for flows downstream of Post Falls is to have a minimum of 6,000 cfs through early June to increase fry survival (Donley, 2003, pers. comm.). As the Avista FERC re-licensing process continues and the operating conditions are specified, future releases from Post Falls may be greater than current releases.

Underwood and Bennett (1992) estimated the population of rainbow trout in 1986 in the 9.9 km (6.2 miles) of river between Post Falls and the Stateline at more than 2,600 fish per mile. This density is similar to self-sustaining populations of rainbow trout in Virginia, Wyoming, and a combined rainbow and brown trout fishery in the Madison River in Montana (Underwood and Bennett, 1992).

Underwood and Bennett (1992) reported growth rates during the first year of life (between about 140 and 155 mm) as above average for the region. However, Underwood and Bennett (1992) also reported that natural mortality of rainbow trout (64 percent mortality annually with total annual mortality of 74 percent) in the Spokane River is not uncommonly high compared to other regional populations, but only allows few fish to reach a large size. This section of the river has substantial year-class variations (Bennett and Underwood, 1988) that are potentially associated with post-spawning mortality, flow fluctuations, high summer water temperatures, over-winter mortality, and high zinc concentrations (Underwood and Bennett, 1992). Prior to 1997, river flows may not have been maintained at or above 6,000 cfs. This would have likely dewatered redds and caused a decrease in fry recruitment, in part, causing the variations observed in the 1984 through 1986 year classes.

During studies conducted by the USGS and Washington State Department of Transportation (WSDOT) in 1998 and 1999, calculated fish IBI for sites at RM 100, RM 96, RM 90, and RM 85 were between 13 and 45 (USGS, 2003a). Sites with scores less than 50 indicate poor biotic conditions where cold-water and sensitive species are infrequent or missing and where tolerant species predominate (USGS, 2003a). These sites typically do not support a cold-water fishery (USGS, 2003a). However, as previously stated, rainbow trout in this reach of the river appear to be adapted to (Avista, 2002), or have developed a resistance to (Kadlec, 2000) elevated water temperatures during the summer months and heightened metals concentrations such as zinc (Whalen, 2000; Kadlec, 2000).

In part, the reason for the low IBI scores at stations in this reach of the river is the lack of sculpin abundance and species diversity. Metrics such as the number of cold-water native species, number of sculpin age classes, and percent sensitive native individuals are used in determining the IBI. Sculpins are a native cold-water species that are very sensitive to elevated metal concentrations (USGS, 2003a). Therefore, the lack or deficit of sculpins at stations in this section of river reduces the overall IBI score. In addition, the presence of non-native and tolerant species such as largemouth bass further reduces the IBI score.

Spokane River water and sediment have elevated metals and PCB concentrations from mining and urban activities, respectively, in the Coeur d'Alene basin (USGS, 2003a; Whalen, 2000). Kadlec (2000) states that metals such as cadmium, lead, and zinc have been found in elevated concentrations in aquatic resources in the Spokane River, with zinc concentrations being the highest. Kadlec (2000) reported that zinc concentrations in several fish species' liver tissues measured 80 to 200 milligrams per kilogram (mg/kg) but there was less than one-quarter to one-half of these amounts in muscle tissue. Zinc bioaccumulation factors of 9,708-fold to 3,835-fold have been found in gill and liver tissue, respectively (Kadlec, 2000).

At these concentrations, zinc is chronically toxic. Kadlec (2000) stated that zinc exposure is typically highest from January through April. Kadlec (2000) also states that the chronic effects during these months may include a reduction in weight in young fish, which may also reduce survival and have population effects from Post Falls to Harvard Road. Zinc concentrations are elevated enough to cause a 25 percent reduction in the largemouth bass population, which is a fish species typically less sensitive to metals than salmonids (Kadlec, 2000). However, Kadlec (2000) stated that Spokane River rainbow trout, which had been acclimated to zinc, could tolerate more than 10 times the amount of zinc of unacclimated trout. This suggests that acclimation can increase tolerance to metal exposure.

Exposure to other contaminants probably has a synergistic effect on fish species. Several environmental factors can also increase the bioavailability of metals to fish. These factors include increasing water temperatures, lower pH, and an increase in DO levels (Kadlec, 2000). There is evidence of metal exposure and degradation in the Spokane River fishery in this section of the river and to at least RM 75, but the severity is unknown (Kadlec, 2000).

Upriver Dam (RM 80) to Nine Mile Dam (RM 58)

Upriver Dam to Monroe Street Dam.

The fish population between Upriver Dam (RM 80) and Monroe Street Dam (RM 74.2) consists of the same general mix of fish species as above Upriver Dam (Donley, 2003, pers. comm.). The overall population for this reach appears to be dominated by cool- and warm-water native largescale sucker, redside shiner, northern pikeminnow, and chiselmouth. Further, westslope cutthroat trout abundance is believed to be extremely low in this section of the river (Whalen, 2000) and there appears to be a small residualized population of chinook within this reach (Donley, 2003, pers. comm.).

There does not appear to be natural reproduction of rainbow trout in this reach. The Riverfront Park area has been stocked with rainbow trout by WDFW since the 1970s to support recreational opportunities (Donley, 2003, pers. comm.). Historically, 5,000 diploid (sexually viable) rainbow trout were stocked there, but more recently, 2,500 triploid (sterile) rainbow trout have been stocked (Donley, 2003, pers. comm.).

Monroe Street Dam to Nine Mile Reservoir.

As with the upper Spokane River, the WDFW under the Wild Salmonid Policy has a goal to protect and enhance wild salmonid populations by protecting remaining suitable salmonid habitats with specific emphasis on spawning and rearing habitats below Monroe Street

(Whalen, 2000). Kleist (1987) describes two distinct segments within this reach. The upstream portion is representative of a riverine environment with riffles, runs, and pools, and the lower portion represents an impounded system formed by the Nine Mile Dam.

As mentioned previously, the riverine segment contains a mix of riffles, runs, and pools that are dominated by substrate that contains a mix of boulders and small, medium, and large cobbles. Although portions of this reach appear to be less than optimum for salmonid habitat, a majority of the reach habitat parameters are favorable for native trout (Kleist, 1987).

Downstream from Monroe Street Dam (RM 74.2), the same general mix of fishes is found as upstream, including whitefish and some brown trout. Rainbow trout densities within this reach are generally low (Donley 2003, pers. comm.). The USGS (2003a) conducted fish surveys within this river segment and found a diversity of species common to the upper Spokane segments (Table 3-4). Natural self-sustaining trout and mountain whitefish reproduction occurs downstream from the Monroe Street Dam (Donley, 2003, pers. comm.). Avista (2002) notes that salmonid habitat characteristics in this reach are marginal to good for juveniles and adults, but appear to be limited in the occurrence of good spawning habitat.

Avista and WDFW, in order to maintain the rainbow trout population in other sections of this reach and provide for recreational opportunities, have a stocking program for rainbow trout (Avista, 2000b). Between 1995 and 1997, the WDFW stocked between 65,000 and 75,000 51- to 76-mm rainbow trout each fall, while Avista has stocked several thousand 203- to 254-mm rainbow trout since 1995 (Avista, 2000b). WDFW has since discontinued stocking in downstream areas (Donley, 2003, pers. comm.).

Avista (2000b) conducted creel surveys during 1996, 1997, and 1999 between Monroe Street Dam and Seven Mile Bridge (approximately 19 km [11.8 miles]). Avista (2000b) reports that the results of the survey indicate that, in this stretch of the river, the fry stocking program did not improve the angling opportunity substantially but that stocking of 203- to 254-mm fish did in some years. As reported by Underwood and Bennett (1992), the annual mortality rate of rainbow trout in the Spokane River is 64 percent or higher. Therefore, stocking of 51- to 76-mm fry by the WDFW would not be expected to increase angling success significantly. Furthermore, stocked fish may emigrate into other areas outside of the creel survey area and would therefore not be available to anglers in this area.

Nine Mile Reservoir to Nine Mile Dam.

The Nine Mile Reservoir operates as a run-of-river system with steep banks and a substrate dominated by silts, loams, and sands (Kleist, 1987). The fishery contains a low density of brown trout that have been stocked occasionally since the 1960s (Donley, 2003, pers. comm.). There are also some stocked rainbow trout, but no natural reproduction occurs. Summertime groundwater inputs generally keep this reach cool enough for rainbow trout rearing. However, resident mountain whitefish migrate upstream into the free-flowing reach for refugia from elevated summer temperatures (Donley, 2003, pers. comm.) Kleist (1987) found rainbow trout and mountain whitefish only occupied the transitional, upstream portion of the reach. Other species within the Nine Mile Reservoir include bridgelip sucker, northern pikeminnow, longnose dace, and redside shiner (Kleist, 1987).

3.3 Long Lake Reservoir (RM 58 to RM 34)

This reach of the Spokane River extends downstream from Nine Mile Dam to Long Lake Dam (see Figure 1-1).

3.3.1 Physical Conditions

A description of the physical conditions within Long Lake Reservoir provides a foundation for the discussion of the biological conditions within the reservoir. Information on the physical habitat of Long Lake Reservoir will be discussed under the following categories:

- Reservoir Morphometry
- Reservoir Hydraulics
- Substrate Type
- Community Zones

Reservoir Morphometry

Geometry.

Long Lake Reservoir was formed by the completion of the Long Lake Dam in 1915 at RM 34. The dam backed up waters within the Spokane River valley approximately 37 km (23 miles) to the existing Nine Mile Dam (Soltero et al., 1992). The reservoir is contained within a long, winding canyon that has eroded about 150 meters into thick glacial-age deposits filling the ancient Spokane River valley (Whalen, 2000). Tributary drainages within the reservoir are short, steep, and consist of small first-, second-, and third- order streams. The only significant surface flows into Long Lake Reservoir are from the Little Spokane and Spokane Rivers. The reservoir impounds water received from the 15,592 square kilometers (km^2) (6,020 square miles) Spokane River drainage basin (Soltero et al., 1992). Other relevant reservoir morphology factors are summarized in Table 3-5. Like most reservoirs, Long Lake Reservoir is long and narrow. Its location within this large drainage basin makes it susceptible to a wider array of physical and chemical influences than those for most natural lakes (Hayes et al., 1999).

TABLE 3-5
Long Lake Reservoir Morphology

Factor	Size
Length	37 kilometers (23 miles)
Volume	305 million cubic meters (270,000 acre-feet)
Surface Area	20 million square meters (4,950 acres)
Mean Depth	15 meters (49 feet)
Maximum Depth	55 meters (180 feet)
Mean Width	580 meters (1,903 feet)
Max Width	1,100 meters (3,609 feet)
Penstock Depth	9 to 14 meters (30 to 46 feet) below full pool water surface

TABLE 3-5
Long Lake Reservoir Morphology

Factor	Size
Dam Height	65 meters (213 feet)
Shoreline Length	86.6 kilometers (53.8 miles)
Shoreline Development	4.6 percent

Note: From Soltero, 1979.

Figure 3-5 is a bathymetric map of Long Lake Reservoir.

Normal operation of Long Lake Reservoir includes keeping the reservoir near (within 1.5 feet of) full pool elevation during the summer recreation period (Parametrix, 2004). This means that more water is available for aquatic species during the sensitive summer period than during periods of winter drawdown. Volume information for the reservoir is shown by depth in Figure 3-6. Using this information, operational changes that affect the reservoir level or improve the surface DO to deeper levels can be quantified. This figure, which is based on the volume available during the summer, shows that 69 percent of the total volume of the reservoir consists of relatively shallow water (above and including a depth of 15 meters [49 feet]). The other 31 percent of the volume contains water below 15 meters (49 feet).

Reservoir slope steepness varies (Figure 3-5). In the upstream reach of the reservoir, gentle upland slopes continue below the waterline, where the typical slope between the reservoir edge and the thalweg is between 12:1 and greater than 50:1. In contrast, much steeper slopes characterize the downstream reach of the reservoir, particularly where former river meanders have incised bedrock. The typical slope between the reservoir edge and the thalweg is typically less than 5:1 in this area, with very steep shorelines that can plunge more than 30 meters (98 feet) directly offshore. There are also occasional underwater benches (at depths of 10 to 20 meters [33 to 66 feet], depths that are well below the limit of the euphotic zone at about 5 to 6 meters [16 to 20 feet]) associated with the inside bend of former riverine meanders.

Channel Types.

Channel types in Long Lake Reservoir can be divided into the following categories:

- **Riverine (RM 57 to RM 53).** This reach of narrow geometry and shallow water (depths of 9 to 12 meters [30 to 39 feet]) has the highest velocities within the reservoir. Riverine areas transport silts and clays, while the coarse fraction of inflowing sediment (primarily from the Little Spokane River) deposits form a small delta. The shallow nature, lack of stratification, and inflow of oxygenated river cause the water column in the riverine area to be aerobic. This area has limited shoreline development (Osborne et al., 2003).
- **Transitional (RM 53 to RM 46).** This area lies between the riverine reach and the lacustrine reach and defines the transitional zone from the transporting of silts and clays to the deposition-dominated zone, typical of the lacustrine portion of reservoirs (Wunderlich, 1971). Gentle slopes and shallow bays with extensive shoreline habitat and

macrophyte beds characterize the transitional reach. Development is also denser here, particularly on the northern side of the reservoir (Osborne et al., 2003).

- **Lacustrine (RM 46 to RM 34).** This reach exhibits characteristics that are more typical of natural lakes, including lower sediment loads accompanied by the deposition of silts and clays and a seasonably stratified water column. Limited shoreline habitat exists within this reach, which is characterized by steep sandy banks and rocky shorelines. The maximum reservoir width (1,100 meters [3,609 feet]) and depth (55 meters [180 feet]) are observed in this reach. This is also defined as the reach that exhibits stratification during the summer.

Reservoir Hydraulics

Soltero et al. (1992) concluded that 98.5 percent of the inflows to Long Lake Reservoir come from surface waters (that is, there is very little influence from groundwater in this section of the basin). The Spokane River and the Little Spokane River combined comprise 99.6 percent of the surface water inflow. The inflow volume varies by year, but the reservoir volume is typically only 4 percent of the average annual flow. As summarized in the Pollutant Loading Assessment (Ecology, 2004a):

> "Soltero et al. (1992) calculated a relatively rapid annual hydraulic retention time in Long Lake Reservoir of 0.04 years (14.6 days) during their 1991 study year, corresponding to a flushing rate of approximately 25 lake volumes per year. Monthly retention time variability ranged from 7 days in May 1991, during the highest inflows, to 56 days in August 1991, during the lowest inflows, emphasizing the flow-through response of the reservoir in connection to the magnitude of inflows. The retention time for June was estimated to be 10 days, and the average retention time for July through October was 44 days."

Long Lake Reservoir is usually mixed, or unstratified, until the beginning or middle of June. Temperature stratification begins to occur within Long Lake Reservoir by June, with fully developed stratification completed by mid-July. By mid-September, fall turnover typically occurs so that the reservoir becomes well mixed again for the start of the next water year. The average residence time (that is, the time required to completely replace water with a body of water) of reservoir water is approximately 16 days. Residence time is as low as 5 days during the peak of snowmelt in the spring, when this period sees a thorough mixing of the reservoir (Ecology, 2004a).

During the summer season, when inflows and corresponding flushing rates are low (Patmont et al., 1987; Soltero et al., 1992), density stratification forms to create a complex mixing regime that partially separates inflows from the reservoir surface and bottom waters. This density-dependent stratification suppresses vertical mixing while enhancing horizontal movements (Wunderlich, 1971), as evidenced by the summer stratification within Long Lake Reservoir. This form of density stratification is common within most reservoirs in the U. S. (Bennett, 1962).

Interflow describes the inflow water movement within Long Lake Reservoir, during stratification, as incoming water travels through the metalimnion to the penstock tube openings in the dam (at a depth of 9 to 14 meters [30 to 46 feet]). Specific conductance profiles collected between June and October have shown a high conductance "tongue" of inflow water centered at a depth of about 10 to 15 meters (33 to 49 feet; Patmont et al., 1987). This "interflow" zone corresponds to the location of the dam penstocks, which suggests that much of the metalimnetic interflow bypasses surface and deeper waters of the reservoir.

In the downstream lacustrine portion of the reservoir, the epilimnion, metalimnion, and hypolimnion layers develop between July and September due to temperature and density differences (Figure 3-7). In lacustrine systems, inputs of oxygen, sunlight penetration, accumulation of dissolved substances, and the distribution of biota are often different in thermally isolated areas. Thus, many of the limnological parameters that define the water quality differ with depth, and the degree of these differences (for example, stratification) varies seasonally.

The epilimnion in Long Lake Reservoir is the upper warm layer of water that is typically well mixed, well illuminated, and generally isothermal (the same temperature throughout). The metalimnion contains the thermocline (a layer of water in which temperature declines rapidly with depth, typically defined as -1°C per meter of depth). It is the middle layer associated with the interflow that restricts the mixing of the upper and lower layers of the reservoir. The hypolimnion in Long Lake Reservoir is the bottom layer of cold water that is isolated from the upper layers. The hypolimnion is very poorly illuminated and generally has little circulation during stratification. Typical temperature and DO profiles are presented for Long Lake Reservoir later in this section.

Substrate Type

Limited information has been collected on the sediments in Long Lake Reservoir. However, given that the reservoir was created in 1915, there is no reason to suspect that it does not follow the typical reservoir sedimentation patterns found in other Pacific Northwest lakes and reservoirs (for example, Coeur d'Alene Lake and Lake Roosevelt). When the inflowing water enters the reservoir reach, density differences cause the inflowing water to slow to a point where the sediment load begins to deposit (Wunderlich, 1971; Morris and Fan, 1998). Typically, the bedload and coarse-grained fractions settle out in the upstream riverine segments and tributary deltas, while the finer-grained fractions are transported deeper into the reservoir.

Soltero and Nichols (1981) found that the sediments that were deposited within the main channel of the upper reach of Long Lake Reservoir are annually scoured of overlying sediment during spring runoff. This scour material is deposited within the lower reaches of the reservoir and likely settles within the deepest part of Long Lake Reservoir. The substrate within the profundal zone of Long Lake Reservoir is likely similar to that of other reservoirs within the Spokane River. For example, the deep substrates within Nine Mile Reservoir are dominated by organic detritus, silts, and sands (Kleist, 1987). The substrates that form the benthos of reservoirs generally originate from the erosional processes within the lakes' immediate drainage area (for example, the shoreline and tributaries), as well as the influences basin-wide (Summerfelt, 1999).

Ecology collected bottom sediment samples in the reservoir in 1998 and 2000. Results for the grain size distribution are presented in Table 3-6 (Ecology, 1999; 2001a).

TABLE 3-6
Grain Size Analysis for Sediments from Long Lake Reservoir

Sample	Gravel (>2 mm)	Sand (0.0625 – 2 mm)	Silt (0.004 – 0.0625 mm)	Clay (<0.004 mm)
Riverine (RM 57 to RM 53)				
RM 54.5	0.0%	86.2%	12.0%	1.8%
RM 53.6	0.6%	80.5%	15.9%	3.0%
Transitional (RM 53 to RM 46)				
RM 46.8	0.6%	3.1%	81.5%	14.8%
Lacustrine (RM 46 to RM 34)				
RM 44	0.0%	1.5%	73.0%	25.1%
RM 36.7	0.0%	2.5%	54.0%	43.5%
RM 35.2	0.02%	3.4%	48.9%	47.8%

Note: The Long Lake Reservoir sample from RM 35.2 was submitted for three replicate analyses, so the average of the three values is presented in this table.

These data indicate that gravel needed to support rainbow trout spawning (10-76 mm; Bennett and Underwood, 1988) is quite limited (less than 1 percent) within the reservoir. WDFW is skeptical that rainbow trout spawning occurs within the reservoir (Donley, 2004, pers. comm.). Sands are more common in the riverine reach, where velocities begin to slow and bedload and coarser suspended loads are deposited.

Photographs taken to document shoreline erosion in Long Lake Reservoir (Earth Systems and Parametrix [ESP], 2004) describe reservoir substrates in the shallower parts of the reservoir. These consist of gravels and cobbles (presumably deposited by the pre-regulated Spokane River) that are overlain by fine silt and clays deposited from tributary and internal reservoir processes. Beaches that are exposed during drawdown consist of gravels and sands, which are also overlain by a veneer of silt and clay. This veneer may result from the many unconsolidated slopes that are near or at their limits of stability (ESP, 2004). Thus, erosion of the shoreline appears to be a relatively minor source of sediment to the reservoir, particularly in the upstream half, because the slopes have stabilized over the 89-year operating history of the reservoir. However, bank erosion from wind- and boat-generated waves is expected to continue along seasonally exposed areas of Long Lake Reservoir (ESP, 2004).

Community Zones

General lacustrine community zones include littoral, limnetic, and profundal zones (Merritt and Cummins, 1996). Littoral zones are shoreline areas that extend down to the depth of light penetration (about 5 to 6 meters [16 to 20 feet]). A stable and well-vegetated littoral zone provides a biological means for protecting and stabilizing shorelines. The riverine and transitional reaches of the reservoir contain the greatest density of littoral habitat, particularly on the southern shore (ESP, 2004). Limited littoral habitat exists within the lacustrine reach, which is characterized by steep sandy banks and rocky shorelines (Osborne et al., 2003; ESP, 2004). The littoral habitat within the lacustrine reach is impacted annually by the winter drawdown of the reservoir that typically ranges from 2 to 4 meters (6 to 14 feet) and lasts several days to over a month (Parametrix, 2003).

Limnetic zones are open-waters areas to the depth of light penetration. Profundal zones are open-water areas below the depth of light penetration, including the substrate. The profundal zone, specifically the bottom, is the principal site for decomposition and is generally the area most susceptible to the DO effects during seasonal stratification.

On a volume basis, the littoral zone encompasses 8 percent, the limnetic zone includes 27 percent, and the profundal zone comprises 65 percent of the total reservoir volume. The extent of these different zones directly affects the aquatic community. Effects include the amount of primary and secondary production as well as the structure and distribution of the fish communities (Hayes et al., 1999), as discussed more in Section 3.3.3.

3.3.2 Chemical Conditions

Within Long Lake Reservoir, relevant chemical conditions for assessing the existing water body uses are DO and temperature. The relationship between these two parameters controls the quality of habitat for the aquatic life that uses the reservoir. The Pollutant Loading Assessment (Ecology, 2004a) provides a good summary of available chemical data from selected locations in the reservoir. The discussion below provides a more integrated view of the data to help answer the question of what uses are existing and attainable.

Data used to develop water temperature and DO isopleths are monthly averages of available monitoring data (Ecology, 2004c).

Water Temperature

As shown in Figure 3-8a, winter water temperatures range from 10 to 14°C. During July and August, the reservoir surface warms rapidly so that the existing Washington State water quality criterion for the reservoir of 20°C is not met. Water temperatures typically range during these warmer months from 12 to 20°C (Figures 3-8b and 3-8c). By September, Long Lake Reservoir cools down again and water temperatures range from 12 to 18°C (Figure 3-8d). These water temperatures are consistent with historical monitoring data collected between 1962 and 1978. These data show mean monthly water temperatures in August peaking at 19°C (Yake, 1979), with surface water temperatures of 23.9 to 25.7°C recorded in 1978 (Soltero et al., 1979).

Figure 3-9 shows typical August temperature values averaged over 3-meter increments in the water column, as well as the relative volume of the reservoir by depth (from Figure 3-6). This figure demonstrates that during the warmest summer period, 65 percent of the reservoir maintains temperatures below 20°C.

Figure 3-10a presents water temperatures observed during August 2001. This is the same year considered to be the "baseline" for the Draft TMDL (Ecology, 2004a; Ecology, 2004e; no data were collected in 2001 from other months).[8] Comparing the August dataset for 2001

[8] Throughout this report, 2001 conditions are presented to represent potentially worst-case conditions. This is consistent with Ecology's use of this water year as a baseline of current conditions and 2001 was a relatively low-flow year with high temperatures and low DO levels.

(Figure 3-10) with the larger dataset (Figure 3-8) shows that year 2001 conditions are not dramatically different during the August 1991, 2000, and 2001 events. In August 2001, temperatures were slightly cooler along the bottom of the reservoir, and still quite warm on the water surface (greater than 22°C).

Dissolved Oxygen

DO isopleths are presented in Figure 3-11. The data represent Ecology sampling efforts conducted in 1991, 2000, and 2001 to develop the TMDL (Ecology, 2004c). The data are based on average DO levels observed during these events. The data show that during winter (defined as October through June), DO levels in the reservoir are above 10.0 mg/L, even though small pockets of DO below 9.5 mg/L can be found along the reservoir bottom (Figure 3-11a). By July, lake stratification is evident, with a band of low DO (5.0 mg/L) beginning to develop along the reservoir bottom (Figure 3-11b). In August, the lowest DO levels are observed, with levels consistently below 5.0 mg/L at depths below 22 meters (72 feet; Figure 3-11c). By September, the turnover usually begins and DO levels improve (Figure 3-11d).

Similar to the findings related to temperature (see Figure 3-9), Figure 3-12 shows typical August DO values averaged over 3-meter increments in the water column, as well as the relative volume of the reservoir by depth (from Figure 3-6). The top axis shows relative DO levels by depth; for example, DO levels remain above 5.0 mg/L down to a depth of 21 meters (69 feet). The bottom axis relates these changes in DO to reservoir volumes; for example, 83 percent of the reservoir is above a depth of 21 meters (69 feet). This means that at a depth of 21 meters (69 feet), during the critical August period, approximately 83 percent of the reservoir remains above hypoxic conditions (greater than 5.0 mg/L).

Figure 3-10b shows the DO levels observed during August 2001. This is the same year considered to be the “baseline” for the Draft TMDL (Ecology, 2004a; Ecology, 2004e; no data were collected in 2001 from other months). Comparing the August dataset for 2001 (Figure 3-10b) with the larger dataset (Figure 3-11c) shows that year 2001 conditions are not dramatically different from conditions observed during August in 1991 and 2000. In August 2001, DO levels were slightly lower along the bottom of the reservoir, but were slightly higher at the water surface.

To put these DO levels in perspective, over a 60-day period (August through September), 17 percent of the total reservoir volume typically falls below 5.0 mg/L, while 3.5 percent of the volume goes anaerobic (less than 1.0 mg/L). The isopleths in Figures 3-10 and 3-11 show that the volume associated with lower DO levels is constrained to the downstream end of the reservoir at depth.

Soltero et al (1982) calculated that, prior to the treatment upgrades in 1978, the volume of reservoir that was less than 5.0 mg/L was 66 percent, while 46 percent of the reservoir was classified as anaerobic (less than 1.0 mg/L). Following treatment upgrades, these percentages improved to 15 percent and less than 5 percent, respectively (Soltero et al., 1982). Combined with more recent data, there is a clear trend of DO improvement over the last 26 years (see Figure 1-2). This is consistent with more recent findings concluding that current nutrient loading rates in the Spokane River are among the lowest in the nation (less than 0.05 mg/L mean annual concentration of total phosphorus for all Spokane River sites; USGS, 2004).

Water Temperature and Dissolved Oxygen Together

The relationship between DO and temperature drives many biological processes in a reservoir (see Section 3.3.3). Temperature, as it relates to seasonal density gradients, becomes the governing parameter in reservoir dynamics because it is responsible for suppressing the vertical mixing within the system and can restrict biological and chemical processes to within their respective stratified zones (Wunderlich, 1971). Similar to many other lacustrine systems, the epilimnion typically contains well-oxygenated waters that have been warmed by solar radiation. In contrast, the hypolimnion typically contains cooler water that is oxygen-deficient.

Data shown in Figures 3-9 and 3-12 are plotted using a different format in Figure 3-13 to provide insight into what volume of Long Lake Reservoir has suitable temperatures (less than 20°C as defined by the current Washington State water quality criterion for the reservoir) and suitable DO levels (greater than 5.0 mg/L) in August. August is when the reservoir is typically most stressed because low DO levels are coupled with the warmest temperatures. Figure 3-13 shows that suitable conditions for temperature and DO levels are present within 48 percent of the volume of the reservoir (that is, 159 million cubic meters [129,000 acre-feet]). In comparison, 35 percent of the volume of the reservoir (within the surface epilimnion) is warmer than what most cool- and cold-water fishes prefer The remaining 17 percent of the volume of the reservoir is more oxygen-deficient than what most fishes prefer.

The oxygen-deficient volume is typically below depths of 21 meters (69 feet). This means that the upper layers of the hypolimnion (generally between 12 and 21 meters [39 to 69 feet]) fall within this “suitable volume.” Figure 3-13 also shows that, on a volumetric basis, the more limiting factor for this “suitable volume” is the warmer water at the surface.

Reservoir systems commonly exhibit similar hypoxic ratios due to their inherent physical constraints and heterogeneity. For example, DO and temperatures in Lake Sammamish constrain the available habitat for returning salmonids to a 10-meter- (33-foot-) deep layer, which is less than half of the total 25- to 30-meter (82- to 98-foot) depth of the lake (King County, 2004a).

3.3.3 Biological Conditions

Long Lake Reservoir has had 89 years to form the existing flora and fauna. These biota have been subjected to changing land-use and management conditions that have affected the current biological conditions. Pertinent existing biological information for Long Lake Reservoir includes the following conditions:

- Trophic Status
- Macrophytes
- Plankton
- Macroinvertebrates
- Fisheries

Trophic Status

The trophic condition of a lake describes its in-situ biological productivity (as a reflection of the nitrogen-phosphorus concentrations, Secchi disk depth, chlorophyll *a* concentrations, and DO) (Huber, 1992). Trophic conditions within reservoirs like Long Lake Reservoir function uniquely compared to natural lakes due, in part, to their shape and location within a drainage system. For example, the average watershed to lake surface ratio in reservoirs is three times that of natural lakes, and phosphorus loading is as much as 200 percent higher in reservoirs than that of natural lakes owing to their location within drainage basins. A consequence of just these two differences is the fast-aging process in reservoirs and the expedited movement of the system from a young, oligotrophic state to a more productive, eutrophic state (Novotny and Olem, 1993; Summerfelt, 1999).

Bennett (1962) stated that most reservoirs are eutrophic. Eutrophication is generally described as the deleterious effect of increased nutrients (nitrogen and phosphorus) on expediting algae and aquatic plant growth with an associated increase in turbidity and reduction in DO (Huber, 1992). Cultural eutrophication (that is, caused by human influences) is the most persistent cause of eutrophication nationwide (Summerfelt, 1999).

Nutrient enrichment and eutrophication of Long Lake Reservoir have been major water quality concerns for the area (Ecology, 2004a). Soltero (1992) provides the most comprehensive description of the trophic status within the reservoir. Long Lake Reservoir shifted its trophic status from an anthropogenic-derived and total phosphorus-driven eutrophic condition prior to 1978 (that is, high biological productivity relative to natural conditions) to a mesotrophic condition in 1991 (that is, intermediate biological productivity; Soltero et al. 1992). The productive condition of the reservoir has been affected by anthropogenic influences (that is, total phosphorus). Therefore, the inception of the advanced wastewater treatment facility at Spokane in 1978 has resulted in reductions in total phosphorus and improvements in the trophic condition within the reservoir (see Figure 1-2).

The results from the 1991 study (Soltero et al. 1992) described an overall mesotrophic status, but the biovolume values described meso-eutrophic conditions and the DO levels described oligotrophic conditions. Given the existing conditions within Long Lake Reservoir, the water quality appears to have stabilized to describe a mesotrophic status (Soltero et al., 1992). Further, Soltero et al. (1992) suggested that Long Lake Reservoir has seen a reduction in primary production with the reduction in the anthropogenic-derived nutrients, and that these reductions may have caused a decline in higher trophic levels. Wetzel (1983) stated that a significant amount of organic production will be permanently incorporated into the fine sediment benthos without complete decomposition. Seasonal mixing, following stratification, and reservoir operations will likely continue to disrupt the benthos, through resuspension, and continue to have some influence on primary production, and thus the trophic status. However, the changes in trophic community structures are difficult to ascertain due to the limited and inconsistent data for the reservoir (Soltero et al., 1992).

Macrophytes

Aquatic plants respond to nutrients, light, toxic contaminants, salt, and management. Submerged and floating macrophytes respond to nutrients in the sediment (Barko et al., 1992, cited in EPA, 2004), and an overabundance of submerged or floating leaved plants can be an indicator of excess nutrients (EPA, 2004). Macrophytes respond more slowly to environmental changes than do phytoplankton or zooplankton, and might be better indicators of overall environmental conditions. Thus, general descriptions of macrophyte distribution within Long Lake Reservoir provide a picture of general reservoir conditions.

A Tetra Tech (2001) report (cited in Parametrix, 2004) noted that a substantial portion of the reservoir's shoreline is covered with dense growths of macrophytes. ESP (2004) describes the vegetation as important in providing stability to the many steep, sandy, and unconsolidated slopes that are found throughout the reservoir. Macrophytes also provide habitat for fish that are vegetation-dependent spawners (for example, yellow perch) and nursery areas for young-of-year fish like largemouth bass (Summerfelt, 1999).

Soltero et al. (1992) identified 15 macrophyte species from three classes in Long Lake Reservoir. Four dominant species are categorized here by riverine, transitional, and lacustrine habitats. In 1992, the riverine portion of the reservoir was dominated by *Potamogeton pectinatus* and *Elodia canadensis* to a depth of 3 meters (10 feet). *P. pectinatus, Nymphoides peltata, E. canadensis*, and *N. odorata* dominated the transitional reach of the reservoir to a depth of 4 meters (13 feet). The lacustrine reach was dominated by *P. pectinatus*, *N. peltata*, and *E. canadensis* to a depth of 4 meters (13 feet).

All of these dominant species are exotic macrophytes. The majority of macrophytes were limited to depths of 3 meters (10 feet) or less. (This depth accounted for approximately 93 percent of the biomass; Soltero et al., 1992.) The remaining 7 percent of the biomass was found at a depth of 4 meters (13 feet) and less than 1 percent was found below 5 meters (16 feet).

Soltero et al. (1992) suggested that both submerged and floating macrophyte coverage has increased substantially over the last 40 years and that areas with cultural development are promoting localized increases. However, Soltero et al. (1992) also concluded that reservoir-wide macrophyte biomass does not appear to be excessive for the system, but reservoir macrophytes account for 1 percent of the total phosphorus budget for the reservoir. This suggests that macrophyte nutrients within the dam pool will continue to have some effect on DO levels (Wetzel, 1983). Annual reservoir drawdowns directly impact macrophyte stability and production (Summerfelt, 1999). Parametrix (2004) provided a summary review of the effects in the drawdown impacts of Long Lake Reservoir on macrophyte production and control within the reservoir. The reservoir has seen a fluctuation in water levels for nearly its entire existence (Parametrix, 2004). The fluctuations are generally restricted to winter months and are considered a means to reduce macrophyte growth while controlling undesirable vegetative growth over a large area of the reservoir. The majority of the macrophytes that inhabit Long Lake Reservoir are exotic plants (Parametrix, 2004). Additionally, Tetra Tech (2001, cited in Parametrix, 2004) suggested that periodic drawdown, combined with vegetative barriers or chemical control within the high use areas, provides an effective means of controlling aquatic macrophytes.

Soltero et al. (1992) recommended drawdown as a method for controlling macrophyte growth and distribution, but recognized the relationship of macrophytes in aiding a productive fishery. Reservoir drawdowns create an unstable littoral zone and appear to be a critical environmental variable relative to the stability of the fisheries (Carline, 1986, cited in Summerfelt, 1999).

Plankton

Soltero et al. (1992) found that phytoplankton production was greatest in the riverine portion of the reservoir, slightly lower in the transitional regions, and lowest in the lacustrine portion of the reservoir. Zooplankton densities tracked similar to phytoplankton production, except that the lower transitional region actually had lower densities of zooplankton than the lacustrine region of the reservoir (Soltero et al., 1992). The 1991 phytoplankton community appeared to have changed when compared to previous studies, with blue-green algae representing the dominant algae (Soltero et al., 1992).

Algae are the base of most lake/reservoir food webs and are very susceptible to human disturbances (EPA, 2004). A dominance of blue-green algae suggests poor water quality conditions (EPA, 2004) that may be linked to excessive nutrient loading. However, this shift from a diatom-dominated environment to a blue-green-algae-dominated environment appeared to have no effect on the zooplankton dynamics or community make-up of Long Lake Reservoir when compared to previous studies (Soltero et al., 1992).

Limnetic zones are dominated by nectonic (swimming) and planktonic (floating) organisms. The scarcity of zooplankton species within this zone is related to the lack of adaptations for swimming (Merritt and Cummins, 1996; Ruttner, 1969). However, primary producers generally dominate limnetic zones where phytoplankton are producing oxygen (Reice and Wohlenberg, 1993; EPA, 2004). Nutrient concentrations, phytoplankton varieties, and the flushing rate of the system determine the rate of production by phytoplankton (EPA, 2004).

Vertical stratification of different sizes and populations of zooplankton can be found within all three zones (that is, limnetic, profundal, and littoral; Odum, 1959). The rate of zooplankton production is closely tied to the rate of phytoplankton production, which is also tied to the trophic development of the reservoir and varies by season (Hayes et al., 1999). Dominant processes of zooplankton within reservoirs generally occur within open-water environments (Reice and Wohlenberg, 1993). However, zooplankton densities are not uniform within a reservoir. They exhibit vertical and horizontal patchiness, as well as daily and seasonal patchiness (Heidinger, 1999). This patchiness can be related to the flushing rate of the reservoir and the internal hydraulics (for example, eddies). Further, pelagic zooplankton densities are known to increase with increasing temperatures (Spokane Tribe, 2003). Understanding the seasonal distribution of zooplankton within Long Lake Reservoir may provide further insight into the distribution of limnetic predators, but this information is currently lacking.

Field and Prepas (1997) describe a number of open-water zooplanktors by their primary habitat (that is, epilimnion, epi-hypolimnion, and hypolimnion). They observed some species that were found only in the deepest portions of the hypolimnion during stratification. These hypolimnetic species appeared to be limited to the hypolimnion and associated with the lower DO levels. However, it appeared that they avoided the very deepest portions of the reservoir due to anoxic conditions. Several of the hypolimnetic species appeared to have a mean DO tolerance of less than 2.0 mg/L (Field and Prepas, 1997). It is unclear how these species would respond to higher DO levels.

Downstream losses of zooplankton are common within reservoirs from flow releases, and this loss can vary by season and with declining pool elevations. Drawdowns appear to increase losses of zooplankton from within reservoirs to downstream and these losses affect food availability for reservoir fisheries resources (May et al., 1988).

Macroinvertebrates

The Long Lake Reservoir benthic community is composed primarily of midges and worms. Pfeiffer (1985) found Chironomidae, Pelecorhyrchidae (Dipteran), and Oligochaeta within riverine, transitional, and deepwater habitats of Long Lake Reservoir, to depths of 11 meters (deeper samples were not collected). Chironomidae were found at all sites (at greater densities in the riverine and transitional reaches) and dominated all but one site (Pfeiffer, 1985). Chironomidae and Oligochaeta tend to dominate the benthos in reservoirs, while Pelecorhyrchidae is considered a riverine species (Merritt and Cummins, 1996). Littoral habitats were not sampled during this survey, so species diversity within shoreline habitat is unknown. However, Pfeiffer (1985) suggested that the benthic densities throughout the Spokane River system appeared to be sufficient to support a large forage base for predatory fishes.

Parametrix (2004) relies on Pfeiffer's data to conclude that seasonal reservoir drawdowns can have varying effects on benthic macroinvertebrates, and suggested that drawdowns can even improve densities of some species (most of which occur in the littoral zones because of the presence of aquatic plants; Voshell, Jr., 2002. However, May et al. (1988) found that the production of aquatic insects (for example, diversity and density) was much lower than its potential because of annual reservoir drawdowns that resulted in the dewatering of the seasonally productive zone. Littoral zones generally contain a diversity of insects that is represented by most orders. Habitats occupied by invertebrates include the benthos, plant surfaces, water column, and surface film. The diversity and abundance of macroinvertebrates within these habitats factor into shaping the overall aquatic community structure (Merritt and Cummins, 2003). Nellson (1961; cited in May et al., 1988) found that trout growth was adversely affected by fluctuating reservoir levels because of the seasonal, "thinning", or dewatering of the insect prey base.

Thus, within Long Lake Reservoir, the greatest diversity of macroinvertebrate species is likely found within the riverine and transitional reaches, where the impact of the seasonal drawdown is less significant. Stream macroinvertebrate surveys conducted upstream of the reservoir (USGS, 2003a) may be representative of species within the littoral zones of the riverine reach of Long Lake Reservoir. USGS (2003a) found 18 genera representing 9 families of macroinvertebrates at the Seven Mile Bridge site (RM 63). All of the identified genera are described by Merritt and Cummins (1996) as either riverine species or those that can be found in littoral zones of lacustrine habitats when associated with hydrophytes. Kleist (1987) also found a reduction in the diversity of macroinvertebrates from the shallow, riverine portion of Nine Mile Reservoir downstream to the deeper lacustrine segment.

Assuming that the euphotic zone (light penetration, macrophyte development) approximates the Secchi disk depths of 1992 and 1999 (about 5 to 6 meters [16 to 20 feet]), at full pool, approximately 35 percent of the total volume of the reservoir is within the euphotic zone (see Figure 3-6).[9] This suggests that approximately 50 percent of the reservoir

[9] In comparison to other lakes within Washington, Secchi depths of about 5 to 6 meters appear to be among the best 1 percent in the state (Ecology, 2004f).

volume is available for primary production and the remainder is near or within the profundal zone. The profundal zone is not evenly distributed throughout the reservoir. The upstream reach is much shallower than the downstream reach toward the dam (see Figure 3-5). The profundal zone is limited to the lacustrine portion of Long Lake Reservoir.

The lacustrine portion likely contains the lowest macroinvertebrate diversity due to the relatively smaller littoral areas zone, the predominance of deepwater habitats (Osborne et al., 2003), and the impact of annual dewatering on macrophytes and macroinvertebrates. The remainder of the macroinvertebrate discussion focuses on the lacustrine reach, as it is most susceptible to the lower DO levels during summer stratification.

The lacustrine portion of Long Lake Reservoir, as described earlier, is dominated by limnetic and profundal zones (estimated at about 5 to 6 meters [16 to 20 feet] for this mesotrophic system), with a limited amount of littoral habitat. This condition is common within reservoirs and less common within natural lakes. The stratified lacustrine reach of Long Lake Reservoir favors limnetic and profundal species because these are the dominant types of habitat. The limnetic and profundal species are less diverse than the species typically found in littoral habitats due to temperature and habitat constraints. Annual dewatering of the littoral zone is likely suppressing the macroinvertebrate potential within that zone of Long Lake Reservoir, as supported by May et al. (1988).

Fine sediments, likely resulting from the age of the reservoir, and deposition from natural and anthropogenic influences (as described above) dominate the substrate within the lacustrine portion of the reservoir. This environment favors decomposers. Decomposition is critical to every aquatic ecosystem, since the broken-down materials are used in primary production. Decomposition involves bacteria, fungi, and macroinvertebrates (Reice and Wohlenberg, 1993). The bacteria and fungi work together in the decomposition process within hypoxic and anoxic conditions. The bacteria often create anaerobic conditions in the sediments by using oxygen faster than it is produced (Odum, 1959).

There are few macroinvertebrate taxa adapted to this environment (for example, Chironomidae, Oligochaetes, *Chaoborus*), and they are limited by the lack of habitat diversity and cover (EPA, 2004). Individuals of a taxon can be numerous but must be able to tolerate cold-water and low DO to anaerobic conditions (Merritt and Cummins, 1996). The order Oligochaete is very common in a variety of aquatic habitats (Pennak, 1978). EPA (2004) suggests that in lakes/reservoirs where hypoxia is severe, tubificid oligochaetes can dominate over chironomids. Kleist (1987) found that chironomids and oligochaetes dominated the deeper, finer sediment portions of Nine Mile Reservoir. It is expected that a similar macroinvertebrate community structure inhabits the deeper, lacustrine portion of Long Lake Reservoir as well.

There are few studies that review the aquatic macroinvertebrate DO requirements at various life stages, particularly those found in benthic environments. Ecology (2002a) provides a literature review and summary of findings of short-term and long-term concentrations of DO that are non-lethal and lethal to some aquatic macroinvertebrates. However, the non-lethal and lethal values do not include species generally considered profundal, such as the Chironomidae larvae that have been found in Long Lake Reservoir. On the extreme end of low DO tolerances, Pennak (1978) describes species of *Chironomus* and *Tubifex* that are able to withstand DO levels below 3.0 mg/L, and even survive several months under anoxic conditions. As discussed in more detail in Section 4.2.3, benthic macroinvertebrate communities are not likely to become significantly more complex or diverse under improved deep-water DO conditions due to water temperature and habitat limitations.

The question of how the benthic macroinvertebrate community might improve under better DO conditions is discussed in Section 4.2.3 as part of the attainable uses evaluation.

Fisheries

Fish populations are powerful structuring forces on lake/reservoir assemblages through feeding interactions (EPA, 2004). These feeding interactions also influence, and are influenced by, nutrient dynamics (Carpenter et al., 1987, cited in EPA, 2004) because fish production is tied to lake/reservoir primary production (EPA, 2004). Because of the age and operating objectives of most reservoir systems, reservoirs have a relatively simple trophic structure compared to natural lakes that is highly vulnerable to environmental variation (Hayes et al., 1999).

Productivity within Long Lake Reservoir has shifted from a eutrophic system to a mesotrophic system with the implementation of reductions in anthropogenic-derived phosphorus (Soltero et al., 1992). Similar to many aquatic systems, the fish abundances and health are a reflection of the reservoir's productivity and stability (Ney, 1999). The fisheries within Long Lake Reservoir have changed through time with water quality and habitat modifications and the introduction of non-native species (Soltero et al., 1992). Soltero et al. (1992) suggested that Long Lake Reservoir has seen a reduction in primary production with the reduction in the anthropogenic-derived nutrients, and that these reductions may have caused a decline in higher trophic levels (for example, the fisheries). However, the changes in trophic community structures are difficult to ascertain due to the limited and inconsistent data for the reservoir (Soltero et al., 1992). The focus on fisheries studies within Long Lake Reservoir has been placed on largemouth bass (as a popular warm-water recreational species) and rainbow trout (as a cold-water native representative) in subsequent discussions of these species.

Long Lake Reservoir is currently managed by WDFW as a mixed fishery. In particular, the reservoir is managed for naturally reproducing populations of cool- and warm-water fishes as an inherited (that is, not stocked) tournament and recreational bass fishery. It has a good crappie and perch fishery as well (Osborne et al., 2003). In addition, catchable rainbow trout are routinely stocked to provide anglers with a cold-water species. However, these species tend to be found within the riverine and transitional portions of the reservoir (Donley, 2004, pers. comm.). WDFW hopes eventually to establish a put-and-take rainbow trout fishery within the reservoir by increasing the numbers stocked to 100,000 annually (Donley, 2003, pers. comm.).

According to Osborne et al. (2003), the upper 4 miles (6.4 km) of the reservoir (from RM 57 to RM 53) is riverine in nature, with limited shoreline development (Figure 3-5). The riverine reach of Long Lake Reservoir may provide good spawning habitat for brown trout but it is only believed to occur within the tailwaters of Nine Mile Dam (Donley, 2004, pers. comm.). Similar to other trout species, brown trout require gravels to spawn in well-oxygenated waters, but are relatively more tolerant of pollution and turbidity (see Table 3-7). Brown trout are non-native species in this system that spawn in mid- to late September to November.

The next 24 km (15 miles) of the reservoir contain heavy growths of macrophyte beds and most of the littoral areas of the reservoir. This portion of the reservoir provides good habitat for largemouth bass and perch (Osborne et al., 2003). The north side of the reservoir is heavily developed and is characterized by shallow bays and gentle slopes. This portion of the reservoir is less influenced by the impacts of dewatering than the lower 10 km (6 miles). The lower 10 km (6 miles) of the reservoir has limited littoral habitat or development and has steep sandy banks and rocky shorelines that provide good seasonal habitat for smallmouth bass (Osborne et al., 2003).

The most recent and comprehensive fisheries description of Long Lake Reservoir is that from Osborne et al. (2003). Osborne et al. (2003) conducted nearshore surveys using electrofishing and net sampling within the three segments of Long Lake Reservoir (that is, riverine, transitional, and lacustrine). Offshore sampling was also conducted using hydroacoustic and gill net methods. Table 3-7 describes the fishes collected during the Osborne et al. (2003) study and includes the general water temperature preferences, DO preferences, and general habitat comments for each species. Figure 3-14 summarizes the survey information for nearshore and open-water sampling by temperature preference for the species observed. Relative abundances of open-water species estimated from hydroacoustic surveys (Osborne et al., 2003) are shown in Figure 3-15.

Results from the Long Lake Reservoir littoral survey indicate that, similar to sampling conducted in the 1980s and 1990s, the relative abundance of non-game species such as northern pikeminnow and largescale sucker remains high (Osborne et al., 2003). Likewise, yellow perch were the most abundant gamefish observed during the 2001 inshore survey, as they were in the offshore lacustrine survey and previous studies. Although low in relative abundance, kokanee and chinook salmon were the only two species observed during offshore lacustrine sampling not collected during inshore sampling. Kokanee and chinook likely entered Long Lake Reservoir from Coeur d'Alene Lake via the Spokane River (Donley, 2004, pers. comm.; Osborne et al., 2003). Chinook are likely entrained within Long Lake Reservoir as they are within other reservoirs of the Spokane River (Donley, 2004, pers. comm.). The chinook found with Long Lake Reservoir may be a residualized form that likely uses the riverine portion of the reservoir (Donley, 2004, pers. comm.). The presence of the fish has created a small sport fishery for chinook within the upper reaches of the reservoir (Donley, 2004, pers. comm.).

Kokanee found within the reservoir may overwinter within Long Lake, but the lack of information on the species provides uncertainty as to the role the reservoir plays in other functions of its life history. Kokanee prefer water temperatures around 50 degrees and are highly dependant on zooplankton (Wydoski and Whitney, 2003). The water temperature conditions, unstable zooplankton production, substrate conditions (Wydoski and Whitney, 2003), competition with warm-water species, and reservoir operational strategy may combine to suppress the kokanee populations. There is no research specific to the species within the reservoir. However, it is likely that the Little Spokane River plays a significant role in the persistence of this population (Donley, 2004, pers. comm.).

Inshore and offshore sampling captured yellow perch within the same size range. Inshore sampling captured a larger size range of northern pikeminnow than was observed during the offshore survey (Osborne et al., 2003). Both smallmouth and largemouth bass also inhabit Long Lake Reservoir, and the reservoir provides quality bass fishing for tournament anglers and the general public.

Overall, the lower portion of Long Lake Reservoir has a limited amount of littoral habitat and vegetation and is dominated by pelagic (i.e., open water) habitats with steep, rocky banks (Osborne et al., 2003). It is likely that this habitat limits the distribution of both cool- and warm-water (for example, largemouth bass) predators and non-game (for example, northern pikeminnow) predators. However, growth of largemouth bass and smallmouth bass was above statewide averages for both species for the sample period and these characteristics likely keep other game species like yellow perch and black crappie from overpopulating, ultimately resulting in higher quality fisheries (Osborne et al., 2003).

Long Lake Reservoir offers a variety of habitats throughout its length, from riverine- (lotic-) type environments at the uppermost end to lacustrine-type environments near the dam. As detailed in Table 3-7, spawning areas for warm-water fishes appear to accommodate vegetation spawners (for example, yellow perch) and nest spawners (for example, largemouth bass). Recruitment of fishes like largemouth bass in many reservoirs is often inadequate because of density-independent factors (Summerfelt, 1999). For example, shorelines exposed to a long fetch (for example, the lacustrine portion of Long Lake Reservoir) receive continuous exposure to wind-driven waves. These waves can be inhospitable to nest and vegetation spawners and may result in poor recruitment within those areas. The lack of vegetation during reservoir fluctuation can create harsh environments and exposure for the young-of-year, resulting in poor recruitment for warm-water fishes like largemouth bass (Summerfelt, 1999) found in Long Lake Reservoir.

TABLE 3-7
Fish Species Present Within Long Lake Reservoir (adopted from Osborne et al., 2003) and Their Habitat Dissolved Oxygen Preferences/Tolerances

Common Name	Scientific Name	Shoreline Survey (% of Total Individuals, n)	Open Water Survey (Gill) (% of Total Individuals, n)	Temperature Preferences (°C)	DO Preferences/ Tolerances (mg/L)	Habitat and Spawning Preferences (Time Period)	Other Comments
Largescale sucker	*Catostomus macrocheilus*	32.4% (1535)	2.1% (6)	Prefer cool water[9]	--	Streams, occasionally lakes – shorelines (fine gravel and sand) (April-June)[2]	Are benthic, in generally shallow water,[2] but down to 24 meters. Feed on macroinvertebrates. Juveniles are usually in shallows or limnetic zone and feed on zooplankton. Spawn in shallow water (mean depth = 203 mm).[9] Are potentially important forage for game species.[2]
Yellow perch	*Perca flavescens*	23.4% (1108)	39.4% (111)	Prefer 21°C, survive at 0 to 26°C[9]	Avoid <5.0 mg/L[9]	Generally lakes – on vegetation, submerged brush, or various bottoms of shoreline (April-May)[2,4]	Travel in schools of same size and age fish. Prefer modest amount of vegetation, clear water[2] 4.5 to 7.6 meters. Stay on bottom. Do not move around much.[9]
Northern pikeminnow	*Ptychocheilus oregonensis*	13.5% (640)	49.3% (139)	20 to 23°C[9]	In summer, will move into deeper areas if DO sufficient[9]	Streams and lakes – gravel cobbles and rubble shorelines (May-July)[2]	Prefer shallows or surface limnetic zone in summer, but down to 30 meters in winter.[9]
Smallmouth bass	*Micropterus dolomieu*	8.4% (399)	--	Prefer 21 to 26°C, avoid <16°C[9]	Avoid <5.0 mg/L[9]	Streams or lakes – nests built on sandy, gravely, or rocky bottoms (<6 meters) (late spring)[4]	Prefer rock or boulder substrate or in reefs. Are not in water <2.4 meters deep when <16°C. Do not travel far.[9] Prefer littoral zone drop-offs.[2]
Black crappie	*Pomoxis nigromaculatus*	5.3% (249)	0.7% (2)	Spawn at 14 to 18°C,[9] tolerate 31°C[10]	--	Generally lakes – nests in mud, sand, or gravel near vegetation (<0.4 meter) (May-June)[2]	Prefer clear water and dense vegetation with sand/mud bottom.[9] In spring, are in water <3 meters deep; in summer are deeper.[9] Adults feed on fish, shrimp, midges. Juveniles feed on zooplankton.[9]

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Fish Species Present Within Long Lake Reservoir (adopted from Osborne et al., 2003) and Their Habitat Dissolved Oxygen Preferences/Tolerances

Common Name	Scientific Name	Shoreline Survey (% of Total Individuals, n)	Open Water Survey (Gill) (% of Total Individuals, n)	Temperature Preferences (°C)	DO Preferences/ Tolerances (mg/L)	Habitat and Spawning Preferences (Time Period)	Other Comments
Tench	*Tinca tinca*	4.0% (189)	--	4 to 24°C[10]	Tolerate low DO[9]	Slow streams or lakes – broadcast eggs in weedy shallows (June-July)[2,4]	Prefer shallow, weedy[9] water <1 meter deep.[10] Feed on aquatic insects.[9]
Largemouth bass	*Micropterus salmoides*	2.3% (109)	--	Optimal at 26°C, inactive at <10°C[9]	Tolerate >2.0 mg/L, avoid <1.5 mg/L[9]	Shallow waters (<3 meters) – nest builder in sand, gravel, or rubble bottoms (May-June)[2,5]	Prefer warm water, shallow weedy lakes, with clear water and cover. Are not deeper than 6 meters,[9] the depth of rooted plants.[2]
Brown bullhead	*Ictalurus nebulosus*	2.1% (99)	0.7% (2)	Survive at 0 to 36°C[9]	Tolerate 0.2 mg/L[9]	Shallow waters (<1 meter) – nest builders in mud or sand with shade (April-June)[2]	Are down to 39 meters deep along shorelines,[2] but prefer shallow bays in large lakes.[9]
Yellow bullhead	*Ictalurus natalis*	2.0% (94)	--	--	--	Shallow waters (<1 meter) – nest builders in mud or sand with shade (May-June)[2]	--
Chiselmouth	*Achrocheilus alutaceus*	1.8% (87)	0.3% (1)	--	--	Tributaries to lakes – possibly broadcast eggs on gravel, rubble, and boulders (May-July)[2]	--
Carp	*Cyprinus carpio*	1.6% (77)	--	Optimal at 21°C, spawning at 18 to 20°C[9]	Tolerate low DO (<2.0 mg/L)[9]	Shallow waters (<1 meter) – broadcast spawners on vegetation and debris (late spring-summer)[2,4]	Prefer shallow vegetated water. Are rarely down to 30 meters.[9] Feed on vegetation and crustaceans.[9] Are tolerant of turbidity, temperature, pollution.[9]
Mountain whitefish	*Prosopium williamsoni*	1.3% (60)	2.5% (7)	Prefer 9 to 11°C, spawn at 9°C[9]	--	Streams and lakes – gravel substrates of riffles and gravel shoals of beaches (September-December)[2]	Prefer rivers, but found in lakes at mouths of tributaries[2] down to 9 meters. Feed on macroinvertebrates, crayfish, shrimp.[9]

TABLE 3-7
Fish Species Present Within Long Lake Reservoir (adopted from Osborne et al., 2003) and Their Habitat Dissolved Oxygen Preferences/Tolerances

Common Name	Scientific Name	Shoreline Survey (% of Total Individuals, n)	Open Water Survey (Gill) (% of Total Individuals, n)	Temperature Preferences (°C)	DO Preferences/ Tolerances (mg/L)	Habitat and Spawning Preferences (Time Period)	Other Comments
Bridgelip sucker	*Catostomus columbianus*	0.7% (31)	--	--	--	Streams[6] (<1 meter) – construct redds in pebble and gravel substrate (April-June)[2]	--
Longnose sucker	*Catostomus catostomus*	0.5% (24)	--	Prefer cold-water lakes (5°C), tolerate 15°C[9]	--	Streams and lakes – shallow rocky shorelines (0-1 meter) (April-May)[1]	Juveniles are in shallow weedy water.[9] Adults are offshore and deeper, down to 180 meters.[10] Feed on benthic organisms.[9]
Brown trout	*Salmo trutta*	0.3% (14)	1.8% (5)	Prefer 18 to 21°C, spawn at 10°C, survive at 27°C[9]	Prefer high DO, but more tolerant to lower DO than other trout[9]	Streams and lakes – shallow rocky shorelines (0-2 meters) (late September[7]-November)[1]	Are tolerant of turbidity.[9]
Pumpkinseed	*Lepomis gibbosus*	0.2% (11)	--	--	--	Lakes (<1 meter) – nest builders in mud, sand, or gravel shores associated with aquatic vegetation (late spring – early summer)[2]	--
Sculpin spp.	*Cottus spp.*	0.1% (4)	--	--	--	Streams and lakes – shallow – shorelines (<1 meter) under rocks and logs (spring)[1,3]	--
Rainbow trout	*Oncorhynchus mykiss*	0.0% (2)	0.3% (1)	Prefer 18°C[1] to <21°C,[9] survive at 0 to 27°C[9]	Avoid <5.0 to 6.0 mg/L;[11] avoid <3.0 mg/L,[13] optimal at 7.0 to 9.0 mg/L[13]	Streams (< 2 meters) – construct redds in riffles (May-June)[7]	Found down to 10 meters.[9] Are opportunistic feeders. Frequent littoral habitats.[13]

TABLE 3-7
Fish Species Present Within Long Lake Reservoir (adopted from Osborne et al., 2003) and Their Habitat Dissolved Oxygen Preferences/Tolerances

Common Name	Scientific Name	Shoreline Survey (% of Total Individuals, n)	Open Water Survey (Gill) (% of Total Individuals, n)	Temperature Preferences (°C)	DO Preferences/ Tolerances (mg/L)	Habitat and Spawning Preferences (Time Period)	Other Comments
Northern pike	*Esox lucius*	0.0% (1)	--	Prefer 19 to 21°C,[2] survive at 10 to 28°C[9]	Tolerate 0.1 mg/L for short periods[2]	Lakes and streams (<3 meters) – broadcast spawners in vegetated floodplains and bays (spring)[2,4]	Prefer clear, heavily vegetated lake shorelines[2] down to 30 meters.[9]
Walleye	*Stizostedion vitreum*	0.0% (1)	--	--	--	Streams and lakes (<2 meters) – broadcast spawners in riffles or rocky shoals and occasionally sand (spring)[2]	--
Channel catfish	*Ictalurus punctatus*	0.0% (1)	--	--	--	Lakes and streams – sheltered areas with existing cavities (spring)[2,5]	--
White crappie	*Pomoxis annularius*	--	--	Spawn at 18 to 20°C,[9] tolerate 31°C[10]	--	Generally lakes – nest in mud, sand, or gravel near vegetation (<0.4 meter) (May-June)[2]	Prefer turbid water.[9] Adults feed on fish and insects; juveniles feed on zooplankton.[9] Are not dependent on vegetation.[2]
Black bullhead	*Ictalurus melas*	--	--	Survive at 8 to 30°C[10]	Tolerate low DO[9]	Shallow waters (<2 meters) – nest builders in mud or sand with cover (April-June)[2]	Are down to 10 meters.[10] Are tolerant of turbidity and pollutants.[9] Are more tolerant than brown bullhead.[9]
Brook trout	*Salvelinus fontinalis*	--	--	Prefer 13 to 19°C, spawn at 5 to 10°C, survive at <25°C[9]	Prefer high DO near bottom[9]	Streams, shallow lake margins (<2 meters) – construct redds in riffles, some observations in upwelling areas in lakes (fall)[2,8]	Are down to 29 meters.[10] Feed on midges in lakes.[9]

TABLE 3-7
Fish Species Present Within Long Lake Reservoir (adopted from Osborne et al., 2003) and Their Habitat Dissolved Oxygen Preferences/Tolerances

Common Name	Scientific Name	Shoreline Survey (% of Total Individuals, n)	Open Water Survey (Gill) (% of Total Individuals, n)	Temperature Preferences (°C)	DO Preferences/ Tolerances (mg/L)	Habitat and Spawning Preferences (Time Period)	Other Comments
Kokanee salmon	*Oncorhynchus nerka*	--	2.5% (7)	Prefer cool-water (10°C)[2]	--	Streams and upwelling areas near lake shores (variable depths) – construct redds (fall)[2] in clear substrates in lakes	Are in open-water.[9, 10] Feed on zooplankton and macroinvertebrate larvae,[9, 10] with greatest volumes between June and October.[12] Feed mainly in upper 20 meters but will feed on benthic organisms.[10] Inhabit deep water[9, 10] down to 249 meters.[10]
Chinook salmon	*Oncorhynchus tshawytscha*	--	0.3% (1)	--	--	Streams (<4 meters) – construct redds in riffles (variable)[2]	Fall chinook are outmigration, mainstem rearers and spring chinook are tributary rearers.[7] Fall and spring chinook are cold-water riverine spawners.

[1]Bradbury et al., 1999
[2] Wydoski and Whitney, 2003
[3]Based on mottled sculpin information
[4]Scott and Crossman, 1973
[5]Cross and Collins, 1995
[6]Spawning information lacking
[7]Donley, 2004, pers. comm.
[8]Simpson and Wallace, 1982
[9] Wydoski and Whitney, 1979
[10] Fishbase on web at http://www.fishbase.org/search.cfm
[11] Ecology, 2002a
[12] Scott and Crossman, 1973
[13] Raleigh et al., 1984 in Bradbury et al., 1999

Nearly all of the cool- and warm-water fish species observed in Long Lake Reservoir spawn in the spring. The dominant spawning period coincides with periods of the year when DO levels are not an issue, particularly in the riverine reach and nearshore littoral zones. During these periods, DO levels consistently remain above the current criterion of 8.0 mg/L because the reservoir has not yet stratified.

Those species that potentially do not complete their spawning cycle by early summer (including smallmouth bass, northern pikeminnow, tench, chiselmouth, and carp) rely on the nearshore littoral zones, which provide adequate protection from predators and suitable substrate (gravels, submerged vegetation; Table 3-7). These dominant spawning areas coincide with areas used for cold-water rearing (riverine and transitional reaches, and the epilimnion within the lacustrine zone).

Largemouth Bass.

Although largemouth bass were introduced to Washington sometime around the 1890s (Wydoski and Whitney, 2003), it is uncertain when they were introduced into Long Lake Reservoir. Largemouth bass are the most popular spiny-rayed fish in Washington, and Long Lake Reservoir is one of the most popular reservoirs within the state for fishing the species. WDFW management goals for Long Lake Reservoir include this species, as it is a very popular target species for both recreation and tournament fishing (Osborne et al., 2003). Largemouth bass are found throughout Long Lake Reservoir. Their body condition within the reservoir generally exceeded the statewide average for all ages observed (Osborne et al., 2003). Largemouth bass are very tolerant of warm water and low DO levels (Zaroban et al., 1999), and appear to prefer shallow areas associated with rooted aquatic plants (Wydoski and Whitney, 2003). Water temperatures up to 26°C provide optimal growth for largemouth bass, and they can tolerate DO levels as low as 2.0 mg/L.

Within Long Lake Reservoir, littoral habitats are likely habitats for solitary adults. Schools of immature largemouth bass are probably most prevalent within the riverine and transitional portions of the reservoir. Largemouth bass are likely present in isolated locations of littoral habitats within the lacustrine portion of the reservoir. Largemouth bass adults will actively feed in open waters at night (Wydoski and Whitney, 2003). However, largemouth bass are piscivorous as adults. It is likely that they use the upper strata of the water column (Table 3-7) for feeding. They seldom swim to depth (greater than 20 meters [66 feet]), since few prey are likely to inhabit that portion of the reservoir. Osborne et al. (2003) suggested that reservoir drawdown may be responsible for the species' low recruitment. They provided several recommendations for improving conditions for largemouth bass within the reservoir.

Rainbow Trout.

WDFW is considering increasing the number of rainbow trout stocked within Long Lake Reservoir. They hope to increase the levels stocked each year to 100,000 fish that are about 150 to 200 mm long (Donley, 2003, pers. comm.). Trout spawning and rearing are limited in Long Lake Reservoir. By stocking the reservoir, these two life stages are not critical for supplementing trout populations (comment from Chris Donley/WDFW; Appendix A1). Spawning is not critical because of the stocking program and rearing is not critical because the objective of the put-and-take fishery is to harvest rainbow trout. Self-reproducing populations of rainbow trout require four kinds of habitat during their various life stages:

spawning, rearing, adult, and overwintering (Behnke, 1992). Factors affecting these types of habitat are described below.

- **Spawning habitat.** Sediment deposition, typical within reservoirs, limits the success of spawning. The uppermost riverine portion of Long Lake Reservoir may provide limited recruitment for trout. The low numbers of native trout and the need for hatchery supplementation suggest that spawning is inadequate to support the needs of the fishery, and it is likely that fine sediments limit the number of adequate redd locations. Spawning habitat for rainbow trout is found within Little Spokane River (Donley, 2004, pers. comm.).
- **Rearing habitat.** Trout require complex rearing habitat that provides protective cover and waters of low velocity (Behnke, 1992). Rearing fishes typically occupy lake/reservoir margins 3 to 6 meters (10 to 20 feet) deep, providing cover is present (Bradbury et al., 1999; Tabor and Wurtsbaugh, 1991). Long Lake Reservoir offers this protective cover within its upstream (riverine) and middle (transitional area) sections and in patchy areas containing macrophytes, spring seeps, or small tributaries. The lower portion of the reservoir contains a limited amount of littoral habitat, since this area is dominated by steep slopes and open-water conditions. Generally, the maximum depth of the macrophytes within this portion of the reservoir does not exceed 4 meters (13 feet). The littoral habitat is absent during the annual drawdown, further reducing available rearing habitat. The combination of limited littoral habitat, reservoir drawdown, predation, and competition likely limits the carrying capacity for rearing rainbow trout.
- **Adult habitat.** In Long Lake Reservoir, adult trout can be found in open waters (Donley, 2004, pers. comm.), even though trout typically inhabit littoral habitats where food is more widely available (Bradbury et al., 1999). The rainbow trout stocked in Long Lake Reservoir are almost strictly zooplanktivorous/insectivorous. This might allow these fish to use the open-water areas efficiently. (Lake Roosevelt, which has similar littoral and open-water habitat to that of Long Lake Reservoir, supports a successful stocked rainbow fishery [Spokane Tribe, 2003].) The diet of these fish may become increasingly dependent on fish as they mature, but insects continue to be an important food source (Beauchamp, 1990, cited in Warner and Quinn, 1995). For example, rainbow trout (n=166) sampled within Lake Roosevelt found that their diets where dominated primarily by zooplankton, other aquatic invertebrates, and to a minor degree by fishes (Spokane Tribe, 2003). Trout typically forage into warm water. They rest and digest food in cool and cold water because this preserves their energy. The riverine portion of the reservoir, and those areas with greater littoral zones, may offer the littoral habitats and available prey needed for adult trout habitat. It appears that prey are most abundant upstream. Prey are less abundant approaching the dam.
- **Overwintering habitat.** The overwintering habitat required by trout generally consists of deep waters with low velocities and sufficient DO (Behnke, 1992). Portions of the reservoir may provide overwintering habitat, providing there is sufficient cover and DO.

Lacustrine trout may exhibit faster growth than resident stream trout, if an adequate food source exists (Behnke, 1992). Lacustrine trout growth also depends on suitable water temperatures, DO, and available habitat for their various life stages. Larger trout may feed within the open-water portions of the reservoir, if an adequate zooplankton food source exists. The diet of open-water trout may be dominated by zooplankton with larger fish exhibiting piscivory. Warner and Quinn (1995) found that pelagic rainbow trout spent 90 percent of their time in the upper 3 meters (10 feet) of the water column. Such trout only ventured into deeper water for short periods. Another study (James and Kelso, 1995) found that the use of lacustrine habitats by rainbow trout varied seasonally. Rainbow trout use littoral habitat primarily in early summer. They shift to limnetic habitat in mid- to late summer, and back to littoral habitat by fall. During the highest summer water temperatures, the rainbow trout moved into the limnetic zone, and back to the littoral zone as temperatures decreased. This pattern was also supported by other studies found in James and Kelso (1995). The fish they tracked also spent most of their time above the thermocline, with occasional deeper dives.

Long Lake Reservoir provides patchy rearing, adult, and overwintering habitat for lacustrine fish. As described earlier, the lacustrine portion of the reservoir has the lowest plankton densities within the reservoir (Bennett and Underwood, 1988) but may offer isolated areas of prey and refuge. Although it is not likely to attract large numbers of rainbow trout for feeding, the limnetic portion of the reservoir may offer thermal refuge in the summer. Raleigh et al. (1994, cited in Bradbury et al., 1999) suggested that rainbow trout appear to prefer (that is, tend to more frequently occur) in those portions of lakes where summer water temperatures are below 18 ºC with DO levels greater than 3.0 mg/L. However, Warner and Quinn (1995) found that rainbow trout stayed within the upper lacustrine strata at temperatures above 20ºC, presumably to take advantage of available food.

The growth and survival of fish are highly dependant on water temperature and availability of food (Hughes and Grand, 2000). It is recognized that these conditions are not uniform throughout the lacustrine portion of Long Lake Reservoir (that is, the CE-QUAL-W2 model provides a 2-dimensional view of reservoir temperature and DO, thus specific microhabitat conditions along the shorelines are not delineated). However, the model does provide a reasonable characterization of overall macrohabitat availability. Thus, the suitable volumes derived from the model are expected to be of the correct order of magnitude. In addition, the focus of the model interpretation is on the conditions in the upper hypolimnion. The habitat conditions become progressively more homogenous with increasing depth.

The concept of "suitable volume" is based on the temperature and DO requirements of rainbow trout within Long Lake Reservoir (temperatures less than 20°C and DO greater than 5.0 mg/L) "Suitable volume" provides a hypothetical model for the potential distribution of rainbow trout in the absence of more specific microhabitat data. The amount of "suitable volume" for hatchery rainbow trout that might potentially be stocked (100,000 added to the reservoir each spring) is nearly 1,600 cubic meters for each trout (conservatively assuming that all of these fish survive to August). This equates to roughly 1.3 acre-feet for each rainbow trout. Thus, it appears very unlikely that trout would be preferentially seeking, or even relying on, deeper cooler water in the lower hypolimnion that is seasonally hypoxic.

Kokanee Salmon.

Kokanee salmon have been found within Long Lake Reservoir during recent surveys, although in small numbers (Osborne et al., 2003). Kokanee are found within isolated portions of the Spokane River drainage system. Native populations appear to be severely depressed and restricted to the Chain Lake portion of the Little Spokane River system (Whalen, 2000). This population appears to remain stable. WDFW believes that it is doubtful that these kokanee are moving into Long Lake Reservoir (Donley, 2004, pers. comm.). Non-native kokanee were introduced into Coeur d'Alene Lake by IDFG in 1937, and have been actively stocked within the lake since that time (Peters et al., 1998). Anderson and Soltero (1984, cited in Osborne et al., 2003) suggested that the limited kokanee found within Long Lake Reservoir are migrants of the stocked fish that have moved down the Spokane River from Coeur d'Alene Lake. However, these fish are not reproducing within the reservoir.

The riverine reach of the reservoir contains limited habitat for kokanee spawning. Because kokanee spawning periods coincide with brown trout spawning periods (fall), protection of potential kokanee spawning is provided in recommendations contained in Section 5.

3.4 Downstream from Long Lake Reservoir (Less than RM 34)

3.4.1 Physical Conditions

Below Long Lake Reservoir (RM 34), the Spokane River flows past Little Falls Dam and into the Spokane Arm of Lake Roosevelt. Little Falls Dam (RM 29) is located approximately 5 river miles below Long Lake Dam. Migrating steelhead, coho, and kokanee were blocked from their spawning tributaries above the dam when Little Falls Dam was constructed in 1911. When Grand Coulee Dam was constructed in 1939 to form Lake Roosevelt, all anadromous fish were permanently blocked from the upper Columbia River, including the Spokane Arm of Lake Roosevelt.

Little Falls Reservoir extends from the Little Falls Dam to the tailrace of Long Lake Dam (Heaton et al., 1993). The forebay extends to 27 meters (89 feet) in depth, although the majority of the reservoir is less than 7 meters (23 feet) deep. Data collected from 1992 through 1993 indicate that Little Falls Reservoir does not stratify during the summer period.

3.4.2 Chemical Conditions

Maximum summer temperatures (July through August 1992) in Little Falls Reservoir ranged from 18.9°C near the tailrace to 19.3°C near the forebay (Heaton et al., 1993). Temperatures of water released from Long Lake Reservoir are cooler than maximum temperatures observed at the surface (Section 3.3.2; Golder and HDR, 2004). Minimum DO levels during the July through September 1992 period ranged from 4.5 mg/L just downstream from Long Lake Dam to 4.8 mg/L in the forebay. Heaton et al. (1993) concluded that the applicable surface water quality standard at that time (incorrectly reported at 8.5 mg/L) was violated between 27 percent (Little Falls forebay) and 45 percent (Long Lake tailrace) of the time on an annual basis.

Recent studies conducted to evaluate fisheries in Lake Roosevelt confirm that, in 2000, temperatures in the Spokane Arm of the reservoir were significantly warmer than in the reservoir as a whole (Spokane Tribe, 2003). Water temperatures tend to peak in August. In 2000, a monthly mean temperature of 20°C was observed in the Spokane Arm. Temperature profiles within this arm indicate that surface temperatures in July and August range between 21 and 23°C, while temperatures at depth (to 35 meters [115 feet]) fall to less than 15°C (Spokane Tribe, 2003). In 2000, warm water temperatures and decomposition of summer algal biomass contributed to low DO concentrations (Spokane Tribe, 2003). Surface DO levels in July and August ranged from 8.0 to 9.0 mg/L, with DO levels dropping to less than 3.0 mg/L at depths of 35 meters (115 feet) in August. (By September, DO levels at this depth had rebounded to 6.9 mg/L.) On an annual basis, mean DO levels in the Spokane Arm (9.5 mg/L) were significantly lower than at other Lake Roosevelt stations (greater than 10.0 mg/L) (Spokane Tribe, 2003).

These trends in downstream chemistry conditions are confirmed by Avista monitoring conducted downstream from Long Lake Dam between 1999 and 2001. This monitoring included hourly temperature and DO measurements in the Long Lake Dam tailrace and the Little Falls Dam tailrace (Avista, 2004a). Data from 2001 are summarized in Table 3-8.

TABLE 3-8
Summary of Riverine Monitoring Data Collected Downstream from Study Area (2001)

	Long Lake Dam Tailrace		Little Falls Dam Tailrace	
Parameter	**July-Sept**	**Oct-June**	**July-Sept**	**Oct-June**
Dissolved Oxygen (mg/L)				
All Data				
Median	8.0	11.1	9.5	12.4
10th Percentile	6.3	8.2	7.8	8.7
1-Day Minimums				
Median	7.4	9.5	8.6	11.4
10th Percentile	5.4	7.3	7.1	8.1
30-Day Average Daily Minimum (30-DADMin)				
Median	7.5	9.0	8.8	11.8
10th Percentile	6.3	8.5	7.5	8.4
Temperature (ºC)				
7-Day Average Daily Maximum (7-DADMax)				
Median	17.5	7.7	16.9	7.1
90th Percentile	18.2	14.8	17.7	13.7

Note: Data from Avista (2004a).
ºC = degrees Celsius
DADMax = day average of the daily maximum
DADMin = day average of the daily minimum
mg/L = milligrams per liter

These data indicate that during worst-case summer conditions (2001), the median 1-day minimum DO levels just downstream from Long Lake Reservoir were 7.4 mg/L during the summer period and improved to 8.6 mg/L downstream from Little Falls Dam. Compared to the isopleths available during the same period (Figure 3-10b), it appears that downstream DO concentrations are controlled by reservoir DO concentrations associated with the interflow zone that is released through the penstocks (ranging from 6.0 to 7.0 mg/L).

At the same time, water temperatures decreased slightly in the downstream direction, with median 7-day average of the daily maximum (DADMax) summer temperatures improving from 17.5 to 16.9°C between Long Lake Dam and Little Falls Dam. The temperatures measured within the Long Lake Dam tailrace are slightly cooler than those observed within the interflow zone (near 18°C) during the same time period (Figure 3-10a).

3.4.3 Biological Conditions

Extensive studies on Lake Roosevelt indicate that this reservoir currently supports 21 species of fish (20 gamefish and 12 non-gamefish). Rainbow trout, kokanee salmon, and walleye are the three primary fish harvested in the reservoir, with smallmouth bass increasing in popularity (Spokane Tribe, 2003). White sturgeon and bull trout fishing are closed, and lesser fisheries exist for other species. Extensive rainbow trout stocking programs are in place and supported by the Spokane Tribe. During 2000, nearly 320,000 fish were caught from the entire reservoir, with smallmouth bass the most abundant species captured. The estimated harvest in 2000 was 176,000 fish, of which nearly 66 percent were rainbow trout (Spokane Tribe, 2003).

3.5 Summary and Discussion of Existing Uses

3.5.1 Spokane River (RM 112 to RM 58)

The Spokane River reach from RM 112 to RM 58 contains five hydroelectric facilities, seven NPDES-permitted point sources, and two major tributaries. The free-flowing reach of the Spokane River between Post Falls Dam and the Upriver Dam provides a variety of habitat types (pool, riffle, run) that support rainbow trout spawning from early April through late May or early June. Since the early 1970s, elevated water temperatures (mean monthly summer temperatures greater than 20°C with maximum temperatures of greater than 24°C) have been recorded consistently. These warm temperatures are due to surface water with elevated temperatures released from Coeur d’Alene Lake into this reach. Because outflows from Coeur d’Alene Lake originate from the epilimnion, releases to the downstream Spokane River reach are also likely warmer now than would naturally occur during the late summer low flow period. Minimum DO levels at the Stateline during the summer low-flow months have typically ranged between 7.5 mg/L and 8.0 mg/L since the 1960s. Even under worst-case conditions, the largest point source in this reach (Kaiser Aluminum) contributes only 6 percent to the mainstem river flow during low-flow August months.

Between Upriver Dam and Nine Mile Dam, three dam structures are operated as run-of-river reservoirs, with upstream pools above each of these facilities. The free-flowing sections between pools are characterized by sequences of riffles, runs, and pools, with mixes of cobbles and boulders. Historical (dating to the early 1970s) and current water temperatures reflect the influence of cooling groundwater recharge. Water temperatures are typically below Washington’s water temperature standard of 20°C for the Spokane River. During the summer, when water temperatures typically rise, recharge of groundwater provides cool-water refugia for salmonids and native cold-water fish species. It is likely that the higher DO levels observed in this reach relative to the Stateline area are because much of this reach is free-flowing, with increasing flows in the downstream direction.

More than 35 species of fishes and hybrids have been found within the Spokane River segment. Of these species, 17 are native to the Spokane River subbasin and the other 18 species were introduced. The Spokane River provides sport fishing and other recreational opportunities in both lacustrine (reservoir) and riverine areas. Non-native species have been introduced, dams have been constructed, and point and nonpoint sources have contributed to an altered system. The current fishery is composed of predominantly cool-water species, with limited numbers of native cold-water species in free-flowing reaches of the river. The overall cool- and warm-water fisheries created by the numerous Spokane River reservoirs are dominated by native largescale sucker, redside shiner, northern pikeminnow, and chiselmouth. The WDFW has set specific goals for the management of fishes within the Spokane River subbasin under the Wild Salmonid Policy. The goals include the protection, restoration, and enhancement of wild salmonid productivity, production, and diversity of native populations within the subbasin. Between Post Falls and Upriver Dam, the rainbow trout appear to be genetically unique and adapted to specific habitats found in the reach. These trout can withstand elevated water temperatures during the summer and heightened contaminant concentrations such as zinc. Spawning and fry emergence is, to a large extent, dependent upon water temperatures and flow. In the upper section of the river, water temperatures of 3.8 to 5°C initiate spawning. Emergence of fry from the redds in this area of the Spokane River occurs as water temperatures reach 13°C, typically by late May or early June.

Natural self-sustaining trout and mountain whitefish reproduction occurs downstream from the Monroe Street Dam. Salmonid habitat characteristics in this reach are marginal to good for juveniles and adults, but good spawning habitat appears to be limited. In addition to native rainbow trout, Avista and WDFW historically stocked this reach with rainbow trout in order to maintain the rainbow trout population in other sections of this reach and provide for recreational opportunities.

Thus, existing aquatic life uses can be described as a resident, interior fishery with a mixture of cold- and cool-water fish being predominant, and with free-flowing reaches that also support a naturally reproducing cold-water rainbow trout population. Macroinvertebrate data collected throughout the riverine reach suggest that low numbers of key taxa may be related to water quality impairment due to metals. The macroinvertebrate community reflects a cool- to warm-thermal regime, even though the reach contains a community of cool- and cold-water fishes that are tolerant of, or have adapted behavior to, seasonally warm temperatures.

3.5.2 Long Lake Reservoir (RM 58 to RM 34)

Long Lake Reservoir was formed by the completion of the Long Lake Dam in 1915. The reservoir impounds water received from the 15,592 km^2 (6,020 square mile) Spokane River drainage basin. Like most reservoirs, Long Lake Reservoir is long and narrow. Its location within this large drainage basin makes it susceptible to a wider array of physical and chemical influences than those associated with most natural lakes.

Based on summer volume, 69 percent of the total volume of the reservoir consists of relatively shallow water (above and including a depth of 15 meters [49 feet]). The other 31 percent of the volume contains water below depths of 15 meters (49 feet). In the upstream reach of the reservoir, gentle upland slopes continue below the waterline, where the typical slope between the reservoir edge and the thalweg is between 12:1 and greater than 50:1. In contrast, much steeper slopes characterize the downstream reach of the reservoir, particularly where former river meanders have incised bedrock. Substrate data indicate that gravel needed to support rainbow trout spawning is quite limited (less than 1 percent) within the reservoir.

Over 98 percent of the inflows to Long Lake Reservoir come from the Spokane River and the Little Spokane River. The inflow volume varies by year, but the reservoir volume is typically only 4 percent of the average annual flow. Long Lake Reservoir typically becomes thermally stratified by June, with fully developed stratification completed by mid-July. By mid-September, fall turnover typically occurs so that the reservoir becomes well mixed again for the start of the next water year. A complex mixing regime partially separates inflows from the reservoir surface and bottom waters. Incoming water travels through the metalimnion to the penstock tube openings in the dam.

The epilimnion in Long Lake Reservoir is the upper warm layer of water that is typically well mixed, well illuminated, and generally isothermal. The metalimnion contains the thermocline (a layer of water in which temperature declines rapidly with depth, typically defined as -1°C per meter of depth). It is the middle layer associated with the interflow that restricts the mixing of the upper and lower layers of the reservoir. The hypolimnion in Long Lake Reservoir is the bottom layer of cold water that is isolated from the upper layers.

Lacustrine community zones in Long Lake Reservoir include littoral (nearshore, 8 percent), limnetic (open-water euphotic, 27 percent), and profundal (open-water photic, 65 percent) zones. The extent of these different zones directly affects the aquatic community. Effects include the amount of primary and secondary production as well as the structure and distribution of the fish communities.

Historical and current temperature data indicate that surface water temperatures commonly exceed the current Washington State water quality criterion of 20°C during the summer. During the warmest summer period, 65 percent of the reservoir maintains temperatures below 20°C. In August, during summer stratification, low DO levels (less than 5.0 mg/L) are consistently observed at depths below 21 meters (69 feet). Over a 60-day period in 2001 (August through September), 17 percent of the total reservoir volume fell below 5.0 mg/L, while 3.5 percent of the volume went anaerobic (less than 1.0 mg/L). These levels are a marked improvement from corresponding volumes calculated in 1978 (66 percent less than 5.0 mg/L and 46 percent less than 1.0 mg/L).

Suitable conditions where temperatures are less than 20°C and DO levels remain greater than 5.0 mg/L are present within 48 percent of the volume of the reservoir during August. In comparison, 35 percent of the volume of the reservoir (within the surface epilimnion) is warmer than what most cool- and cold-water fishes prefer. The remaining 17 percent of the volume of the reservoir is more oxygen-deficient than what most fishes prefer.

Long Lake Reservoir has had 89 years to form the existing flora and fauna. These biota have been subjected to changing land-use and management conditions that have affected the current biological conditions. Given the existing conditions within Long Lake Reservoir, the water quality appears to have stabilized to a mesotrophic status. A substantial portion of the reservoir's shoreline is covered with dense growths of macrophytes (of which all of the dominant species are exotic). These provide stability to the many steep, sandy, and unconsolidated slopes. Macrophytes also provide habitat for fish that are vegetation-dependent spawners and nursery areas for young-of-year fish like largemouth bass. The macrophytes within the lacustrine portion of Long Lake are also impacted annual dewatering and this has likely suppressed the macrophyte potential (that is, diversity and distribution) within this portion of the reservoir. Finally, reservoir-wide macrophyte biomass does not appear to be excessive for the system, and reservoir macrophytes account for only 1 percent of the total phosphorus budget for the reservoir.

Phytoplankton production appears to be greatest in the riverine portion of the reservoir, slightly lower in the transitional regions, and lowest in the lacustrine portion of the reservoir. A shift from a diatom-dominated environment to a blue-green-algae dominated environment appears to have no effect on the zooplankton dynamics or community make-up of Long Lake Reservoir. Zooplankton densities tracked similar to phytoplankton densities, except that the lower transitional region actually had lower densities of zooplankton than the lacustrine region of the reservoir. It is likely that the scarcity of zooplankton species within the open-water (limnetic) zone is related to the lack of adaptations for swimming, the patchy nature of zooplankton distributions, and potentially more importantly, the flushing rate and dewatering impacts within this portion of the reservoir.

The Long Lake Reservoir benthic community is composed primarily of midges and worms. Within Long Lake Reservoir, the greatest diversity of macroinvertebrate species is likely found within the riverine and transitional reaches. The lacustrine portion likely contains the lowest macroinvertebrate diversity, due to the relatively smaller littoral areas zone, the predominance of deepwater habitats, the impact of annual dewatering on macrophytes and macroinvertebrates, and a substrate composed of fine sediments and organic substrates. There are few macroinvertebrate taxa adapted to this environment, and they are limited by the lack of habitat diversity, cover, and water temperature constraints. Further, dewatering of the littoral zone has likely limited the potential development for macroinvertebrates within the lacustrine reach.

Similar to many aquatic systems, the fish abundances and health are a reflection of the reservoir's productivity and stability. The fisheries within Long Lake Reservoir have changed through time with water quality and habitat modifications and the introduction of non-native species. Long Lake Reservoir is currently managed by WDFW as a mixed fishery. In particular, the reservoir is managed for naturally reproducing populations of cool- and warm-water fishes as an inherited (that is, not stocked) tournament and recreational bass fishery. It has a good crappie and perch fishery as well. In addition, catchable rainbow trout are routinely stocked to provide anglers with a cold-water species. WDFW hopes eventually to establish a put-and-take rainbow trout fishery within the reservoir by increasing the numbers stocked to 100,000 annually.

Recent nearshore and offshore surveys indicate that, similar to sampling conducted in the 1980s and 1990s, the relative abundance of non-game species such as northern pikeminnow and largescale sucker remains high in nearshore areas. Likewise, yellow perch were the most abundant gamefish observed during the 2001 inshore survey, as they were in the offshore lacustrine survey and previous studies. Low in relative abundance, kokanee and chinook salmon were the only two species observed during offshore lacustrine sampling not collected during inshore sampling. Kokanee likely entered Long Lake Reservoir from Coeur d'Alene Lake via the Spokane River. Chinook may represent a small residualized population from Coeur d'Alene Lake as well. Overall, Long Lake Reservoir has a limited amount of littoral habitat and vegetation, within the lacustrine portion. It is likely that this has limited the abundance of both cool- and warm-water (for example, largemouth bass and smallmouth bass) predators and non-game (for example, northern pikeminnow) predators. Nearly all of the cool- and warm-water species in Long Lake Reservoir spawn in the spring. The dominant spawning period coincides with periods of the year when DO levels remain high, particularly in the riverine reach and nearshore littoral zones. Long Lake Reservoir is one of the most popular reservoirs within the state for fishing largemouth bass. WDFW management goals for Long Lake Reservoir include this species, as it is a very popular target species for both recreation and tournament fishing.

Because trout spawning is unlikely, and rearing is limited in Long Lake Reservoir, WDFW stocking eliminates these from being critical life stages for the supplemented trout population. Self-reproducing populations of rainbow trout require four kinds of habitat during their various life stages: spawning, rearing, adult, and overwintering. Sediment deposition, typical within reservoirs, and general lack of necessary substrates limit the success of spawning. The low numbers of native trout from the Little Spokane River, and the need for hatchery supplementation suggest that if spawning is occurring in the upper portions of the reservoir, it is inadequate to support the needs of the fishery. Long Lake Reservoir offers protective rearing cover within its upstream (riverine section) and middle (transitional area) sections and in patchy areas containing macrophytes, spring seeps, or small tributaries. Annual dewatering of the lacustrine portion of the reservoir creates an unstable fishery and increases predation on susceptible species like rainbow trout.

Within the lacustrine portion of the reservoir, stocked rainbow trout likely inhabit littoral habitats where food is more widely available and diverse, but there are likely patchy abundances of rainbow trout within the pelagic zone. The rainbow trout stocked in Long Lake Reservoir are almost strictly zooplanktivorous/insectivorous until they are adults, and may shift to piscivory to supplement their diet as they mature. The pelagic fishes likely spend most of their time within the epilimnion during stratification, but venture into the metalimnion or hypolimnion for short periods to feed. Warner and Quinn (1995) found that pelagic rainbow trout spent most of their time in the upper 3 meters (10 feet) during stratification, but made occasional, and brief, "dives" into deeper strata. Further, fishes in the Warner and Quinn (1995) study stayed primarily within the waters above the thermocline (10 to 20 meters [33 to 66 feet]) during stratification, even though these temperatures were recorded as high as 21^{o}C.

The amount of "suitable volume" for hatchery rainbow trout that might potentially be stocked (100,000 added to the reservoir each spring) is nearly 1,600 cubic meters for each trout (conservatively assuming that all of these fish survive to August). This equates to roughly 1.3 acre-feet for each rainbow trout. Although the equal distribution of trout within this "suitable volume" is unlikely, the model area does provide an approximation of the useable area within which these fishes would spend a majority of their time, with occasional dives into deeper habitats. Thus, it appears very unlikely that trout would be preferentially seeking, or even relying on, deep water in the lower hypolimnion that is seasonally hypoxic.

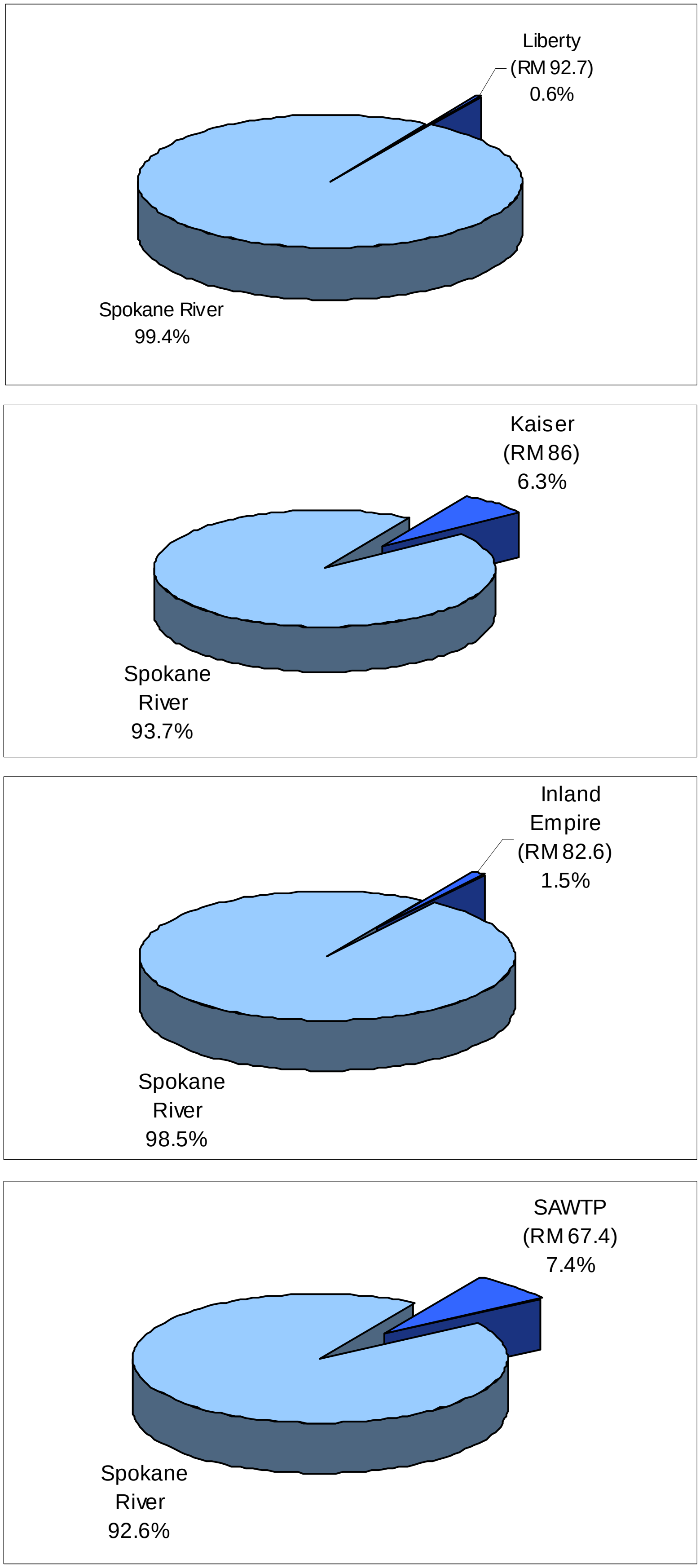

Figure 3-1. Relative Contribution of Washington Dischargers to Spokane River Flows During Low Flow Periods.

NOTE: Data represent August 2001 conditions.

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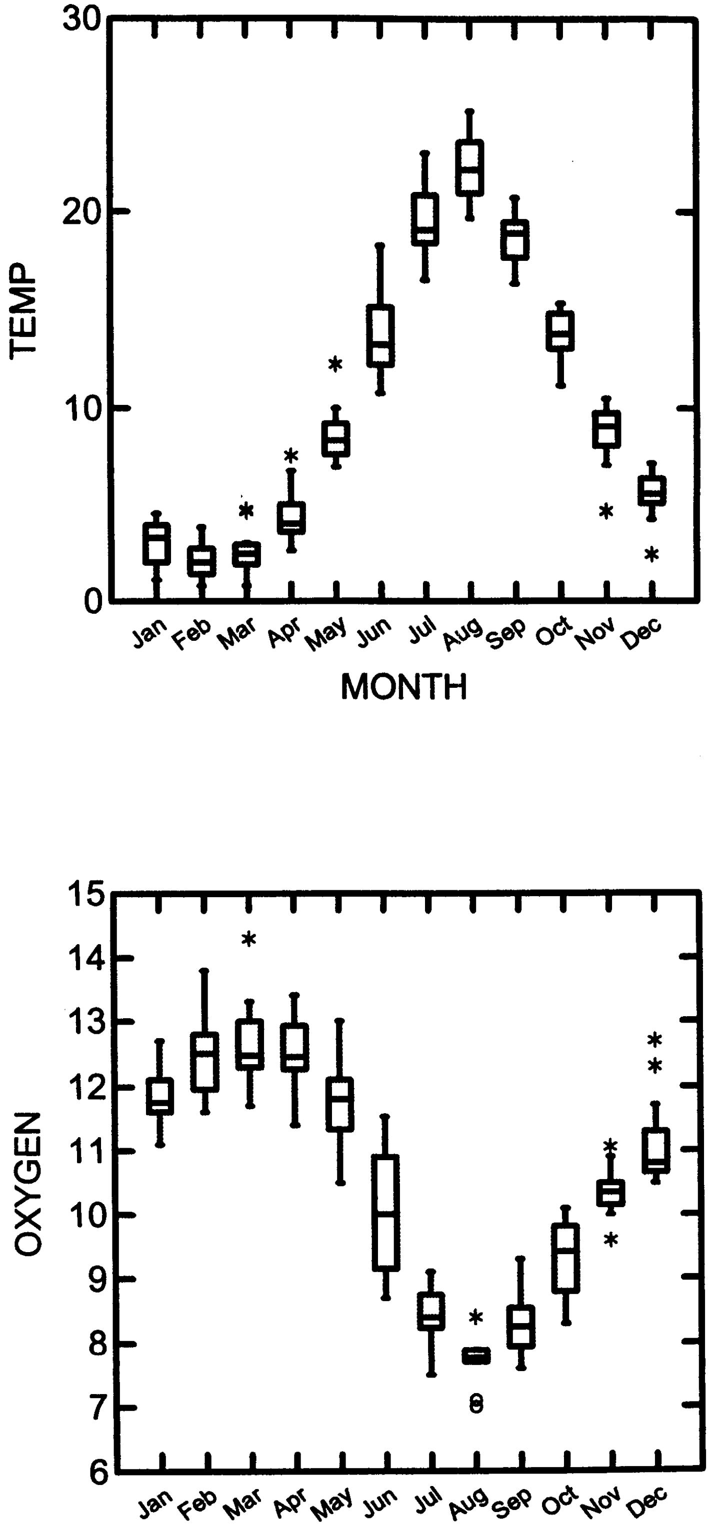

Figure 3-2. Monthly Ranges of Temperature and DO at Stateline (RM 96) (1990-2002). From Ecology, 2004a.

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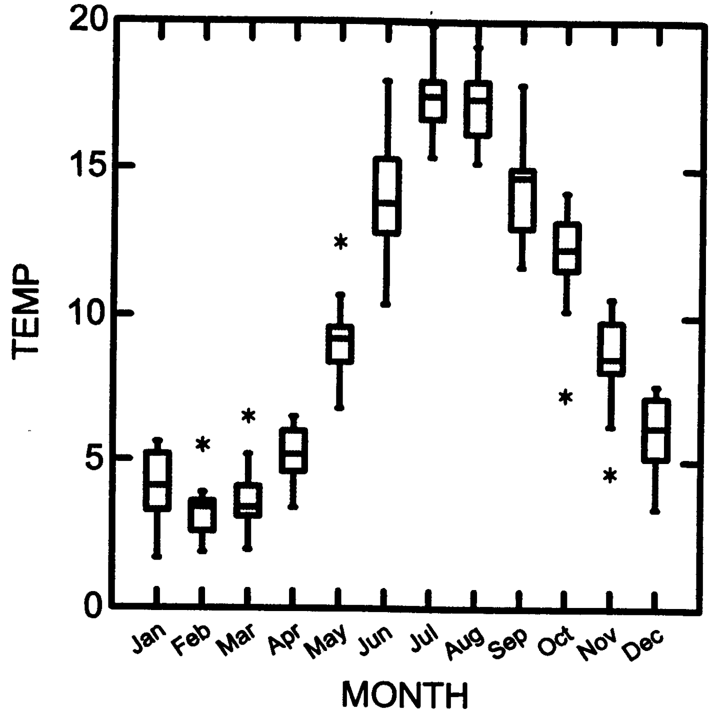

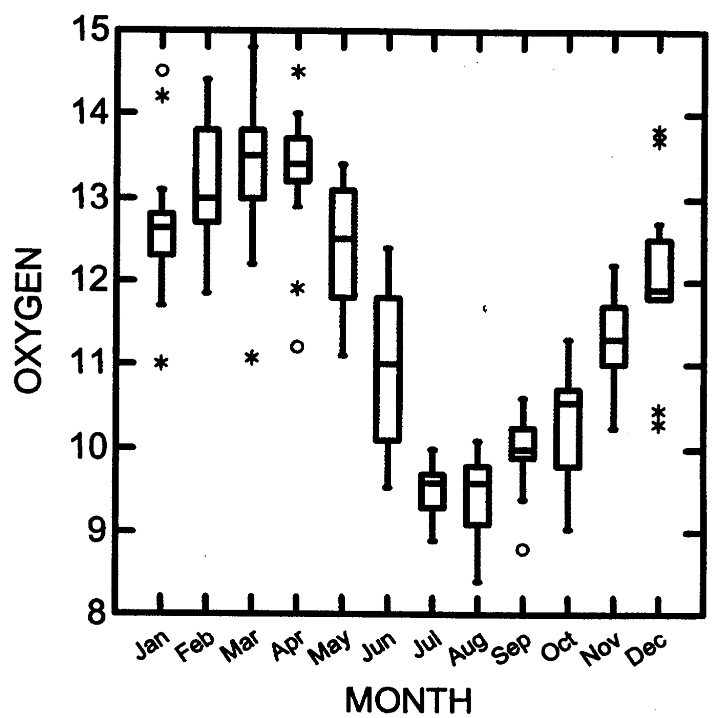

Figure 3-3. Monthly Ranges of Temperature and DO at Riverside State Park (RM 66) (1990-2002).
From Ecology, 2004a.

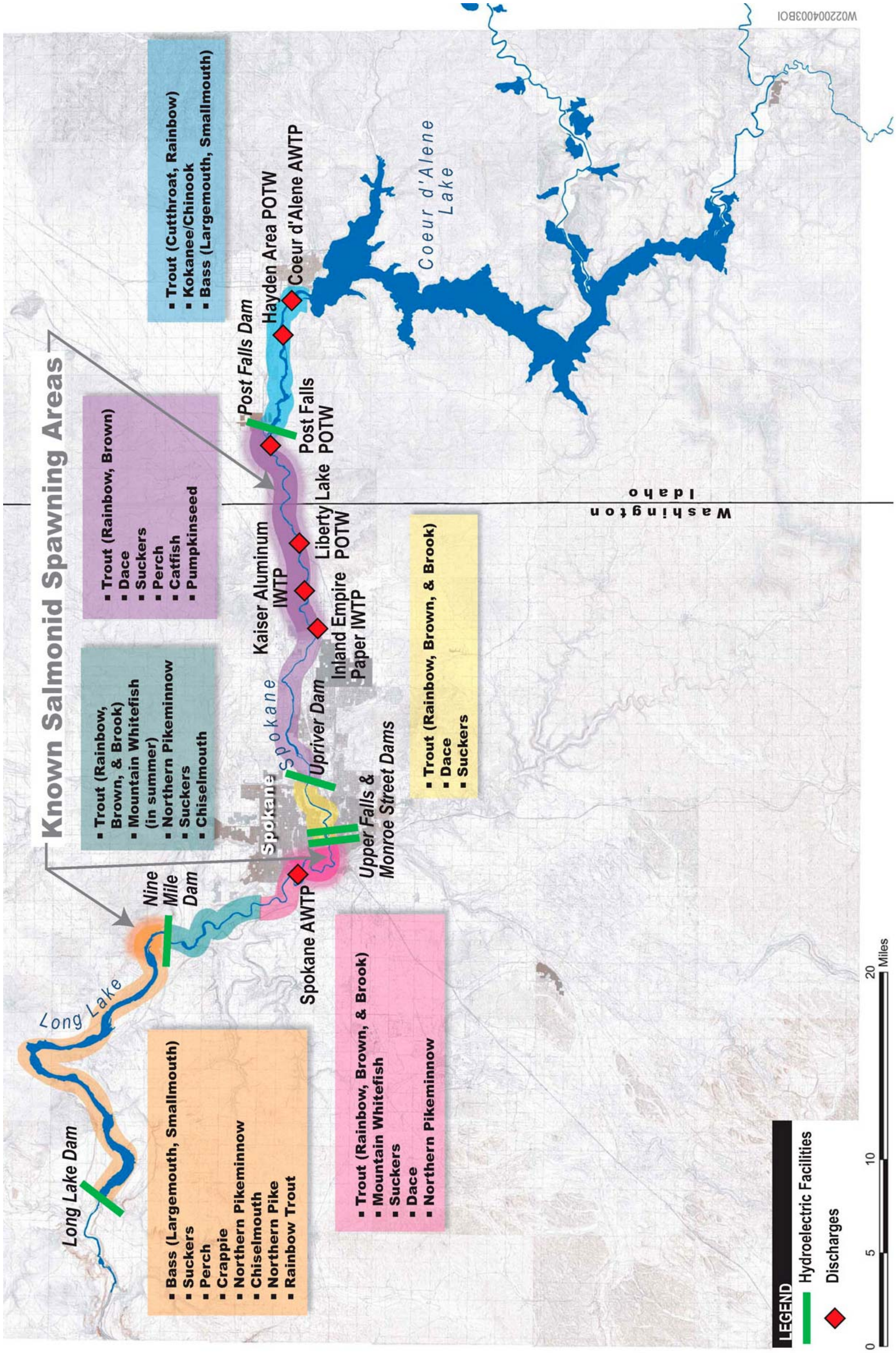

Figure 3-4. Summary of the Predominant Fish Communities and Salmonid Spawning Uses.

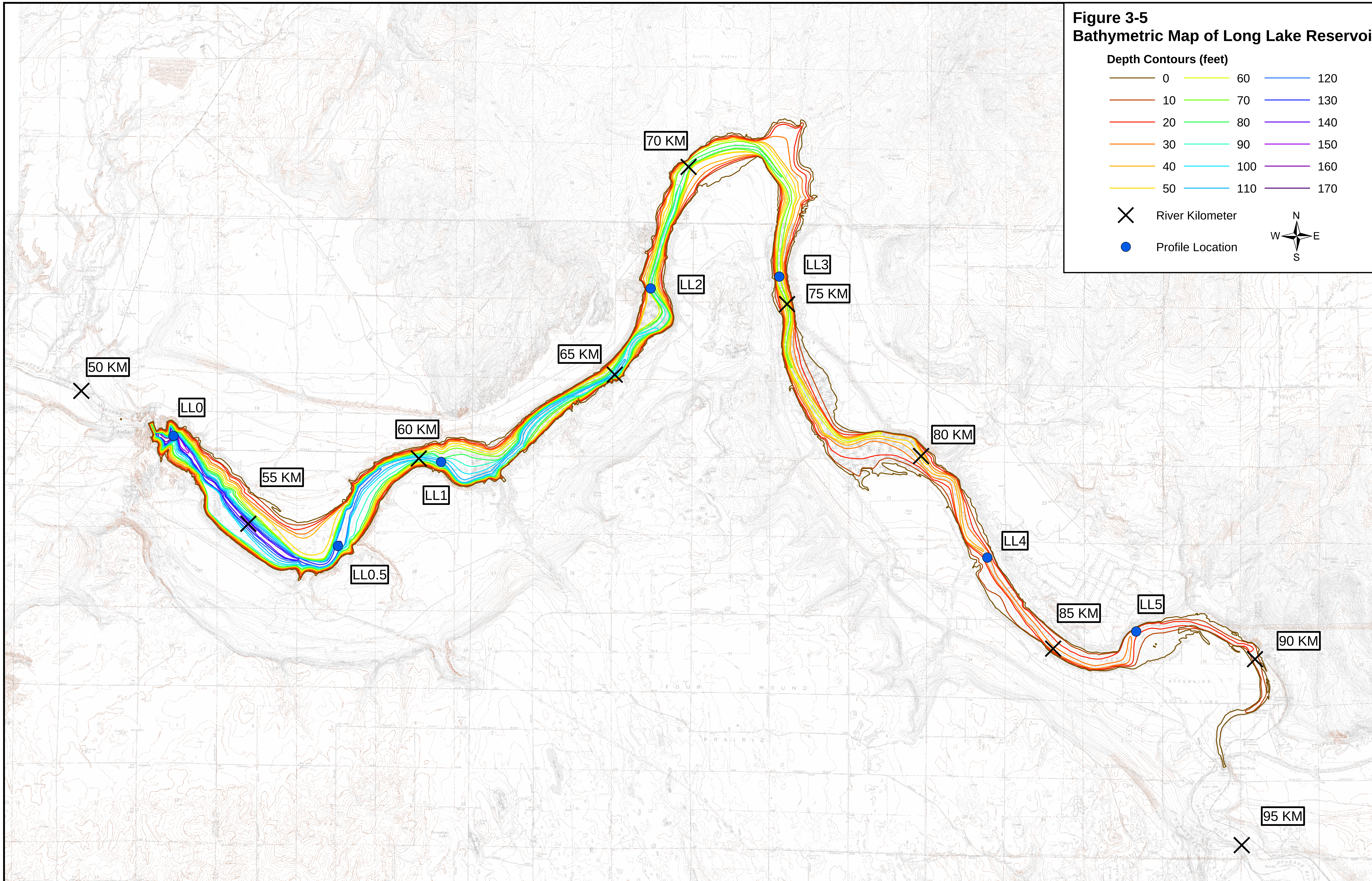

Figure 3-5
Bathymetric Map of Long Lake Reservoir
Depth Contours (feet)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
River Kilometer
Profile Location
N
W
E
S
50 KM
55 KM
60 KM
65 KM
70 KM
75 KM
80 KM
85 KM
90 KM
95 KM
LL0
LL0.5
LL1
LL2
LL3
LL4
LL5

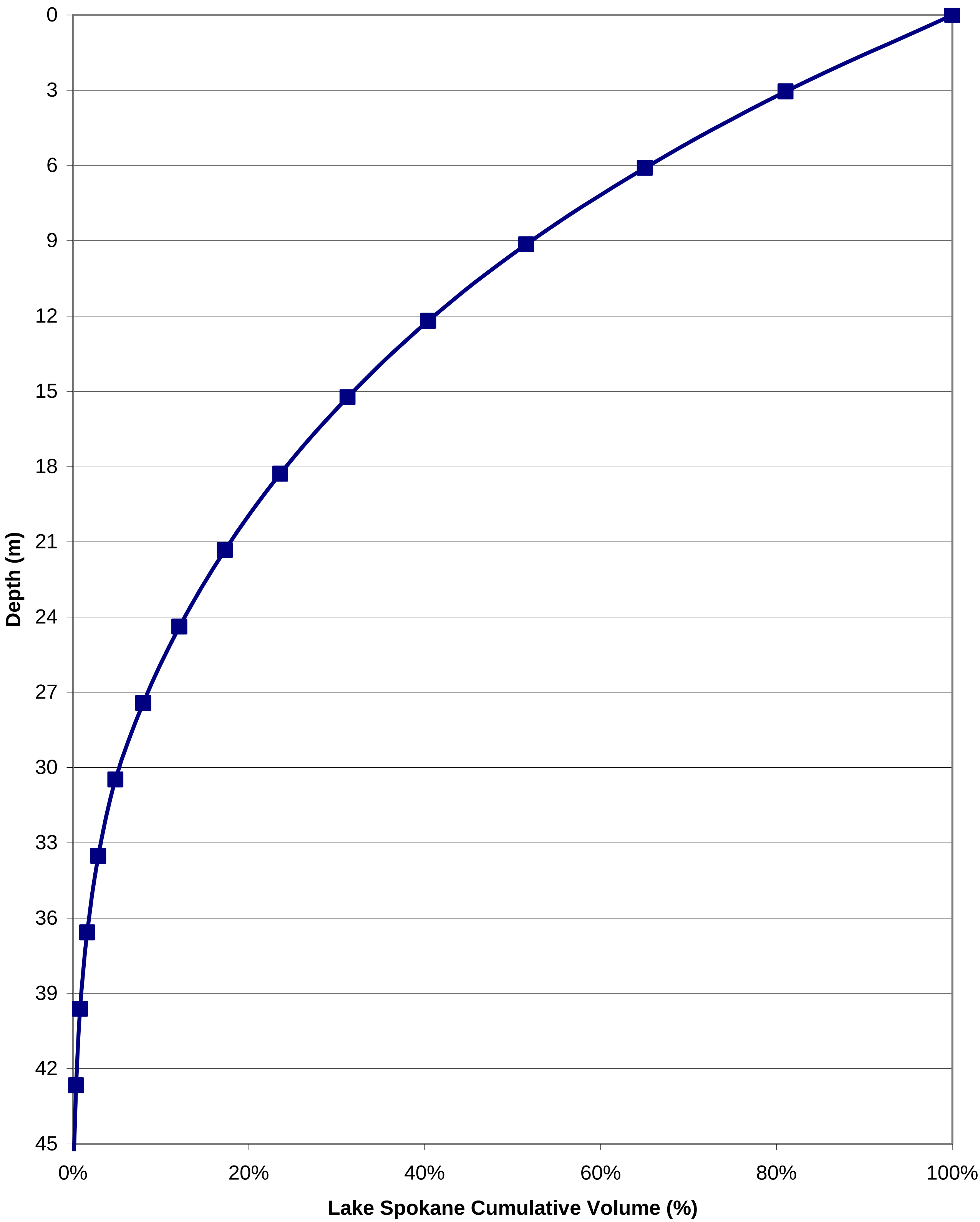

Figure 3-6. Relative Proportion of Long Lake Reservoir Volume, Compared to Depth.

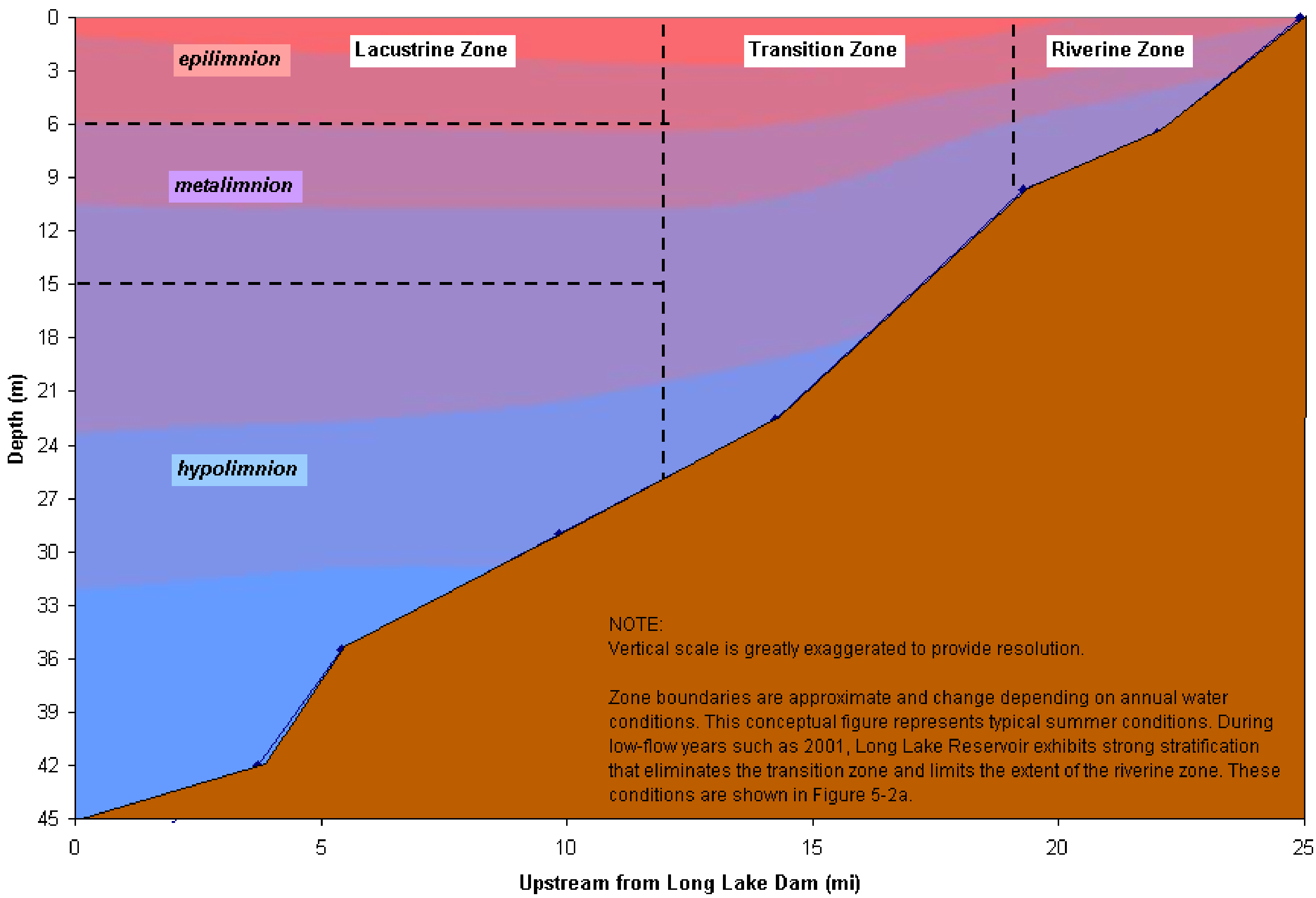

Figure 3-7. Conceptual Location of Separate Summer Reservoir Zones within Long Lake Reservoir (Typical Water Conditions).

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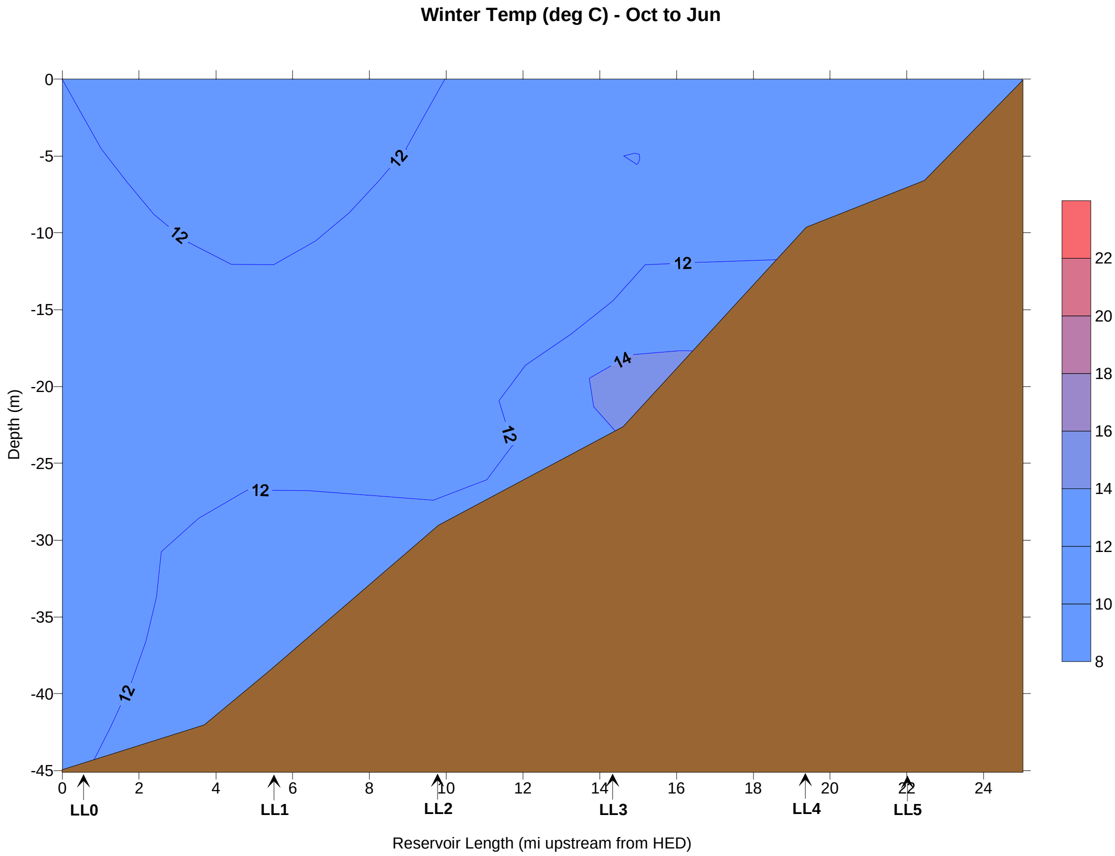
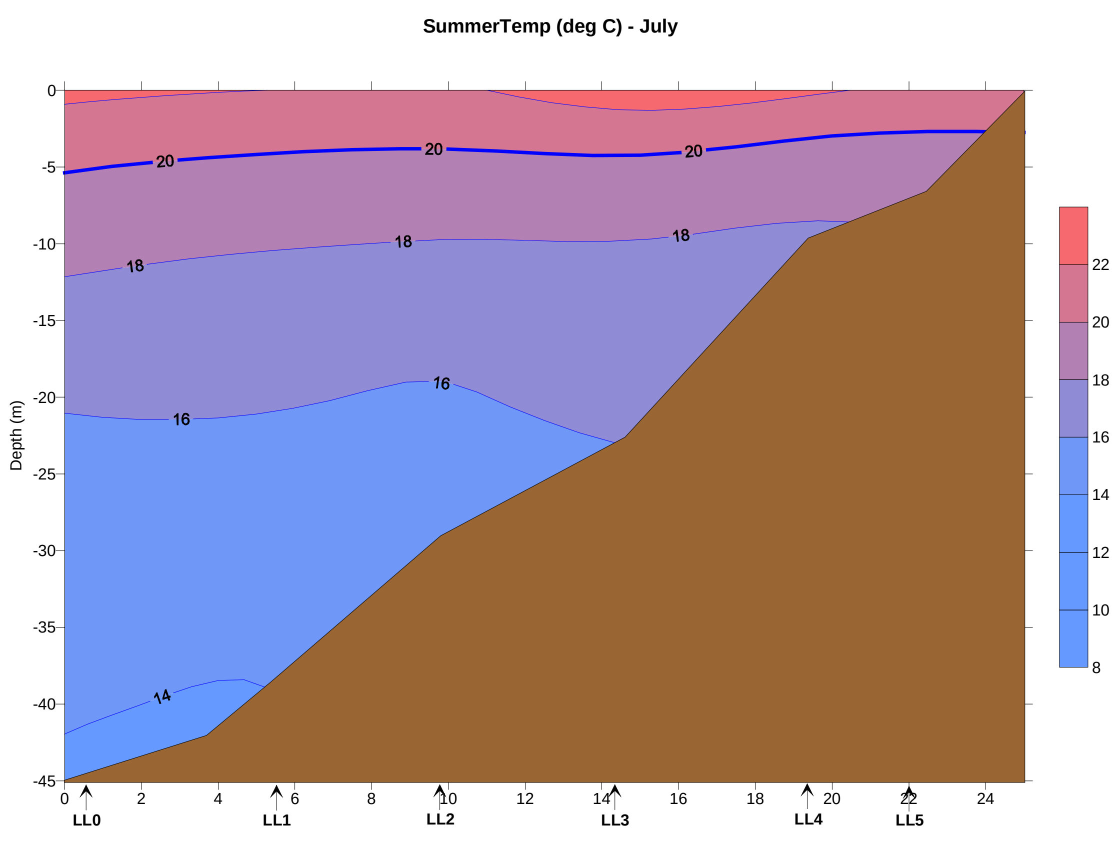
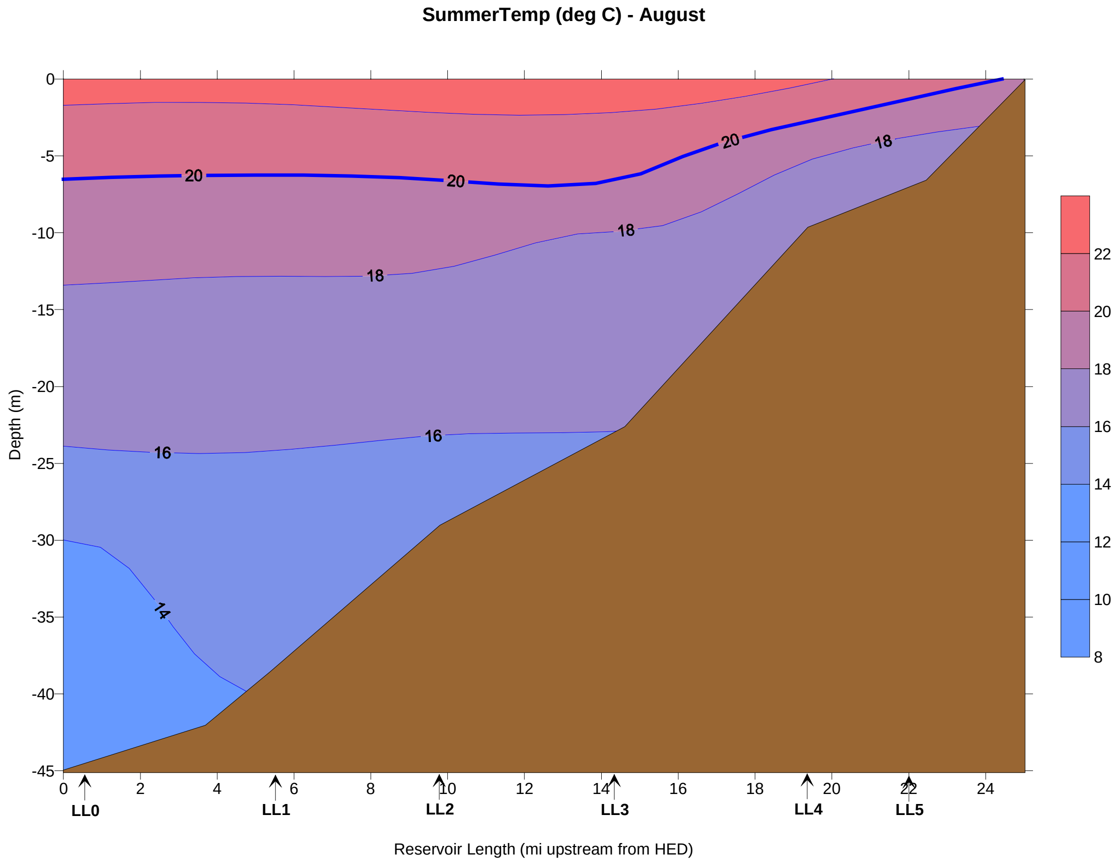
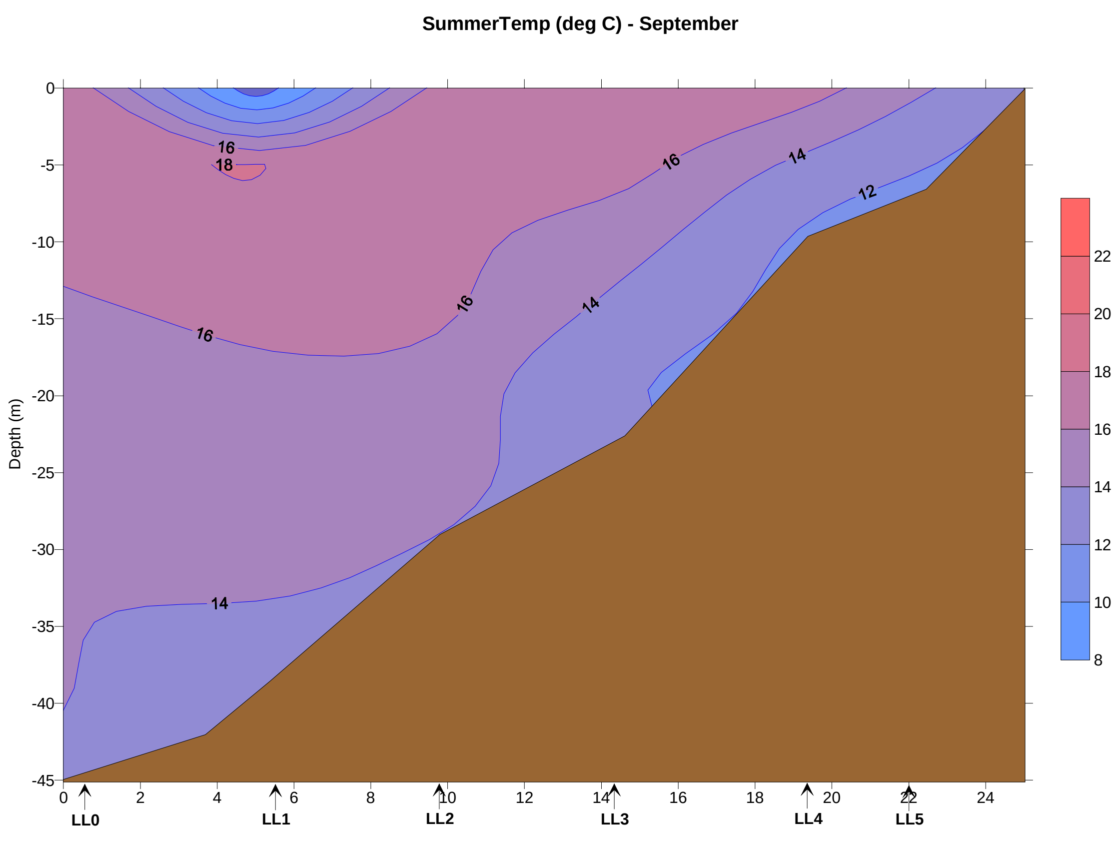




Figures 3-8a and 3-8b. Long Lake Reservoir Temperature Isopleths for Winter (3-8a) and July (3-8b).

NOTE: Data represent Ecology sampling from 1991, 2000, and 2001 events. LLO through LL5 represent Ecology sampling stations.





Figures 3-8c and 3-8d. Long Lake Reservoir Temperature Isopleths for August (3-8c) and September (3-8d).

NOTE: Data represent Ecology sampling from 1991, 2000, and 2001 events. LLO through LL5 represent Ecology sampling stations.

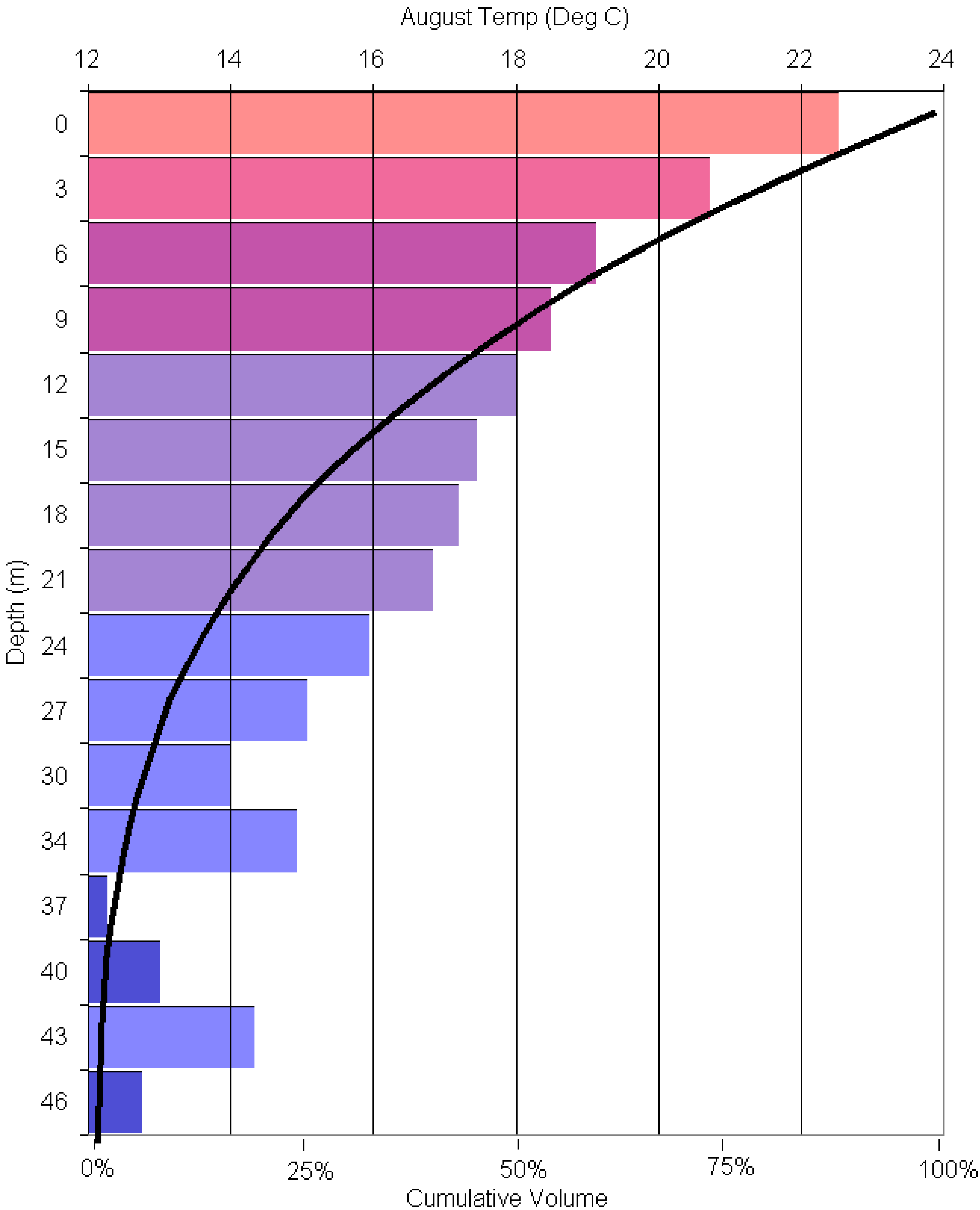


Figure 3-9. Typical August Temperature Values by Depth, Compared to Cumulative Reservoir Volume
NOTE: Adapted from Figure 3-6.

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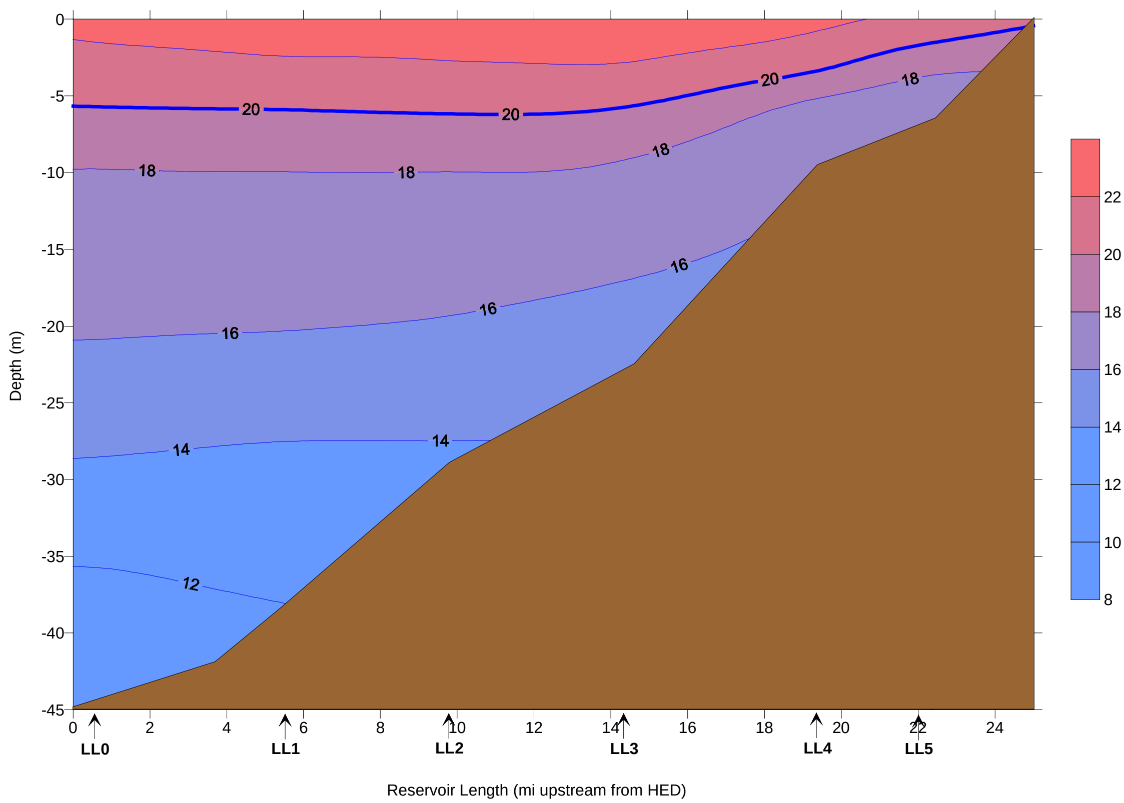
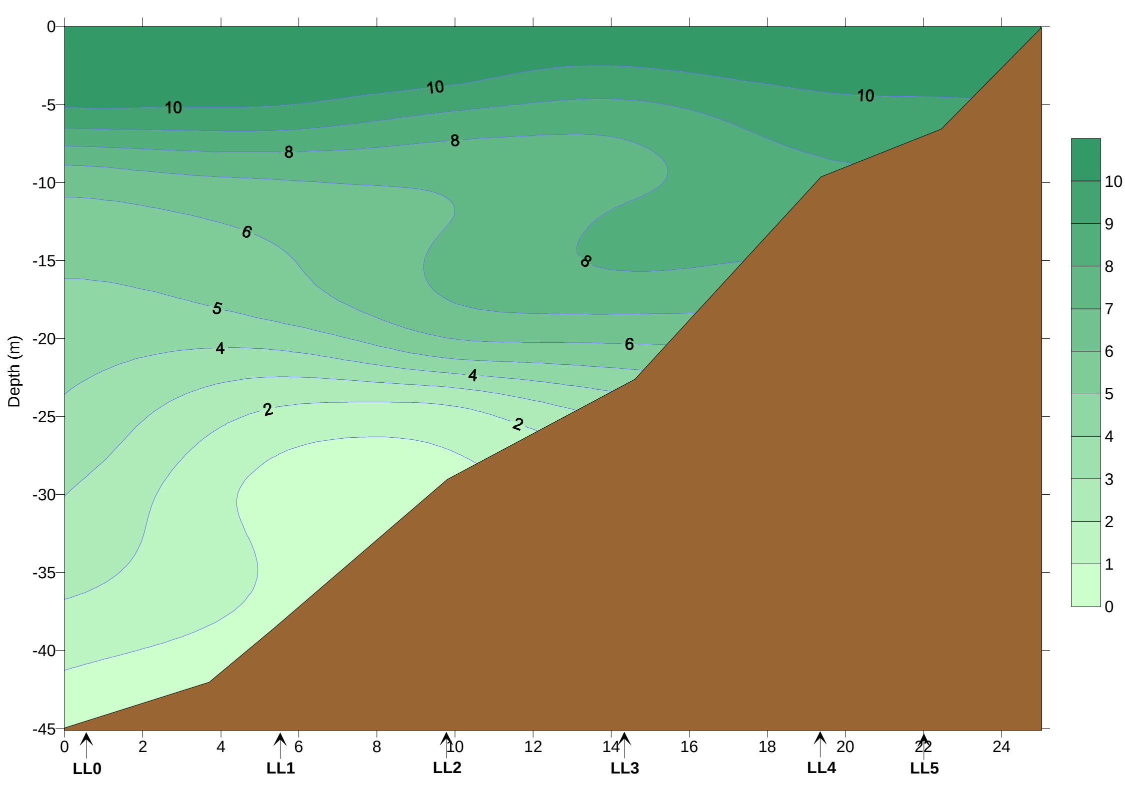
SummerTemp (deg C) - August 2001



Summer DO (mg/L) - August 2001



Figures 3-10a and 3-10b. Long Lake Reservoir Temperature (3-10a) and DO (3-10b) Isopleths for August 2001.

NOTE: Data represent Ecology sampling only from August 2001 event. LLO through LL5 represent Ecology sampling stations.

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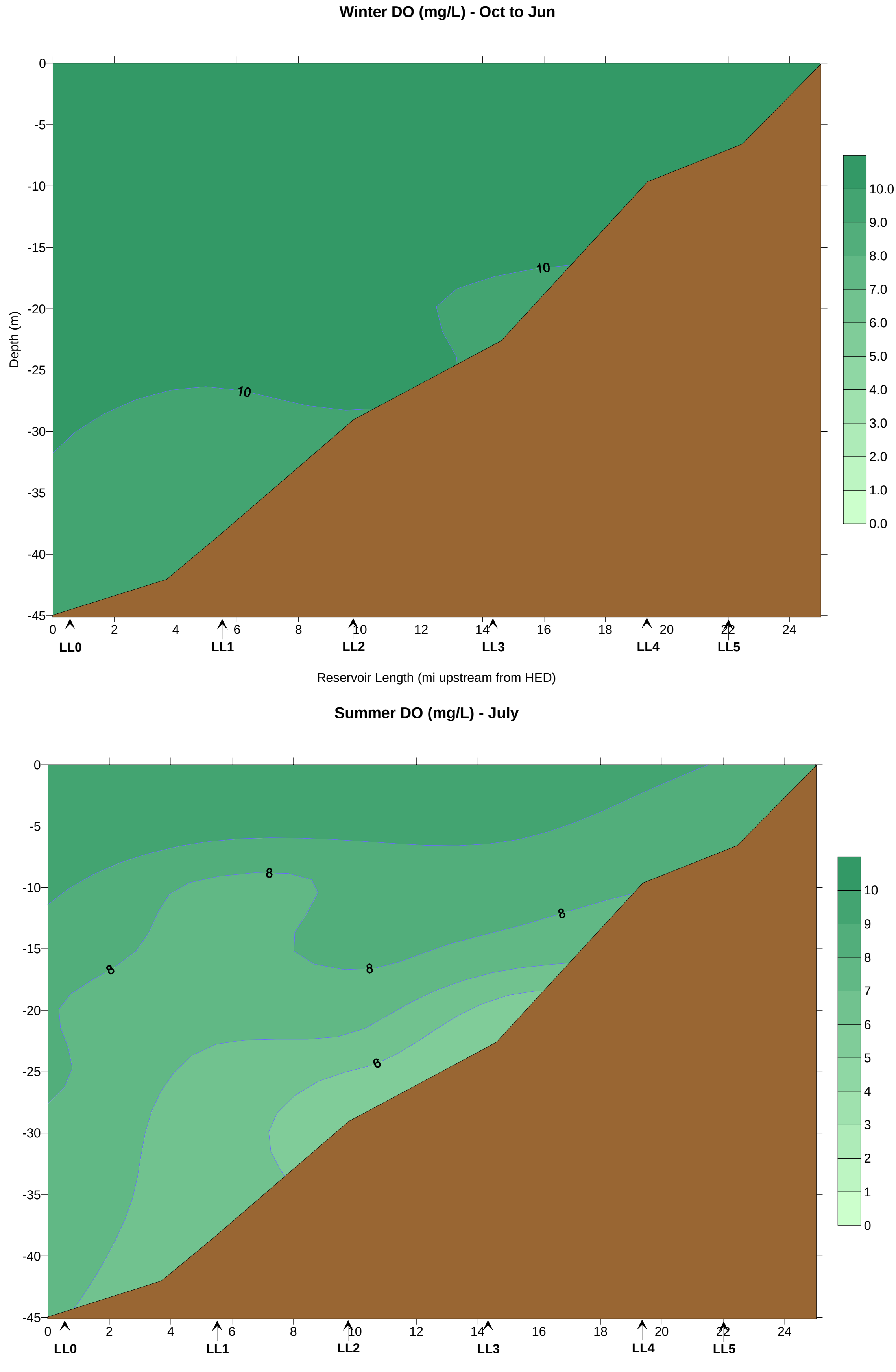
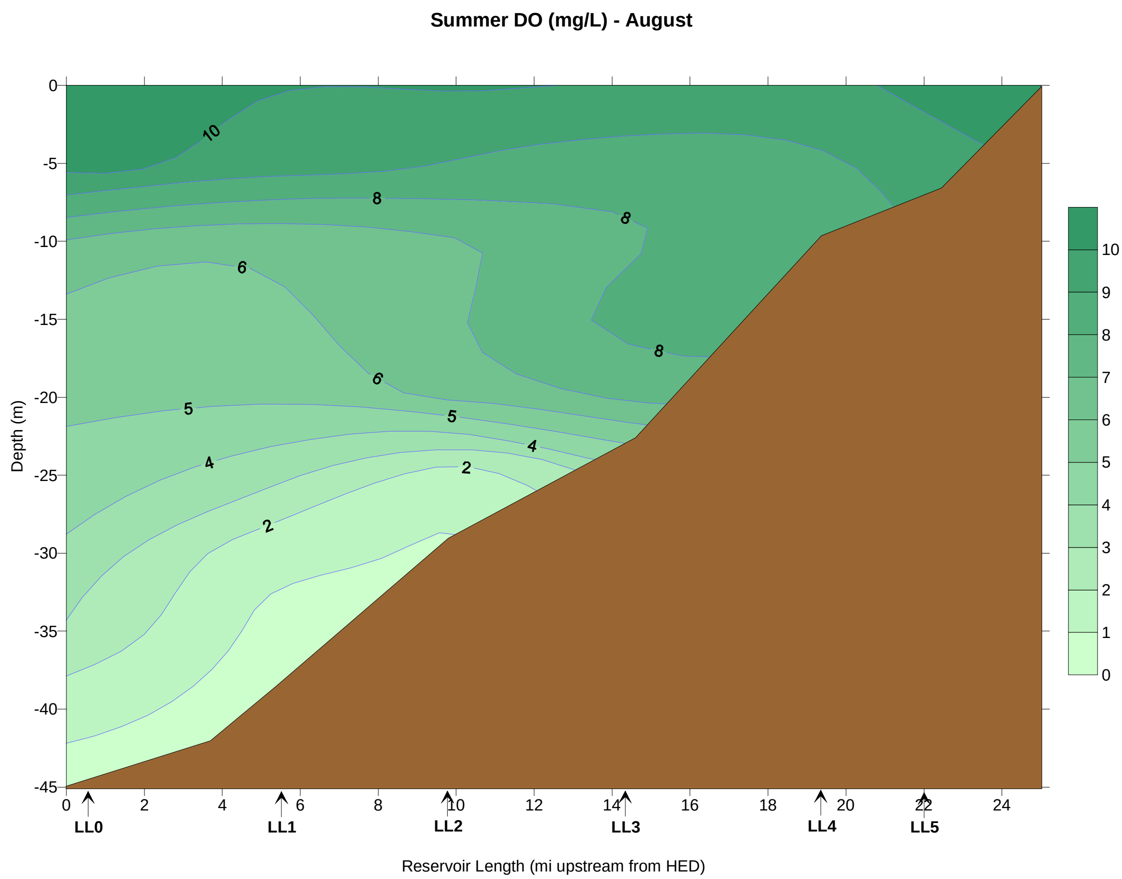
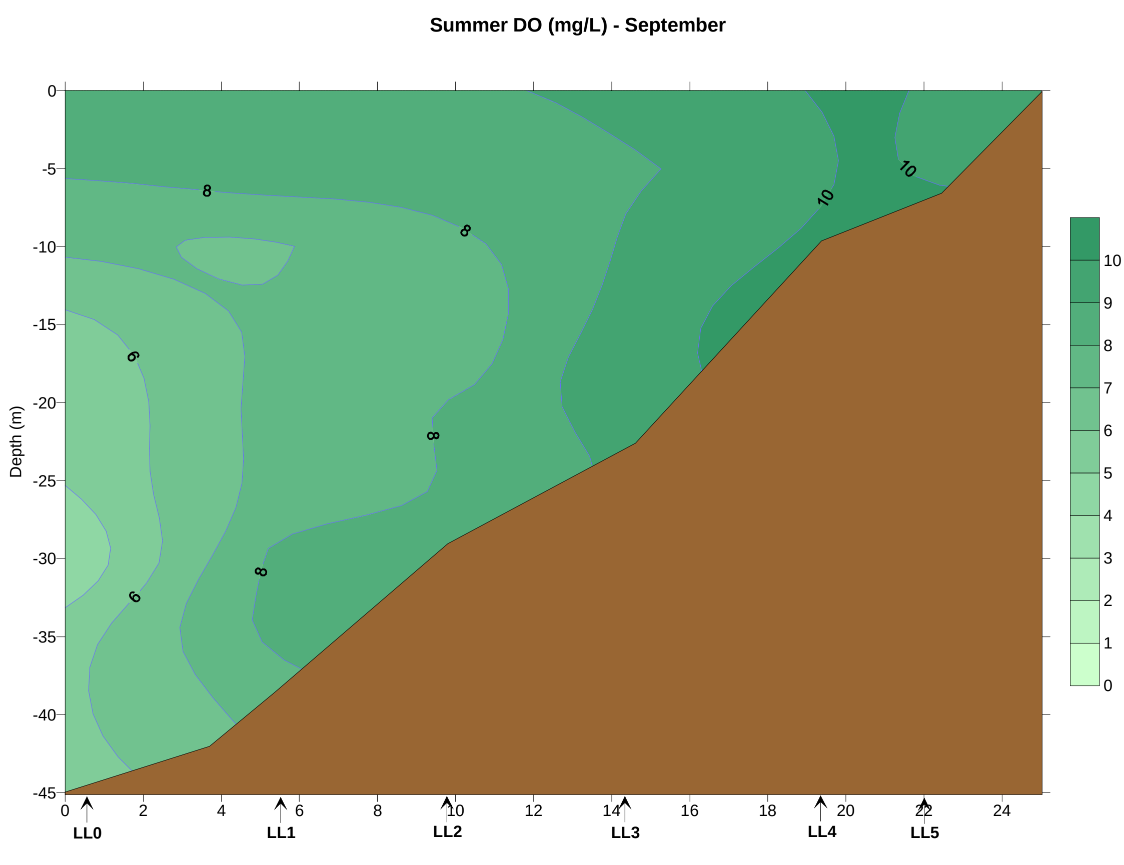


Figures 3-11a and 3-11b. Long Lake Reservoir DO Isopleths for Winter (3-11a) and July (3-11b).

NOTE: Data represent Ecology sampling from 1991, 2000, and 2001 events. LLO through LL5 represent Ecology sampling stations.





Figures 3-11c and 3-11d. Long Lake Reservoir DO Isopleths for August (3-11c) and September (3-11d).

NOTE: Data represent Ecology sampling from 1991, 2000, and 2001 events. LLO through LL5 represent Ecology sampling stations.

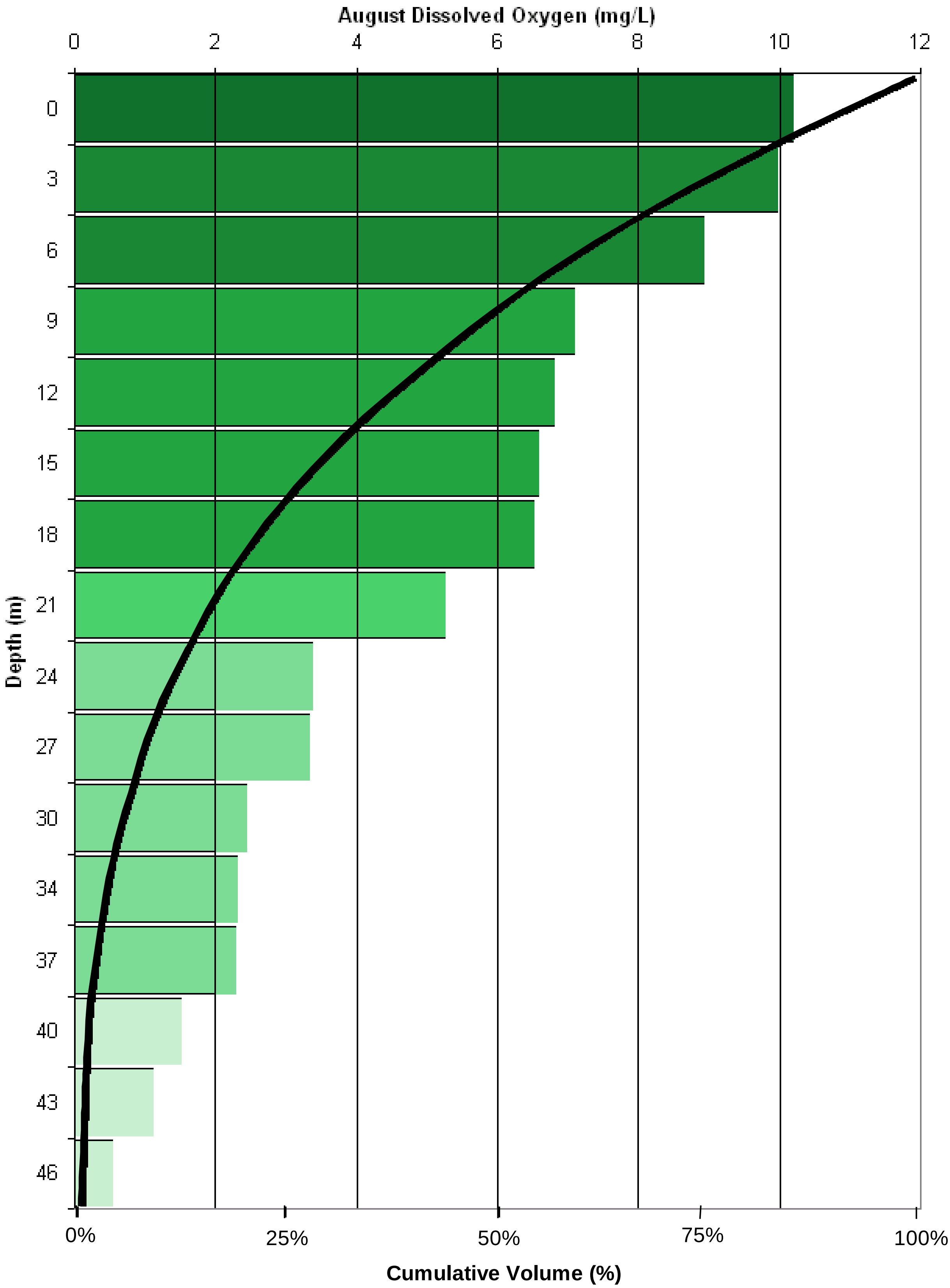


Figure 3-12. Typical August DO Values by Depth, Compared to Cumulative Reservoir Volume

NOTE: Adapted from Figure 3-6.

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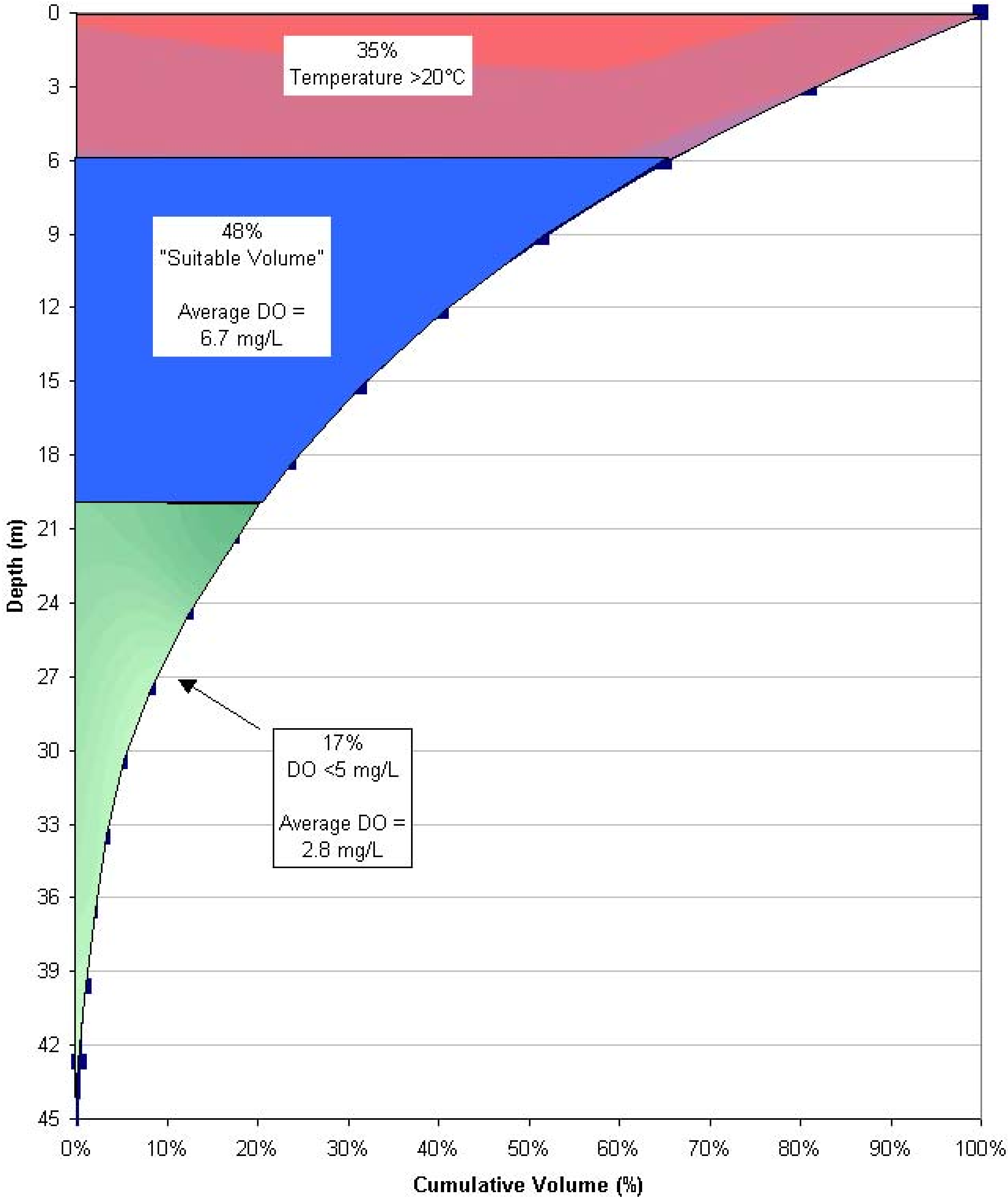

Figure 3-13. Summary of "Suitable Volume" During August as Compared to Overall Long Lake Reservoir Volume.

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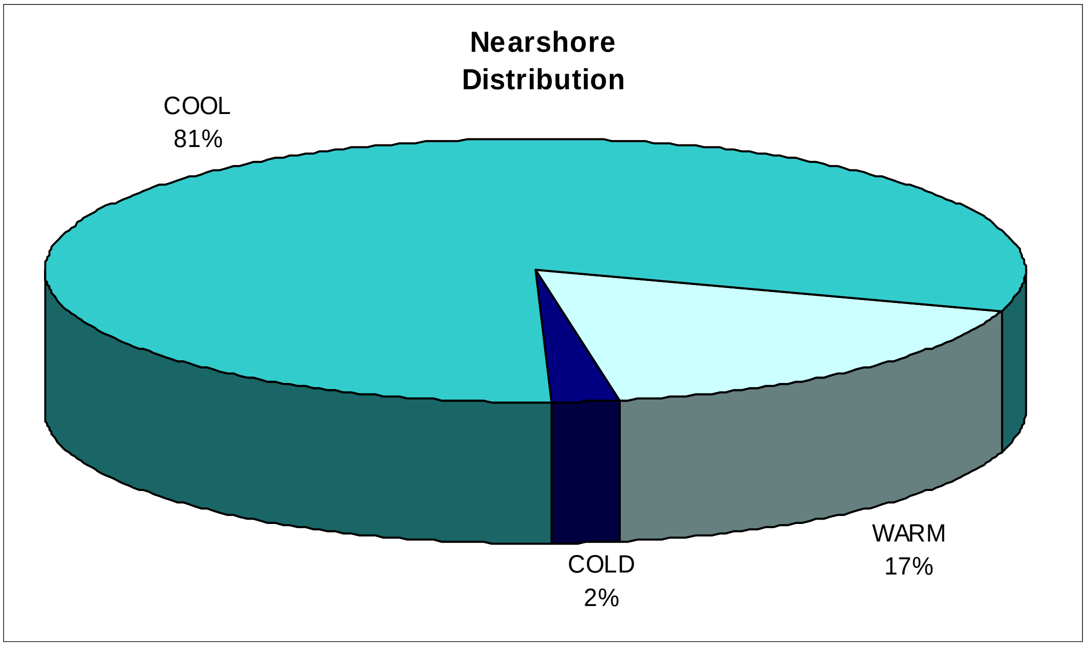

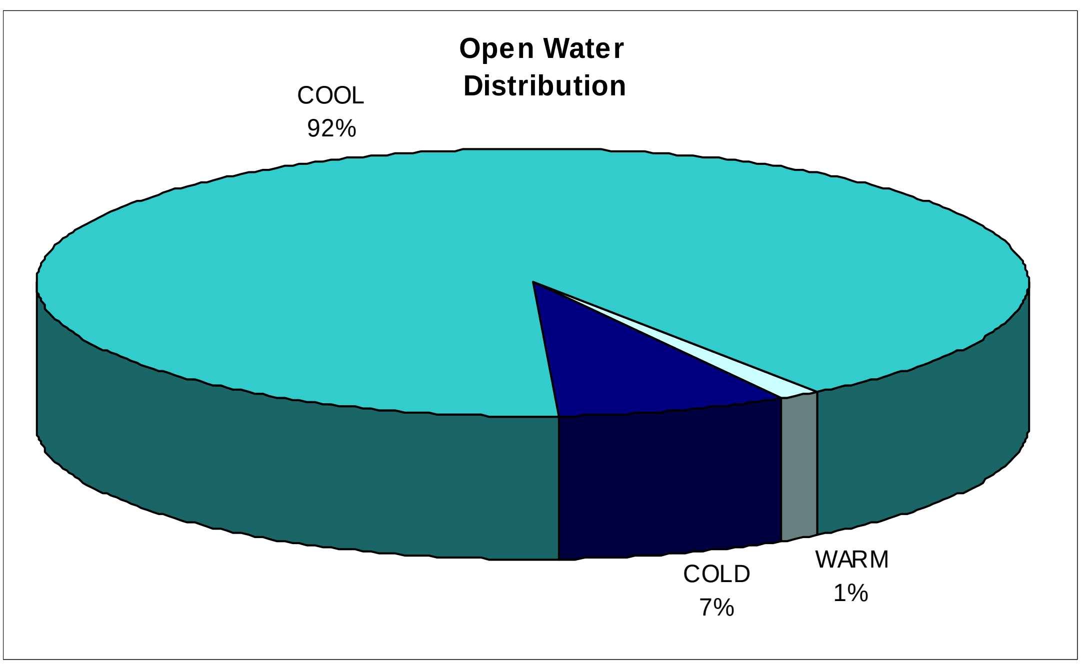

NOTE:
COLD - Cold-water fish
COOL - Cool-water fish
WARM - Warm-water fish

Figure 3-14. Relative Abundance of Species Observed During 2001 in Nearshore and Open-water (Gill-netting) Surveys.
From Osborne et al., 2003.

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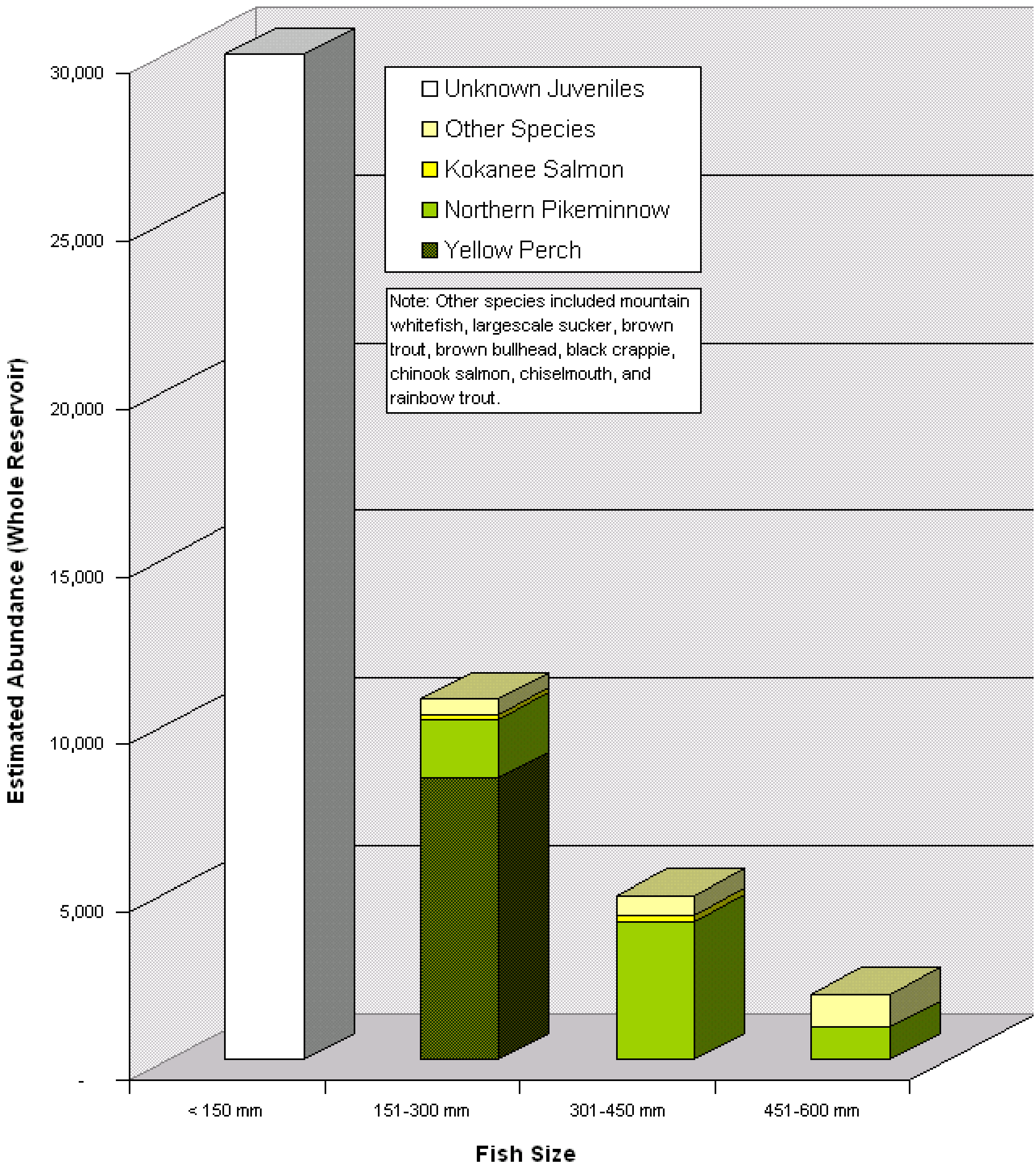

Figure 3-15. Estimate of Reservoir-wide Open-water Abundance Extrapolated from 2001 Hydroacoustic Survey.
From Osborne et al., 2003.

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4. Attainable Beneficial Uses

Identifying attainable beneficial uses requires consideration of whether the dams on the Spokane River should remain in place and of reductions in point and nonpoint sources. Reductions in sources might include technology-based permit conditions for point sources and cost-effective and reasonable BMPs for nonpoint sources. A use that does not, in fact, exist, but which can be attained with additional feasible treatment of point sources and controls on nonpoint sources, is considered attainable.

In this section, the following topics are discussed:

- Hydroelectric development facilities (dams) on the Spokane River
- Application of the CE-QUAL-W2 model to the river and reservoir
- Attainable uses for the Spokane River (RM 112 to RM 58)
- Attainable uses for Long Lake Reservoir (RM 58 to RM 34)
- Summary and discussion of attainable uses

4.1 Hydroelectric Development (HED) Facilities (Dams) on Spokane River

The purpose of a UAA is to identify existing and attainable uses of water bodies and to recommend appropriate surface water quality standards that protect those uses, based on scientific analyses. When dams are involved, in addition to the chemical and physical criteria of surface water quality standards, other factors may be relevant in determining what uses are attainable in a water body. This is true for the Spokane River, where the dams on the Spokane and Columbia Rivers have a profound effect on the ecology of the water system. For example, Long Lake Reservoir does not function as a typical lake. It is a man-made reservoir, and its ecological systems are affected by physical factors associated with the dam (such as the steeply sloped sides of the reservoir) and with dam operations. Grand Coulee Dam on the Columbia River blocks all migratory fish passage to the Spokane River and other upriver tributaries. These facilities and their operations influence the environment within which existing and attainable uses may exist on the Spokane River. Because attainable uses may change, based on whether or not these dams and their operations remain, and to address comments raised by Ecology, this report addresses the following question:

> *Is it reasonable for the Spokane River UAA to assume that the dams in the Spokane River (from Long Lake Dam to Post Falls Dam) will remain in place?*

This section provides the rationale for concluding that the Spokane River UAA should be based on existing and attainable uses within the study area as an impounded river. The following topics are discussed:

- History
- UAA regulations related to dams

- Keeping Spokane River dams in place
- Removing Spokane River dams
- Economic feasibility
- Schedule
- Feasibility of removing dams or modifying dam operations

4.1.1 History

There are seven dams and associated reservoirs located on the Spokane River in an area encompassing northern Idaho (Kootenai and Benewah counties) and eastern Washington (Spokane, Stevens, and Lincoln counties). The Spokane River originates at the outlet of Coeur d'Alene Lake in Idaho. It flows westerly, approximately 112 miles to its confluence with the Columbia River in eastern Washington, which is now within Lake Roosevelt (an impoundment created by Grand Coulee Dam). For each dam, Table 4-1 provides the name (listed in downstream order), owner and operator, date completed, and the power production (Avista, anticipated public release 2005; see also Table 3-1).

TABLE 4-1
Hydroelectric Development Facilities (Dams) on the Spokane River

HED Name	River Mile (RM)	Owner and Operator	Date Completed	Maximum Power Production Megawatts (MW)
Post Falls Dam	102.0	Avista	1906	14.75
Upriver Project Dam	80.2	City of Spokane	1936	17.70
Upper Falls Dam	74.2	Avista	1922	10.00
Monroe Street Dam	74.0	Avista	1890	15.00
Nine Mile Dam	58.0	Avista	1910	26.40
Long Lake Dam	34.0	Avista	1915	71.00
Little Falls Dam	29.3	Avista	1911	32.00
Total Production:				**186.85**

4.1.2 UAA Regulations Related to Dams

Federal regulations have established conditions for states to reference in determining what designated uses are not attainable. These regulations reference dams as noted below:

> *States may remove a designated use which is not an existing use, or establish subcategories of a use requiring less stringent criteria if the state can demonstrate the designated use is not attainable . . . (4) dams, diversions, or other types of hydrologic modifications preclude the attainment of use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would*

> *result in the attainment of the use . . . (*40 CFR 131.10[g] Water Quality Standards, Subpart B Establishment of Water Quality Standards)

Note that all of the dams were constructed 68 or more years ago. This is well before November 28, 1975, the baseline date that is referenced by regulation for establishing existing uses of water bodies (Ecology, 2004b). Uses that have existed as of or after November 28, 1975, are to be protected and are considered attainable uses. Because the dams were established well before that date, and because dams on the Spokane River and the Columbia River preclude the attainment of some uses that occurred before dam construction, these pre-dam uses are not existing.

In respect to the second part of the regulation that discusses the feasibility of restoration of the water body to its original condition or to operate such modification in a way that would result in the attainment of use, it must be recognized that restoration of the Spokane River to its original condition would not result in a return of an anadromous fishery. This is because migratory fish would be blocked at the Grand Coulee Dam. Anadromous fisheries are neither an existing use nor one that is attainable by restoring only the Spokane River to its original condition. Modifying operations on the Spokane River might benefit the productivity of existing and attainable uses, but it would not change what are found to be the existing and attainable uses.

(FERC will be reviewing changes to the operation of HED facilities. The DO recommendations in this Spokane River UAA report protect existing and attainable uses and will provide a sound biological basis for FERC to determine the feasibility of operational changes.)

4.1.3 Keeping Spokane River Dams in Place

The dams on the Spokane River provide socioeconomic benefits associated with local power production, flood control, the lake recreational economy, fisheries, and property values and lake aesthetics.

Local Power Production

Regional energy groups forecast a continued increase in electrical demand. Meeting this demand while maintaining system reliability will require additional generation resources, energy conservation, and preservation of existing generation facilities. Generation facilities that are able to respond to the seasonal and/or daily changes in electric demand will be particularly important to maintain future system reliability. HED facilities that are capable of quickly responding to load demand changes (that is, operate by peaking or by load following, such as the Long Lake Dam) are among the most important of these demand-following generation facilities (Avista, anticipated public release 2005).

Hydropower is by far the most important generating resource in the Pacific Northwest. It provides about two-thirds of the generating capacity and more than 50 percent of electric energy on average within the Pacific Northwest (Northwest Power and Conservation Council, 2004). As noted in Table 4-1, the total power production capability of all HED facilities from Long Lake to Post Falls is approximately 187 megawatts (MW).

When determining total power generated from Avista dams within the UAA study area, two of the dams need to be excluded from the total production of power that is shown in

Exhibit 4.1.1 because Little Falls Dam is located below Long Lake Dam (outside of the UAA study area) and the Upriver Project Dam is within the UAA study area but owned and operated by the City of Spokane. Therefore, the Spokane River Avista HED facilities within the UAA study area have a maximum generating capacity of 137 MW of electricity and an average production of 100 MW. This electricity is enough to supply power to approximately 65,000 average residences, and supplies approximately 10 percent of Avista's electrical load. The 10 percent is based on dividing the 137 maximum MW possible by 1,270 MW, which represents the total anticipated power needed in 2004 (Avista, anticipated public release 2005). Because Avista must import power, "all electricity produced by Avista benefits local customers" (Howard, pers. comm., 2004).

Flood Control

The Spokane River dams play a minor role in flood management, with flood control influences relevant only upstream of the Post Falls Dam. Control of water levels at Post Falls Dam is limited to periods when water elevations are at or below 2,128 feet MSL. Avista draws Coeur d'Alene Lake down during the fall. This increases the storage capacity in Coeur d'Alene Lake to accommodate fall through spring precipitation and spring snowmelt that would otherwise raise lake levels (Avista, anticipated public release 2005).

Lake Recreational Economy

Certain reservoir levels are favorable for recreational activities. Dams are operated to maintain those levels to the extent possible within the operational objectives of the HED facilities. When shorelines drop too far, good beaches can disappear, boat launching can become difficult to impossible, and fisheries can be affected. The Coeur d'Alene Lake reservoir elevation is maintained near 2,128 feet MSL and Long Lake Reservoir elevation is maintained near 1,536 feet MSL. Maintaining shorelines at certain elevations is important for lake resorts, property owners along the lake shorelines, and the public that uses the lake for recreational activities such as swimming, fishing, motor boating, sailing, personal watercraft, and water skiing.

Coeur d'Alene Lake is a recreation resort destination that offers many different recreational opportunities and experiences. Recreation amenities include a private resort and golf course, day-use and overnight facilities adjacent to the lake, public and private boat launches, and other water and shoreline access sites. There are 24 day-use and overnight recreational facilities around Coeur d'Alene Lake that are operated by federal, state, county, and city authorities. Fifteen privately operated facilities also exist (Avista, anticipated public release 2005).

The local citizens and tourists that use the recreational opportunities provided by the dams supply local jurisdictions with revenues via sales and use taxes, lodging taxes, permits, and user fees. There are also benefits associated with employment provided by the resorts and businesses that support a recreation industry.

Fisheries

Numerous species of fishes and hybrids (both native and non-native) have been found within the Spokane River and Long Lake Reservoir (see Section 3). They are in cold-water, cool-water, and warm-water habitats. The warm-water habitats are found primarily within the reservoirs.

Dam operations can be managed to benefit downstream fisheries. However, these operations would not change the attainable uses. Each spring, Avista monitors flows, rainbow trout spawning, and rainbow trout emergence in the free-flowing reach of the Spokane River downstream of the Post Falls Dam (RM 102) and the Monroe Street Dam (RM 74). Based on monitoring results, Avista operates the Post Falls Dam in a manner that attempts to maintain downstream river flows that are sufficient to keep the majority of rainbow trout spawning redds wetted through the fry emergence period. In addition, lake fisheries created by the dam reservoirs provide an attraction to the public for lake fishing and other lake activities[10] (Avista, anticipated public release 2005).

Property Values and Lake Aesthetics

Because of the reservoirs that were created behind the dams, private residential and commercial properties that are located along the shorelines of these reservoirs have both aesthetic and monetary values. Three counties (Spokane, Stevens, and Lincoln) share the 53.8-mile shoreline of Long Lake Reservoir. Spokane County has 25 miles of shoreline. There are 457 parcels on this shoreline with approximately $42.5 million in assessed value. They include:

- 253 residential parcels valued at approximately $37.3 million
- 2 commercial parcels valued at approximately $52,000
- 168 vacant parcels valued at approximately $5 million
- 24 vacant parcels underwater valued at approximately $145,000

Of these 457 parcels, 2 are Spokane County parks, 3 are owned by the Washington State Department of Natural Resources, 10 are owned by the Washington State Department of Parks and Recreation, and 28 owned by the Avista (Kirk, pers. comm., 2004).

Stevens County has approximately 27.5 miles of shoreline, and Lincoln County has about 2 miles of shoreline. Stevens County has more residential and commercial land than Spokane County. Both counties have lake resorts. Therefore, the estimated assessed value of shorelines in Stevens County would be more than $42.5 million. The total assessed value of property around Long Lake Reservoir is estimated to be more than $85 million, excluding the value of the Long Lake Dam HED.

Coeur d'Alene Lake is larger than Long Lake Reservoir. The cities of Coeur d'Alene and St. Maries are located on Coeur d'Alene Lake, along with more lake resorts than Long Lake Reservoir. Therefore, it can be assumed that the assessed value of lake property on Coeur d'Alene Lake would be much more than the assessed value estimated for Long Lake Reservoir.

4.1.4 Removing Spokane River Dams

Environmental and socioeconomic costs can be associated with the presence of dams and the removal of dams. This Spokane River UAA does not provide a detailed analysis of these cost factors. However, this report describes the rationale for concluding that it is reasonable to assume that the dams should remain in-place. Some of the reasons include the following:

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[10] Specific economic information based on number of annual angler days on Long Lake Reservoir and Lake Coeur d'Alene, and the correlating economic value was not available for this report.

- Removal of the dams on the Spokane River to return the river to its original condition would not, by itself, restore designated uses that are not attainable in the Spokane River UAA.
- It is unlikely that the recreational and commercial values created by returning the river to its original condition would overcome the quantitative costs of dam removal, both economic and environmental.
- Given the experience in Washington State related to decommissioning the Elwha and Glines Canyon dams (see Section 4.1.6.2 below), it would take longer to make a determination to return the river to its original condition through regulatory and administrative due process than the period of time during which this Spokane River UAA and any currently proposed TMDLs might apply.

4.1.5 Economic Feasibility

Removal of the dams to restore the river to its original condition would have to overcome widespread and significant economic and environmental consequences. Without additional modifications to Grand Coulee Dam, an anadromous fishery could not be restored. It is reasonable to conclude that the value of the recreational and commercial benefits of re-creating a natural, free-flowing river would be less than the costs related to such things as:

- The loss of hydropower production
- Physically removing the dams
- Environmental restoration
- Decreases in residential property value
- Decreases in existing recreational values

Both quantitative and non-quantitative factors would probably be taken into account to determine whether to return the river to its original condition. The following sections describe potential costs associated with returning the river to its original condition.

Quantitative Costs

Decommissioning is defined as the full or partial removal of an existing dam and its associated facilities or significant changes to the operations thereof. The economic considerations associated with decommissioning a dam are significant. Careful advance planning is required, including analysis of alternatives, preliminary cost estimates, permitting requirements, environmental studies, design (including modeling), and consensus-building with concerned parties.

Potential Economic Gains.

Economic gains associated with dam removal might include:

- Establishment of a riverine recreational industry
- Restoration of riverine waterfront property
- Restoration of a riverine ecological system that would support riverine fisheries, biodiversity, and riverine water quality.

- Dam licenses require that owners and operators of the facilities spend money to mitigate the ecological losses created by dams. Riverine restoration would eliminate the need for such mitigation programs.
- The costs of maintaining, operating, and improving an aging dam would no longer be necessary.

Economic Losses.

Direct costs of dam removal include the following:

- Removal of the dam structure, turbines, and transmission lines
- Management and remediation of accumulated sediments that may be contaminated
- Reforestation and/or reclamation of the previously submerged land
- Construction of access roads
- Post-construction monitoring

The indirect economic losses due to discontinuing operation of the dam must also be considered. These include:

- Flood protection
- Irrigation
- Power generation
- Lake recreational uses
- Loss of residential land and the associated assessed value

Table 4-2 lists some of the economic cost factors that would need to be taken into account if an attempt was made to return the Spokane River to its original condition.

TABLE 4-2
Economic Cost Factors Associated with Returning the River to its Original Condition

Potential Gains	Costs/ Losses
Improve biodiversity by restoring movement of organisms previously blocked by the dam, enhancing ecology.	Conduct planning, permitting, environmental studies, and design (including modeling) for dam removal.
Discontinue repairing and rebuilding costs associated with maintaining a safe dam and discontinue operational costs.	Conduct construction actions that include draining the reservoir; reconfiguring and stabilizing the trapped sediments; dam demolition; and removal of power generating and transmission equipment.
Restore downstream water quality (river temperature, nutrient load, turbidity, dissolved gases).	Conduct contaminated sediment remediation, sediment removal and stabilization, and activities to protect structures and water supplies downstream.
Eliminate mitigation costs required by dam license.	Conduct river valley restoration and reforestation, construction of access roads, and post-construction monitoring.
Restore the rhythm of the river and the habitats that depend on this rhythm.	Incur future property damage and associated costs because flood protection has been removed.
Restore downstream morphology by redistributing sediment loads, which discontinues sediment deposition behind dams and provides nutrients for downstream habitats.	Lose reliable, renewable, and secure power production for local area. Incur the social, economic, and environmental costs of alternative energy production to supplant lost power production.

TABLE 4-2
Economic Cost Factors Associated with Returning the River to its Original Condition

Potential Gains	Costs/ Losses
Gain riverine recreational jobs, possibly including river-based resorts.	Lose Avista jobs, lose jobs indirectly related to supporting Avista, lose jobs related to local industries and commercial operations dependent on local power, and lose recreational jobs (including jobs resulting from lake resort closures).
Restore riverine river shore properties.	Lose lakeshore residential properties and assessed values.
Restore riverine fisheries.	Lose lake fishing anglers.

Non-quantitative Costs

It is difficult to place economic values on some of the positive outcomes that would be anticipated from decommissioning dams on the Spokane River. For example, restoring the free-flowing river could restore cultural and spiritual value, particularly for the Tribes. Holy and spiritual sites that had been submerged might possibly be restored. Old tribal customs and tribal heritage might be strengthened. Also, there is a value related to a free-flowing river.

It is also difficult to place economic values on some of the negative outcomes that would be anticipated from decommissioning dams on the Spokane River. For example, the lake community would be lost. Replacement power produced at a different location would cause environmental impacts. Hydropower might be replaced with a combination of conservation measures, “green power” (such as wind farms), and thermal power. (It is asserted that burning of fossil fuels causes global warming, a negative potential outcome related to decommissioning.) The costs of these activities would need to be factored into a decision to remove dams on the Spokane River.

4.1.6 Schedule

TMDL Schedule

TMDLs should be reviewed periodically to determine the appropriateness of the standards and to re-evaluate water quality management programs. The original phosphorus TMDL for the Spokane River was created in 1989. Ecology has developed a Draft TMDL (Ecology, 2004e) that will require more stringent control of phosphorus loading. The time frame until revision of the original phosphorus TMDL was approximately 15 to 16 years. Therefore, it is assumed that once a TMDL is adopted, that TMDL would be re-evaluated in 20 years or less.

Returning the River to Its Original Condition

If a dam were removed from a river system such as the Spokane River, it would probably take 20 to 40 or more years to remove the dam structure because of the planning and permitting requirements. An example of this regulatory process in Washington is the decommissioning of the Elwha and Glines Canyon dams.

In 1968, the licensing process for the Elwha and Glines Canyon dams began. Because it was extremely contentious, Congress enacted the Elwha River Ecosystem and Fisheries

Restoration Act in 1992. Pursuant to the Elwha Act, the Secretary of the Interior determined that both dams must be removed to meet the goal of the act, which was full restoration of the Elwha River ecosystem and native anadromous fisheries. The National Park Service completed the associated environmental impact statements in 1996 (National Park Service, 1997).

A Record of Decision, signed on December 23, 1996, determined the preferred method of dam removal (PBS, 2004). Work is scheduled to begin in 2008 for removal of both dams and the restoration of the Elwha River (Associated Press, 2004; Gawley, 2004). In other words, 24 years passed from the submittal of the dam re-licensing paperwork to creation of the Act that was designed to restore the Elwha River. Another 16 years will have passed before dam removal activities are scheduled to begin. It will then take an unspecified number of years to completely restore the Elwha River ecosystem and fisheries in addition to the 40-year time period that will have preceded the actual removal of the dam. This is an example of the process experienced for two dams that were recognized to be inefficient, no longer serving their industrial customers, and in need of significant upgrades to be safe and effective.

The Avista dams on the Spokane River are in the re-licensing process. At the present time, there is no reason to expect that these dams will not be re-licensed and, thus, it is accurate to assume that these dams will remain in place.

4.1.7 Feasibility of Removing Dams or Modifying Dam Operations

Removal of Dams

Based on the experiences related to removing the Elwha and Glines Canyon dams, even if a decision were made today to remove a dam within the study area, the dam would probably remain in place for the next 20 to 40 years. After a new TMDL is adopted, it is expected that it would be in effect for the next 20 years or less. Therefore, it is reasonable to assume that the existing and attainable uses within the study area discussed in the Spokane River UAA are within an environment that is affected by the presence of dams.

This Spokane River UAA recommends standards to protect existing and attainable uses based on the biological and physical conditions of the riverine and reservoir segments of the river. It is expected that FERC licensing (including Section 401 Certification) will be consistent with the attainment of these recommended standards. It is not expected that FERC licenses for Avista dams (with terms of 30 to 50 years) will require the removal of any of the dams on the Spokane River. If dams were removed in the future, the 20- to 40-year time frame needed for dam removal would be longer than the time frame expected for the duration of the next TMDL (20 years or less).

Feasibility

Returning the Spokane River to its original condition would not restore anadromous fisheries without the removal of Grand Coulee Dam or the construction of fish ladders to enable the fish to swim upstream to the Spokane River. It is even less likely that the Grand Coulee Dam would be removed and/or fish ladders constructed because of its large size and power generation capabilities. The infeasibility of removing the dams is further supported by the recently completed Columbia River Basin salmon plan, which concludes that major hydroelectric dams on the Columbia River do not jeopardize the survival of wild fish runs. Federal fishery officials have officially dropped dam removal as an option for these dams (New York Times, December 1, 2004).

Modification of Dam Operations

Modifying dam operations could contribute to maintaining surface water quality standards on the Spokane River. Currently, Avista is seeking relicensing under FERC procedures. River flows and dam operations will be a condition of future licenses. FERC decisions on river flows will take into account many social, economic, and environmental factors, including the achievement of surface water quality standards. Most importantly, changes in the operation of HED facilities will not change the attainable uses designated in this Spokane River UAA.

In addition, as discussed in detail in sections 4.3 and 4.4 below, operational changes that might derive from the relicensing process will not change the fundamental definition of aquatic life uses in the Spokane River or Long Lake Reservoir, although there may be enhancements of those uses.

4.2 Application of the CE-QUAL-W2 Model to the River and Reservoir

An important tool in the analysis of attainable beneficial uses is the Spokane River CE-QUAL-W2 water quality modeling application being used to support development of the DO TMDL. Extensive effort has been invested in developing and calibrating this model. A number of stakeholders in the Spokane River watershed are using this model to evaluate a variety of issues. Although there is ongoing technical dialogue associated with the modeling effort, the sponsors of the Spokane River UAA project believe that the model has been refined to achieve better calibration and provides a useful tool at this time to help define attainable uses and associated criteria.

The model extends throughout the study reach from below Coeur d'Alene Lake through Long Lake Dam. The area of application in Washington has been calibrated using 2001 drought conditions. The area of application in Idaho has been developed, but has not yet been calibrated. An important modeling assumption is that the upstream boundary condition for the model (at the Stateline) was based on data collected by Ecology, rather than the alternative of basing it on uncalibrated Idaho model outputs.

Model calibration resulted in root mean square (RMS) error of 1°C for water temperature and 1.0 mg/L for DO (Berger et al., 2002). Mean errors of this magnitude are not unusual for complex systems such as this. For example, the RMS error of the CE-QUAL-W2 model developed by USGS for the Tualatin River in Oregon ranged from 1.1 to 2.3 mg/L for DO, depending on location (Rounds and Wood, 2001). The important point is that this error should be recognized, and the results of the various scenarios have to be interpreted with care and professional judgment. In the Draft TMDL (Ecology, 2004e), Ecology has used the model to judge compliance with a 0.2 mg/L DO deficit standard. Ecology has also interpreted the model as being able to accurately predict DO levels at all times and all places. The model accuracy is not amenable to this degree of rigor of application. However, the model does provide the best tool currently available to estimate relative improvements in water quality associated with various treatment scenarios. Hence, it provides insight into the attainability of the current DO criteria and those proposed in this Spokane River UAA and, therefore, the associated aquatic life uses. However, because of model error and uncertainty, it is appropriate that some spatial and temporal averaging of results be a component of the estimates and insights that the model provides.

For the purposes of this section, uses that are attainable have been evaluated similar to the scenarios identified in the Pollutant Loading Assessment (Ecology, 2004a). Ecology defined and ran a number of potential future scenarios:

- **CURRENT.** The baseline reflecting 2001 calibration for drought conditions.
- **NO-POINT.** The CURRENT scenario without point source loads (flows retained and concentrations set to groundwater levels).
- **NO-SOURCE.** The CURRENT scenario without point source loads (flows retained and concentrations set to groundwater levels), tributaries, and upstream boundary conditions set at background conditions. This scenario essentially models complete control of nonpoint sources from tributaries.
- **Sediment Oxygen Demand (SOD).** The CURRENT scenario without point source loads (flows retained and concentrations set to groundwater levels), tributaries and upstream boundary conditions set at background conditions, and SOD set at oligotrophic levels.
- **PERMIT.** The CURRENT scenario with point source loads increased to current permit limit levels.

Based on Ecology's interpretation of the results of the above model scenarios, Ecology concluded the following (Ecology, 2004a):

- "Dissolved oxygen depletion predicted by the model due to human causes is far in excess of the allowable 0.2 mg/L from the current and permitted loads (both point and nonpoint loading). The impacts of future population growth will be even greater.
- "On an annual basis, the effects of point source BOD [biochemical oxygen demand] and phosphorus loading on dissolved oxygen concentrations during summer are predicted to be the greatest in the interflow zone or metalimnion of the lake. The greatest effects of the nonpoint sources are predicted to be in lower depths. Point sources are the major sources of pollutant loading to the Spokane River during the summer and during the spring the major sources are nonpoint tributary loading. The summer point source and spring nonpoint source dominated pollutant loading to the lake mostly affects dissolved oxygen in different zones of the lake because the residence time is shortest in the interflow zone and longest in the lower depths …. The residence time predictions indicate that loading that occurs from the middle of June and later causes the algal blooms that occur in the upper end of the lake in late summer and early fall that produce internal loading of BOD. In addition, loading that occurs in the late spring affects bottom water dissolved oxygen concentrations during late summer and early fall.
- "Diurnal dissolved oxygen concentrations in the river are caused by photosynthesis and respiration of periphyton. Reducing phosphorus loading to the river reduces the diurnal range of dissolved oxygen.

- "Although a few river model segments are predicted to have diurnal minimum dissolved oxygen concentrations that violate the criterion under 2001 loading conditions, the results indicate that Lake Spokane is the most critical area of the modeled river system for determining pollutant TMDL limits and associated allocations. Managing pollutant loads and associated oxygen deficits in the lake also will likely protect water quality in the river.
- "Current monthly permitted BOD5 [biochemical oxygen demand after five days] loading would cause significant degradation of dissolved oxygen in Long Lake Reservoir beyond current levels."

Ecology describes several other model scenarios in the Draft TMDL (Ecology, 2004e). These runs include:

- **NO-POINT WA&ID.** A scenario where Idaho point source loads were also removed using the uncalibrated Idaho model. Point source flows were retained in the run.
- **Effluent Treatment.** The CURRENT scenario except that effluent quality was improved for all dischargers so that total phosphorus was 0.020 mg/L, ammonia was 0.1 mg/L, and carbonaceous biochemical oxygen demand (CBOD) was 2.0 mg/L.
- **Flow Augmentation.** Minimum flow was altered so that it never dropped below 745 cfs through September at the Post Falls gage. Four scenarios (CURRENT, NO-POINT WA&ID, NO-SOURCE, and Effluent Treatment) were run with these higher augmentation flows.

Ecology derived the following additional conclusions from these latest scenarios (Ecology, 2004e):

- The Effluent Treatment scenario using effluent quality of 20 ug/L [micrograms per liter] TP resulted in a 0.44 mg/L decrease in DO in the worst spot (Segment 188) and an average of 0.22 mg/L decrease from the NO-POINT scenario in portions of the water column were DO was already below 8.0 mg/L.
- Maintaining higher minimum flows to around 700 cfs in the river can significantly reduce phosphorus concentrations and phytoplankton productivity in the upper part of Lake Spokane. However, significant immediate changes in same-season DO were not predicted in the lower lake strata (hypolimnion) as previously predicted using regression models developed for Long Lake in the 80's (Patmont et al., 1987). It is anticipated that any DO changes due to reduced productivity will likely be delayed at least a year and exhibited as gradual changes in future SOD and hypolimnetic DO as unoxidized organic matter decrease in the sediment.

Under sub-contract to CH2M HILL, Limno-Tech, Inc. (LTI) also ran several scenarios using Ecology's CE-QUAL-W2 model (Appendix D1). These include:

- **Scenario 1: Baseline** (Also referred to as "Scen 1")**.** Current flow and concentration conditions using 2001 calibration year.
- **Scenario 2: Next level of treatment (NLoT)** (Also referred to as "Scen 2")**.** For municipal discharges, defined for these initial model runs as future municipal effluent quality set

equal to improvements observed at the Rock Creek treatment facility on the Tualatin River in Oregon (for example, median discharges of 0.05 mg/L total phosphorus, about 99 percent treatment efficiency). This run also used a 65 million gallons per day (mgd) flow for SAWTP to account partially for future growth and/or the County's proposed flow from a new plant. See Appendix D2 for a more detailed description of NLoT effluent quality for all dischargers.

- **Scenario 3: NLoT+25 percent NPS BMPs** (Also referred to as "Scen 3")**.** Identical to NLoT with an additional 25 percent reduction in nonpoint source loads through implementation of BMPs to control phosphorus loading (other nutrients will also probably be reduced as part of these BMPs but only phosphorus removals were modeled to be conservative).
- **Scenario 4: PS = 0 Concentration** (Also referred to as "Scen 4")**.** Point source pollutant concentrations set to zero (point source flows remain in the river). Another version of this scenario removed the flow for the City of Spokane discharge only (that is, retained the flows for other point sources but set their pollutant concentrations to zero. That version is referred to as "new Scen 4" or "UNLOT Scenario 4" in various LTI charts).

LTI model output is summarized in time-series and reservoir profile charts in Appendix D1 for the following model segments:

- River Segments (all unstratified):
  - Segment 2: Stateline (free-flowing reach)
  - Segment 17: Mid-point between Stateline and Sullivan Road, just downstream of Liberty Lake WWTP (free-flowing reach)
  - Segment 42: Mid-point between Sullivan Rd. and Upriver pool, upstream of Kaiser and Inland Empire Paper (free-flowing reach)
  - Segment 63: In the Upriver Dam pool near the dam
  - Segment 69: Between Upriver Dam and Upper Falls Dam (impounded reach)
  - Segment 110: Upstream of SAWTP (free-flowing reach)
  - Segment 142: Mid-point of Nine Mile pool (impounded reach)
  - Segment 154: Just upstream of Long Lake Reservoir (impounded reach)
- Long Lake Reservoir Segments:
  - Segment 155: Upper end of reservoir (unstratified reach, nearest sampling station LL5)
  - Segment 167: Upstream of Tum Tum (stratified reach, nearest sampling station LL3)
  - Segment 183: Upstream of Long Lake Dam (stratified reach, nearest sampling station LL0.5)

The figures in Appendix D1 include the following:

- DO Concentration
  - By Day for the Spokane River from 2001 Idaho Stateline Boundary Study (Figure D1-1-1)

  - For Segment 155 (Figure D1-4-1)
  - For Segment 167 (Figure D1-4-2)
  - For Segment 183 (Figure D1-4-3)
- Hypolimnion Algae Levels by Scenario
  - By Hours of Day (Figure D1-4-4)
  - By River Segment (Figure D1-4-5)
  - By Days of Year (Figure D1-4-6)
- Hypolimnion DO Levels by Scenario
  - By River Segment (Figure D1-4-7)
  - By Days of Year (Figure D1-4-8)
- Minimum DO Profiles by Depth
  - For Segment 155 (Figure D1-4-9)
  - For Segment 167 (Figure D1-4-10)
  - For Segment 183 (Figure D1-4-11)
- DO Contours at 5 meters for Segment 155
  - Scenario 1 (Figure D1-4-12)
  - Scenario 2 (Figure D1-4-13)
  - Scenario 3 (Figure D1-4-14)
  - Scenario 4 (Figure D1-4-15)
- DO Contours for Segment 167
  - Scenario 1 (Figure D1-4-16)
  - Scenario 2 (Figure D1-4-17)
  - Scenario 3 (Figure D1-4-18)
  - Scenario 4 (Figure D1-4-19)
- DO Contours for Segment 183
  - Scenario 1 (Figure D1-4-20)
  - Scenario 2 (Figure D1-4-21)
  - Scenario 3 (Figure D1-4-22)
  - Scenario 4 (Figure D1-4-23)
- Minimum Daily DO Concentrations
  - Segment 63 (Figure D1-4-24)
  - Segment 2 (Figure D1-4-25)
  - Segment 17 (Figure D1-4-26)
  - Segment 42 (Figure D1-4-27)
  - Segment 69 (Figure D1-4-28)
  - Segment 110 (Figure D1-4-29)
  - Segment 142 (Figure D1-4-30)
  - Segment 154 (Figure D1-4-31)
- Thirty-Day Running Average Minimum DO Concentrations
  - Segment 63 (Figure D1-4-32)
  - Segment 2 (Figure D1-4-33)

  - Segment 17 (Figure D1-4-34)
  - Segment 42 (Figure D1-4-35)
  - Segment 69 (Figure D1-4-36)
  - Segment 110 (Figure D1-4-37)
  - Segment 142 (Figure D1-4-38)
  - Segment 154 (Figure D1-4-39)

Appendix D3 includes additional LTI model output figures for DO at various depths as well as temperature profiles:

- Segment 167 DO
  - At Depth of 5 Meters (Figure D3-1)
  - At Depth of 15 Meters (Figure D3-2)
  - At Depth of 20 Meters (Figure D3-3)
- Segment 183 DO
  - At Depth of 5 Meters (Figure D3-4)
  - At Depth of 15 Meters (Figure D3-5)
  - At Depth of 20 Meters (Figure D3-6)
  - At Depth of 25 Meters (Figure D3-7)
  - At Depth of 35 Meters (Figure D3-8)
- Temperature Profiles
  - Segment 155 (Figure D3-9)
  - Segment 167 (Figure D3-10)
  - Segment 183 (Figure D3-11)

The following sections examine potential improvements to physical or chemical conditions to assess whether existing uses are different than attainable uses for each of the study reaches. Results of the CE-QUAL-W2 modeling runs are discussed in more detail in Sections 4.3.2 (Spokane River) and 4.4.2 (Long Lake Reservoir).

4.3 Attainable Uses for the Spokane River (RM 112 to RM 58)

4.3.1 Physical Conditions

Habitat

In the case of the riverine section, physical habitat is constrained by the presence of HED facilities and natural conditions. The completion of Post Falls Dam, Upriver Dam, Upper Falls Dam, Monroe Street Dam, and Nine Mile Dam have physically separated important habitats (such as those used for spawning) and isolated rearing opportunities. Independent of how these hydropower systems are operated, their presence precludes the required distribution of habitats necessary to support excellent salmonid migration, rearing, and spawning.

In addition, natural physical conditions of the multiple reservoirs do not support salmonid spawning and rearing completely throughout this reach. Reservoirs cause the river's substrate to change from that found in free-flowing reaches. Complex pool-riffle-run habitat is replaced by more uniform channel geomorphology, even in run-of-river reservoirs. Sediments in reservoirs are fine-grained silts, sands, and clays that preclude redd deposition. Water velocities are slower, which reduce highly-oxygenated flows required for spawning and rearing. Macroinvertebrate diversity is reduced compared to riffle and run areas, which hinders juvenile growth rates and reduces the overall food supply. Finally, although historical ambient temperatures in water released from Coeur d'Alene Lake into the free-flowing Spokane River were also relatively warm, the presence of additional reservoirs increases summer temperatures due to increased residence times and solar radiation.

The urbanization of the Spokane metropolitan area has resulted in increased shoreline development and storm water runoff, decreased water quality (USGS, 2004), and impairment of nearshore habitat. This activity has also resulted in increased fishing pressures within the urbanized area, which probably has an overall detrimental effect on the aquatic life unless the stocking program can be improved. Urbanization will continue in the Spokane Valley and will present a significant challenge for protecting beneficial uses of the river.

Reservoir Operations

Because the physical constraints (that is, dams and associated impoundments) are not going to be removed, uses that might otherwise be present (for example, salmonid spawning and core rearing) are not attainable and should be deleted from the surface water quality standards. Stated another way, because the presence of the dams falls into the fourth category of 40 CFR 131.10(g) ("dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use"), restoration of uses associated with a free-flowing river is neither feasible nor attainable (see Section 4.1).

However, potential changes in operational policies should be considered in the context of defining what is attainable. Although Avista's FERC relicensing efforts are underway in parallel to the Spokane River UAA, the final relicensing decisions will not be made before the Spokane River UAA process is scheduled to be completed. At this point in time, it is only possible to speculate about whether or how operational changes to the reservoir system might affect what beneficial uses are attainable. This speculation would be based on possible protection, mitigation, and enhancement measures (PM&Es) that have been discussed in various relicensing work groups.

Potential PM&Es that have been identified (as of June 2004; Avista, 2004b) that could potentially affect the riverine study reach include:

- **Evaluation and Implementation of Anadromous Fish Passage Feasibility and Needs at the Long Lake and Nine Mile Dams.** The purpose of this measure is to establish a commitment through the next FERC license term to evaluate and implement appropriate fish passage programs in the event that anadromous species are reintroduced into the lower Spokane River.
- **Spokane River Fish Protection, Mitigation, and Enhancement Program.** The purpose of this measure is to assist and provide financial support to mitigate for the operational impacts on wild rainbow trout and also to enhance the sport fishery for rainbow trout.

As discussed in more detail in Section 5, the recommendations from the Spokane River UAA are supportive of the potential return of anadromous runs under the existing modified conditions within the Spokane River system. (That is, there are lacustrine conditions within the existing reservoirs.) Specifically, salmonid spawning and rearing uses continue to drive the proposed site-specific subcategories and criteria for determining the TMDL. In addition, protective DO criteria are recommended specifically to protect rainbow trout spawning when and where that use occurs. Therefore, these recommendations will continue to support wild stocks of rainbow trout in the river.

A Water Resource Work Group consisting of a wide array of stakeholders is advising Avista on potential PM&Es. Although the Water Resource Work Group has not identified any PM&Es for operational parameters, elements that could affect water quality in the Spokane River include (Golder and HDR, 2004):

- Powerhouse hydraulic capacity and depth of turbine intakes
- Spillway elevation, location, and operation
- Reservoir characteristics (for example, useable storage volume, length, depth, and residence time)

Several alternatives regarding a minimum summer flow release for relicensing purposes have been discussed. Two of these alternatives include:

- Modifying outflows from Post Falls Dam during the trout spawning/incubation period to enhance inundation of redds (NHC and HDI, 2004).
- Increasing the minimum summer release from Post Falls Dam. Avista has made several CE-QUAL-W2 model runs with increased minimum summer flow release from Post Falls Dam of 600 to 800 cfs (as compared to the current minimum release of 300 cfs). Avista has presented results showing that increased summer minimum flows would decrease water temperatures from Post Falls to Barker Road (RM 90.3), but would increase water temperatures downstream of Barker Road (HDR, 2004).

To date, no decisions have been made regarding a minimum summer flow release for relicensing purposes.

Summer instream flow increases might enhance the existing rainbow fishery in the riverine segments. However, they would not change the fundamental nature of the fishery to the extent that the attainable uses would be different in definition than the existing uses described in Section 3. Stated another way, potential operational modifications would be expected to provide benefits to the aquatic community. However, it is not likely that these actions would bring this reach of the Spokane River to the “non-core” rearing conditions generally associated with relatively pristine headwater systems that support excellent salmonid migration, rearing, spawning, and harvesting conditions.

4.3.2 Chemical Conditions

Water Temperature

As discussed in Section 3, temperature in the riverine reach is elevated above the current Washington State water quality criterion for the Spokane River of 20°C. Elevated temperatures in the Spokane River system result from a number of factors. These factors include:

- Warm surface waters released from Coeur d'Alene Lake
- Temperature warming within impounded areas
- Warm ambient summer air temperatures
- Decline of groundwater levels

If summer releases from Coeur d'Alene Lake increase, preliminary modeling by Avista (HDR, 2004) suggests that temperatures in some segments of the river (particularly downstream of Barker Road) are also likely to increase. Because downstream Avista impoundments are expected to continue to be operated essentially as run-of-river operations (with hydraulic residence times of less than ½ day), only minor improvements would be anticipated in these reaches.

Temperature warming, to some extent, would be expected in the impounded areas due to slower travel times and increased opportunities for solar warming. For example, warming of several degrees Celsius within the Upriver Dam pool from RM 85 to RM 80 was documented by HDR (2004).

Elevated ambient water temperatures reflect the fact that this system is subject to warmer air temperatures than other areas in the state. Available data from the Western Regional Climate Center (2004) indicate that the Spokane Airport climate station averages summer air temperatures in the top 25 percent of the state (that is, August air temperatures across 75 percent of the state are, on average, cooler than air temperatures in Spokane). Other studies have shown a direct relationship between air temperatures and water temperatures (Sinokrot and Stefan, 1994; Smith, 1981). So, unless there is a cooling trend in ambient summer air temperatures, elevated summer water temperatures will continue to be likely.

The steady decline of groundwater levels may increase water temperatures (Ecology, 2004a). Although groundwater contributes low DO levels, it also provides significant cooling to the Spokane River. As groundwater levels drop, particularly during low-flow periods, warmer surface water temperatures are likely.

Dissolved Oxygen

It is anticipated that DO levels will increase in the Spokane River as additional point source treatment is implemented and nonpoint sources are better controlled. LTI ran various scenarios using Ecology's CE-QUAL-W2 model (Appendix D1). The results indicate that incremental improvements in DO above current conditions are minimal, including no substantial difference in DO conditions among the three treatment scenarios (NLoT, NLoT+25 percent NPS BMPs, and PS=0 Concentration; Figures D1-4-24 through D1-4-39 in Appendix D1). Thus, it is not expected that marginally improved DO conditions alone would either restore salmonid spawning within the riverine reaches where it is not currently occurring (Donley, 2003, pers. comm.) or substantially enhance it where it is occurring. Suitable substrate availability, temperatures, and competition within this modified environment are likely more important factors limiting spawning of rainbow trout (see Section 4.3.3).

It is important to note that there is a substantial difference in model-predicted DO at the Stateline segment for the Baseline run compared to the three treatment scenarios (NLoT, NLoT+25 percent NPS BMPs, and PS=0 Concentration). Potential reasons for this discrepancy include the following:

- The baseline model is Ecology's calibrated model for Washington that set boundary DO conditions based on infrequent monitoring data at Stateline during 2001
- There may be reduced algal productivity in the river in relation to reduced nutrient discharges from treatment facilities in Idaho

This discrepancy represents an uncertainty in the Spokane River UAA and TMDL processes. However, long-term monitoring for DO at Stateline shows that DO during the critical rainbow trout spring spawning/emergence period is typically higher than 11.0 mg/L and summertime values are typically higher than 8.0 mg/L (Figure 3-2). Diurnal DO data at Stateline for August 2001 show minimum DO values above 7.0 mg/L (Figure 4-1a).

Other Parameters

Upstream metals issues associated with the Coeur d'Alene system have not been discussed in detail. However, elevated levels of metals are present throughout the Spokane River system (USGS, 2004). These metals likely contribute to impairment of the aquatic system, particularly with respect to sensitive macroinvertebrates that are a critical source of food for fish. As these metals sources are controlled and cleaned up, the macroinvertebrate community may improve, if water temperatures are conducive. However, this improvement would likely not result in the restoration of cold-water aquatic life and salmonid spawning within the lacustrine portions of the river due to other limiting factors such as temperature and physical habitat.

4.3.3 Biological Conditions

The physical habitat modifications created by the presence and operations of the HED facilities within the Spokane River segment will continue to limit the potential of the biological conditions (see Section 4.3.1). The presence of the dams has created isolated segments of the Spokane River between dams that have varying qualities and quantities of temperature and physical habitat conditions. These modified conditions include:

- Warmer water below the Coeur d'Alene Lake outlet
- The creation of lacustrine-like conditions (that is, slower water, fine sediment substrates) within segments of the river
- Establishment of migratory barriers within the Spokane River

These post-dam conditions, which have replaced the free-flowing aquatic environment that once existed within the Spokane River, function independent of the DO parameter. The conditions within these segments are further described in Section 3.2.3.

The minor improvements in DO levels proposed under the treatment alternatives within this segment may provide some benefits to species densities within portions of the upper Spokane River. However, these benefits will be minor because of the physical habitat conditions that will continue to limit the systems' biological potential. Further, the system will likely never support an "excellent" salmonid fishery for the following reasons:

- The upstream migration corridor will continue to be suppressed

- The backwater areas created by the dams, as well as the hydrologic constraints, will continue to limit the available spawning habitats
- The presence of introduced warm-water piscivors will continue to limit spawning and rearing survival in the reservoir segments

Thus, it is not expected that the minor improvements from the various DO treatment levels within the upper Spokane River system will change the attainability of the biological component.

4.4 Attainable Uses for Long Lake Reservoir (RM 58 to RM 34)

4.4.1 Physical Conditions

Habitat

Reductions in point or nonpoint source loads to the reservoir will not improve the physical habitat constraints that are currently present in Long Lake Reservoir. For example, the fine reservoir substrate and steep littoral habitat does not support salmonid spawning activities, and reductions in pollutant loads will have no effect on these physical limitations. Since shoreline erosion is limited, coarse material from such erosion that could potentially be used by salmonids for spawning is not readily available within the reservoir.

Reservoir Operations

PM&Es that have been identified (as of June 2004; Avista, 2004b) that could potentially affect Long Lake Reservoir include:

- **Evaluation and Implementation of Anadromous Fish Passage Feasibility and Needs at the Long Lake and Nine Mile Dams.** The purpose of this measure is to establish a commitment through the next FERC license term to evaluate and implement appropriate fish passage programs in the event that anadromous species are reintroduced into the lower Spokane River.
- **Spokane River Fish Protection, Mitigation, and Enhancement Program.** The purpose of this measure is to assist and provide financial support to mitigate for the operational impacts on wild rainbow trout and also to enhance the sport fishery for rainbow trout.
- **Long Lake Reservoir Aquatic Weed Management Program.** The purpose of this measure is for Avista to assist and provide financial support in the monitoring and control of exotic aquatic weeds within and adjacent to Long Lake Reservoir.

As discussed in more detail in Section 5, the recommendations from the Spokane River UAA are consistent with the potential that anadromous fish runs might return. Some of the factors that support anadromous fish runs include the following:

- Salmonid spawning and rearing uses continue to drive the proposed site-specific subcategories and criteria for determining the TMDL

- Seasonal DO issues in the lacustrine portion of Long Lake Reservoir do not appear to overlap with any of the critical periods or life stages (spring or fall spawners) of potential anadromous species
- The recommendations in this Spokane River UAA also support wild and hatchery stocks of rainbow trout in the reservoir, since protective DO criteria are recommended specifically to protect rainbow trout rearing when and where that use occurs

Although the Water Resource Work Group has not identified any PM&Es for operational parameters, elements that could affect water quality in Long Lake Reservoir include (Golder and HDR, 2004):

- Powerhouse hydraulic capacity and depth of turbine intakes
- Spillway elevation, location, and operation
- Reservoir characteristics (for example, useable storage volume, length, depth, and residence time)

Potential PM&Es that are currently being evaluated do not include any significant change in summer operational rule curves. Winter drawdowns are being evaluated to determine potential effects to fish and aquatic habitat (Parametrix, 2004) because Avista attempts to keep the reservoir within 1.5 feet from full pool elevation during the summer recreation season.

Ecology has recently evaluated other reservoir modifications associated with upstream facilities (Ecology, 2004e). A CE-QUAL-W2 model run was made that assumed a minimum summer flow release from Post Falls Dam of 745 cfs (compared to the current minimum release of 300 cfs). Ecology concluded that this condition would reduce algae in the upper end of Long Lake Reservoir by 50 percent. However, the results indicated that DO profiles in the lower end of the reservoir near the dam would not change significantly. This model run did not account for possible changes in SOD resulting from reduced algae. Additional discussion related to improved DO conditions is provided in Section 4.4.2.

Potential operational modifications tied to PM&Es might provide benefits to the aquatic community. However, it is not likely that these actions would bring Long Lake Reservoir to the “core” rearing conditions generally associated with systems that support extraordinary salmonid migration, rearing, spawning, and harvesting conditions.

4.4.2 Chemical Conditions

Water Temperature

Temperature conditions in Long Lake Reservoir would not be expected to change in relation to further control of nutrient sources (see Figures 4-2 and D3-9 to D3-11 in Appendix D3). Thus, management of anthropogenic pollutant loads will neither change the thermal regime of the reservoir nor increase the “suitable volume” of water that falls below 20°C.

Avista does not currently anticipate incorporating any summer operational changes at Long Lake Dam related to PM&Es. (Avista is only evaluating Long Lake Dam winter drawdown PM&Es [Parametrix, 2004]).

Dissolved Oxygen

It is possible that improvement in light penetration due to improved sediment and algae management may change current limiting conditions in what is currently the hypolimnion. Typically, Secchi depth measurements increase as the trophic state improves. (The current average Secchi depth of about 5 to 6 meters (16 to 20 feet) in Long Lake Reservoir is already greater than the Secchi depth in most reservoirs and lakes in Washington [Gilliom, 1984]). For example, Lake Washington Secchi depths improved from a minimum of 0.8 meter (30 inches) to a maximum of 7.6 meters (25 feet) following phosphorus reductions of 77 percent (King County, 2004b).

Modeling results for all three treatment scenarios (NLoT, NLoT+25 percent NPS BMPs, and PS=0 Concentration) show substantial improvements in metalimnion and hypolimnion DO compared to current baseline conditions (Figures 4-3 and 4-4 and Figures D1-4-1 through D1-4-23 in Appendix D1). On a relative basis, the NLoT+25 percent NPS BMPs scenario (Scenario 3) and the PS=0 Concentration scenario (Scenario 4) provide much less improvement relative to the initial improvement provided by the NLoT scenario (Scenario 2). Model results also suggest that, due to reduced algal production, there is a decrease in surface water DO levels for each of the three treatment scenarios compared to baseline conditions.

An increase in "suitable volume" is predicted to occur as a result of treatment scenarios. This "suitable volume" may increase by 5.2 percent (or 17 million cubic meters [14,000 acre-feet]). More importantly, under baseline conditions, the volume-weighted average DO level in the volume below the "suitable volume" is 2.8 mg/L. The NLoT scenario (Scenario 2) is expected to improve volume-weighted average DO levels to 4.0 mg/L. Coupling the NLoT with control of nonpoint sources (Scenario 3, NLoT+25 percent NPS) may provide a marginal DO improvement in the deepest portions of the reservoir by increasing the volume of water with DO concentrations greater than 5.0 mg/L. These improvements are shown in Figures 4-4 through 4-7.

LTI has also completed model runs that show the independent relative effects of point and nonpoint source phosphorus and BOD. These sensitivity runs showed that the relative effects of pollutant loads on the hypolimnion include:

- Phosphorus from nonpoint sources has the dominant effect on DO, with phosphorus from point sources having a relatively minor effect (Figures D1-4-4 through D1-4-6 in Appendix D1)
- Phosphorus from point sources has a measurable effect on algae (shown as sum of biomass of three species), but phosphorus from nonpoint sources has an even greater effect (Figures D1-4-7 and D1-4-8 in Appendix D1)
- Point source BOD and nonpoint source BOD have little effect on DO or algae (Figures D1-4-4 through D1-4-8)

4.4.3 Biological Conditions

Trophic Status

Given that Long Lake Reservoir has stabilized to a mesotrophic status (Soltero et al., 1992), a decrease in phosphorus and resulting increases in DO levels might alter the future trophic status, but it is uncertain to what degree. Operational requirements of reservoirs create an unstable and, due to the lack of research, apparently unpredictable, environment for definitively predicting how further nutrient reductions would affect the trophic status. If the reservoir was able to move toward a more oligotrophic system, the effects on biological productivity and the associated effects to the existing fisheries community would be uncertain.

Macrophytes

The dense growth of macrophytes, particularly along the southern reservoir shoreline, currently provides stability to the shoreline and mitigates erosion. The shallow macrophyte beds that provide critical habitat for spawning and rearing for the dominant cool- and warm-water fish species are likely impacted more by reservoir operations within the lacustrine zone (May et al., 1988) than by additional, relatively minor, nutrient reductions given that the reservoir has apparently settled into a mesotrophic status (as described by Soltero et al., 1992). Further reductions in anthropogenically derived nutrients may or may not result in measurable impacts to macrophytes, since additional reductions would be minor given the history of the system.

Plankton

Zooplankton are limited within the limnetic zone. This is due to their lack of adaptations for swimming, residence time, and drawdown and not to the adverse temperature or DO conditions. It is likely that improvements in DO conditions, particularly in the metalimnion and hypolimnion, would not provide great benefit to the limited number of open-water fish species. Cold-water fishes like rainbow trout appear to use these deeper zones infrequently and would not likely use the deepest zones for zooplankton feeding. Predicted improvements of up to 1.5 mg/L are likely within the tolerated ranges for pelagic species that are routinely exposed to fluctuating levels of DO within large stratified systems such as Long Lake Reservoir.

Macroinvertebrates

The greatest diversity and density of macroinvertebrates occur in the littoral (inshore) zone, where light can penetrate and DO levels are not depressed. Because 50 percent of the total volume of the reservoir is within the euphotic zone, improvements in areas below the euphotic zone would not provide much benefit to the majority of the macroinvertebrate community. For those benthic macroinvertebrates in the euphotic zone, densities might already be high enough to support the large forage base for predators (Pfeiffer, 1985, cited in Parametrix, 2004). However, it is likely that reservoir operations limit the macroinvertebrate potential within this zone (May et al., 1988).

If it was possible to limit pollution sources of nutrients (which is not a feasible technical option), the benthic macroinvertebrate community would not likely improve substantially because:

- Oxygen-deficient conditions found in the hypolimnion appear to be related to internal SOD (Ecology, 2004a)
- Anoxic conditions are only present two months out of the year (August and September; data from the remaining ten months show that DO levels at the bottom of the reservoir range from 5.5 to 9.5 mg/L [Figure 3-11])

Ecology's modeling shows that, even if oligotrophic SOD conditions could be achieved (which is not likely given the 89-year operating history of the reservoir), the highest DO values that could be achieved would still remain in the 5.0 to 6.0 mg/L range (Ecology, 2004a; 2004e). Thus, the expected benthic species would still need to be highly tolerant of hypoxic conditions (less than 5.0 mg/L) on a two-month basis.

Since the deeper waters of Long Lake Reservoir have low DO levels, macroinvertebrate data from Lake Roosevelt were examined as a surrogate data source. Lake Roosevelt provides an opportunity to observe a macroinvertebrate setting in a man-made environment similar to that of Long Lake Reservoir.

Lake Roosevelt is located approximately 5 miles below Long Lake Dam on the Spokane River. Two sites with macroinvertebrate data were examined (Griffith et al., 1991 and Voeller, 1993). Site 1 is Porcupine Bay (approximately 20 miles downstream of Long Lake Dam) and Site 2 is Seven Bays (approximately 35 miles downstream of Long Lake Dam). Three habitats were sampled at each site: shallow water (less than 15 meters [49 feet]), mid-depth water (15 to 26 meters [49 to 85 feet]), and deep water (greater than 26 meters [85 feet]). Data for deep-water habitats at Porcupine Bay and Seven Bays are summarized in Table 4-3.

TABLE 4-3
Lake Roosevelt Benthic Macroinvertebrate Data in Deep-Water
(Number / m² [relative abundance])

	Benthic DO Levels (max-min, mg/L)	Basommatophora (Snails)	Pelecypoda (Clams)	Diptera (Midges)	Trichoptera (Caddisflies)	Oligocheata (Worms)	Amphipoda (Scuds)
		Lymnaeidae	Sphaeridae	Chironomidae	Limnephillidae	Lumbriculidae	Gammarus
Porcupine Bay							
1991	11.8 (Feb) - 2.5 (Sept)	- -	982 (13%)	5,996 (78%)	- -	678 (9%)	- -
1993	11.4 (Dec) - 3.4 (Aug)	3 (<1%)	- -	243 (48%)	- -	94 (18%)	171 (33%)
Seven Bays							

TABLE 4-3
Lake Roosevelt Benthic Macroinvertebrate Data in Deep-Water
(Number / m² [relative abundance])

		Basommatophora (Snails)	Pelecypoda (Clams)	Diptera (Midges)	Trichoptera (Caddisflies)	Oligocheata (Worms)	Amphipoda (Scuds)
	Benthic DO Levels (max-min, mg/L)	**Lymnaeidae**	**Sphaeridae**	**Chironomidae**	**Limnephillidae**	**Lumbriculidae**	**Gammarus**
1991	12.7 (Feb) - 8.3 (Sept)	7 (<1%)	14 (<1%)	1,572 (80%)	31 (1%)	353 (17%)	- -
1993	13.0 (Dec) - 8.3 (Aug)	- -	- -	223 (40%)	9 (2%)	104 (19%)	223 (40%)

NOTE: Deep water is defined as water greater than 26 meters (85 feet) in depth

1991 data from Griffith et al. (1991)
1993 data from Voeller (1993)

- - No species observed.

DO levels measured during the studies at Porcupine Bay fluctuated more widely than those during the studies at Seven Bays. For example, in 1991, DO levels at Porcupine Bay measured at 2.5 mg/L in September increased to 8.3 mg/L by October. DO conditions such as these require the macroinvertebrates to be highly adapted to extreme changes in DO levels.

The Voeller (1993) survey found *Gammarus* to be the most dominant macroinvertebrate family at the Porcupine Bay site in September as well as at the Seven Bays site during August and September. Johnson et al. (1993) suggested that *Gammarus* prefers well-oxygenated environments, but provided no actual DO levels for evaluation. The presence of *Gammarus* in this deep water environment during low DO levels (Voeller, 1993) may result from the species' ability to tolerate periods of low DO levels given greater requirements of cold temperatures and dark environments (Pennak, 1978).

The presence of the caddisfly family Limnephilidae during the Griffith et al. (1991) sampling seems unusual. Typically, Limnephilidae are associated with littoral zones. However, some genera may be found in a variety of lentic habitats (Merritt and Cummins, 1996).

The Lake Roosevelt dataset is important in that it suggests that even at benthic sites where DO levels are greater than 8.0 mg/L, the macroinvertebrate community continues to be dominated by Chironomidae and Oligocheata. This suggests that species diversity may not be solely DO-limited. Thus, if macroinvertebrates in Long Lake Reservoir respond to varying and marginally increased DO levels similarly to those in Lake Roosevelt, only minor improvements to benthic macroinvertebrate community richness might be expected.

Moreover, the dominance of fine sediments and organic substrates (typical of deep-water reservoirs) and the cold temperatures will continue to limit the diversity of macroinvertebrates within the deepest parts of Long Lake Reservoir, even with minor improvements in seasonal DO levels.

Fisheries

The fisheries in Long Lake Reservoir have changed over time with water quality and habitat modifications, as well as with the introduction of non-native species (Soltero et al., 1992). As with macroinvertebrates, the greatest diversity and density of fishes occur in the littoral (inshore) zone. Spawning areas for cool- and warm-water fish species accommodate vegetation spawners and nest spawners, both of which rely on shallow areas with rooted aquatic plants. These areas coincide with areas where light currently can penetrate and where DO levels currently are not depressed.

In terms of protecting rainbow trout that will be stocked in the future, increases in DO levels will likely not benefit these species. This is because these fish likely utilize the epilimnion and metalimnion for a majority of their needs. Only occasionally, and for short periods, did tracked rainbow trout venture into the deeper hypolimnion as observed by Warner and Quinn (1995) and James and Kelso (1995). The majority of food resources and water temperature needs for the fishes appeared to be available within the upper strata. Rearing habitat within covered and low-velocity areas is provided in the riverine and transitional sections of the reservoir. Adult trout will likely inhabit the same littoral habitats used for rearing because of food availability.

Trout that forage within the open-water portions of the reservoir feed on zooplankton and smaller fish will be exposed, at some strata, to marginal increases in DO levels. Within the “suitable volume” (detailed previously) of water with temperatures below 20°C and DO levels at or above 5.0 mg/L, weighted-average (by volume) DO values might increase from 6.7 mg/L under the Baseline scenario (Scenario 1) to only 6.8 mg/L with the NLoT scenario (Scenario 2). In the scenario that adds 25 percent control of nonpoint sources (NLoT+25 percent NPS BMPs, Scenario 3), the actual volume might increase (from 48 percent to 53 percent, see Figures 3-13 and Figure 4-5), but weighted-average DO levels in this “suitable volume” would remain the same (at 6.8 mg/L).

This means that roughly 1.4 acre-feet (1,725 cubic meters) of suitable water would be available for each of the potentially-stocked rainbow trout (100,000 annually), which is slightly greater than the 1.3 acre-feet (1,600 cubic meters) available per fish under the current Baseline scenario (Scenario 1). Although the “suitable volume” is only a hypothetical depiction of the potential use of the reservoir by rainbow trout, it provides useful and important insights into the relatively minor improvements in the rainbow trout fishery from increases in DO levels with respect to the area available per fish within the reservoir.

Comparing Figure 3-13 with Figure 4-5 shows that weighted-average DO values within the lower portion of the hypolimnion (DO levels of less than 5.0 mg/L) are predicted to increase from an average of 2.8 mg/L to 4.0 mg/L if the NLoT+25 percent NPS BMPs scenario (Scenario 3) was implemented. Since prey tend to avoid low DO conditions and the majority of the prey-base is located within the upper strata, it is expected that there would be limited exposure of rainbow trout to low DO levels. If DO conditions were improved in the open-water portion of the reservoir, additional intermittent foraging might occur. However, this benefit is expected to be small given the trout's preference for easier prey in shallower environments.

4.4.4 Other Washington Case Studies

Lake Washington is often cited as the best example of the recovery of a lake system following control of anthropogenic influences. Direct effluent discharge was completely removed, which reduced total phosphorus concentrations from 70 µg/L to about 16 µg/L, (a reduction of 77 percent). Water transparency improved from a minimum of 30 inches (0.8 meter) to a maximum of 25 feet (7.6 meters; King County, 2004b). In addition to reduced phosphorus loading, a certain portion of this improvement has been attributed to changes in the composition and relative abundance of the algae, zooplankton, and fish.

Recent assessments (King County, 2003) have concluded that:

> "The key to such a rapid and complete recovery was the lake's [large] depth, which prevented anoxia from developing in the hypolimnion. The lake's relatively fast flushing rate accelerated recovery…. Comparison of Lake Washington with other western Washington lakes illustrates that depth and the relatively short period of enrichment were instrumental in accounting for the rapid recovery of Lake Washington."

Long Lake Reservoir has different conditions than Lake Washington. Long Lake Reservoir is shallower (15 meters mean depth versus 33 the meters mean depth of Lake Washington) and has had a much longer period of nutrient enrichment (63 years from the time that Long Lake Dam was constructed to the completion of SAWTP versus the 27 years of direct effluent discharge into Lake Washington; King County, 2004b). Further recovery of Long Lake Reservoir following the implementation of all feasible control technologies will likely occur at a much slower rate than that seen in Lake Washington. This is due to the longer period of accumulated SOD materials in Long Lake Reservoir and the relatively stable trophic status created by phosphorus treatments within the Spokane River system.

The prediction that Long Lake Reservoir will recover slower than Lake Washington has recovered is consistent with a study of lakes in western Washington (other than Lake Washington) that have been monitored during summer conditions (Welch and Jacoby, 2001, cited in King County, 2003). This study concluded that in 14 of 17 lakes, internal phosphorus loading was found to be more important than external phosphorus loading (that is, internal phosphorus loading was 68 ± 21 percent of total phosphorus loading). Six of these 14 lakes stratify, and all are shallower than Lake Washington. These conditions are consistent with those at Long Lake Reservoir. Although all of these lakes are located in western Washington, Welch and Jacoby (2001, cited in King County, 2003) concluded that the relatively greater importance of internal versus external phosphorus loading was due to generally dry summers with low water input, which is consistent with eastern Washington summertime conditions.

Lakes with high internal phosphorus loading usually retain that condition for many years following reduction in external input (Sondergaard et al., 2001). This study concluded that "the duration of the recovery period following [phosphorus] loading reduction depends on the loading history, but it may last for decades in lakes with a high sediment [phosphorus] accumulation." Long Lake Reservoir has a long enrichment period, with intense enrichment for 63 years up to the completion of SAWTP in 1978, plus additional moderate enrichment for the 26 years since then from point and nonpoint sources. Therefore, the recovery of Long Lake Reservoir will likely take many decades. Even if oligotrophic SOD conditions were possible, results from Ecology's Spokane River CE-QUAL-W2 model scenarios indicate that hypolimnion DO values in Long Lake Reservoir would not increase above 5.0 to 6.0 mg/L.

4.5 Summary and Discussion of Attainable Uses

4.5.1 Spokane River (RM 112 to RM 58)

An attainable beneficial use must take into consideration potential reductions in point and nonpoint sources. An important tool in this analysis is the Spokane River CE-QUAL-W2 water quality modeling software being used to support development of the TMDL. Although this tool provides valuable information, particularly in evaluating relative improvements afforded by varying pollutant management scenarios, it cannot predict absolute improvements. Model calibrations resulted in RMS errors of 1°C for water temperature and 1.0 mg/L for DO.

In the case of the riverine section, physical habitat is constrained by the presence of HED facilities and natural conditions. The completion of Post Falls Dam, Upriver Dam, Upper Falls Dam, Monroe Street Dam, and Nine Mile Dam have physically separated important habitats (such as those used for spawning) and isolated rearing opportunities. Independent of how these hydropower systems are operated, their presence precludes the required distribution of habitats necessary to support excellent salmonid migration, rearing, and spawning. In addition, natural physical conditions of the multiple reservoirs do not support salmonid spawning and rearing completely throughout this reach.

It is neither reasonable nor feasible to remove the physical barriers (dams). Therefore, uses that might otherwise be present in an undeveloped riverine environment (for example, salmonid spawning and core rearing) are not attainable in the existing, highly altered lacustrine environment. The presence of the dams falls into the fourth category of 40 CFR 131.10(g) ("dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use"). Thus, under EPA regulations, restoration of uses associated with a free-flowing river is neither feasible nor attainable. However, potential changes in operational policies should be considered in the context of defining what is attainable. As part of the relicensing procedures for Avista's HED facilities, PM&Es have been identified (as of June 2004) that could eventually change the physical character of the riverine study reach. These PM&Es could include constructing anadromous fish passages and changing operations to benefit rainbow trout. Potential operational modifications, if implemented, would potentially provide benefits to the aquatic community. However, it is not likely that these actions would bring this reach of the Spokane River to the "non-core" rearing conditions generally associated with relatively pristine headwater systems that support excellent salmonid migration, rearing, spawning, and harvesting conditions.

Elevated temperatures in the Spokane River system are the result of a number of factors, including warm surface waters released from Coeur d'Alene Lake, temperature warming within impounded areas, warm ambient summer air temperatures, and the decline of groundwater levels. Elevated ambient water temperatures reflect the fact that this system is subject to warmer air temperatures than other areas in the state.

It is anticipated that DO levels will increase in the Spokane River as additional point source treatment is implemented and nonpoint sources are better controlled. LTI ran various scenarios using Ecology's CE-QUAL-W2 model. The results indicate that incremental improvements in DO above current conditions would be minimal, including no substantial differences in DO conditions among the three treatment scenarios (NLoT, NLoT+25 percent NPS BMPs, and PS=0 Concentration). Thus, it is not expected that marginally improved DO conditions alone would restore salmonid spawning within the riverine reaches where it is not currently occurring or substantially enhance it in reaches where it is occurring.

In summary, the existing uses, including those present since November 28, 1975, are the same as the attainable uses. There may be some enhancement possible above the existing chemical quality (for example, decreasing metals contamination). However, physical conditions (for example lacustrine environments and reservoir operations) and water temperature will continue to favor cool-water species and limit cold-water aquatic life. Therefore, consideration should be given to establishing a new subcategory of use appropriate for this cool- and cold-water fishery in the Washington portion of the Spokane River (RM 96 to RM 58).

4.5.2 Long Lake Reservoir (RM 58 to RM 34)

Reductions in point or nonpoint source loads to the reservoir will not improve the physical habitat constraints that are currently present in Long Lake Reservoir. For example, the fine reservoir substrate and steep littoral habitat does not support salmonid spawning activities, and reductions in pollutant loads will have no effect on these physical limitations.

Long Lake Dam is not a remediable physical barrier (that is, it is not anticipated that it will be removed). Therefore, uses that might otherwise be present in an undeveloped riverine environment (for example, salmonid spawning and core rearing) are not attainable in the existing, highly altered lacustrine environment. However, potential changes in operational policies should be considered in the context of defining what is attainable. Potential PM&Es that have been identified (as of June 2004) that could potentially affect Long Lake Reservoir include the feasibility of constructing anadromous fish passages, the mitigation of operations on rainbow trout, and the evaluation of an aquatic weed management program. Potential PM&Es that are currently being evaluated do not include any significant change in summer operational rule curves.

Potential operational modifications tied to PM&Es might provide benefits to the aquatic community. However, it is not likely that these actions would bring Long Lake Reservoir to the "core" rearing conditions generally associated with systems that support extraordinary salmonid migration, rearing, spawning, and harvesting conditions.

Temperature conditions in Long Lake Reservoir would not be expected to change in relation to further control of nutrient sources. Thus, management of anthropogenic pollutant loads will neither change the thermal regime of the reservoir nor increase the “suitable volume” of water that falls below 20°C.

As point and nonpoint sources of pollution are controlled, the volume of hypolimnion (below the thermocline) would likely decrease and a smaller area of hypoxia would be observed. Modeling results show that there is substantial improvement in metalimnion and hypolimnion DO levels for all three treatment scenarios (NLoT, NLoT+25 percent NPS BMPs, and PS=0 Concentration) compared to the current Baseline scenario. On a relative basis, NLoT+25 percent NPS BMPs scenario (Scenario 3) and the PS=0 Concentration scenario (Scenario 4) provide much less improvement relative to the initial improvement provided by the NLoT scenario (Scenario 2). Model results also suggest that, due to reduced algal production, there is a decrease in surface water DO levels for each of the three treatment scenarios compared to baseline conditions.

A small increase in “suitable volume” is predicted to occur when nonpoint source controls are coupled with the NLoT (Scenario 3, NLoT+25 percent NPS BMPs). More importantly, under baseline conditions, average DO levels in the volume below the “suitable volume” are 2.8 mg/L. The NLoT+25 percent NPS BMPs scenario (Scenario 3) is expected to improve average DO levels to 4.0 mg/L.

Given that Long Lake Reservoir has stabilized to a mesotrophic status, a decrease in phosphorus and resulting increases in DO levels might alter the future trophic status. If the reservoir was able to move toward a more oligotrophic system, the effects on biological productivity and the associated effects to the existing fisheries community would be uncertain. The shallow macrophyte beds that provide critical habitat for spawning and rearing for the dominant cool- and warm-water fish species are likely impacted more by reservoir operations within the lacustrine zone than by additional, relatively minor, nutrient reductions given that the reservoir has apparently settled into a mesotrophic status. Further reductions in anthropogenically derived nutrients may or may not result in measurable impacts to macrophytes, since additional reductions would be expected to be minor given the history of the system.

Because 50 percent of the total volume of the reservoir is within the euphotic zone (that is, the riverine, transitional, and lacustrine reaches), improvements in areas below the euphotic zone would not provide much benefit to the majority of the macroinvertebrate community because of limitations on available substrate and temperature conditions. Ecology’s modeling shows that, even if oligotrophic SOD conditions could be achieved (which is not likely given the 89-year operating history of the reservoir), the highest DO values that could be achieved in the hypolimnion would still remain in the 5.0 to 6.0 mg/L range. Assuming that some increases in hypolimnion DO levels could be achieved by reducing anthropogenic nutrient loading, the benthic species that would be expected to live there would still need to be highly tolerant of hypoxic conditions (less than 5.0 mg/L) on a short-term basis.

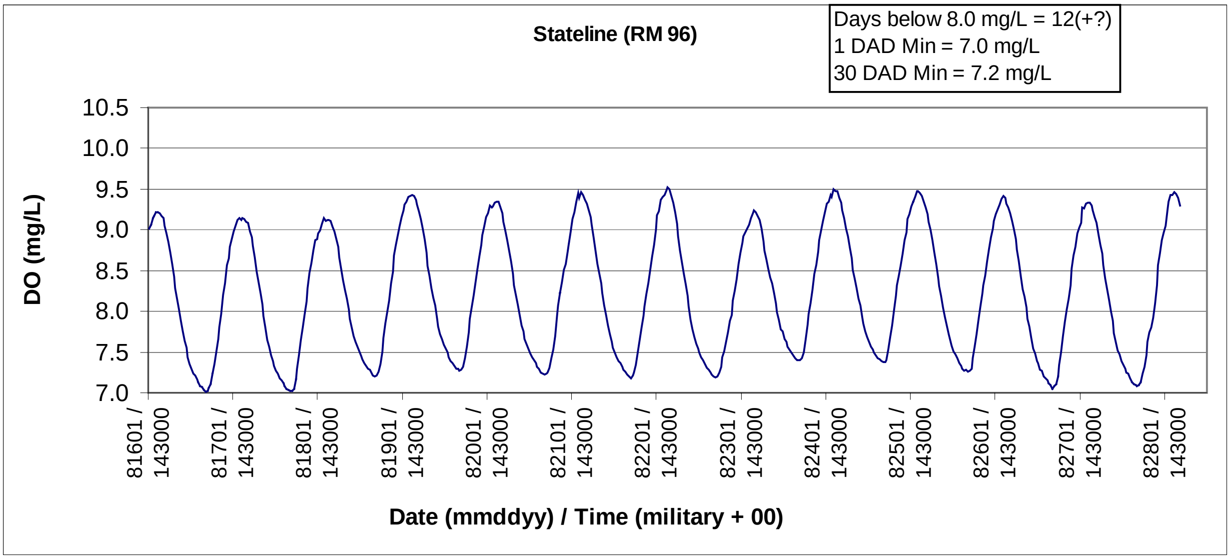
Since the deeper waters of Long Lake Reservoir have low DO levels, macroinvertebrate data from Lake Roosevelt were examined as a surrogate data source. The Lake Roosevelt dataset is important in that it suggests that where DO levels are greater than 8.0 mg/L, the macroinvertebrate community continues to be dominated by Chironomidae and Oligocheata. This suggests that species diversity may not be solely DO-limited. Although not an ideal comparison, Lake Roosevelt and Nine Mile Reservoir do provide additional support related to the limitations of the benthic community structure within deeper environments. Thus, if macroinvertebrates in Long Lake Reservoir respond to varying and marginally increased DO levels similarly to those in Lake Roosevelt, only minor improvements to benthic macroinvertebrate community richness might be expected. In addition, these environments are further limited by substrate composition (fine sediments and organic substrates) and cold temperatures.

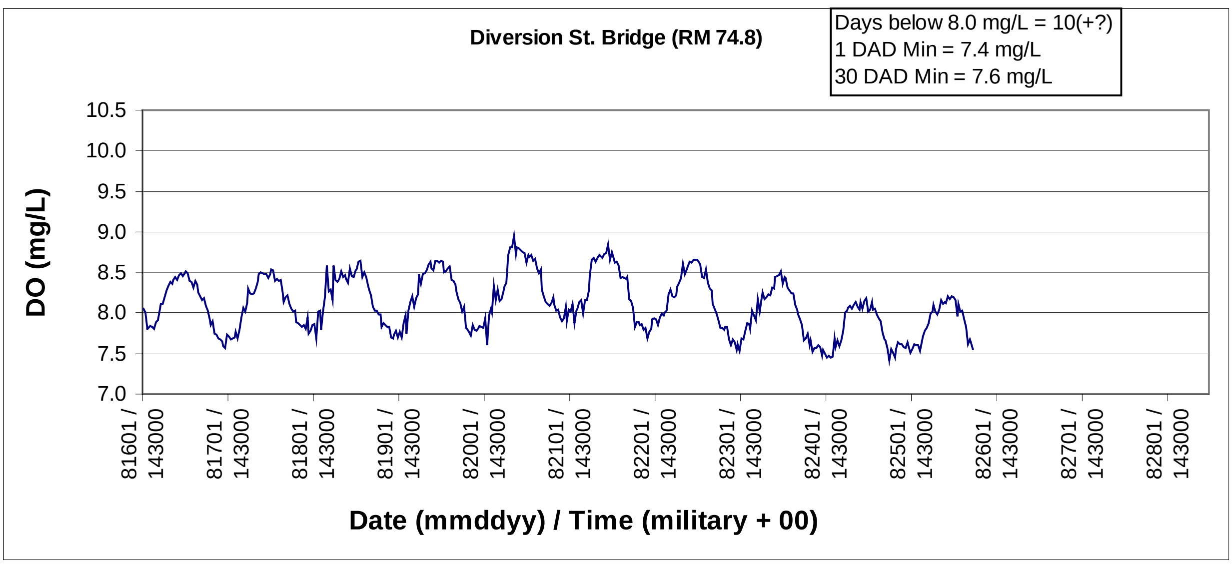
The fisheries in Long Lake Reservoir have changed over time with water quality and habitat modifications, as well as with the introduction of non-native species. As with the macroinvertebrates, the greatest diversity and density of fishes occur in the littoral (inshore) zone. Spawning areas for cool- and warm-water fish species accommodate vegetation spawners and nest spawners, both of which rely on shallow areas with rooted aquatic plants. These areas coincide with areas where light currently can penetrate and where DO levels currently are not depressed.

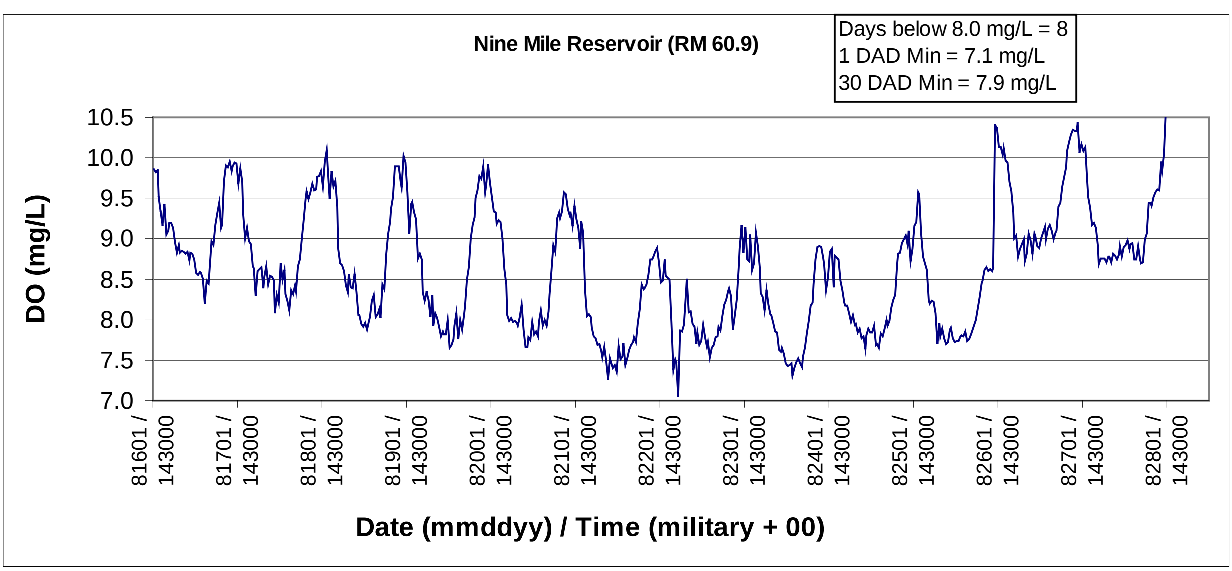
In terms of protecting rainbow trout that will be stocked in the future, increases in DO levels will likely not benefit these species. This is because these fish likely utilize the epilimnion and metalimnion for a majority of their needs. Only occasionally, and for short periods, did tracked rainbow trout venture into the deeper hypolimnion. The majority of food resources and water temperature needs for the fishes appeared to be available within the upper strata. Rearing habitat within covered and low-velocity areas is provided in the riverine and transitional sections of the reservoir. Adult trout will likely inhabit the same littoral habitats used for rearing because of food availability.

Trout that forage within the open-water portions of the reservoir feed on zooplankton and smaller fish will be exposed, at some strata, to marginal increases in DO levels. Within the "suitable volume" of water with temperatures below 20°C and DO levels at or above 5.0 mg/L, weighted-average (by volume) DO values might increase from 6.7 mg/L under the Baseline scenario (Scenario 1) to only 6.8 mg/L with the NLoT scenario (Scenario 2). In the scenario that adds 25 percent control of nonpoint sources (NLoT+25 percent NPS BMPs, Scenario 3), the actual volume might increase (from 48 percent to 53 percent), but weighted-average DO levels in this "suitable volume" would remain the same (6.8 mg/L). This means that roughly 1.4 acre-feet (1,725 cubic meters) of suitable water would be available for each of the potentially-stocked rainbow trout (100,000 annually), which is slightly greater than the 1.3 acre-feet (1,600 cubic meters) available per fish under the current Baseline scenario (Scenario 1). Although the "suitable volume" is only a hypothetical depiction of the potential use of the reservoir by rainbow trout, it provides useful and important insights into the relatively minor improvements in the rainbow trout fishery from increases in DO levels with respect to the area available per fish within the reservoir.

In summary, the existing uses, including those present since November 28, 1975, are the same as the attainable uses. There may be some enhancement possible above the existing chemical quality (for example, decreasing metals contamination and increasing DO levels). However, physical conditions and water temperature will continue to favor cool- and warm-water species and limit cold-water aquatic life. Therefore, consideration should be given to establishing a new subcategory of use appropriate for this mixed reservoir fishery.







Figures 4-1a, 4-1b, and 4-1c. Summary of Available Diurnal Monitoring Data Collected by Ecology in 2001 at Stateline (4-1a), Diversion Street Bridge (4-1b), and Nine Mile Reservoir (4-1c). From Ecology, 2004a; 2004c.

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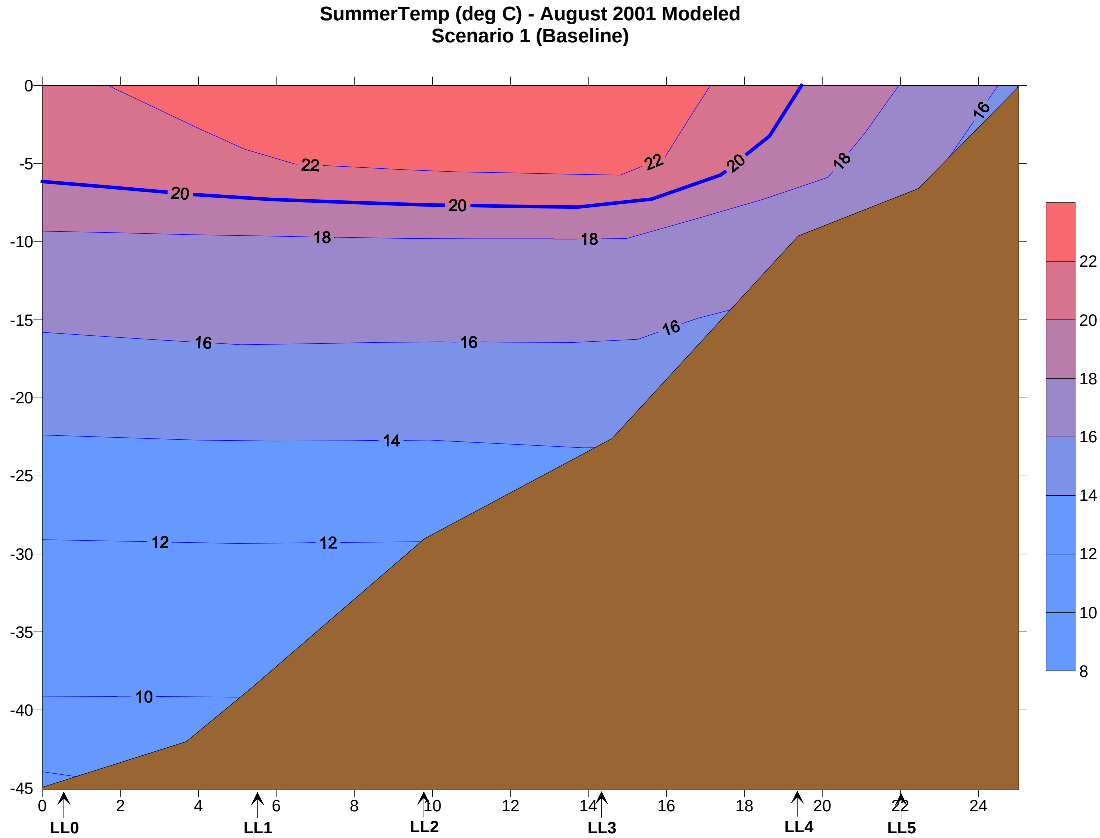

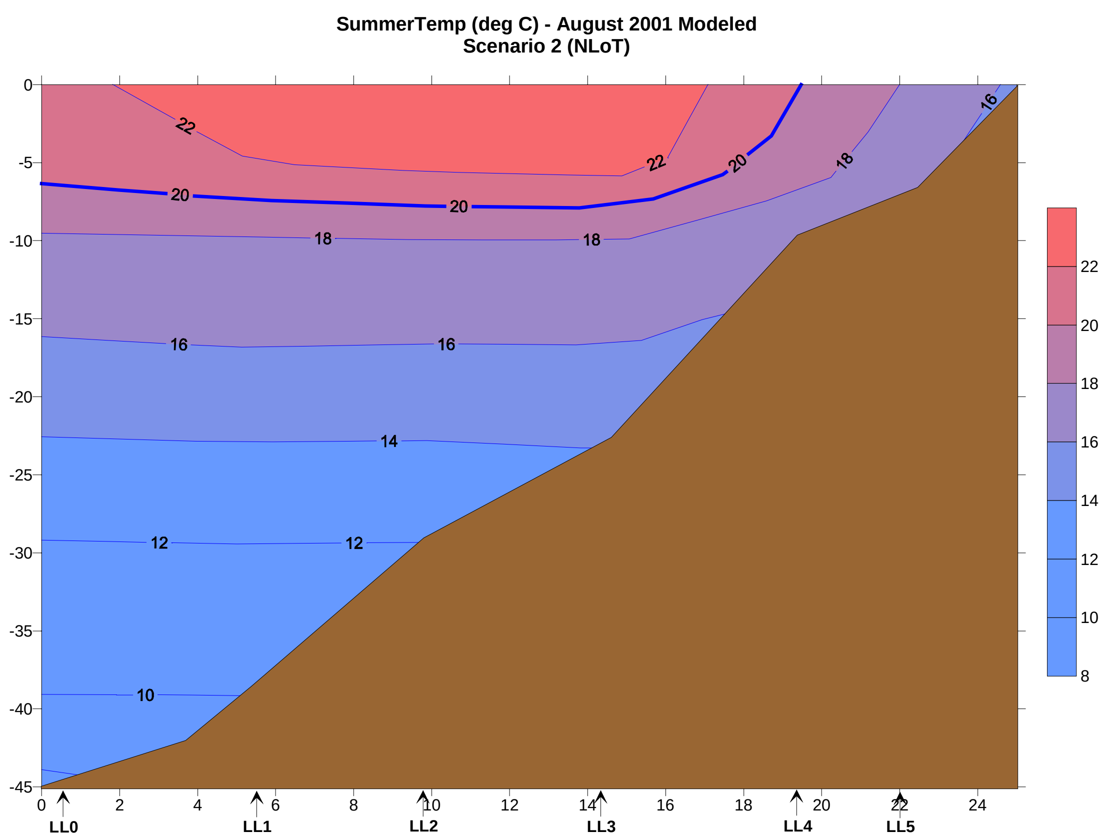

Figures 4-2a and 4-2b. Modeled Improvements in Long Lake Reservoir Temperature Concentrations from Baseline (Scenario 1; 4-2a) Compared with NLoT (Scenario 2; 4-2b).
NOTE: LLO through LL5 represent Ecology sampling stations.

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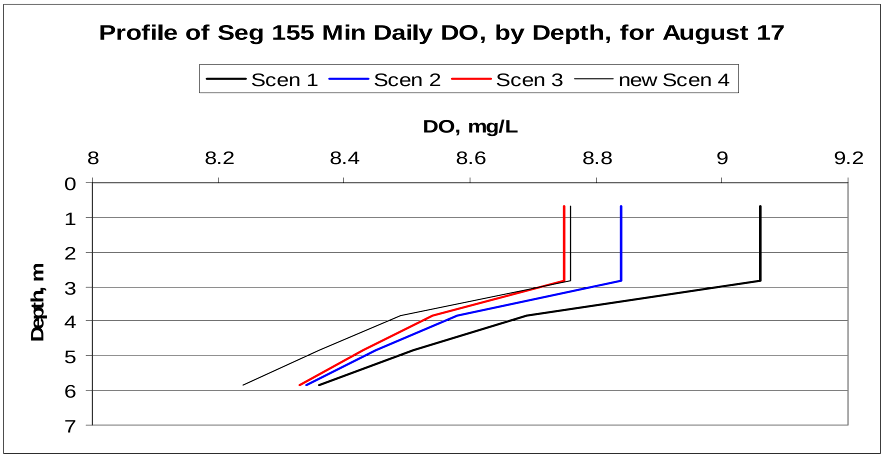

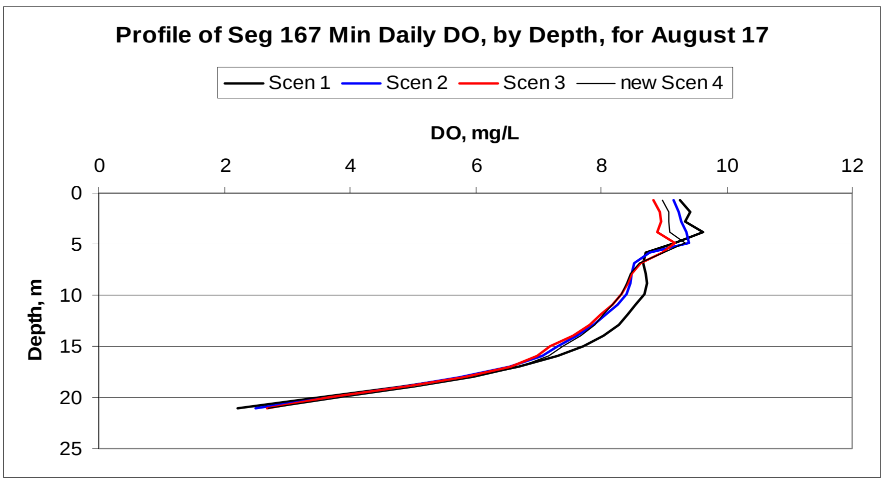

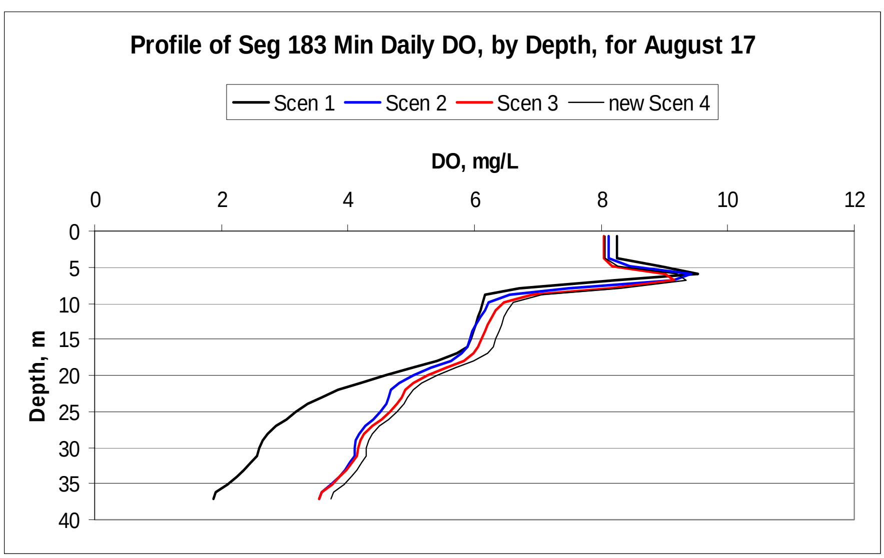

NOTE: Scen 1 is 2001 Baseline, Scen 2 is Next Level of Treatment (NLoT), Scen 3 is NLoT+25% NPS Reduction, and Scen 4 is PS = 0 Concentration (point source flow included, concentrations set to zero).

Figures 4-3a, 4-3b, and 4-3c. Long Lake Reservoir DO Profiles for Model Segment 155 (4-3a), Segment 167 (4-3b), and Segment 183 (4-3c)

NOTE: Model output represents instantaneous values for mid-day for August 17, 2001.

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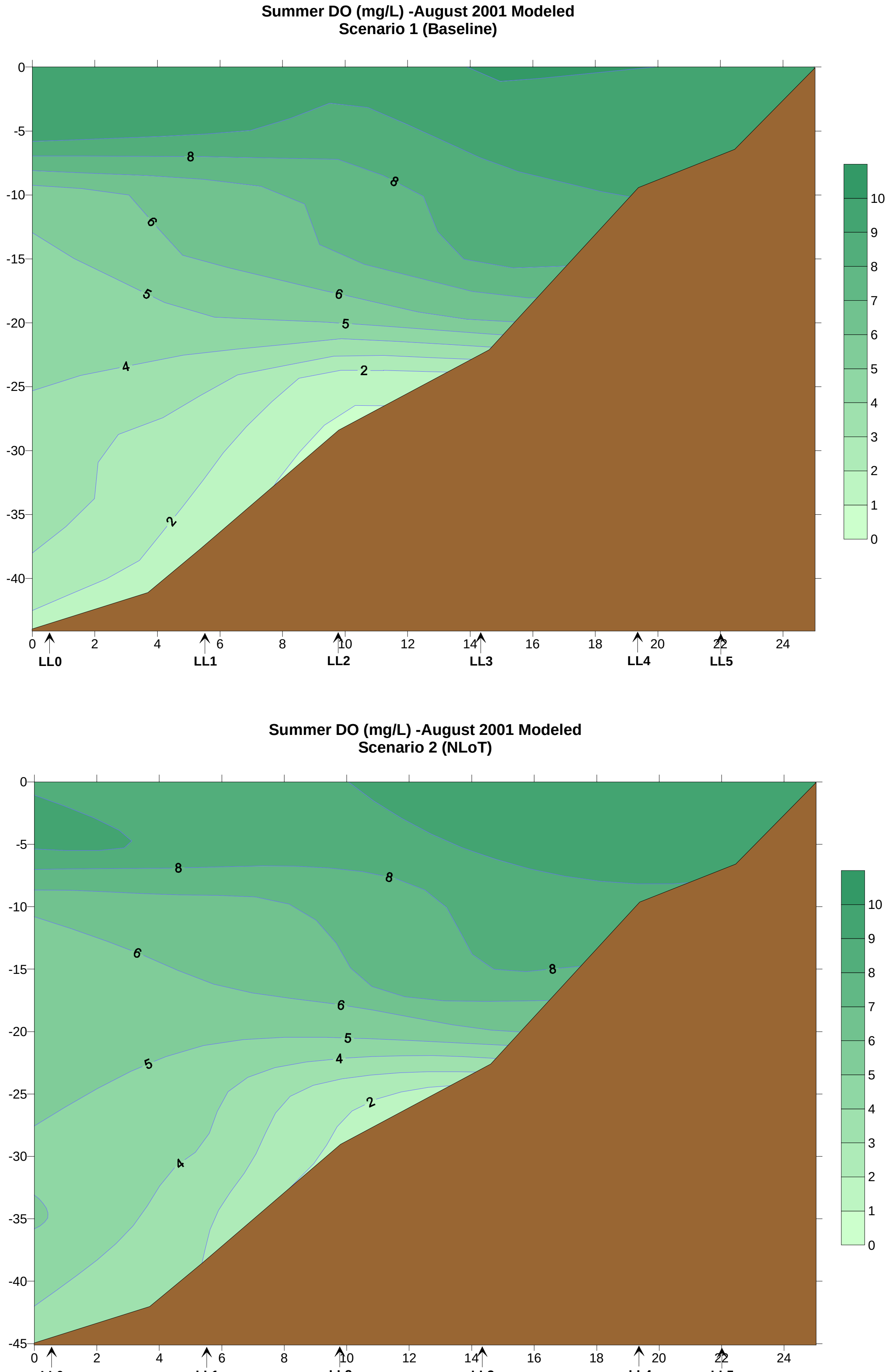

Figures 4-4a and 4-4b. Modeled Improvements in DO Concentrations from Baseline (Scenario 1; 4-4a) Compared with NLoT (Scenario 2; 4-4b).

NOTE: LLO through LL5 represent Ecology sampling stations.

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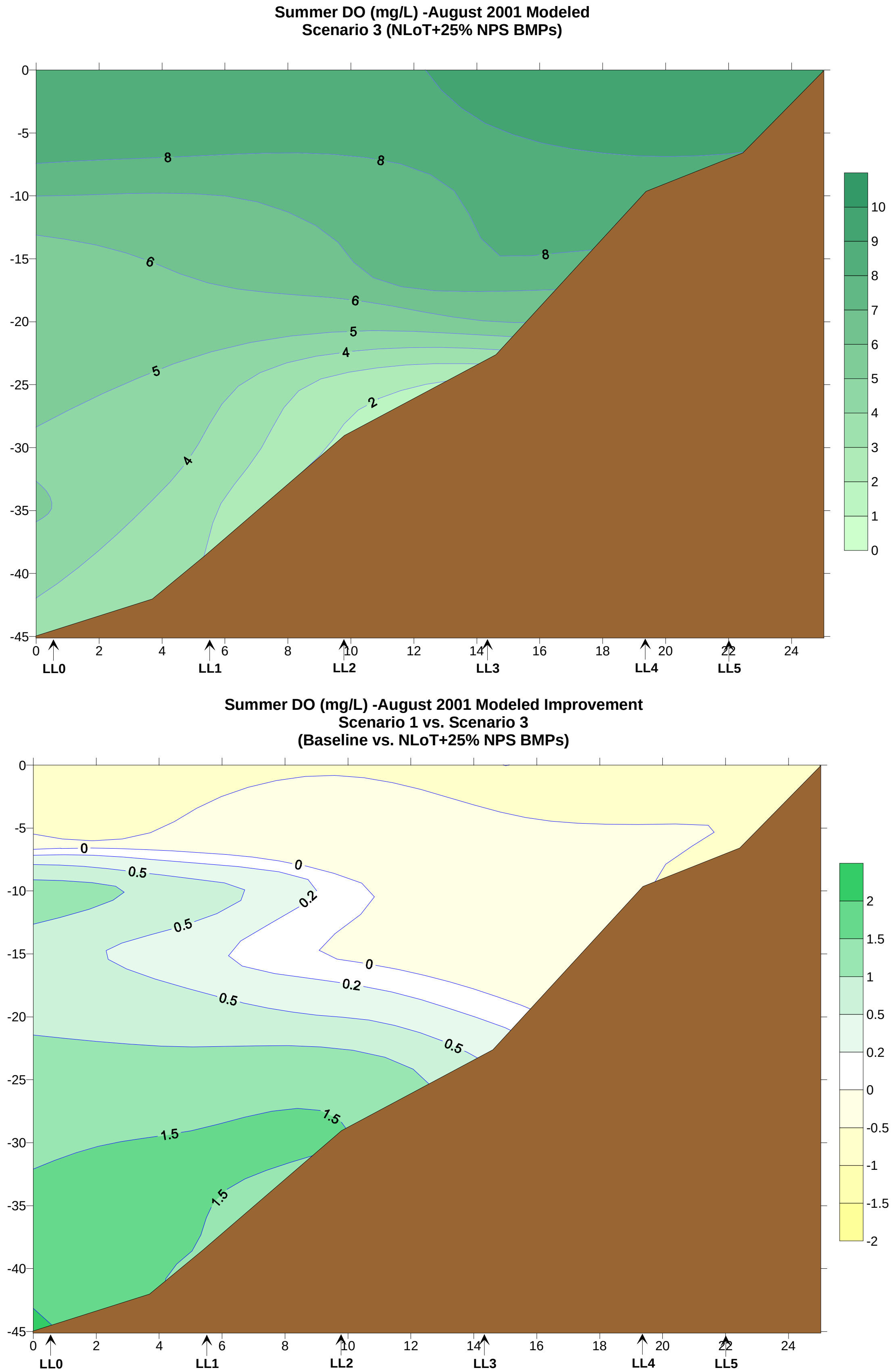

Figures 4-4c and 4-4d. Modeled Improvements in DO Concentrations Compared with Control of Nonpoint Sources (Scenario 3; 4-4c) and Marginal Improvements (4-4d).
NOTE: LLO through LL5 represent Ecology sampling stations.

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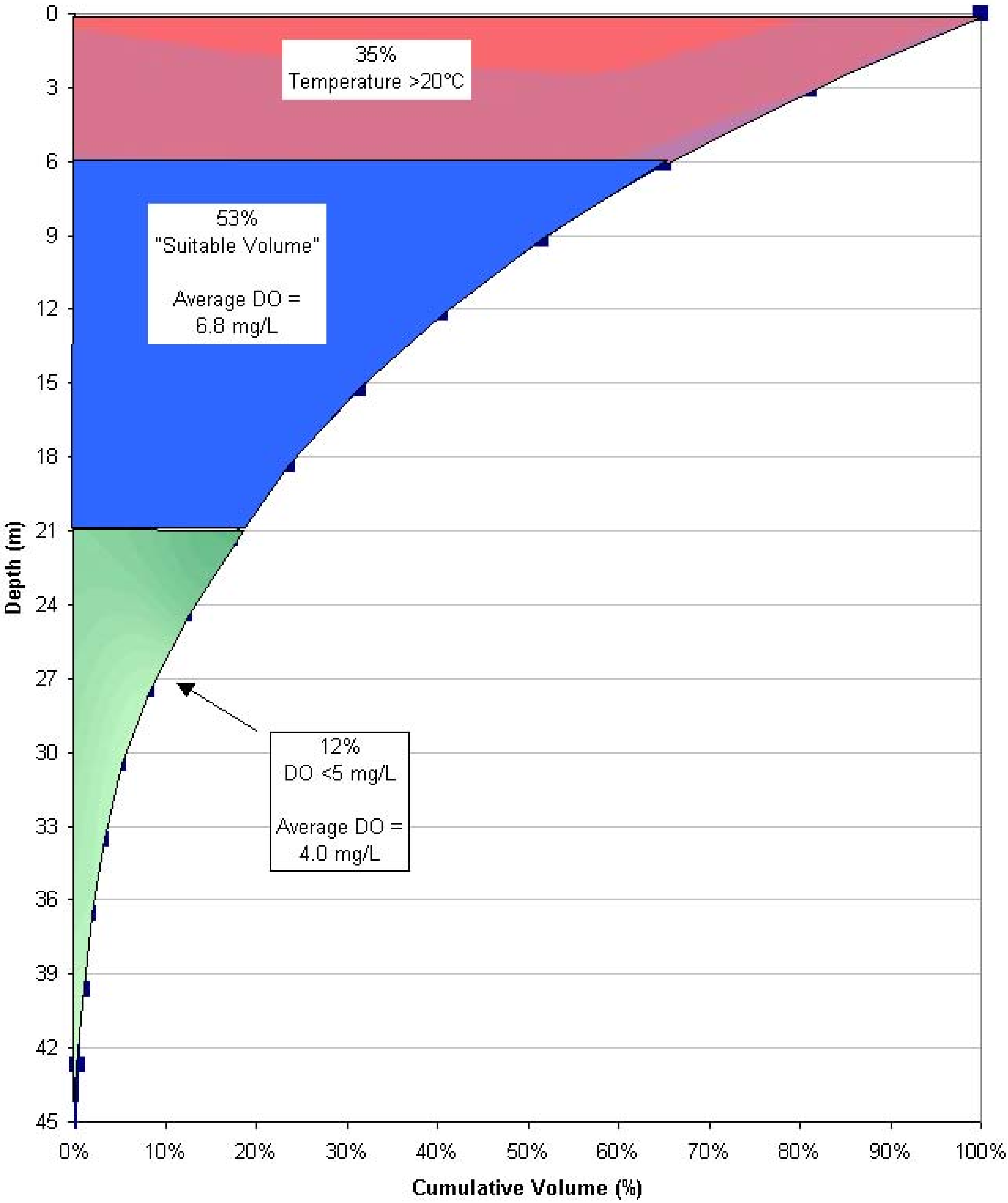

Figure 4-5. Summary of “Suitable Volume” During August as Compared to Overall Long Lake Reservoir Volume Under NLoT+25% NPS BMPs (Scenario 3).

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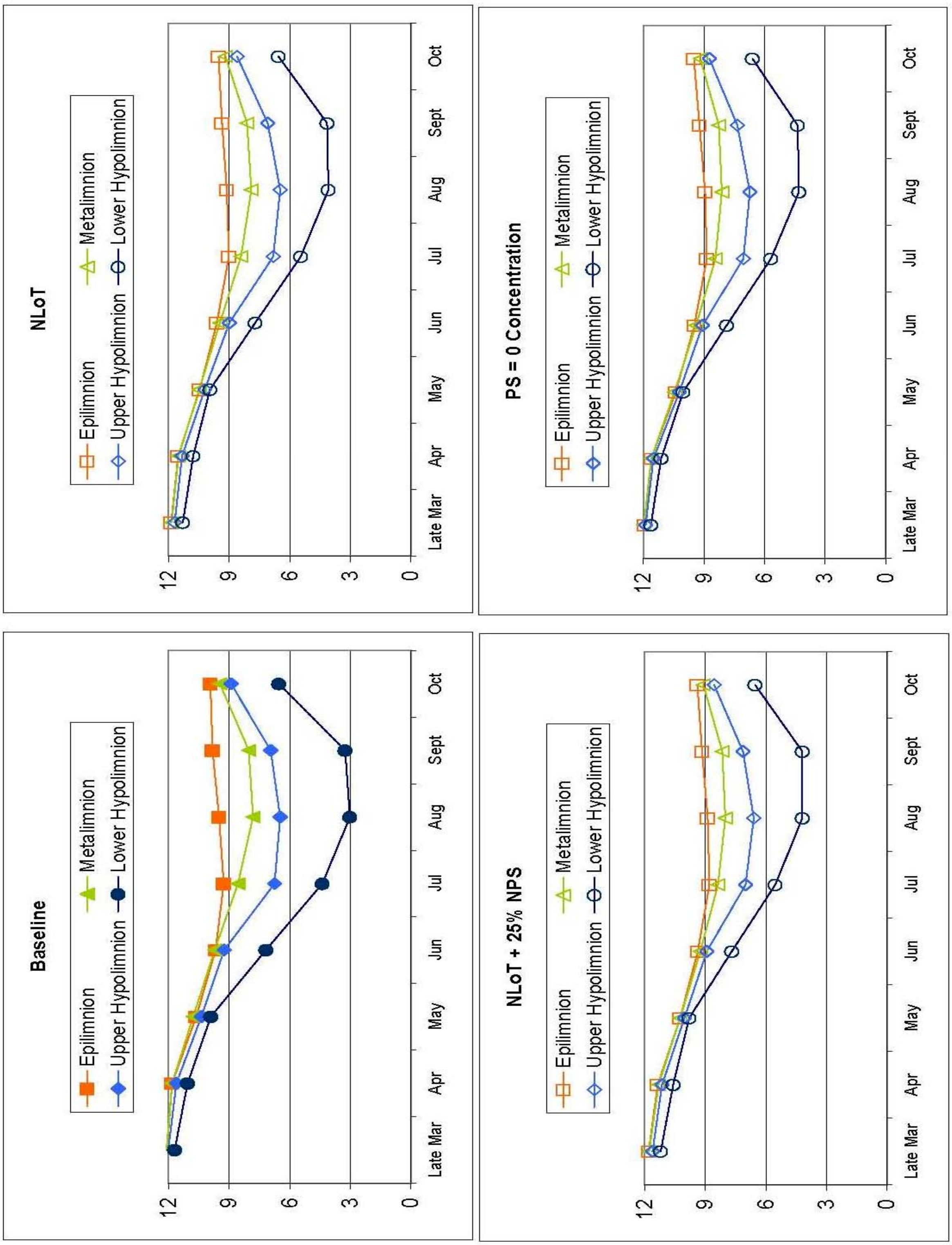

Figure 4-6. Weighted Average DO by Month for Each Reservoir Layer by Model Scenario.

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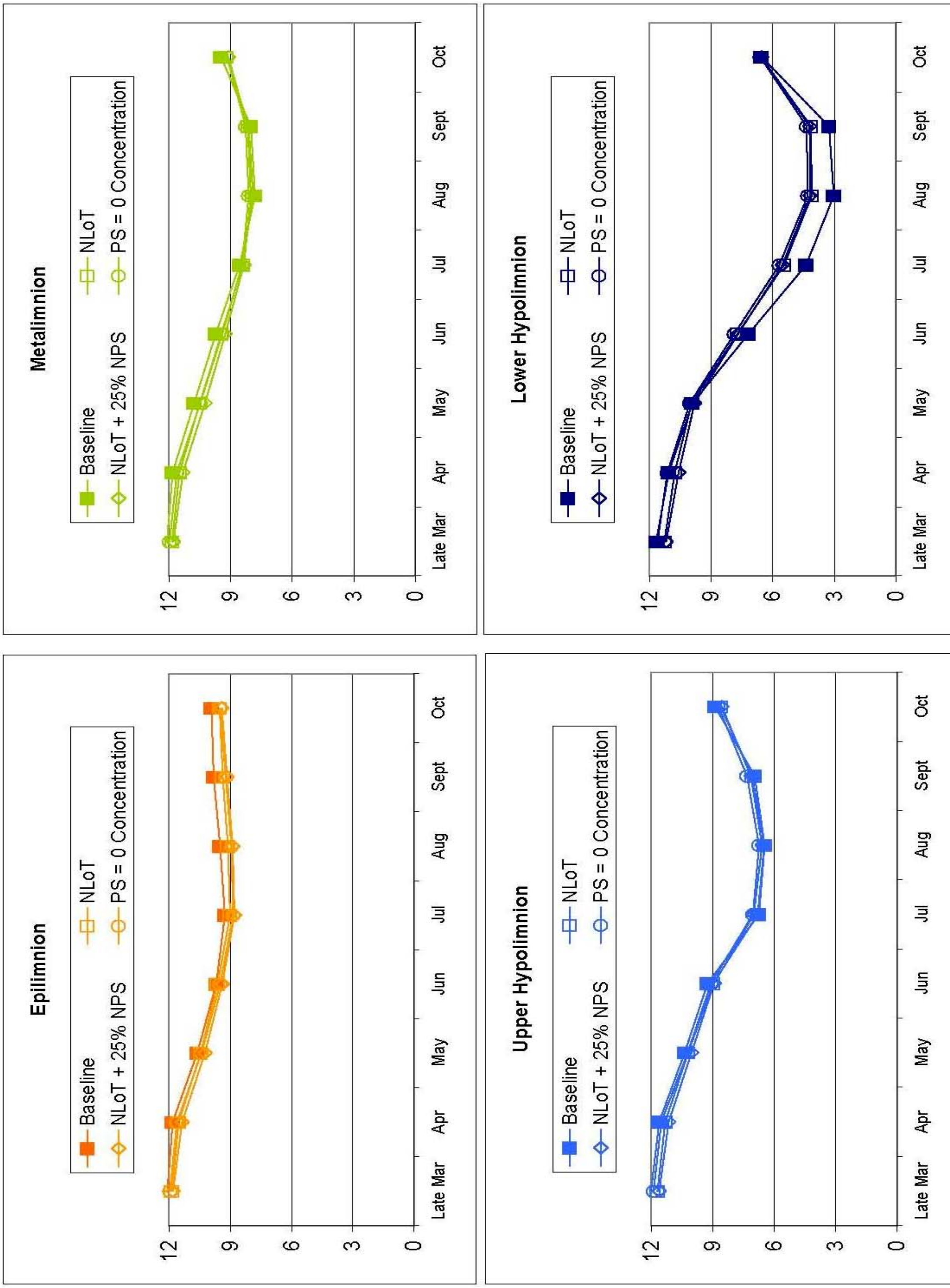

Figure 4-7. Weighted Average DO by Month for Each Model Scenario by Reservoir Layer.

5. Recommendations

To develop recommendations for spatial and temporal resolution of DO criteria to protect varied uses, five principal considerations were taken into account in this analysis:

- Habitat used in common by sets of species and during particular life stages should be delineated as separate designated uses
- Natural variations should be accounted for by the designated uses
- Seasonal use of different habitats should be factored into the designated uses
- The criteria should be tailored to support each designated use
- The refined uses should support the Clean Water Act and state goals for uses existing since 1975 and attainable uses.

These goals are the same as those established within the Chesapeake Bay program (EPA, 2003b).

The recommended criteria detailed below rely on the traditional expression of DO as a 1-Day absolute minimum value (which is consistent with current Ecology standards), as well as the accompanying 30-DADMin DO values during spawning and summer rearing periods. This combination helps to ensure that low DO levels in both the short term and the long term do not cause unacceptable harm to target species.

A common concern for resource managers is whether 30-DADMin DO values could still be met, even if 1-day minimum DO values are exceeded. For example, if a number of low-DO-level days were associated with diurnal swings that caused DO levels to drop below 6.0 mg/L, would it still be possible to meet a longer-term (monthly) 30-DADMin DO target of 8.0 mg/L? In the case of the Spokane River, this is not expected to occur. This is because the constraints on DO are relatively consistent over the summer period (that is, elevated summer water temperatures; steady municipal and industrial discharges; and diffuse nonpoint source discharges, such as storm water).

Diurnal DO monitoring results collected in 2001 (Ecology 2004a; 2004c) are shown in Figure 4-1. Although data are only available for a maximum of 12 days, DO levels trend downward and upward in a smooth fashion. Modeling results using 2001 as a baseline extend these observations (Ecology, 2004a). LTI modeling results confirm that 30-DADMin DO values under current conditions hover between 7.0 and 9.0 mg/L during the summer period (Figures D1-4-24 through D1-4-39). Simultaneously, 1-day minimum DO values range between 6.0 and 8.0 mg/L, with very few sharp increases or decreases on a day-to-day basis.

The implementation of both the 1-day minimum and 30-DADMin DO criteria will be dependent upon the availability of monitoring technology to conduct continuous modeling of DO. There has been extensive application of continuous DO monitoring throughout the U.S., including Oregon and Idaho. As with any such devices, the instrumentation must be properly installed, calibrated, and maintained. The USGS has established reliable procedures and is collecting defensible data (e.g., Tualatin River in Oregon). In addition, the CE-QUAL-W2 model that has been used throughout the northwest for DO TMDLs, including the Spokane system, produces continuous output data that can be directly compared to average-based criteria (again, see EPA-approved Tualatin River TMDL [Rounds and Wood, 2001]). Thus, a combination of monitoring and modeling may provide a reasonable approach for compliance evaluations. This is consistent with the implementation plans for the Chesapeake Bay.

5.1 Spokane River (RM 96 to RM 58)

This UAA report recommends water quality standards changes only for the State of Washington. This is primarily because Ecology's Draft TMDL is focused on DO conditions in Long Lake Reservoir. As noted in Sections 3 and 4, and 5.3 below, the river reach in Washington is expected to meet current and proposed DO criteria. Thus, phosphorus sources in both Idaho and Washington will be most affected by the standards governing Long Lake Reservoir.

The uses identified in Ecology's surface water quality standards do not accurately describe the existing and attainable uses in the Spokane River. Therefore, a new subcategory of use, referred to as "Spokane River Cold- and Cool-Water Mixed Fishery," should be established in Washington's surface water quality standards. This subcategory provides for:

- The protection of indigenous and non-indigenous cold- and cool-water fish species and other associated aquatic life
- Limited spawning, rearing, and migration of rainbow trout
- A more site-specific temporal application of biologically based criteria

To protect downstream uses, this subcategory should be applied to the entire reach of the Spokane River (RM 96 to RM 58), even though only the free-flowing reaches between the reservoirs currently support salmonid spawning. Including this new subcategory of use in the Washington surface water quality standards would not interfere with downstream uses and criteria because biologically based criteria are also being proposed for the downstream reach that includes Long Lake Reservoir.

Ecology's Draft UAA guidance (2004b) states that new subcategories of use may be appropriate in some circumstances. This approach is consistent with the EPA Region 3 approach adopted for the Chesapeake Bay UAA (EPA, 2003b). Consistent with 40 CFR 131.10(g), the current designated use of Salmon and Trout Spawning, Non-core Rearing, and Migration is neither existing nor attainable for the following reasons:

- <u>*Dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use*</u>. Post Falls Dam, Upriver Dam, Upper Falls Dam, Monroe Street Dam, and Nine Mile Dam (all of which have been in place since well before November 28, 1975) have all dramatically reduced the historical spawning and rearing grounds for former salmon runs. These facilities physically separate important habitats (such as those used for spawning) and isolate rearing opportunities. Independent of how these HED facilities are operated, their mere presence eliminates the suitable distribution of habitats necessary to support salmonid migration, rearing, and spawning. Section 4.1 provides documentation for why it not feasible to remove the dams.

- *Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses*. The physical conditions of the multiple reservoirs do not support complete pathways for salmonid spawning and rearing life stages. Reservoirs cause the river's substrate to change from that found in free-flowing reaches. Complex pool-riffle-run habitat is replaced by more uniform channel geomorphology, even in run-of-river reservoirs. Sediments in reservoirs are fine-grained silts, sands, and clays that preclude redd deposition. Slower water velocities reduce the highly oxygenated flows required for salmonid spawning and rearing. Macroinvertebrate diversity is reduced compared to riffle and run areas, which hinders juvenile salmonid growth rates and reduces the overall food supply. Finally, although historical ambient temperatures in water released from Coeur d'Alene Lake into the free-flowing Spokane River were also relatively warm, the presence of additional reservoirs increases summer water temperatures due to increased residence times and solar radiation.

It is important to protect salmonid habitat. The proposed DO criteria for the riverine reach (RM 96 to RM 58) are tailored specifically to provide protection to important salmonid life stages that either exist or are attainable given the constraints identified above.

This reach alternates between both free-flowing cold- and cool-water stretches and cool- and warm-water pool/reservoir environments. The macroinvertebrate community reflects a cool- to warm-thermal regime, even though the reach contains a community of cool- and cold-water fishes that are tolerant of seasonally warm temperatures.

Because any criterion must protect downstream uses, this subcategory should be applied to the entire reach. In this framework, the free-flowing and lacustrine reaches can be treated as one unit because these water bodies are not considered lakes. (That is, in this Spokane River reach with run-of-river operations, mean hydraulic residence times are less than 1/2 day [Golder and HDR, 2004]. This is considerably shorter than the 15-day residence times defined for lakes in WAC 173-201A-020). In addition, should future HED operations marginally increase the amount of available salmonid habitat required for spawning, these uses would be covered by this geographic application.

Recommended uses and DO criteria for the Spokane River vary depending on the timing when different life stages and activities need to be supported:

- Spawning and emergence
- Summer rearing
- Winter uses

This recommendation relies on a seasonal application of DO values that protects the most sensitive life stages of salmonids (notably, rainbow trout) when those life stages occur. Each use above is described in a sub-section below.

5.1.1 Spawning and Emergence

Ecology's (2002a) literature review and discussion paper for DO provides a comprehensive summary of existing literature and field studies for salmonids (as well as non-salmonids). Ecology concludes that "to fully protect developing salmonids, the average of the daily minimum oxygen concentrations in the water column should remain at or above 9.0-11.5 mg/L." This value is similar to the final value Ecology promulgated for spawning and core rearing (moderate- to high-density salmon and trout juvenile rearing during the period of maximum summer water temperatures). Many of the studies cited by Ecology to develop the new criteria rely on salmonid species not currently present in the Spokane River system (for example, coho and steelhead). However, these studies indicate that at a DO level of 9.0 mg/L, the size of hatched fry would be reduced by 8 percent from that observed at a DO level of 10.5 mg/L (Ecology, 2002a).

Avista studies have shown that the majority of rainbow trout spawn between the first and third weeks of April, when temperatures reach 4 to 5°C (for both the upper and lower spawning reaches). They have incubation periods of between 44 and 74 days (Avista, 2000a; Parametrix, 2003). The core spawning period is generally considered to be during April and May,[11] with limited fry emergence occurring in early June during years with cooler water temperatures (Parametrix, 2003). A combination of high flows and cooler water temperatures typically control a delay in emergence until early June. In these situations, cooler water temperatures are associated with higher DO values. (Data collected from Stateline [RM 96] between 1960 and 2001 demonstrate this relationship clearly; Ecology, 2004c.) Thus, DO levels during years associated with late emergence in June and with water temperatures near 13°C should be within the 10.5 to 11.0 mg/L range, even in June.

For the Spokane River, a 1-day minimum DO value of 9.5 mg/L and a 30-DADMin DO value of 11.0 mg/L should be applied between April and May. This 1-day minimum DO value is more protective than the lowest concentration (9.0 mg/L) that has "no appreciable impact (less than 1 percent) on survival, creates no detectable avoidance (stress) reaction in alevin, is found to support healthy incubation in both field and laboratory research, and only has a minor (8 percent) expected impact on potential size at hatching" (Ecology, 2002a). The 30-DADMin DO target of 11.0 mg/L is higher than Ecology's 10.5 mg/L DO level (2002a) associated with the highest probability of protection (which also corresponds to a single incubation period of approximately 45 days).

5.1.2 Summer Rearing

Growth effects in juvenile salmonids are the primary drivers for rearing targets. Recognizing that fish rely on the summer growth period to sustain them through winter, this life stage is as important as spawning. Lab studies conducted on rainbow trout determined that the critical level of DO for food consumption ranged between 6.0 and 7.0 mg/L, depending on the feeding regime (Pedersen, 1987, cited in Ecology, 2002a). Field studies conducted on rainbow trout fingerlings found that growth rates at 7.9 mg/L DO levels were comparable to average DO control values for fingerlings of 12.3 mg/L. Growth rates of fingerlings were only slightly depressed at average DO control values of 6.3 mg/L

[11] Although specific dates and standardized times are not necessarily reliable predictors of fry emergence (Parametrix, 2003), a simple analysis indicates that an average incubation period of 59 days after April 1st roughly corresponds to incubation occurring in late May.

(Young, 1987, cited in Ecology, 2002a). Hatchery water reuse tests found that fish length was significantly reduced when DO was less than 5.0 mg/L (Larmoyeaux and Piper, 1973, cited in Ecology, 2002a). Based on studies for a number of salmonid species, Ecology (2002a) concluded that growth rates in juveniles are essentially indistinguishable from control groups at DO concentrations above 8.0 mg/L over periods of 20 days or more.

Juvenile growth studies conducted on white sturgeon found that growth rates were reduced at a median DO concentration of approximately 4.0 mg/L (Carlson, Mitchell, and Wragg, 1984, cited in Ecology, 2002a).

Macroinvertebrate studies have concluded that mayflies and damselflies (associated with mid- to upper-elevation streams) do not suffer short-term mortality at DO levels of 6.5 to 6.8 mg/L (Jacob, Walther, and Klenke, 1984, cited in Ecology, 2002a). Long-term (monthly or seasonal) mortality to macroinvertebrates is expected at DO levels below 6.5 to 7.1 mg/L in mid-elevation streams (EPA, 1973, cited in Ecology, 2002a). Ecology translated these laboratory values into field conditions that maintain DO levels above 6.0 mg/L. Ecology recommends that DO concentrations above 5.5 to 6.0 mg/L be maintained to protect sensitive macroinvertebrate species in lower elevation streams.

For the Spokane River, a 1-day minimum DO value of 6.0 mg/L and a 30-DADMin DO value of 8.0 mg/L should be applied between June and September. This combination of criteria is aimed at ensuring that no single month of severely depressed DO levels will cause harm to developing juveniles. Although rearing of rainbow trout occurs on an annual basis, it is recommended that the period to which the criteria should apply would end in September so that higher winter DO criteria (See Section 5.1.3) help support spring spawning activities.

5.1.3 Winter Uses

For all other life stages and uses for the Spokane River, a 1-day minimum DO value of 8.0 mg/L should be applied between October and March. (No 30-DADMin DO criterion has been developed for this period because it is not anticipated that low DO levels would occur.) This recommended criterion is designed to ensure that DO levels during the winter are high enough to protect continued rearing activities, overwintering, and spring spawning activities.

5.1.4 Riverine Recommended Subcategory and Criteria Summary

Table 5-1 provides a summary of recommended DO criteria for the riverine reach (RM 96 to RM 58).

TABLE 5-1
Spokane River Cold- and Cool-Water Mixed Fishery (RM 96 to RM 58): Summary of Recommended DO Criteria

Geographic Area	April to May	June to September	October to March
Entire River			
1-Day Minimum Value	9.5 mg/L	6.0 mg/L	8.0 mg/L
30-DADMin Value	11.0 mg/L	8.0 mg/L	- -

DADMin = day average of the daily minimum

5.2 Long Lake Reservoir (RM 58 to RM 34)

The uses identified in Washington's surface water quality standards (see Section 2.2.2) do not accurately describe the existing and attainable uses in Long Lake Reservoir. Therefore, a new subcategory of use, referred to as "Long Lake Reservoir Mixed Fishery," should be established in Washington's surface water quality standards. This subcategory provides for:

- The protection of indigenous and non-indigenous fish species and other associated aquatic life
- Trout rearing, which exists within this reach
- A more site-specific temporal and geographic application of biologically based criteria

This subcategory relies on a seasonal and reservoir zone application of DO criteria, which protects the most sensitive life stages of salmonids (notably, rainbow trout) when and where those life stages occur.

Establishing subcategories of uses that are defined geographically and/or spatially and seasonally is consistent with recently issued use refinements promulgated by EPA Region 3 in Chesapeake Bay. In the Chesapeake Bay UAA (EPA, 2003b), new refined subcategories of uses (migratory fish spawning and nursery, open-water fish and shellfish, deep-water seasonal fish and shellfish, and deep-channel seasonal refuge) were adopted. These subcategories replaced broad aquatic life designated uses. The new subcategories of uses were derived to address spatially and seasonally distinctive habitats and aquatic communities with widely varying DO requirements.

Consistent with 40 CFR 131.10(g), the current designated use of Salmon and Trout Spawning, Core Rearing, and Migration is neither existing nor attainable in Long Lake Reservoir for the following reasons:

- *Dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use.* The completion of Long Lake Dam in 1915 eliminated the historical spawning and rearing grounds for former salmon runs in this reach. Independent of how this HED facility is operated, its mere presence minimizes the suitable distribution of habitat necessary to support extraordinary salmonid migration, rearing, spawning, and harvesting conditions (such as those found in relatively pristine headwater streams). Section 4.1 provides details on why it is not feasible to remove the dam.

In addition, benthic sediments in Long Lake Reservoir have accumulated 89 years of upstream nutrient inputs. Even if SOD levels typical of oligotrophic conditions were possible (which is highly unlikely given this long period of enrichment), the reservoir would still stratify. It is not predicted that the DO values in the lowest level (hypolimnion) of Long Lake Reservoir would increase above 5.0 to 6.0 mg/L (Ecology, 2004a; 2004d), a level that cannot support salmonid spawning.

- *Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses*. The natural physical conditions of Long Lake Reservoir (though not natural in itself) do not support salmonid spawning and rearing throughout this reach. Reservoirs cause the river's substrate to change from that found in free-flowing reaches. Complex pool-riffle-run habitat is replaced by more uniform channel geomorphology. Sediments in reservoirs are fine-grained silts, sands, and clays that preclude redd deposition. Slower water velocities reduce the highly oxygenated flows required for salmonid spawning and rearing. Macroinvertebrate diversity is reduced compared to riffle and run areas, which hinders juvenile salmonid growth rates and reduces the overall food supply. Finally, the presence of Long Lake Reservoir increases summer water temperatures due to increased residence times and solar radiation.

It is important to protect salmonid habitat. The proposed DO criteria for the reservoir reach (RM 58 to RM 34) are tailored specifically to provide protection to important salmonid life stages that either exist or are attainable given the constraints identified above.

Similar to the Chesapeake Bay system, recommended uses and DO criteria for Long Lake Reservoir vary depending on the location in the reservoir where different life stages and activities need to be supported (refer to Figure 3-7):

- **Cold-water species summer rearing**. Rainbow and brown trout rearing and migration in the riverine and transition reaches and in the epilimnion and metalimnion in the lacustrine reach.
- **Brown trout spawning**. Potential brown trout spawning between Nine Mile Dam and the Little Spokane River (mid-September to November).
- **Cool- and warm-water species spawning, summer rearing, and migration.** Cool- and warm-water fish spawning, summer rearing, and migration in the riverine and transition reaches.
- **Cold-water species summer foraging**. Limited tolerance cold-water species foraging below the euphotic zone. This use includes the protection of benthic organisms.
- **Winter uses**. To ensure that DO levels during the winter are high enough to protect continued rearing activities, overwintering, and spring spawning activities.

The spatial extent of specific zones varies annually depending on runoff conditions. In addition, the boundaries of these zones may change as water quality continues to improve. To ensure that attainable uses are protected following point and nonpoint source controls, these zones are specified qualitatively as follows:

- **Euphotic zone.** Depth to which photosynthesis and primary production occurs[12]
- **Epilimnion.** Surface zone above the thermocline[13]
- **Metalimnion.** Transition zone that contains the thermocline
- **Hypolimnion.** Deeper zone below the thermocline

Qualitative definitions of zones are consistent with other systems such as the Chesapeake Bay (EPA, 2003b).

5.2.1 Cold-water Species Summer Rearing

Rainbow and brown trout rearing occurs in the riverine and transition reaches of Long Lake Reservoir and in the epilimnion and metalimnion in the lacustrine reach (Figure 5-1a). Although the number of cold-water species is limited compared to cool- and warm-water species (Figure 3-14), protection of cold-water rearing is certainly warranted.

The recommended criteria recognize that trout rear and migrate through the metalimnion during limited periods.

Similar to cold-water rearing requirements in the riverine section (Section 5.1.2), ***for Long Lake Reservoir (riverine, transitional, lacustrine-epilimnion, lacustrine-metalimnion), a 1-day minimum DO value of 6.0 mg/L and a 30-DADMin DO value of 8.0 mg/L should be applied between July and September***.

Although rearing of wild rainbow trout occurs on an annual basis, the period to which the recommended criteria apply is recommended to end in September. The higher winter DO criteria would then be in place to protect the potential for fall-spawning and to help support spring-spawning activities, particularly near the Little Spokane River confluence.

5.2.2 Brown Trout Spawning

The upper riverine reach of the reservoir (Nine Mile Dam tailrace) provides suitable habitat where brown trout may spawn (Table 3-7). Similar to other trout species, brown trout require gravels in well-oxygenated waters, but are relatively more tolerant of pollution and turbidity (see Tables 3-6 and 3-7). Brown trout are a non-native species in this system that spawn between mid- to late-September and November (Donley, 2004, pers. comm.). To protect potential brown trout spawning activities, ***for Long Lake Reservoir (riverine), a 1-day minimum DO value of 8.0 mg/L should be applied between mid-September and November*** (Figure 5-1b).

The dominant spawning areas coincide with areas already protected by winter uses. Therefore, the recommended winter DO reservoir criterion (***1-day minimum DO value of 8.0 mg/L applied between October and June***; see Section 5.2.5) provides protection for brown trout fall spawning. To protect early spawners, the recommended winter DO reservoir criterion should also be applied within the riverine reach from mid-September (September 15) through the end of September (September 30).

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12 Available Secchi depth measurements suggest that the euphotic zone in Long Lake Reservoir currently extends to about 5 to 6 meters.

13 As noted previously, the thermocline is a layer of water in which temperature declines rapidly with depth, typically defined as -1°C per meter of depth).

5.2.3 Cool- and Warm-water Species Spawning and Summer Rearing

Spawning

Non-salmonids typically require lower DO levels than salmonids for protection of critical life stages (Ecology, 2002a). Incubation survival rates for these species (including smallmouth bass and northern pike) remained similar to control groups at concentrations above 6.5 to 7.0 mg/L. Survival rates were only slightly depressed at DO levels of 5.5 to 6.0 mg/L.

Nearly all of the cool- and warm-water species observed in Long Lake Reservoir spawn in the spring in the nearshore littoral zones that provide adequate protection from predators and suitable substrate (gravels, submerged vegetation; Table 3-7). A small number of cool- and warm-water species potentially do not complete their spawning cycle by late spring (including smallmouth bass, northern pikeminnow, tench, chiselmouth, and carp; Table 3-7).

For Long Lake Reservoir (riverine, transition, lacustrine-epilimnion, lacustrine-metalimnion), a 1-day minimum DO value of 6.0 mg/L and a 30-DADMin DO value of 7.0 mg/L should be applied between March and June (Figure 5-1c).

The dominant spawning areas coincide with areas already protected by cold-water rearing uses (riverine and transitional reaches and the epilimnion/metalimnion within the lacustrine zone). Therefore, the recommended winter DO reservoir criterion (***1-day minimum DO value of 8.0 mg/L applied between October and June***; see Section 5.2.5) provides protection for non-salmonid spring and early summer spawning.

Summer Rearing

Ecology (2002a) recommends that full support for juvenile growth of non-salmonid species is expected when average DO concentrations remain above 7.0 to 8.0 mg/L, with daily minimum values of 5.0 to 6.0 mg/L to avoid short-term harm. ***For Long Lake Reservoir (riverine, transition, lacustrine-epilimnion, lacustrine-metalimnion), a 1-day minimum DO value of 6.0 mg/L and a 30-DADMin DO value of 7.0 mg/L should be available between July and September*** (Figure 5-1c).

The dominant rearing areas coincide with areas already protected by cold-water rearing uses (riverine and transitional reaches, and the epilimnion/metalimnion within the lacustrine zone). Recommended summer DO reservoir criterion for cold-water rearing (***1-day minimum DO value of 6.0 mg/L and a 30-DADMin DO value of 8.0 mg/L applied between July and September***; see Section 5.2.1) provides protection for non-salmonid summer rearing.

5.2.4 Cold-water Species Summer Foraging

Upper Hypolimnion

A limited number of cold- and cool-water species in the reservoir forage into cooler, deeper waters during periods of warmer surface temperatures (Figure 5-1d). For these short-duration exposures, DO levels should not be a barrier to migration nor should they be lethal.

Avoidance behavior in rainbow trout in a large reservoir has been observed at DO concentrations less than 5.0 mg/L (Hampton and Ney, 1993, cited in Ecology, 2002a). This is consistent with other studies showing that fish typically avoid DO concentrations below 5.0 mg/L (Matthews and Berg, 1997, cited in Ecology, 2002a). Matthews and Berg (1997, cited in Ecology, 2002a) noted a population of rainbow trout congregating in a refugia pool fed by cooler groundwater that provided relief from overlying water temperatures of greater than 27°C. DO levels in this pool ranged between less than 1.0 mg/L and 5.0 mg/L over a 24-hour period. This study suggests that rainbow trout preferentially find cooler water, even under low DO conditions. However, maximum temperatures in Long Lake Reservoir are well below these levels. Thus, refugia from extreme temperatures is not expected to be an issue for Long Lake Reservoir.

Acute lethality for salmonids appears to be prevented at mean DO concentrations of 4.0 to 4.5 mg/L (Ecology, 2002a). These are similar to DO levels that are believed to prevent lethal effects to non-salmonids (3.5 to 4.6 mg/L; Ecology, 2002a).

For Long Lake Reservoir (lacustrine-upper hypolimnion), a 1-day minimum DO value of 5.0 mg/L should be applied between July and September (Figure 5-1d).

As described in Section 3.3.3, a "suitable volume" of water (temperatures less than 20°C and DO greater than 5.0 mg/L) is on the order of 159 million cubic meters (129,000 acre-feet). This "suitable volume" includes the upper hypolimnion (Figure 3-13). Osborne et al. (2003) calculated rough estimates of 49,000 fish (including approximately 250 kokanee) for the reservoir as a whole (Figure 3-15). Even if every one of these fish ventured into open water to seek cooler water (a conservative assumption given well-documented preferences of the majority of fish for the protection and food sources provided by littoral habitats; Table 3-7), approximately 3,250 cubic meters within this "suitable volume" are available for each one of these fish during August (roughly 2.6 acre-feet per fish).

In addition, 100,000 hatchery rainbow trout may be added to the system each spring. Conservatively assuming that all of these fish survived to August, nearly 1,600 cubic meters within the "suitable volume" are available for each stocked rainbow trout (that is, roughly 1.3 acre-feet per rainbow trout). *Thus, it appears unlikely that fish would need to rely on, or even preferentially seek, the deeper, cooler water below the upper hypolimnion that is hypoxic.*

Lower Hypolimnion

The protection of fish that forage deeper into, and benthic organisms that rely on, the lower hypolimnion is a management issue in any reservoir system that stratifies. Monitoring data indicate that DO levels in the hypoxic volume (less than 5.0 mg/L) of the lower hypolimnion averages 2.8 mg/L in August (Figure 3-13). This average is above the acute (short-term, between 1 and 4 hours) levels of DO (1.5 to 2.5 mg/L) that have been found to be lethal to trout (rainbow, brown, and brook). However, this average is below the DO level recommended by Ecology to avoid any lethality (3.5 to 4.6 mg/L for short-term and long-term exposure; Ecology, 2002a). However, modeling estimates are that the Next Level of Treatment proposed in this UAA would provide an average of 4.0 mg/L in the lower hypolimnion. This would avoid lethal conditions. A DO goal for the lower hypolimnion is discussed later in this sub-section.

Appropriate treatment of an oxygen-deficient hypolimnion has been addressed in a number of ways throughout the country. Two case studies and alternative approaches are presented below.

- **Brownlee Reservoir.** The SR-HC TMDL, which included Brownlee Reservoir (IDEQ and ODEQ, 2004), and was approved by EPA Region 10 in September 2004, made the following conclusions regarding treatment of hypolimnion DO concentrations:

  "Dissolved oxygen concentrations in Brownlee Reservoir need to increase substantially (by more than 4 mg/L in some conditions), in order to meet the SR-HC TMDL target of 6.5 mg/L for support of salmonid rearing/cold water aquatic life. Brownlee Reservoir is a narrow, deep channel with a relatively short retention time. The deep sections of the reservoir, below the thermocline, are well below the photic zone and provide little growth potential. These deep layers (the hypolimnion) are relatively stagnant during stratification and experience little if any circulation or recharge during the summer months…

  "Both the metalimnion and the epilimnion offer greater potential for habitat than the hypolimnion. The middle layers of the reservoir (the metalimnion and the epilimnion below the immediate surface layers) provide adequate temperature conditions throughout much of the summer. During late summer and early fall, cold water tributaries provide refugia for cold-water species living in the reservoir. These upper layers (the upper column of the metalimnion and the lower volume of the epilimnion) represent the portion of the reservoir most likely to support aquatic populations. Improvements in dissolved oxygen in these areas will therefore provide greater, more immediate benefits to aquatic life within the reservoir. These areas have been targeted directly as high priorities for improvements in dissolved oxygen. Areas of the hypolimnion known to experience low dissolved oxygen … are located well below the photic zone of the reservoir, [thus] these deep waters represent less of a viable habitat than do the waters above the hypolimnion. Because of this, they have been targeted as a secondary priority for dissolved oxygen improvement…

  "For this reason, the hypolimnetic waters will take longer to meet water quality standards. Sustained reductions over time have been shown to have a positive effect on hypolimnetic waters in other systems and have been projected to occur in Brownlee Reservoir through modeling, but time frames are lengthy, extending many years in some cases....

  "In an overall assessment of the immediate benefits, it is obvious that improvements projected to occur in hypolimnetic waters will act to better support designated uses. The dissolved oxygen concentrations, without application of the 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets, consistently drop to lethal concentrations, well below 3 mg/L. In all cases with application of the total phosphorus target the dissolved oxygen concentration stayed near or above 3 mg/L.

  "… Dissolved oxygen improvements are realized in all sections of the reservoir from application of the 0.07 mg/L total phosphorus target… In those sections and times when dissolved oxygen concentrations are currently very low in Brownlee Reservoir (the metalimnion and hypolimnion in July and August) substantial improvements in dissolved oxygen are realized through the attainment of water quality targets upstream, although the dissolved oxygen target is not attained.

"In order to meet water quality targets in Brownlee Reservoir, further implementation of additional mechanisms will have to be employed (in addition to the 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets already in place). This difference in assimilative capacity is assumed to be due to the transition from a riverine to a reservoir system. Because this change is anthropogenic in nature, further augmentation of dissolved oxygen in the system will be the responsibility of the impoundments…

"It should be clarified that [upstream] pollutant sources are responsible for [their] water quality problems… [not] for those water quality problems that are exclusive to the reservoir and that would occur if the waters flowing into Brownlee Reservoir met water quality standards. Similarly, Idaho Power Company (as operator of the Hells Canyon Complex) is responsible for those water quality problems related exclusively to impoundment effects that would occur if inflowing water met water quality standards."

The SR-HC TMDL is consistent with Oregon's proposed rules recognizing that not all strata must meet temperature, DO, and pH surface water quality standards simultaneously (OAR 340-041-0061). Oregon has recognized that as long as one stratum provides protective conditions, the reservoir should not be considered impaired.

- **Winchester Lake.** The approach taken at Brownlee Reservoir is similar to how EPA Region 10 addressed severe hypoxia conditions in Winchester Lake (EPA, 1999). Winchester Lake reservoir routinely exhibited blue-green algal blooms. EPA concluded that the "combination of oxygen depletion and warm waters greatly reduces the volume of water in the lake that supports a cold water fishery to less than 16 percent of the total lake volume." The Winchester Lake TMDL sets nonpoint source load reductions and in-lake management techniques so that, in addition to increasing DO levels to meet criteria, a "sufficient volume of lake [can] meet both the dissolved oxygen and temperature criteria to support a cold water fishery" (EPA, 1999). Thus, EPA has previously developed and endorsed a volumetric analysis of reservoir conditions, recognizing that not all of a stratified water body must meet absolute criteria at all times.

The epilimnion, metalimnion, and upper hypolimnion should be the focus of continued water quality improvements. (Together these zones currently represent 83 percent of the reservoir volume during August, which is the most stressed period of the year. This month corresponds with the warmest water temperatures and lowest DO levels.

Simultaneously, ***for Long Lake Reservoir (lacustrine-lower hypolimnion), a narrative criterion that requires sources to maximize the "suitable volume" of layers that can meet the applicable criteria and support designated beneficial uses should be applied.*** (See

Figure 5-1d.)[14] This narrative criterion would be applicable to roughly 40 percent of the hypolimnion.

When adopting water quality criteria to protect designated uses, the criteria must be based on sound scientific rationale (40 CFR 131.11[a]). States may adopt numeric and/or narrative water quality criteria (See 33 USC 1344[a]). The federal water quality standards regulation states that water quality criteria "are elements of State water quality standards, expressed as constituent concentrations, levels or narrative statements . . . ." (40 CFR 131.3[b]). In establishing criteria, States may establish narrative criteria when numerical criteria cannot be established or to supplement numerical criteria (40 CFR 131.11[b][2]). Washington State's surface water quality standards currently contain narrative standards. See, for example, the "aesthetic values" criteria set forth in WAC 173-201A-200(b)(ii). The approach the Spokane River UAA has taken to establish the proposed narrative criterion is consistent with the regulatory requirements that require a scientific approach to setting criteria and that authorize the use of narrative criteria.

This narrative criterion will be implemented via the TMDL process because it requires that point and nonpoint sources continue to implement controls that minimize the volume of water with DO levels below 5.0 mg/L. Given that low DO values have been consistently observed since the 1970s, continued improvements to benthic conditions will ensure that existing uses within the lower hypolimnion will continue to be protected.

We also recommend that the narrative criterion include a goal to achieve a 1-day minimum daily DO of 4.0 mg/L in the lower hypolimnion on a spatially averaged basis. This goal would be protective of this use (see Figure 2-2 and the discussion above). A 30-DADMin DO value goal is not appropriate because fish that forage briefly into the deeper lower hypolimnion layer will not be exposed for long periods of time, while the benthic macroinvertebrate community consists of tolerant species. Although modeling suggests that this goal can be met with the NLoT, it is included as a narrative goal rather than a numeric criterion because of the substantial uncertainty and error associated with the model, in particular the lack of its capability to predict long-term changes in SOD in relation to treatment scenarios.

5.2.5 Winter Uses

Similar to the riverine reach, ***for Long Lake Reservoir (riverine, transitional, lacustrine-epilimnion, lacustrine-metalimnion, lacustrine-hypolimnion), a 1-day minimum DO value of 8.0 mg/L should be applied between October and March***. (No 30-DADMin DO targets have been developed for this period because it is not anticipated that low DO levels would occur.) This recommended criterion is designed to ensure that DO levels during the winter are high enough to protect continued rearing activities, overwintering, and spring spawning activities.

5.2.6 Reservoir Recommended Subcategory and Criteria Summary

Table 5-2 provides a summary of recommended DO criteria for the Long Lake Reservoir reach (RM 58 to RM 34). Figure 5-2 provides this same information graphically.

[14] Figure 5-1d is somewhat misleading because the vertical scale is exaggerated; Figure 3-13 is a more accurate representation of the relative volumes of the hypolimnion.

TABLE 5-2
Long Lake Reservoir Mixed Fishery (RM 58 to RM 34): Summary of Recommended DO Criteria

Geographic Area	July to September 14 [1]	October to June
Riverine		
1-Day Minimum Value	6.0 mg/L	8.0 mg/L
30-DADMin Value	8.0 mg/L	- -
Transitional		
1-Day Minimum Value	6.0 mg/L	8.0 mg/L
30-DADMin Value	8.0 mg/L	- -
Lacustrine – Epilimnion		
1-Day Minimum Value	6.0 mg/L	8.0 mg/L
30-DADMin Value	8.0 mg/L	- -
Lacustrine – Metalimnion		
1-Day Minimum Value	6.0 mg/L	8.0 mg/L
30-DADMin Value	8.0 mg/L	- -
Lacustrine – Hypolimnion (Upper)		
1-Day Minimum Value	5.0 mg/L	8.0 mg/L
30-DADMin Value	- -	- -
Lacustrine - Hypolimnion (Lower)		
1-Day Minimum Value	Narrative [2]	8.0 mg/L
30-DADMin Value	- -	- -

[1] To protect early brown trout spawners, the recommended winter DO reservoir criterion (8.0 mg/L applied as a 1-day minimum) should also be applied within the riverine reach from mid-September (September 15) through the end of September (September 30). (The winter criterion already applies beginning on October 1.)

[2] The narrative criterion for the lower hypolimnion (expected to be less than 12 percent of the reservoir volume during August when the warmest temperatures and lowest DO levels are observed) requires sources to maximize the “suitable volume” (defined as water with temperatures below 20°C and DO levels above 5.0 mg/L). The narrative criterion also includes a long-term goal to achieve a 1-day minimum DO value of 4.0 mg/L on a spatially averaged basis. This narrative criterion will be implemented via the TMDL process, since it requires that point and nonpoint sources continue to implement controls that minimize the volume of water that falls below 5.0 mg/L. Given that low DO values have been consistently observed since the 1970s, continued improvements to benthic conditions will ensure that existing uses within the lower hypolimnion will continue to be protected.

DADMin = day average of the daily minimum

5.2.7 Dissolved Oxygen Saturation Considerations

The above recommendations for DO criteria do not take into account the fact that DO concentrations are a function of temperature and elevation, in addition to the other factors already discussed at length in this Spokane River UAA report. The saturation concentration for DO is the maximum that can be expected in water, taking temperature and elevation into account. For example, 100 percent saturation at an elevation of 2,000 feet (an elevation that corresponds to the project area) and a temperature of 25ºC is 7.8 mg/L. This is lower than the 30-DADMin DO value criterion recommended for the summer season. Similarly, the DO level at 100 percent saturation at 2,000 feet and 10ºC is 11.4 mg/L, very close to the

30-DADMin DO value criterion we recommend for the spring season. These temperatures have occurred historically within the project area during each of these seasons (see Figures 3-2 and 3-3).

As a result, the DO criteria shown in Tables 5-1 and 5-2 should be applicable unless barometric pressure, altitude, and water temperature conditions preclude attainment of these criteria, in which case DO levels should not be less than 90 percent saturation. A percent saturation qualifier is included in both Idaho and Oregon surface water quality standards. Ecology has recognized the importance of this in another recent process on the Chehalis River (Ecology, 2004g).

5.3 Attainability of Proposed Dissolved Oxygen Criteria

A number of comments on the August 2004 draft Spokane River UAA report questioned if the Spokane River UAA would lead to any substantial modifications in the TMDL outcomes, that is, if there would be any “relief” for point sources. The answer to this question will be determined by whether:

- The 0.2 mg/L DO deficit criterion (compared to “natural” conditions) will continue to apply to Long Lake Reservoir
- The DO criteria that are proposed in this Spokane River UAA report are attainable with the next level of treatment and reasonable control of nonpoint sources

These issues are addressed below.

Deficit criterion of 0.2 mg/L DO. The outcome related to the Draft TMDL (Ecology, 2004e) is almost totally driven by Ecology’s conclusion that there is no assimilative capacity in the system for point sources. Ecology reaches this conclusion because of its application of the 0.2 mg/L DO deficit criterion to Long Lake Reservoir. This Spokane River UAA report provides analysis of why the 0.2 mg/L DO deficit criterion should not be applied to the reservoir, which is not a natural system, and recommends that this criterion not apply to the reservoir and that Washington’s surface water quality standards be amended to reflect this recommendation. As a result, the answer to this question related to “relief” for point sources depends on whether the DO criteria that are proposed in this Spokane River UAA report are attainable with the next level of treatment and reasonable control of nonpoint sources.

Next level of treatment. The modeling that has been conducted for this Spokane River UAA and the implementation language that has been developed (see Part 3: Implementation Plan) strongly indicate that the DO criteria recommended in this report can be attained with the next level of treatment and 25 percent reduction of nonpoint source total phosphorus. (This is subject to the appropriate considerations regarding model uncertainty and adaptive management.) The evidence for this assertion is described below for the Spokane River (RM 96 to RM 58) and Long Lake Reservoir (RM 58 to RM 34):

- **Spokane River (RM 96 to 58).** Figures D1-4-24 through D1-4-31 show the predicted DO concentrations on a minimum daily basis for key and representative river segments using LTI model results. These figures show that the Spokane River UAA-proposed 1-day minimum DO criteria are currently being met and will continue to be met with the proposed treatment. Figures D1-4-32 through D1-4-39 show the predicted DO concentrations as 30-day running averages of the minimum daily values using LTI model results. The 30-day DO values for April and May are strongly influenced by the Stateline boundary condition assumption. (The Stateline boundary condition was based on data collected by Ecology, rather than the alternative of basing it on uncalibrated Idaho model outputs. The discrepancy between boundary conditions assumptions is illustrated in Figure D1-1-1. The greatest discrepancy between boundary condition DO occurs during the spring months. The Ecology boundary condition during summer months also does not reflect the diurnal variation in DO predicted by the uncalibrated Idaho model. Although calibration of the Idaho model would be desirable, this is an area of uncertainty not only for this UAA but also for Ecology's TMDL. It is not possible at this time to determine which set of inputs is most representative or appropriate. However, as discussed in this UAA report, DO monitoring provides strong evidence that the DO criteria that are proposed in the UAA are currently being met at Stateline. The calibrated Washington model also shows that our proposed criteria will be met in the Spokane River segment (RM 96 to 58) downstream of Stateline using the NLoT. This is a conservative (i.e., protective) approach because the treatment scenario runs suggest lower DO values with the higher degrees of treatment in Idaho.) For the summer and early fall periods, LTI model results indicate that, generally, the 8.0 mg/L 30-day DO criterion is also met. One exception is Segment 17. In this segment, the lowest 30-day value is about 7.4 mg/L. There also are slight dips below 8.0 mg/L in Segment 42 and 69. These are well within the calibrated error range of the model. Note that these exceptions occur in late August. River temperatures in August in the upper reach of the river are in the 20 to 25ºC range. Thus, for reasons discussed above, in the warmest drought years (such as the Baseline scenario year of 2001), the 8.0 mg/L criterion will be a challenge to meet irrespective of effluent discharges. That is why the percent saturation constraint has also been proposed. In addition, Avista's model runs using the Spokane River CE-QUAL-W2 model show that increases in minimum summer releases from Post Falls Dam that are being evaluated as potential relicensing PM&Es would actually increase temperatures downstream of Barker Road in this reach of the river (HDR, 2004). It should also be noted that varying the degree of treatment (including setting effluent concentrations to zero) does not substantially affect the DO concentrations in the river segments. The overall conclusion for the river reach is that the recommended criteria are likely to be achievable.

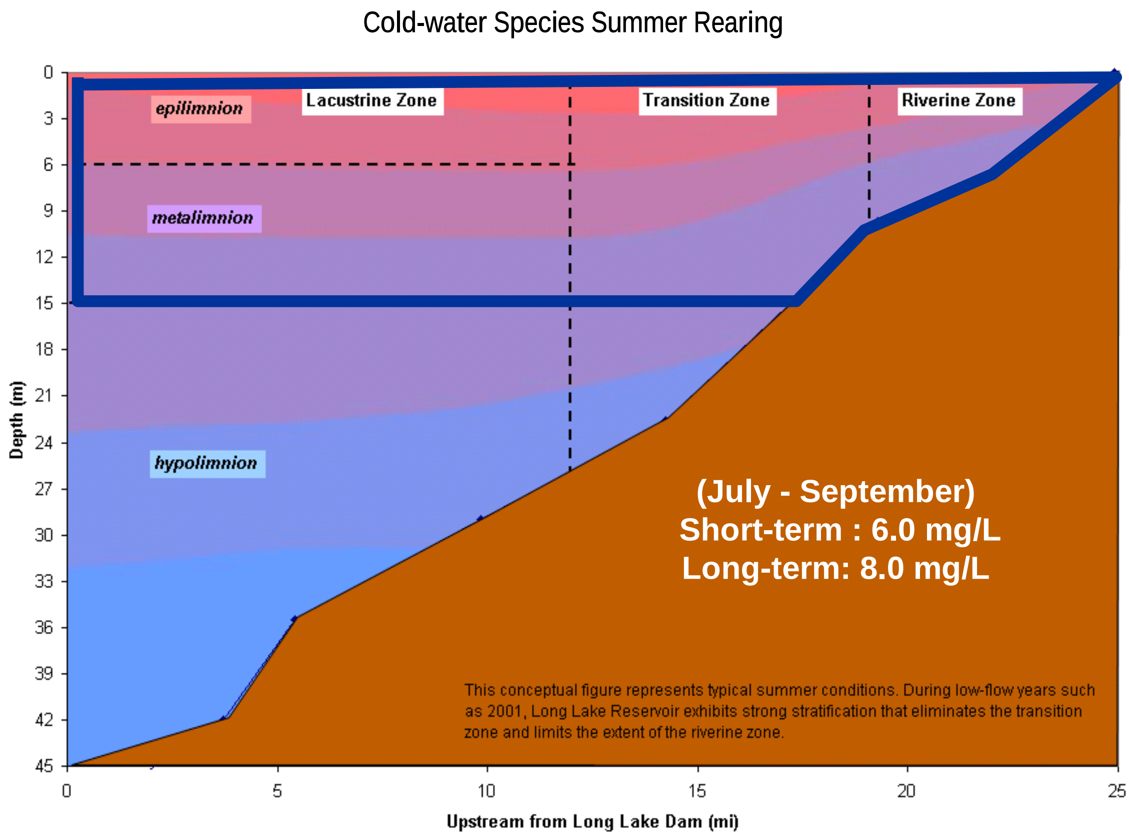
- **Long Lake Reservoir (RM 58 to RM 34).** Using the LTI modeling results, Figures 4-4c, D1-4-1, D1-4-18, and D1-4--22 best illustrate the prospects for attaining proposed reservoir criteria shown in Figure 5-2. Figures 4-4c and D1-4-1 (Segment 155) show that the criteria would readily be met in the riverine zone of the reservoir. Figures 4-4c and D1-4-22 (Segment 183) show that the proposed criteria would also be met in the stratified lacustrine zone near the dam. Figures 4-4c and D1-4-18 (Segment 167) show that the criteria are met in the metalimnion and epilimnion, and most of the upper hypolimnion, in the transition zone. The 5.0 mg/L criterion for the upper hypolimnion is not met at some times at a depth of 20 meters (66 feet) in this segment. However, since this depth is near the sediment/water interface, it is expected to represent the extreme condition for this segment. As recommended in the Implementation Plan (Part 3), the average DO value for the upper hypolimnion of Segment 167 readily meets the proposed DO criterion. Figure 5-3 provides additional insights into attainability of DO criteria. This figure shows that Ecology's current surface water quality criteria (9.5 mg/L absolute DO level and 0.2 mg/L differential DO level) cannot be met a high percentage of the time, regardless of treatment scenario, including removing the point source loads entirely from the Spokane River. It does shows that the criteria proposed in this Spokane River UAA (protective of existing and attainable uses) can be met under most conditions, even recognizing the severity of 2001 low flows as the basis for the evaluation.

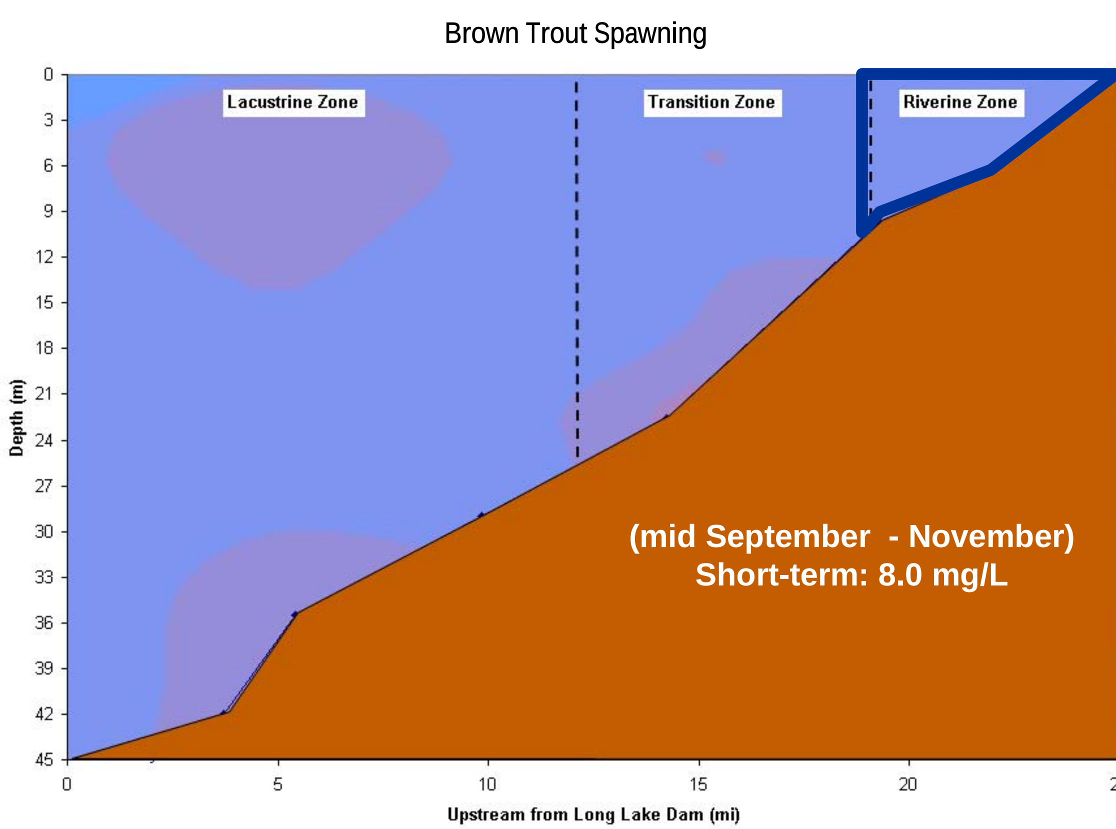
Attainability of proposed DO criteria. The overall conclusion is that the proposed DO criteria are likely to be attainable. This conclusion assumes a reasonable and rational approach to model and criteria interpretation that recognizes the following factors:

- The extremity of conditions during 2001, the year used for the Baseline scenario
- The uncertainty of model predictions (about 1.0 mg/L for DO RMS error)
- The appropriateness and applicability of spatial averaging

Adaptive management approach. An adaptive management approach still would be appropriate for the TMDL when it is based on standards proposed in this Spokane River UAA. This adaptive management approach incorporates a long-term goal to achieve a 1-day minimum daily DO of 4.0 mg/L in the lower hypolimnion on a spatially averaged basis. Although modeling suggests that this goal can be met with the NLoT, it is included as a narrative goal rather than a numeric criterion because of the substantial uncertainty and error associated with the model, in particular the lack of its capability to predict long-term changes in SOD in relation to treatment scenarios.

The sponsors of the UAA have conducted an initial investigation of aeration of Long Lake Reservoir. Based on this initial investigation, it appears that reservoir aeration would provide significant benefit to DO in the reservoir. In addition, very preliminary estimates of potential costs associated with reservoir aeration suggest that it appears to be a feasible technology. Therefore, the sponsors believe that reservoir aeration should be further investigated and included as part of the Spokane River UAA implementation plan.





Figures 5-1a and 5-1b. Recommended Subcategories of Uses and Biological DO Requirements for Cold-water Summer Rearing (5-1a) and Brown Trout Spawning (5-1b) in Long Lake Reservoir.

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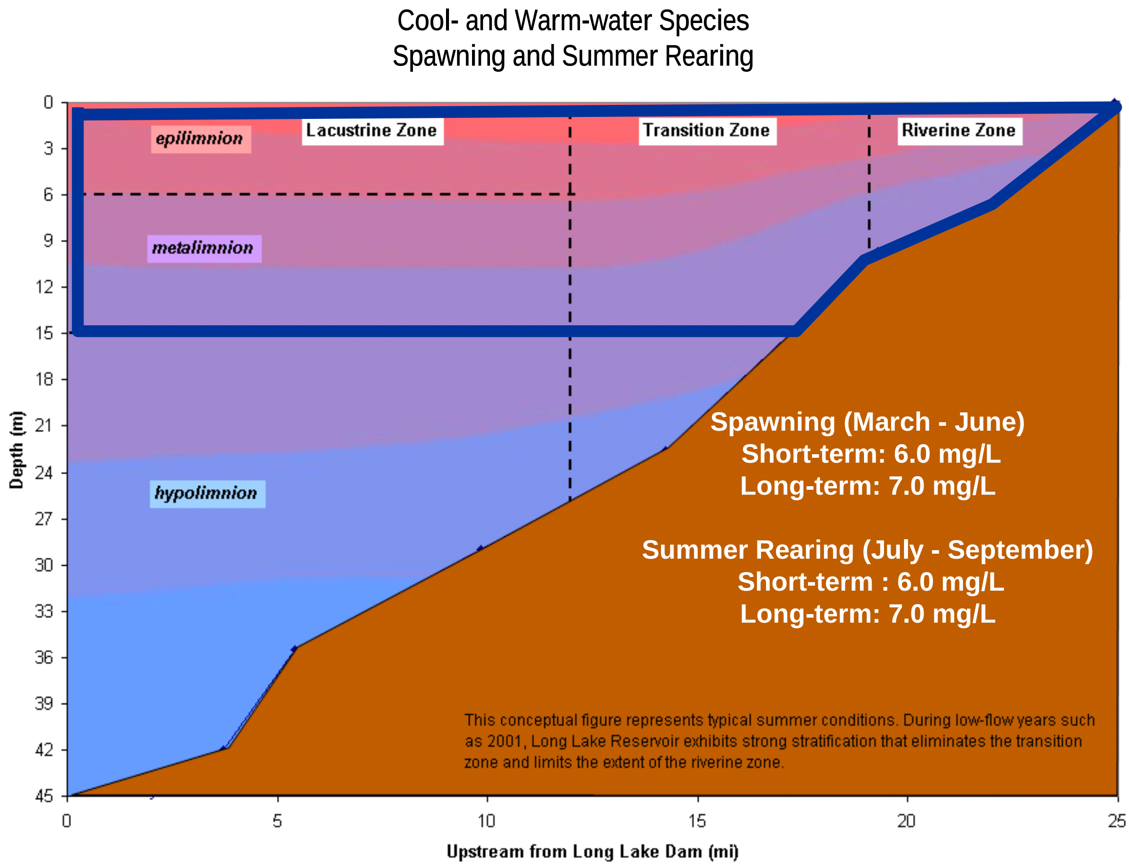

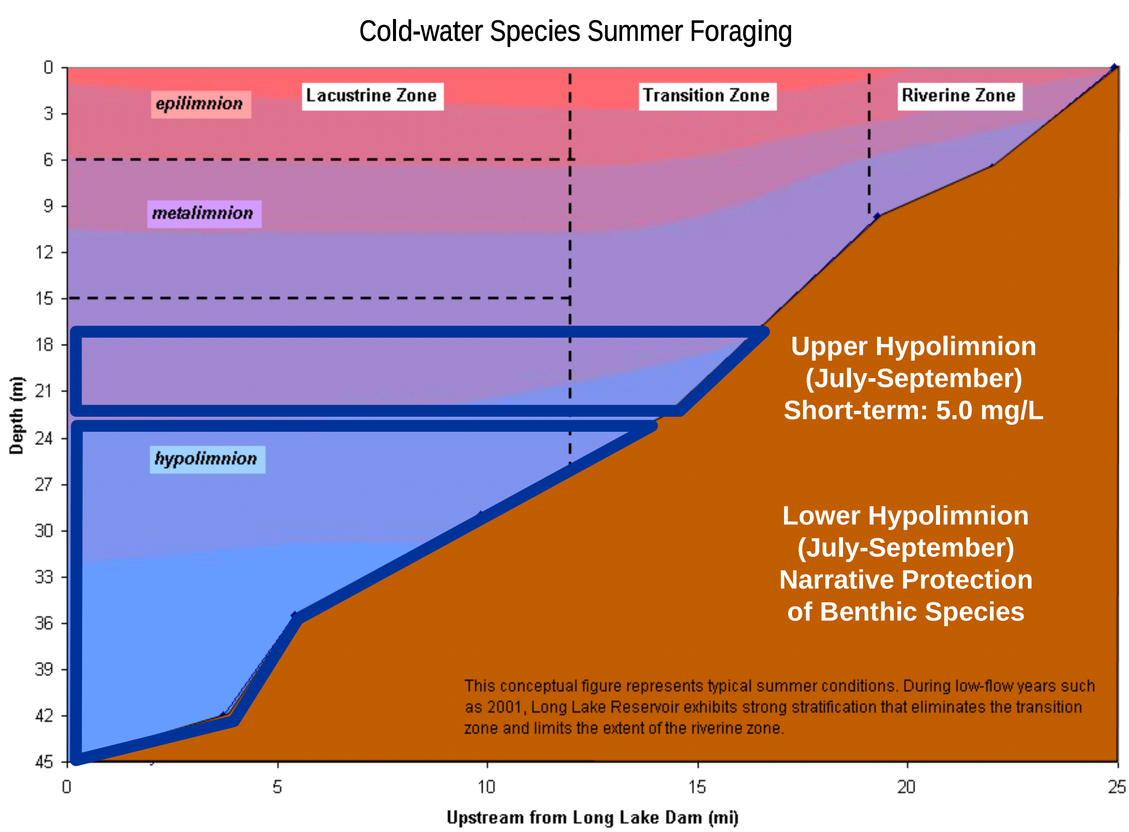

Figures 5-1c and 5-1d. Recommended Subcategories of Uses and Biological DO Requirements for Cool- and Warm-water Spawning and Summer Rearing (5-1c) and Cold-water Summer Foraging (5-1d) in Long Lake Reservoir.

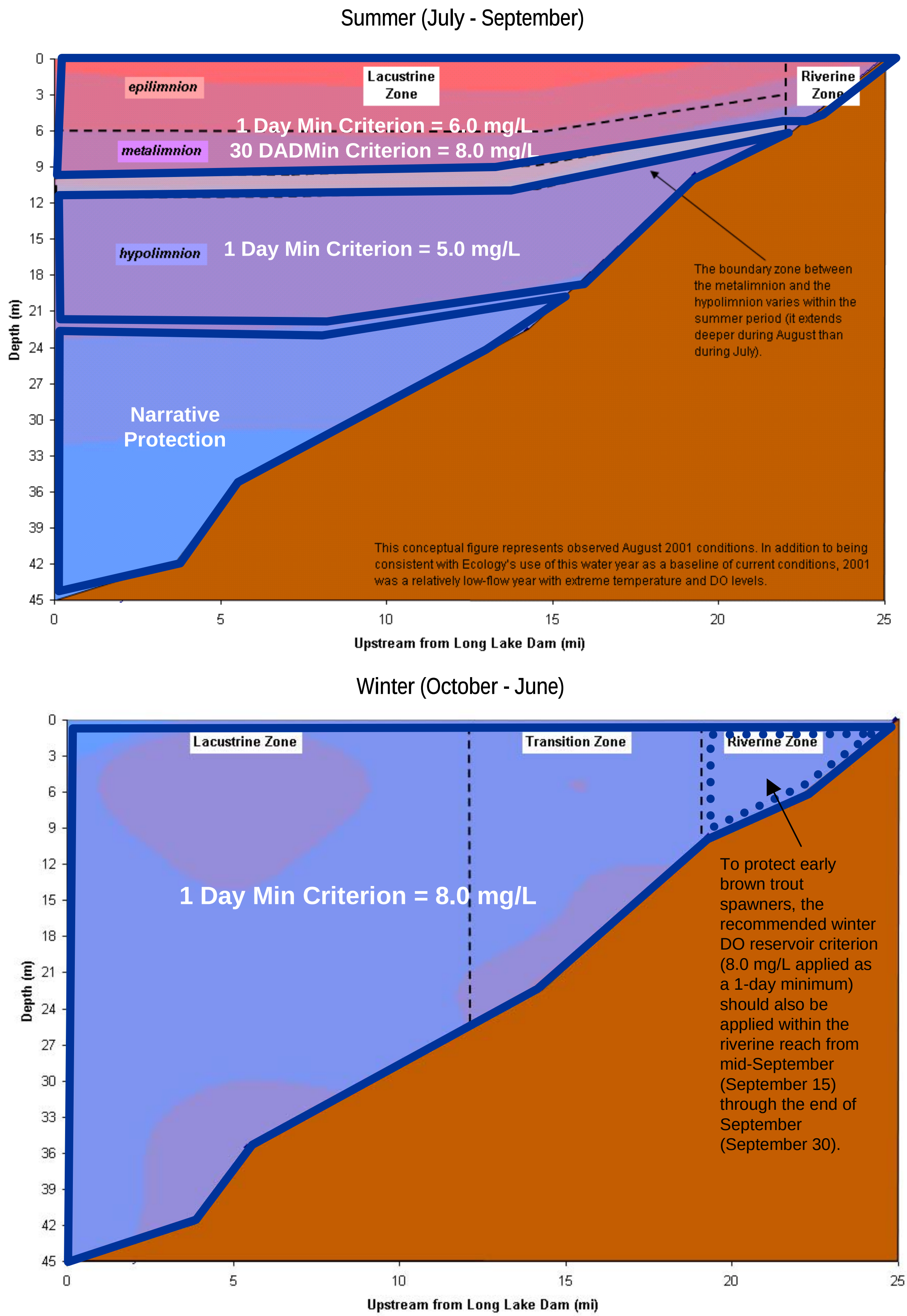

Figure 5-2. Summary of Recommended DO Criteria for Long Lake Reservoir.

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Baseline		Begin	End	# Days	% Time
Existing Criteria	9.5 mg/L	18-May	30-Oct	165	> 45 %
	0.2 Delta	21-Mar	30-Oct	223	> 61 %
Proposed Criteria					
Spring (through June)					
Epi/Metalimnion	8 mg/L	- -	- -	0	
Upper Hypolimnion	8 mg/L	- -	- -	0	
Lower Hypolimnion	8 mg/L	08-Jun	30-Jun	22	8 %
July - Sept					
Epi/Metalimnion	6 mg/L	- -	- -	0	
Upper Hypolimnion	5 mg/L	- -	- -	0	
Lower Hypolimnion	4 mg/L	22-Jul	30-Sep	70	77 %
Fall (from October)					
Epi/Metalimnion	8 mg/L	- -	- -	0	
Upper Hypolimnion	8 mg/L	01-Oct	07-Oct	6	2 %
Lower Hypolimnion	8 mg/L	01-Oct	21-Oct	20	7 %

NLoT		Begin	End	# Days	% Time
Existing Criteria	9.5 mg/L	24-May	30-Oct	159	> 44 %
	0.2 Delta	24-Mar	30-Oct	220	> 61 %
Proposed Criteria					
Spring (through June)					
Epi/Metalimnion	8 mg/L	- -	- -	0	
Upper Hypolimnion	8 mg/L	30-Jun	30-Jun	1	0 %
Lower Hypolimnion	8 mg/L	13-Jun	30-Jun	17	6 %
July - Sept					
Epi/Metalimnion	6 mg/L	- -	- -	0	
Upper Hypolimnion	5 mg/L	- -	- -	0	
Lower Hypolimnion	4 mg/L	18-Aug	11-Sep	24	26 %
Fall (from October)					
Epi/Metalimnion	8 mg/L	- -	- -	0	
Upper Hypolimnion	8 mg/L	01-Oct	07-Oct	6	2 %
Lower Hypolimnion	8 mg/L	01-Oct	23-Oct	22	8 %

NLoT + 25% NPS		Begin	End	# Days	% Time
Existing Criteria	9.5 mg/L	23-May	30-Oct	160	> 45 %
	0.2 Delta	24-Mar	30-Oct	220	> 61 %
Proposed Criteria					
Spring (through June)					
Epi/Metalimnion	8 mg/L	- -	- -	0	
Upper Hypolimnion	8 mg/L	30-Jun	30-Jun	1	0.4 %
Lower Hypolimnion	8 mg/L	12-Jun	30-Jun	18	7 %
July - Sept					
Epi/Metalimnion	6 mg/L	- -	- -	0	
Upper Hypolimnion	5 mg/L	- -	- -	0	
Lower Hypolimnion	4 mg/L	20-Aug	11-Sep	22	24 %
Fall (from October)					
Epi/Metalimnion	8 mg/L	- -	- -	0	
Upper Hypolimnion	8 mg/L	01-Oct	07-Oct	6	2 %
Lower Hypolimnion	8 mg/L	01-Oct	23-Oct	22	8 %

PS = 0 Concentration		Begin	End	# Days	% Time
Existing Criteria	9.5 mg/L	25-May	30-Oct	158	> 43 %
	0.2 Delta	25-Mar	30-Oct	219	> 60 %
Proposed Criteria					
Spring (through June)					
Epi/Metalimnion	8 mg/L	- -	- -	0	
Upper Hypolimnion	8 mg/L	- -	- -	0	
Lower Hypolimnion	8 mg/L	12-Jun	30-Jun	18	7 %
July - Sept					
Epi/Metalimnion	6 mg/L	- -	- -	0	
Upper Hypolimnion	5 mg/L	- -	- -	0	
Lower Hypolimnion	4 mg/L	22-Aug	10-Sep	19	21 %
Fall (from October)					
Epi/Metalimnion	8 mg/L	- -	- -	0	
Upper Hypolimnion	8 mg/L	01-Oct	05-Oct	4	1 %
Lower Hypolimnion	8 mg/L	01-Oct	21-Oct	20	7 %

Figure 5-3. Frequency of DO Excursions in Each Layer of Long Lake Reservoir by Season and Model Scenario.

6. References

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Report

Part 3: Implementation Plan

Spokane River and Long Lake Reservoir Use Attainability Analysis

Prepared for

Spokane River UAA Sponsoring Committee

December 2004

Prepared by

CH2MHILL

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Abbreviations and Acronyms

Avista	Avista Utilities
CFR	Code of Federal Regulations
DADMin	day average of the daily minimum
DO	dissolved oxygen
Ecology	Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
IDEQ	Idaho Department of Environmental Quality
LTI	Limno-Tech, Inc.
mg/L	milligrams per liter
NLoT+25 percent NPS BMPs	next level of treatment plus 25 percent reduction in nonpoint source loads through implementation of best management practices
NPDES	National Pollutant Discharge Elimination System
ODEQ	Oregon Department of Environmental Quality
RM	River Mile
SOD	sediment oxygen demand
Spokane River UAA	Spokane River and Long Lake Reservoir Use Attainability Analysis
Spokane Tribe	Spokane Tribe of Indians
TAC	Technical Advisory Committee
TMDL	total maximum daily load
UAA	use attainability analysis
WAC	Washington Administrative Code

1. Application of Recommended Criteria

Consistent with 40 Code of Federal Regulations (CFR) 131.10(g), use changes and recommendations contained in Section 5 of Part 2 have been based on protecting the existing and attainable uses of the Spokane River and Long Lake Reservoir. To facilitate total maximum daily load (TMDL) implementation, the intent is that these numeric criteria be straightforward to apply.

1.1 Temporal Issues

1.1.1 Spokane River (River Mile [RM] 96 to RM 58)

In the riverine reach, the 1-day minimum dissolved oxygen (DO) values should be applied to diurnal or other monitoring data collected throughout the reach. The 30-day average of the daily minimum (DADMin) DO values should be applied to monitoring data collected over more than a 30-day period throughout the reach. The ability to assess criteria depends on the time scale of available data and on the capacity of models to estimate conditions at those time scales. Monitoring of the riverine reach should be conducted on a periodic basis (for example, annually or bi-annually) to confirm modeling predictions and assess long-term trends.

1.1.2 Long Lake Reservoir (RM 58 to RM 34)

Oregon's multiple DO criteria have been in place for several years. In Oregon Department of Environmental Quality's (ODEQ's) 1995 issue paper on DO, ODEQ recognized that "determining compliance with statistical criteria implies much more detailed data than the Department usually collects at any location" (ODEQ, 1995). Because minimum criteria approach acute levels, ODEQ believes that limited data should be compared to average concentrations unless adequate data exist to evaluate the minimum criteria.

In its nutrient guidance (U.S. Environmental Protection Agency [EPA], 2000), EPA recognizes that, because the timing of flows and stratification will vary from year to year, the controls of nutrients in the ***surface layer*** (emphasis added) of a lake or reservoir are unpredictable except as a long-term average. EPA is silent on controls in the hypolimnion. However, from a scientific standpoint, there are inherent difficulties in controlling nutrients and low DO levels in passive areas of stratified systems (for example, well below typical interflow zones).

Vermont has taken this long-term average approach. Lake criteria have been set as seasonal or annual mean values rather than instantaneous "not to exceed" values (EPA, 2000). Therefore, in practical terms, reservoir monitoring should be conducted on a periodic basis (for example, annually or bi-annually) to confirm modeling predictions and assess long-term trends.

1.2 Spatial Issues

1.2.1 Spokane River (RM 96 to RM 58)

In the riverine reach, DO issues are generally not driving the implementation of nutrient control strategies. However, the ways the recommended criteria are applied should be evaluated relative to actual uses. For example, summer monitoring activities related to National Pollutant Discharge Elimination System (NPDES) permitting should probably be focused on stations that are located within areas that support cold-water rearing. During warmer summer periods, rainbow trout and mountain whitefish commonly find refuge from warmer reservoir pools in relatively cooler free-flowing reaches (see Section 3 of Part 2 of the Spokane River and Long Lake Reservoir Use Attainability Analysis [Spokane River UAA]). Thus, even though the criteria are intended to apply to the entire riverine reach, as a practical matter, summer monitoring should target free-flowing reaches known to support summer rearing uses.

1.2.2 Long Lake Reservoir (RM 58 to RM 34)

In both the prior and current Washington surface water quality standards, DO criteria are expressed as 1-day minimum values. It appears that the standards are silent on the spatial interpretation of this minimum for DO values. However, the salinity standards (Washington Administrative Code [WAC] 173-201A-260) specify that “where different criteria for the same use occurs for fresh and marine waters, the decision to use the fresh water or the marine water criteria must be selected and applied on the basis of vertically averaged daily maximum salinity.” Since salinity differences in estuarine situations are analogous to thermal stratification in fresh water, a vertical-averaging approach for DO is appropriate and reasonable.

In the reservoir reach, application of the recommended criteria to every point in the water column at any given time does not reflect the inherent heterogeneity in a large reservoir. Further, this approach is not consistent with the diverse nature of surface water systems. Inputs of oxygen, sunlight penetration, accumulation of dissolved substances, and the distribution of biota are often different in the thermally isolated areas. Many of the limnological parameters that define the water quality differ with depth, and the degree of these differences (for example, stratification) varies seasonally.

Therefore, for any given monitoring event, the recommended criteria should be applied to the subject reservoir area (or zone) on a spatially averaged basis within each zone. Support for the use of a spatially averaged monitoring approach is provided below:

- **Limnology texts.** This approach is consistent with well-regarded limnology texts (for example, Wetzel, 1983) wherein volume-weighted averages are widely considered as the most representative estimate of the mass of dissolved oxygen (for example, in calculating hypolimnetic oxygen depletion rates; Ecology, 1998).
- **EPA’s nutrient criteria guidance manual (2000).** In EPA (2000), Virginia’s criteria Technical Advisory Committee (TAC) recommended that numeric nutrient criteria for phosphorus be applied either as a weighted-mean based on water mass or as a mixed layer mean value (Appendix B of EPA, 2000).

- **Brownlee Reservoir TMDL.** This is consistent regionally with how the Brownlee Reservoir nutrients TMDL addressed DO deficits by evaluating each section (or zone) of the reservoir as a whole and presuming fully mixed conditions (Idaho Department of Environmental Quality [IDEQ] and ODEQ, 2004).
- **Behavior of aquatic organisms.** It is well known that fish and other aquatic organisms seek more optimal conditions over sub-optimal conditions when given a choice. For example, salmonids often find refugia in cooler pockets of smaller tributaries during warm summer months rather than remaining in warmer areas (EPA, 2003a).

1.3 Consideration of Natural Conditions

1.3.1 Spokane River (RM 96 to RM 58)

Washington's current surface water quality standards state that where natural conditions are less than the DO criterion, natural conditions shall constitute the criterion with no measurable decrease (that is, 0.2 milligrams per liter [mg/L] or less reduction below the background concentration). In this reach of river, there are two free-flowing segments and four relatively shallow reservoir pools. The free-flowing segments are not natural because critical season summer flows are strongly influenced by releases from Post Falls Dam (warm upper layer Lake Coeur d'Alene water). The reservoir pools slow the velocity of water substantially, leading to increased warming and a sediment deposition bottom substrate. Thus, this reach is not "natural" because it has been substantially modified hydrologically and physically. Federal use attainability analysis (UAA) regulations recognize that dams are not natural (40 CFR 131.10[g][4]). These regulations allow incorrectly designated uses to be modified.

1.3.2 Long Lake Reservoir (RM 58 to RM 34)

Ecology recognizes that the "natural condition" (plus the small 0.2 mg/L incremental DO allowance for human degradation) does not completely address stratified conditions such as those commonly found in lakes and reservoirs (Ecology, 2003).

Reservoirs are man-made water bodies that are not "natural," so applying the "natural conditions" language of the surface water quality standards to dams or other hydrologic modifications is not appropriate. WAC 173-201A-260 defines "natural conditions" as water quality that was present before any human-caused pollution. Identical anthropogenic pollution sources have very different effects on lakes than on reservoirs because of the physical nature of these two types of systems. For example, lakes may be more susceptible to pollution loading than reservoirs because of their relatively longer hydraulic residence times. However, reservoirs typically receive point source, nonpoint source, and natural loading from much larger drainage areas (per unit volume or area of the reservoir) than natural lakes. In the case of phosphorus, once nutrients are deposited in sediments at the bottom of the reservoir, recovery is extremely slow, and the reservoir might not ever recover to "natural conditions."

2. Spokane River UAA and Total Maximum Daily Load Implementation

Parallel to this Spokane River UAA process, local stakeholders have been engaged in the TMDL process and have developed potential implementation strategies. For example, Spokane County and the City of Spokane jointly sponsored a one-day workshop on August 23, 2004, to evaluate advanced wastewater treatment technologies (CH2M HILL, 2004; Appendix F of the Spokane River UAA). The main objective of this workshop was to identify all proven and emerging technologies and to estimate what ranges of effluent phosphorus concentrations could be consistently and reliably achieved utilizing those technologies.

The Spokane River UAA and TMDL are necessarily linked. The uses designated in Washington's current surface water quality standards do not accurately reflect existing and attainable uses of the river and reservoir. As a result, the current designated uses do not provide a rational or scientific basis to calculate the assimilative capacity of the system. Without an accurate and scientific calculation of assimilative capacity, a TMDL cannot appropriately calculate waste load and load allocations for point and nonpoint sources.

It is clear that conditions in the river and reservoir continue to require additional source control of nutrients beyond current levels. Following the trend of improvement over the last 26 years, the Spokane River UAA sponsors are committing to the next level of treatment and additional implementation elements. The heart of the plan is a commitment to implement technologies to achieve 95 percent reduction in the point source phosphorus load to the Spokane River. The following discussion provides examples of the elements the Spokane River UAA sponsors expect to provide or participate in:

- **Rock Creek treatment facility, Oregon.** The next level of treatment technology is represented by the best proven large-scale treatment processes that are currently being applied at the Rock Creek treatment facility on the Tualatin River in Oregon (owned and operated by Clean Water Services). This technology typically reduces median effluent phosphorus to 0.05 mg/L, which provides a treatment efficiency of greater than 99 percent. The Spokane River UAA sponsors have proposed to implement final effluent filtration to achieve this effluent phosphorus concentration in recognition of the fact that, during much of the time, the plants will operate significantly below this concentration. (This is documented with the Clean Water Services plant on the Tualatin River and with the Upper Occoquan plant in Northern Virginia, which achieves 0.01 mg/L effluent phosphorus about 40 percent of the time). Because some phosphorus is currently being removed by secondary treatment, the reduction in load to the river due to final effluent filtration will be about 95 percent.

- **Best proven technology**. The next level of treatment represents the best currently available, proven technology for point sources that will have any net environmental benefit on the Spokane River and Long Lake Reservoir. Improvements beyond this scenario reflect human-caused conditions that cannot be remedied. This is consistent with the conclusion from a very similar UAA process for the Chesapeake Bay (EPA, 2003b).

- **Water conservation and reuse.** The Spokane River UAA sponsors have proposed the implementation of water conservation and reuse programs that will reduce hydraulic flow and further reduce the pounds of phosphorus discharged directly to the Spokane River.
- **Contributing to the control of nonpoint sources**. The Spokane River UAA sponsors have proposed to contribute to the control of nonpoint sources, which Ecology recognizes to be the major contributor to Long Lake Reservoir DO sags (Ecology, 2004a).
- **Adaptive management strategy.** The federal Clean Water Act requires that all feasible steps be taken to achieve the highest quality water attainable. However, in watersheds where nonpoint sources are a major contributor to pollution, feasible steps may be difficult to identify and implement. This situation is particularly applicable to the bottom (lower hypolimnion) of Long Lake Reservoir. The recommendation in this Spokane River UAA requires that sources maximize the volume of water in the lower hypolimnion to DO levels above 4.0 mg/L. The extent to which this volume can be maximized depends not only on the feasible control of point and nonpoint loads to the reservoir, but also on potential changes in sediment oxygen demand (SOD) as phosphorus loads decrease.
- **On-the-ground implementation.** The concept of adaptive management as it applies to TMDL implementation allows for on-the-ground implementation to proceed where uncertainty exists about how and when reduction targets will be met. The adaptive management approach acknowledges that water quality improvement may require a long period of time. However, this approach provides a short-term pathway by which to gauge progress toward that long-term goal.
- **Continuation of monitoring to ascertain water quality improvements**. The Spokane River UAA sponsors have proposed to continue collecting samples and analyzing the results of water quality monitoring methods.
- **Reservoir aeration.** The Spokane River UAA sponsors have conducted an initial investigation of aeration of Long Lake Reservoir. Based on this initial investigation, it appears that reservoir aeration would provide significant benefit to DO levels in the reservoir and downstream water quality. In addition, very preliminary estimates of potential costs associated with reservoir aeration suggest that it appears to be a feasible technology. Therefore, the Spokane River UAA sponsors believe that reservoir aeration should be further investigated.
- **Work with Avista Utilities (Avista)**. The Spokane River UAA sponsors propose to work with Avista to incorporate Federal Energy Regulatory Commission (FERC) considerations and concerns and to implement a comprehensive workable solution.

3. Protectiveness of Downstream Uses

Currently, state and Spokane Tribe of Indians (Spokane Tribe) surface water quality standards for temperature and DO are not consistently being met downstream of Long Lake Reservoir (see Section 3.4 of Part 2 of the Spokane River UAA). It is important to note here that reservoir modeling by both Ecology and Limno-Tech, Inc. (LTI) has shown that Ecology's Draft TMDL (2004e) would not meet Ecology's or the Spokane Tribe's downstream DO surface water quality standards.

Fisheries studies have linked warm water temperatures and decomposition of summer algal biomass to low DO concentrations (Spokane Tribe, 2003). The Spokane Arm of Lake Roosevelt drains a warmer subbasin than other arms of the reservoir, which is reflected in temperatures that can be significantly warmer than in the reservoir as a whole (Spokane Tribe, 2003). Amending Washington's surface water quality standards to designate uses and criteria for Long Lake Reservoir consistent with the criteria recommended in this Spokane River UAA would not exacerbate those downstream problems.

Modeling by LTI indicates that the next level of treatment combined with reasonable control of nonpoint sources (Scenario 3, the next level of treatment plus 25 percent reduction in nonpoint source loads through implementation of best management practices [NLoT+25 percent NPS BMPs] scenario) should increase DO levels in the vicinity of the Long Lake Reservoir. This improvement represents the highest attainable conditions based on feasible control of pollutant sources. If other direct improvements in Long Lake Reservoir DO levels were implemented (for example, aeration), it is very likely that downstream criteria would be met. As noted above, the Spokane River UAA sponsors have conducted an initial investigation of reservoir aeration. This investigation has shown that aeration appears to be feasible and should be further evaluated. In addition, Ecology and/or the Spokane Tribe could develop an appropriate DO TMDL for Lake Roosevelt and the Spokane River below Long Lake Dam.

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Report

Part 4: Economic Assessment

Spokane River and Long Lake Reservoir Use Attainability Analysis

Prepared for

Spokane River UAA Sponsoring Committee

December 2004

Prepared by

CH2MHILL

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Abbreviations and Acronyms

Ccf	hundred cubic feet
City	City of Spokane
County	Spokane County
CSO	combined sewer overflow
Draft TMDL	Draft Total Maximum Load to Restore and Maintain Dissolved Oxygen in the Spokane River and Lake Spokane (Long Lake) (Draft TMDL; Ecology, 2004e)
Ecology	Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
GO	General Obligation
mg/L	milligrams per liter
mgd	million gallons per day
MHI	median household income
NA	not applicable
O&M	operation and maintenance
RO	reverse osmosis
Spokane River UAA	Spokane River and Long Lake Reservoir Use Attainability Analysis
STEP	Septic Tank Elimination Program
TP	total phosphorus
Washington	state of Washington

1 Introduction

This part of the Spokane River and Long Lake Reservoir Use Attainability Analysis (Spokane River UAA) provides an economic assessment associated with treatment alternatives proposed by the implementation plan contained in Washington Department of Ecology's (Ecology's) Draft Total Maximum Daily Load to Restore and Maintain Dissolved Oxygen in the Spokane River and Lake Spokane (Long Lake) (Draft TMDL; Ecology, 2004e) and treatment alternatives recommended in the Implementation Plan of the Spokane River UAA (Part 3). Preparation of this economic assessment was encouraged by Ecology and prepared as part of the Spokane River UAA sponsors' proposed modifications to Washington's surface water quality standards. This analysis is not intended to be a demonstration of "widespread economic and social impacts" pursuant to 40 CFR 131.10(g)(6).

Using order-of-magnitude cost estimates, this assessment is an initial determination of the affordability of alternatives. Costs are presented in this assessment only for upgrades to the City of Spokane (City) plant and for the costs to build the new Spokane County (County) regional treatment plant. References to total phosphorus (TP) removed are for all point source discharges to the river. The costs associated with the removal of TP from the Spokane River for the dischargers other than the City and the County were not included in this assessment. Because of the relatively minor contribution of TP to the river from these other point source dischargers, the additional capital costs are not expected to significantly increase the total costs of TP removal. Regardless of Ecology's and EPA's final decisions on the TMDL or the Spokane River UAA report, any recommendations related to rates would be prepared by the staff of the City and the County. Ultimately, these decisions would be subject to the approval of elected officials taking into consideration a wide array of factors that are not considered in this economic assessment.

The alternatives evaluated were:

- Implementation of final filtration for point source phosphorus reduction to achieve a 95 percent reduction in total point source loading to the Spokane River
- Land application of municipal wastewater in an agricultural operation
- Implementation of reverse osmosis (RO) technology to achieve 99 percent reduction in municipal phosphorus loads

The discussion of the cost of each alternative relative to the median household income (MHI) provides an assessment of the sensitivity of cost per household ratepayer or equivalent. It is neither a recommendation nor evaluation of any jurisdiction's rates or rate structure. It is anticipated that the treatment plant improvement would be operational in 2012. The City conducted its analysis in constant 2004 dollars. The sensitivity of the residential sewer rate under each alternative was compared to the City's 2004 MHI to calculate the revised residential indicator. The County, by contrast, conducted its analysis in 2012 dollars. In order to calculate the revised residential indicator for the County based on the implementation of each alternative, the County's 2004 MHI was inflated by an annual escalation factor of 2.4 percent to estimate the County's 2012 MHI. The different methodologies provide residential indicators for assessing the affordability of each alternative. Questions regarding the calculations of the rate for each alternative should be directed to the City's Public Works and Utilities Department or the County's Public Works Department.

This part of the Spokane River UAA includes the following sections:

- **Existing Conditions.** This section presents the current rates for the City and the County. It compares their rates to other communities in the state of Washington (Washington) on the basis of a median household affordability index or residential indicator.
- **Alternatives.** This section presents the estimated capital and operation and maintenance (O&M) costs for each of the proposed alternatives.
- **Total Phosphorus/Dissolved Oxygen.** This section presents the percent of TP removed from the Spokane River over existing conditions as well as the capital costs for each of the alternatives. It also presents the dissolved oxygen levels for current conditions and for the filtration and zero point source concentrations.
- **Rate Sensitivity Analysis.** This section estimates the sensitivity of the City's and the County's residential sewer rates to the capital costs associated with each alternative.
- **Financial Capacity.** This section qualitatively discusses the impact of implementing the different alternatives on the fiscal resources of each community.
- **Conclusions.** This section presents the conclusions derived from the economic assessment.
- **References.** This section provides bibliographic information about the sources cited in this economic assessment.

This assessment incorporates methodologies from the U.S. Environmental Protection Agency's (EPA's) Combined Sewer Overflow: Guidance for Financial Capability Assessment and Schedule Development (1997). The first level of measurement analyzes a household's ability to pay. This is measured by the annual household's sewer cost as a percentage of MHI and is referred to as the residential indicator. Other measures include an examination of unemployment rates, poverty levels, and the financial capacity of the City and the County.

2 Existing Conditions

2.1 Median Household Income

Table 1 presents the MHI for the U.S., Spokane County, and the City of Spokane. The 2004 MHI for each census area was estimated by applying an escalation factor of 1.1 to the 2000 MHI reported in the 2000 U.S. Census (U.S. Census Bureau, 2004). The EPA guidelines (EPA, 1997) recommend comparing the estimated 2004 MHI of the impacted communities to the adjusted MHI for the nation as a whole to gauge each community's earning capacity.

In 2004, the MHIs of the U.S., the County, and the City are estimated to be $46,187, $41,033, and $35,495, respectively. The MHIs of the County and the City are 89 and 77 percent, respectively, of the national average. This suggests that the households of each community have a below-average earning capacity relative to the nation as a whole.

TABLE 1
Median Household Incomes

	United States	Spokane County	City of Spokane
Median Household Income, 2000 Census	$41,994	$37,308	$32,273
Median Household Income, 2004 estimate	$46,187	$41,033	$35,495
Percent of National Average, 2004 estimate	NA	89%	77%

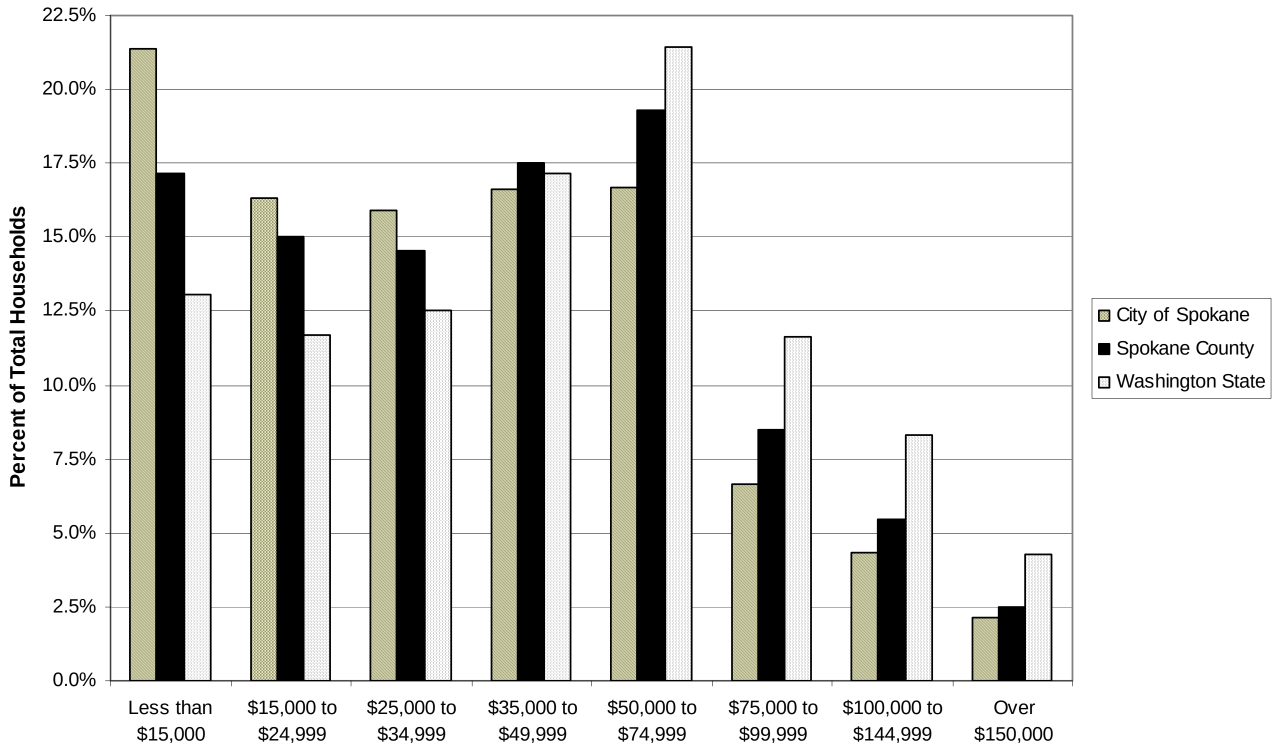
Source: 2000 Census, U. S. Census Bureau (2004); Washington Department of Ecology (2004h)
NA = not applicable

Figure 1 presents the distribution of household incomes as reported by the 2000 U.S. Census for the City, County, and Washington. The City and the County had approximately 70 percent and 64 percent, respectively, of their populations with MHIs less than $50,000. Washington reported nearly 54 percent of all households with MHIs less than $50,000. Nationally, 55 percent of households reported an MHI less than $50,000.

2.2 Residential Indicator

The existing residential sewer rates for the City and the County are presented in Table 2. Historically, the City's residential sewer rate includes a sewer O&M component, a storm water component, and a rate stabilization charge. The storm water charge is for a combined sewer overflow (CSO) and correction program and helps pay for the storm water program. The city's rate also includes a utility tax. Historically, the County's residential sewer rate includes a capital facilities rate charge, an O&M charge, and a rate stabilization charge. The capital facilities rate charge is the rate that is charged to customers as part of the County's mandatory Septic Tank Elimination Program (STEP). The County does not charge a utility tax.

FIGURE 1
Household Income Distribution, 2000 Census



Source: U.S. Census Bureau, (2004)

TABLE 2
2004 Sewer Rates for the City of Spokane and Spokane County

Community	2004 Sewer Rate
City of Spokane	$24.07
Spokane County	$61.15

Source: City of Spokane Public Works and Utilities Department (2004) and Spokane County Public Works Departments (2004)

The City of Spokane recently approved a sewer rate increase effective January 2005. The new residential sewer rate will be $24.47 per month. For this analysis, the City's 2004 sewer rate was used as the baseline rate. This was done in order to be consistent with the rates reported for other communities (which were all in 2004 dollars) and to be consistent with Ecology's estimated 2004 MHI for each community. Capital and O&M costs for each alternative were also estimated in 2004 dollars.

A residential indicator illustrates a typical customer's sewer billing as a percent of the MHI for a community. Residential indicators were calculated for 16 communities in Washington. The survey of these residential indicators incorporated a broad cross section of communities in the state, including large metropolitan cities in western Washington and smaller communities in eastern Washington. These communities included the following:

- Spokane County
- Spokane
- Bellevue
- Bellingham
- Ellensburg
- Everett
- Federal Way
- Kennewick
- Olympia
- Pullman
- Puyallup
- Renton
- Seattle
- Tacoma
- Vancouver
- Walla Walla

Average annual sewer bills were estimated for each community based on current (2004) monthly sewer rates posted on each community's web site. Water consumption was estimated to be 12 hundred cubic feet (Ccf) per month, based on Ecology statistics (Ecology, 2004j).

Under EPA guidelines, a residential indicator of:

- Less than 1.0 percent of MHI is considered a low financial impact
- Between 1.0 and 2.0 percent of MHI is considered a mid-range financial impact
- Greater than 2.0 percent of MHI is considered a high financial impact.

Ecology, by comparison, defines financial hardship as when the residential indicator for an individual community is greater than 1.5 percent of MHI (Ecology, 2004i). This designation is used in conjunction with Ecology's funding programs for community sewer projects.

The residential indicators for all 16 communities are presented in Figure 2. Currently, the City and the County have residential indicators of 0.8 percent and 1.8 percent, respectively. At their current levels, the existing sewer rates for the City are considered to be within the affordable range, while the County's sewer rates are considered to have a mid-range financial impact to the community based on EPA guidelines. Under Ecology's guideline (2004i), the County would currently meet the criterion for hardship based on its residential indicator. For the other communities surveyed, the City of Seattle has the highest residential indicator (1.7 percent) and the City of Kennewick has the lowest residential indicator (0.4 percent). The average residential indicator for all of the communities was 1.0 percent.

Figure 3 presents the percent difference in residential indicators for each community indexed against the 16-city average. This figure represents the relative rate effort for each community. Currently, the City and the County are 17 percent below and 82 percent above the 16-city average, respectively.

It should be noted that rate comparisons between municipalities are difficult to interpret because of differences in rate structures, customer classes, system design and costs, and average water consumption. The purpose of the rate evaluation conducted for this assessment is to estimate the relative rate effort for each community compared to the rate efforts for the City and the County.

2.3 Unemployment Rates

Unemployment rates can be used to provide a general statement about the overall health of a community's economy. The historical unemployment rates from 1980 to 2003 for the City, Washington, and the U.S. are presented in Figure 4. According to statistics from the Bureau of Labor Statistics (2004), the City and the County report the same unemployment rate. Therefore, separate rates for the City and the County are not presented in Figure 4. The historical rate for the City has generally followed the overall trend for Washington, and it is typically higher than the national average. For a period from 1990 through 1996, while the U.S. was experiencing a slight downturn in the economy, the average annual unemployment rates for the City slipped below the national rates. In 2003, the unemployment rates for the City, Washington, and the U.S. were 6.8 percent, 7.5 percent, and 6.0 percent, respectively. Based on EPA guidelines (1997), an unemployment rate within 1 percent of the national average indicates that the City's economic climate is average and the potential financial burden would have a mid-range impact.

2.4 Poverty Level

The percent of the total population below the poverty level for the City, the County, and the U.S. are presented in Figure 5. According to the 2000 U.S. Census (U.S. Census Bureau, 2004), the City had a poverty rate of 15.9 percent, approximately 3.5 percentage points higher than the national average. The County reported a poverty level of 12.3 percent, approximately 0.1 percentage point less than the national average. The 2000 U.S. Census reported the poverty threshold for a four-member family with two members under the age of 18 was $16,895 (U.S. Census Bureau, 2003).

FIGURE 2
Residential Indicators for Surveyed Communities (2004)

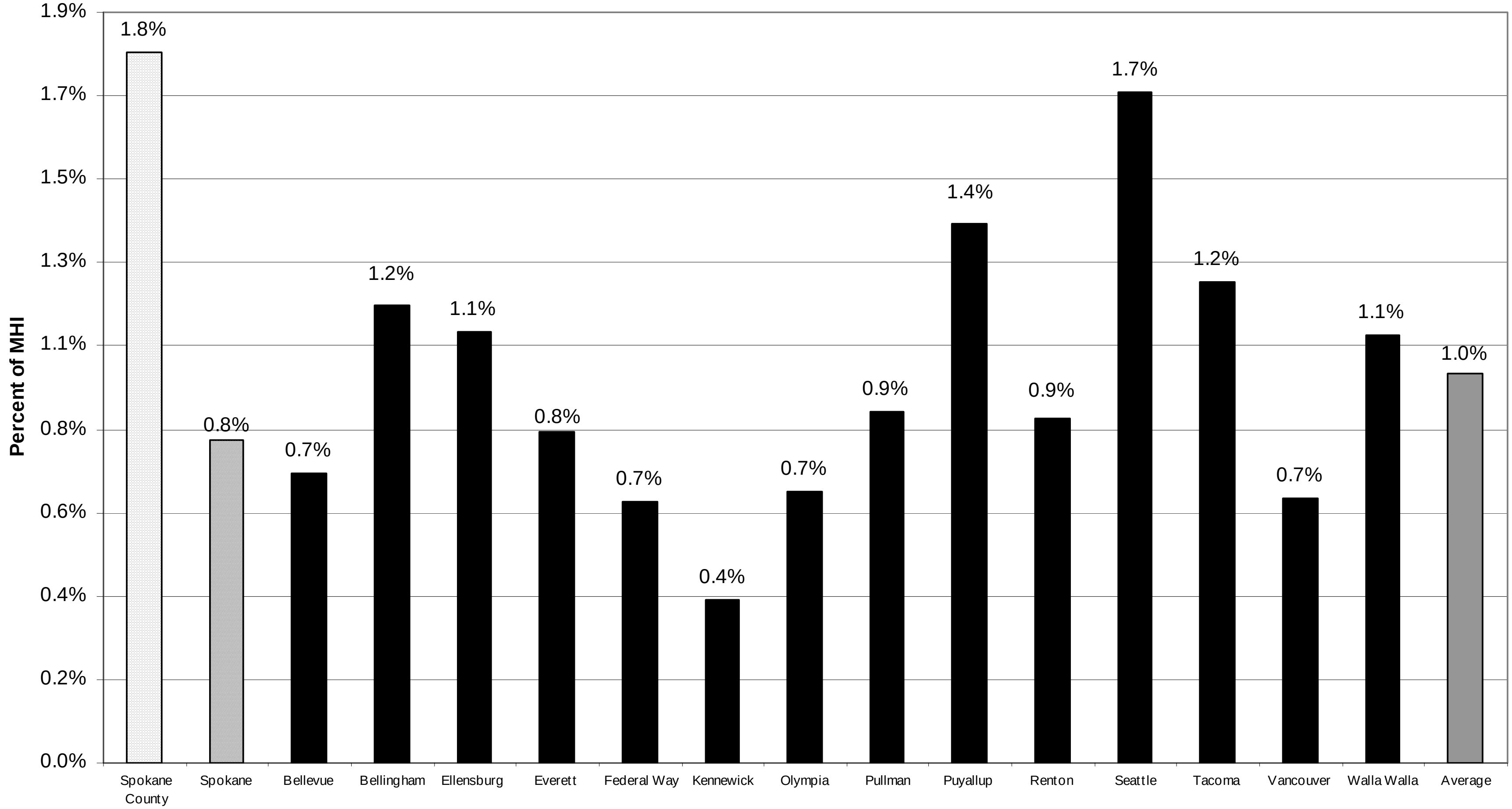


FIGURE 3
Percent Difference of Each Community's Residential Indicator against the Average of the Surveyed Communities (Relative Rate Effort; for example, Spokane County is 82 percent above the average.)

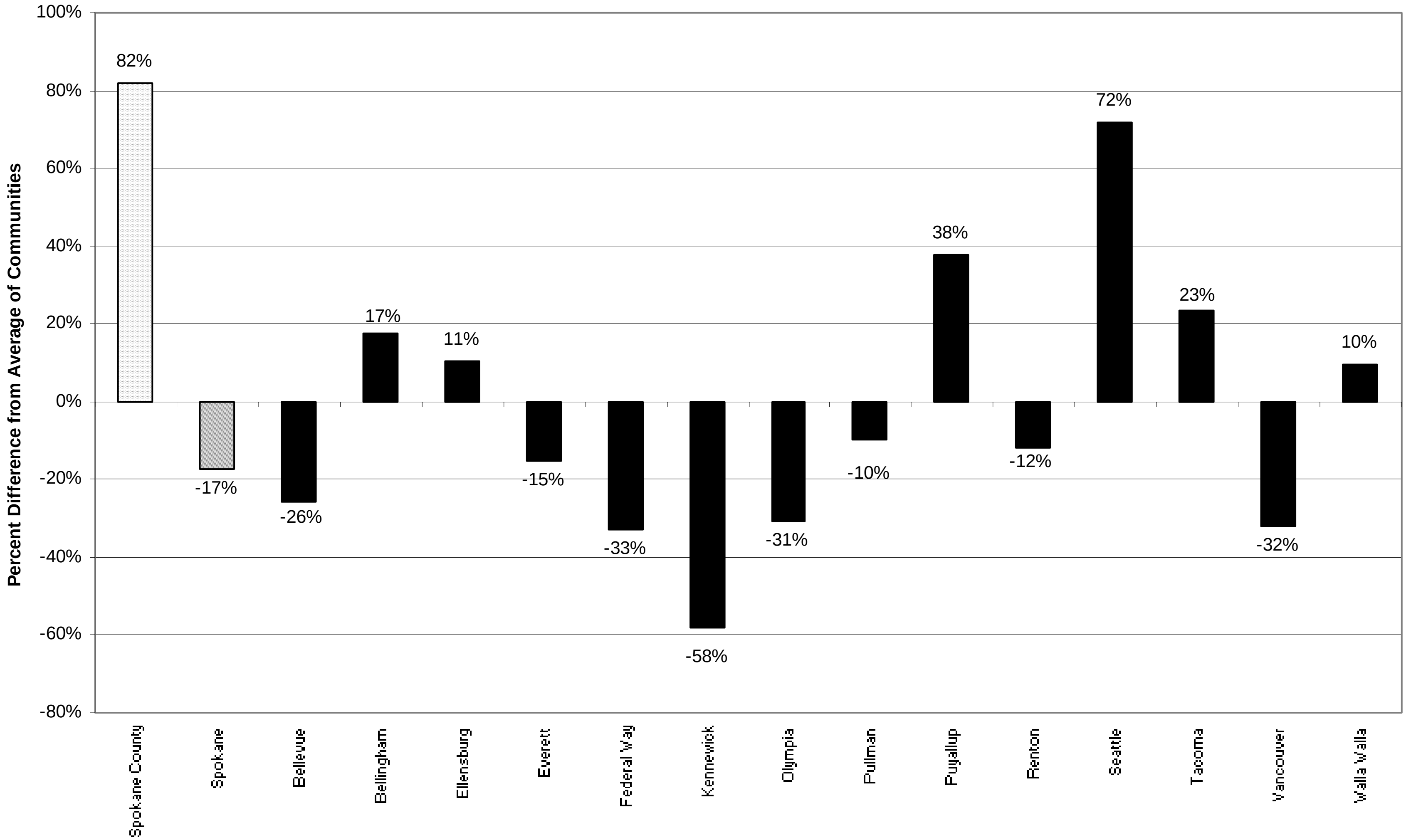
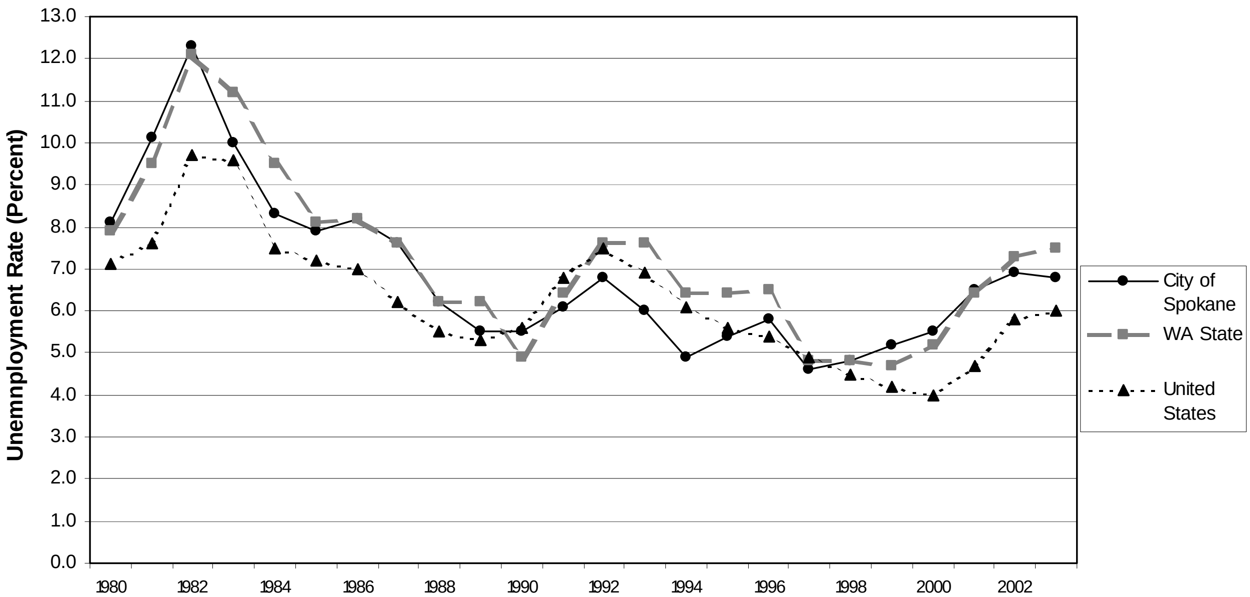
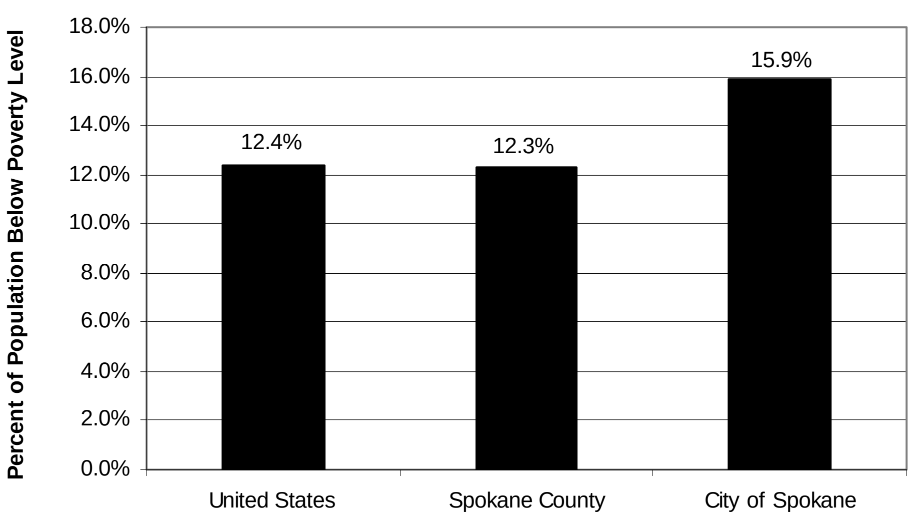


FIGURE 4
Historical Unemployment Rates for Spokane Metropolitan Statistical Area, Washington State, and the U.S. (1980-2003)



Source: Bureau of Labor Statistics (2004)

FIGURE 5
Percent of Total Population below Poverty Level, 2000 Census



Source: U.S. Census Bureau (2000)

3 Alternatives

CH2M HILL prepared a separate analysis of three wastewater treatment and effluent disposal alternatives for the City. These analyses are included in three separate appendixes of the Spokane River UAA report as follows:

- Appendix E1: Land Application of Reclaimed Water (CH2M HILL, 2004a)
- Appendix E2: Conceptual Design and Cost Estimate of Reverse Osmosis System for Phosphorus Removal from Secondary Effluent (CH2M HILL, 2004b)
- Appendix E3: Spokane Phosphorus Removal Costs (CH2M HILL, 2004c)

The analyses included an update to the City's facility plan cost estimate for final filtration with full year river discharge (Appendix E3), land application of wastewater during the period April through October (Appendix E1), and reverse osmosis (RO) treatment for the same period (Appendix E2). The County Public Works Department has an approved wastewater facilities plan for filtration with river discharge, and prepared a separate evaluation of the cost of land application of wastewater during the period April through October and the cost of RO treatment technologies (HDR Engineering, Inc., 2004). The results of the County's analysis were provided for this economic assessment and are contained in Appendix E4 of the Spokane River UAA. Cost estimates are order-of-magnitude estimates and are considered to be accurate to +50/-30 percent of actual costs. Total capital costs include the total price to build the facility, including all equipment, construction, land, and additions such as legal, engineering, contingency fees, and local sales tax. Cost opinions for O&M include labor, energy consumption, and additional supplies and chemicals. The costs have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimates. The final costs will depend on such criteria as actual labor and material costs, competitive market conditions, actual site conditions, final project scope, and other variables. For purposes of this analysis, it was assumed that the treatment plant improvements for both the City and the County would be operational in the year 2012.

The capital cost estimates for the proposed facilities for the existing City plant and the proposed new County regional plant are presented in Table 3. The City's capital costs range from $57.0 million for the final filtration alternative to $558.7 million for RO. Annual O&M costs range from $1.2 million for final filtration to $17.0 million for the RO facility. The County's capital costs range from $108.1 million for the final filtration alternative to nearly $191 million for RO. Annual O&M costs range from $5.0 million for final filtration to $7.9 million for the RO facility.

TABLE 3
Capital Cost Estimates for Proposed Facilities for the City of Spokane and Spokane County (2004$)

	City of Spokane			Spokane County[4,5]		
Costs	**Final Filtration[1]**	**Land Application[2]**	**Reverse Osmosis[3]**	**Final Filtration**	**Land Application**	**Reverse Osmosis**
Capital	$57.0 million	$404.7 million	$558.7 million	$108.1 million	$161.6 million	$190.9 million

Capital costs represent estimated expenditures by the City and County. They are not adjusted for the allocation of costs between the City and County for that portion of the City Reclamation Plant that Spokane County will pay.

Footnotes:

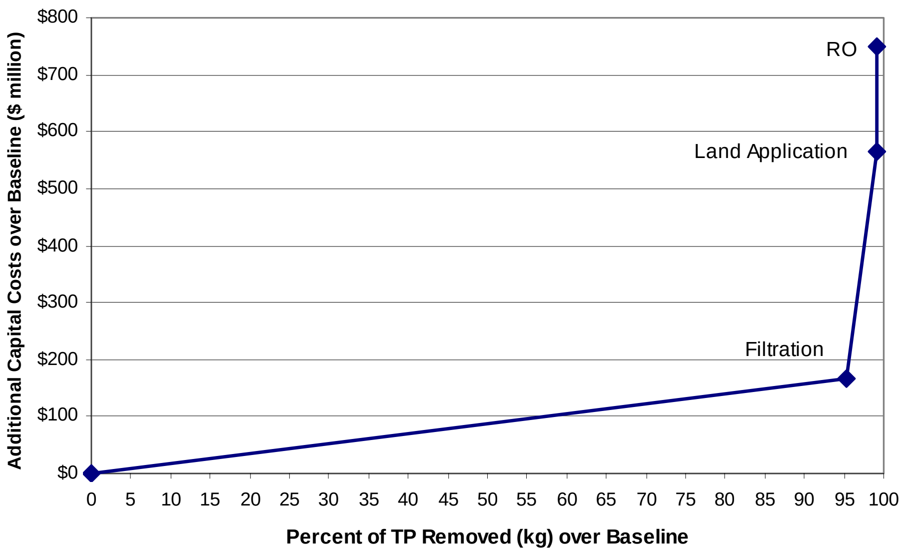
[1] CH2M HILL, 2004c (Appendix E3).
[2] CH2M HILL, 2004a (Appendix E1).
[3] CH2M HILL, 2004b (Appendix E2).
[4] HDR Engineering, Inc., 2004 (Appendix E4).
[5] Capital costs provided by Bruce Rawls, Spokane County Utilities Director. These capital costs are for an 8 million gallons per day (mgd) plant and include, for the land application and RO alternatives, costs for a facility plan amendment and an environmental assessment.

The cost of the land application of wastewater assumes that net irrigation requirements published in the State of Washington Irrigation Guide (U.S. Department of Agriculture, Soil Conservation Service, 1990) could be used in the design of the facility. Without leaching or assumed sprinkler efficiencies, an additional 2,564 to 8,060 acres of land would be required, as well as the associated equipment to operate the expanded facility. The additional capital cost is estimated to range from $32.0 million to $122.0 million. Thus, the land application alternative could range in capital cost from $566 million to $688 million, depending on whether leaching of salts would be permitted. This assessment has used the lower range of these estimates to demonstrate the impact of these capital costs on sewer rates and MHI.

4 Total Phosphorus/Dissolved Oxygen

Figure 6 presents the percent of TP removed from the Spokane River over existing conditions as well as the capital costs for each of the alternatives. The capital costs are the combined totals of the estimated costs for the City and the County alternatives and represent additional capital costs over existing conditions. Filtration is expected to remove approximately 95 percent of the remaining TP at a capital cost of $165 million. Land application and RO would have capital costs of $566 million and $750 million, respectively, and would remove 99 percent of TP from the Spokane River. The City's wastewater facility, and the County's proposed regional wastewater facility, could attain the load allocations presented in the Spokane River UAA Report using filtration technology. Land Application and RO technologies would be required to attain the load allocations in Ecology's proposed TMDL (2004e).

FIGURE 6
Percent of Total Phosphorus Removed from the Spokane River over Baseline Conditions



Note: The capital cost of the land application alternative could range from $566 to $688 million, depending on whether leaching of salts would be permitted. This assessment has used the lower range of these estimates to demonstrate the impact of these capital costs on sewer rates and median household income.

Table 4 presents absolute dissolved oxygen (DO) levels for current conditions and for the final filtration and the land application/RO concentrations. It was assumed that the land application would achieve zero point source discharge of phosphorus on a seasonal basis and that RO would achieve a concentration below 0.01 mg/L phosphorus, thus approaching zero seasonal discharge. The epilimnion zone was not included in this analysis since DO levels, while remaining above the proposed Washington surface water quality standard of

8.0 mg/L, decrease slightly under each alternative. This is because algae productivity (oxygen production) declines with reductions in TP.

TABLE 4
Dissolved Oxygen Levels by Alternative

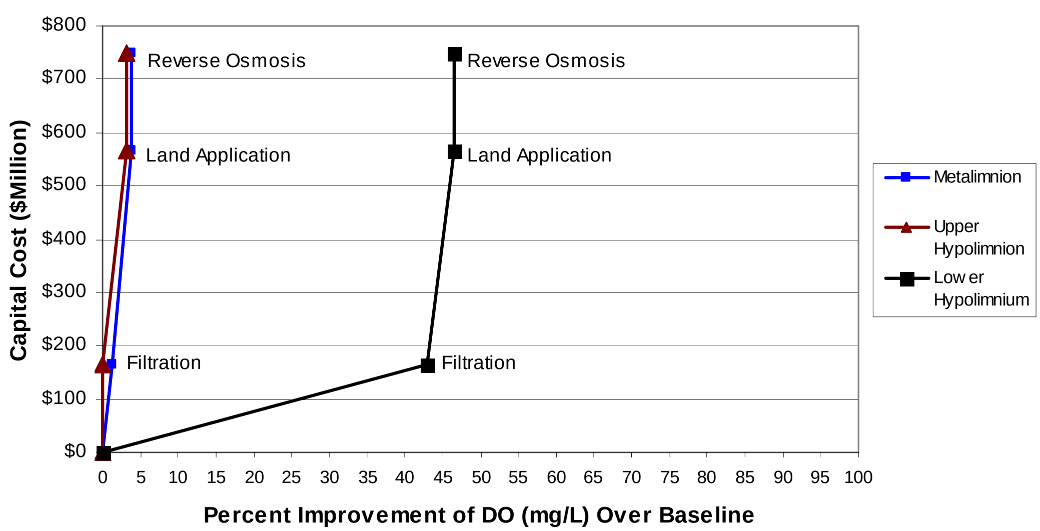
	Absolute Values (mg/L)			Percent Change from Current Conditions	
Zone	Current	Final Filtration	Land Application/ Reverse Osmosis	Final Filtration	Land Application/ Reverse Osmosis
Metalimnion	7.8	7.9	8.1	1%	4%
Upper Hypolimnion	6.5	6.5	6.7	0%	3%
Lower Hypolimnion	2.8	4.0	4.1	43%	46%

mg/L = milligrams per liter

Source: CH2M HILL analyses of CE-QUAL-W2 output data provided by Limno-Tech, Inc.

The information in Table 4 was used to generate Figure 7, which presents the percent improvement of DO over baseline for each alternative. The capital cost for each alternative was included to indicate the efficiency of each alternative. For example, the metalimnion zone in Long Lake Reservoir experienced improved levels of DO under the filtration and land application/RO alternatives of 1 percent and 4 percent, respectively.

FIGURE 7
Percent Improvement of Dissolved Oxygen over Baseline by Alternative



Note: The capital cost of the land application alternative could range from $566 to $688 million, depending on whether leaching of salts would be permitted. This assessment has used the lower range of these estimates to demonstrate the impact of these capital costs on sewer rates and median household income.

Figures 6 and 7 show that point source reductions beyond 95 percent removal of TP do not significantly increase DO levels in the reservoir. Nonpoint, internal recirculation, and natural sources of TP are the dominating factors related to existing DO levels. Even if 100 percent of TP removal was achieved via any of the proposed alternatives, the DO levels in the reservoir would still not meet the Washington surface water quality standard of 8.0 mg/L proposed by Ecology (2004e). In addition, neither the land application alternative nor the RO alternative would significantly improve the DO levels beyond filtration technologies.

It would be an inefficient use of public resources to require the City and the County to spend the additional hundreds of millions of dollars to implement land application or RO facilities while not achieving significant marginal benefits over the least-cost alternative. In addition, land application of effluent would likely cause a decrease in summer river flows and could potentially reduce the DO levels in the reservoir.

Initial investigations of aeration in the reservoir suggest that aeration, when used in conjunction with filtration, could provide significant benefits to the DO levels in the reservoir and should be investigated further. A combination of aeration and reducing phosphorus discharge using filtration technology may be the most economically efficient means of protecting existing and attainable beneficial uses in the river.

5 Rate Sensitivity Analysis

The City and the County each conducted a financial analysis to estimate the sensitivity of rates to capital costs associated with implementing the proposed alternatives. The analyses incorporated capital costs, estimated changes to O&M costs, and assumptions regarding debt financing. All of the analyses assumed that the new facilities would be operational by 2012. The City conducted its analysis in constant 2004 dollars. The sensitivity of the residential sewer rate under each alternative was compared to the City's 2004 MHI to calculate the revised residential indicator. The County, by contrast, conducted its analysis in 2012 dollars. In order to calculate the revised residential indicator for the County based on the implementation of each alternative, the County's 2004 MHI was inflated by an annual escalation factor of 2.4 percent to estimate the County's 2012 MHI. Whether using 2004 constant dollars or 2012 inflated values, the residential indicator allows for consistent assessment of household income sensitivity to sewer rates and the affordability of each alternative. Questions regarding the calculations of the rate for each alternative should be directed to the City's Public Works and Utilities Department or the County's Public Works Department.

Table 5 presents the estimated cost per household ratepayer or equivalent and the residential indicator for each alternative. The City would experience a 62 percent increase under the final filtration alternative, a 195 percent increase under the land application alternative, and a 284 percent increase under the RO alternative. The County would experience increases of 19 percent, 38 percent, and 64 percent under the final filtration, land application, and RO alternatives, respectively.

As discussed previously, a residential indicator of less than 1.0 percent of MHI is considered a low financial impact under EPA guidelines. A residential indicator between 1.0 and 2.0 percent of MHI is considered a mid-range financial impact, and a residential indicator of greater than 2.0 percent of MHI is considered a high financial impact. The City is expected to experience a mid-range impact under the final filtration alternative and a high impact under the land application and RO alternatives. The County would experience mid-range financial impacts under the final filtration alternative and high financial impacts under the land application and RO alternatives.

Figure 8 presents the residential indicators for the City and the County under current conditions and under each of the proposed alternatives except for the City's RO alternative. The average residential indicator for the 16 communities under current conditions is also included. The City's residential indicator increases from 0.8 percent under current conditions to 2.4 percent under the land application alternative and 3.1 percent under the RO alternative. The County's residential indicator increases from 1.8 percent under current conditions to 2.0 percent under the land application alternative and 2.4 percent under the RO alternative.

TABLE 5
Estimated 2012 Sewer Rates

	Final Filtration		Land Application		Reverse Osmosis	
	Monthly Sewer Estimated Rate	**% of MHI**	**Monthly Sewer Estimated Rate**	**% of MHI**	**Monthly Sewer Estimated Rate**	**% of MHI**
City of Spokane	$39.05	1.3%	$71.05	2.4%	$92.50	3.1%
Spokane County	$72.54	1.8%	$84.15	2.0%	$100.10	2.4%

Notes:

1) Estimated rates for the City are in 2004 Dollars
2) Estimated rates for the County are in 2012 Dollars.
3) Estimated MHI for City of Spokane in 2004 = $35,495
4) Estimated MHI for Spokane County in 2012 = $49,634
5) Estimated sewer rates for the City of Spokane under the RO alternative could range from $90 to $95 per month. The midpoint of the range ($92.50) was used for this analysis.
6) Estimated sewer rates for Spokane County include the following charges: Capital Facilities charge, O&M charge, and Rate Stabilization charge
7) The capital costs of the land application alternative could range from $566 to $688 million, depending on whether leaching of salts would be permitted. This assessment has used the lower range of these estimates to demonstrate the impact of these capital costs on sewer rates and median household income.

Figure 9 displays the percentage difference of the residential indicators indexed against the 16-city average under current conditions. When compared to the average of all 16 cities, the City's residential indicator moves from 17 percent less than the 16-city average residential indicator under current conditions to 218 percent greater than the average if the RO alternative was implemented. When compared to the average residential indicator, the RO alternative would raise the County's indicator from 82 percent greater than the 16-city average residential indicator (under the current conditions) to 146 percent greater than the average.

Table 6 presents the estimated residential indicators by household income distribution for the City and the County. A range is presented to illustrate the estimated annual sewer bills as a percentage of MHI for each income level. The highlighted cells indicate which segments of the population would be designated as having rates that cause financial hardship under Ecology's guidelines (2004i).

FIGURE 8
Annual Average Sewer Bill as a Percent of MHI (Residential Indicator) after Implementation of Proposed Alternatives

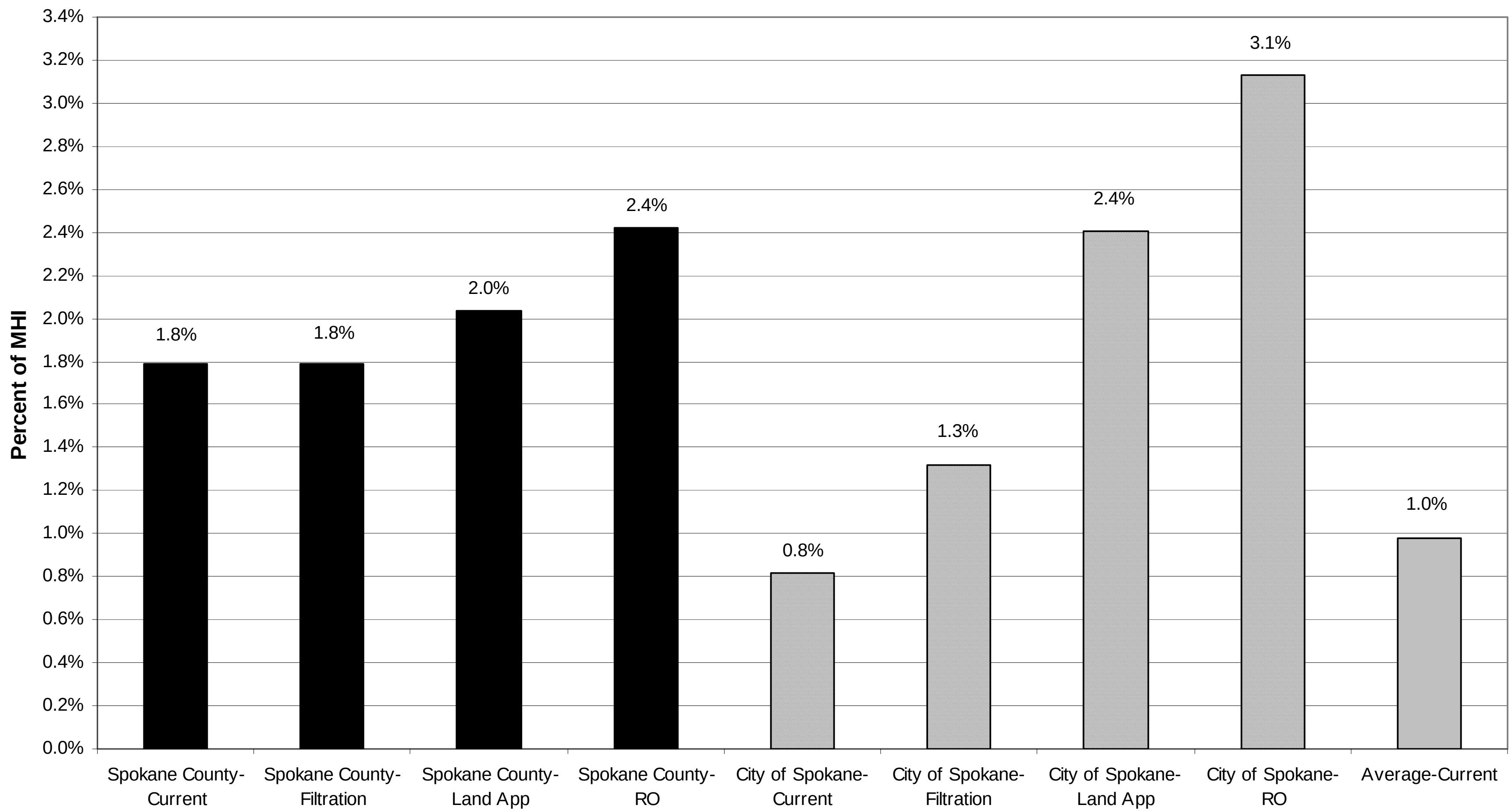


FIGURE 9
Percentage Difference of the City and County's Residential Indicator after Implementation of Proposed Alternatives against the Average of the Surveyed Communities

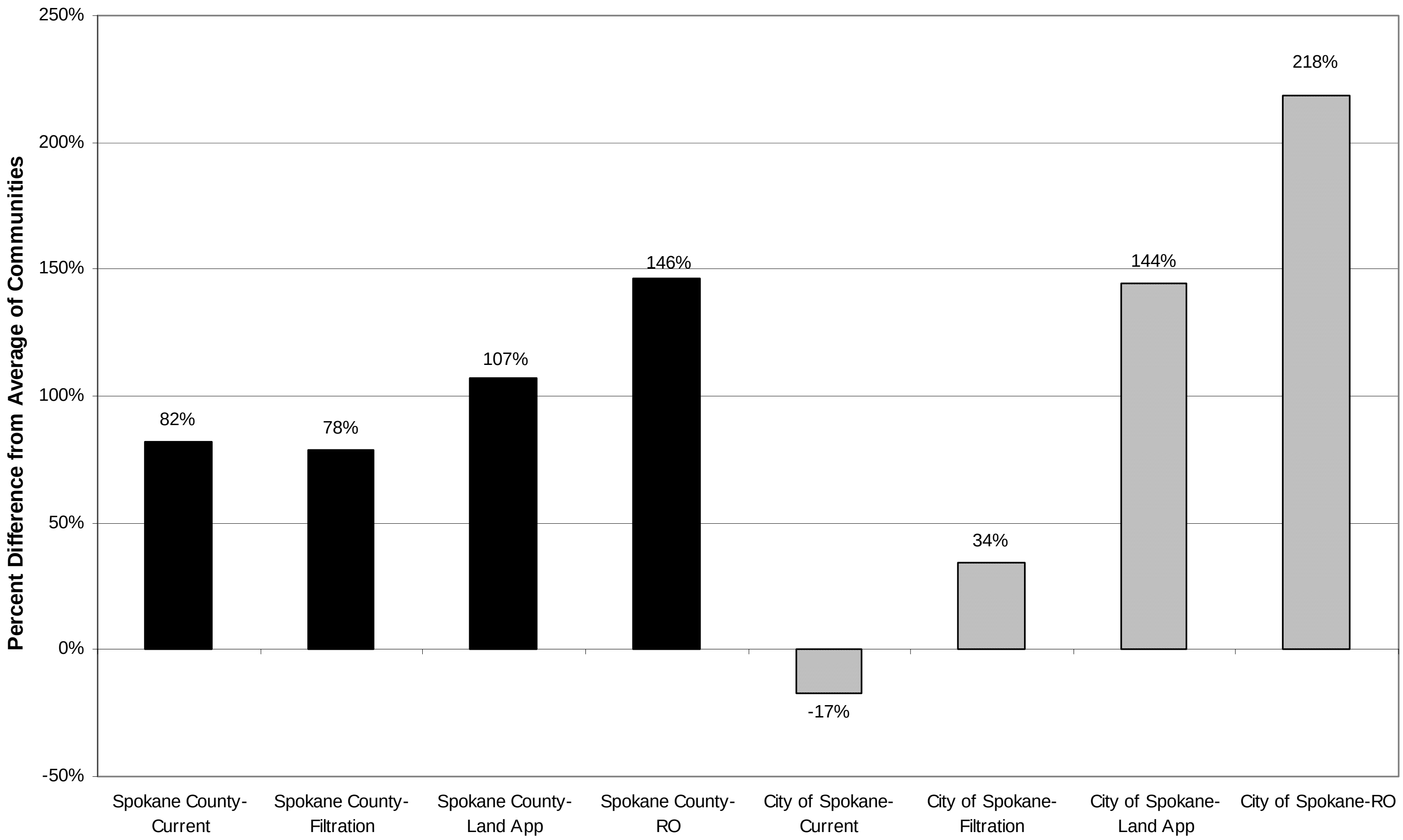


TABLE 6
Estimated Residential Indicator by Household Income Distribution Levels

Income Level	Distribution	Cumulative[1]	Current	Filtration	Land Application	Reverse Osmosis
City of Spokane			**Residential Indicator Range by Alternative**			
Less than $15,000	21.4%	21.4%	> 1.9%	> 3.1%	>5.7%	>7.4%
$15,000 to $24,999	16.3%	37.7%	1.9% to 1.2%	3.1% to 1.9%	5.7% to 3.4%	7.4% to 4.4%
$25,000 to $34,999	15.9%	53.6%	1.2% to 0.8%	1.9% to 1.3%	3.4% to 2.4%	4.4% to 3.2%
$35,000 to $49,999	16.6%	70.2%	0.8% to 0.6%	1.3% to 0.9%	2.4% to 1.7%	3.2% to 2.2%
$50,000 to $74,999	16.7%	86.9%	0.6% to 0.4%	0.9% to 0.6%	1.7% to 1.1%	2.2% to 1.5%
$75,000 to $99,999	6.6%	93.5%	0.4% to 0.3%	0.6% to 0.5%	1.1% to 0.9%	1.5% to 1.1%
$100,000 to $144,999	4.3%	97.9%	0.3% to 0.2%	0.5% to 0.3%	0.9% to 0.6%	1.1% to 0.7%
Over $150,000	2.1%	100%	<0.2%	<0.3%	<0.6%	<0.7%
Spokane County						
Less than $15,000	17.2%	17.2%	> 4.9%	> 5.8%	> 6.7%	> 8.0%
$15,000 to $24,999	15.0%	32.2%	4.9% to 2.9%	5.8% to 3.5%	6.7% to 4.0%	8.0% to 4.8%
$25,000 to $34,999	14.6%	46.7%	2.9% to 2.1%	3.5% to 2.5%	4.0% to 2.9%	4.8% to 3.4%
$35,000 to $49,999	17.5%	64.3%	2.1% to 1.5%	2.5% to 1.7%	2.9% to 2.0%	3.4% to 2.4%
$50,000 to $74,999	19.3%	83.6%	1.5% to 1.0%	1.7% to 1.2%	2.0% to 1.3%	2.4% to 1.6%
$75,000 to $99,999	8.5%	92.1%	1.0% to 0.7%	1.2% to 0.9%	1.3% to 1.0%	1.6% to 1.2%
$100,000 to $144,999	5.4%	97.5%	0.7% to 0.5%	0.9% to 0.6%	1.0% to 0.7%	1.2% to 0.8%
Over $150,000	2.5%	100%	< 0.5%	< 0.6%	< 0.7%	< 0.8%

Source: U.S. Census Bureau (2004); City of Spokane Public Works and Utilities Department (2004) and Spokane County Public Works Departments (2004)

[1] Cumulative numbers may not add to total due to rounding.
[2] Shaded areas indicate a residential indicator that would qualify for financial hardship under Ecology funding guidelines (2004i).
[3] The capital cost of the land application alternative could range from $566 to $688 million, depending on whether leaching of salts would be permitted. This assessment has used the lower range of these estimates to demonstrate the impact of these capital costs on sewer rates and median household income.

6 Financial Capacity

The previous sections of this economic assessment discuss the affordability of the alternatives as well as the effectiveness of each alternative in achieving improved DO levels in the reservoir. The discussion that follows introduces additional information relevant to the City's and the County's ability to fund additional capital projects.

- The City has been relying on money saved from previous years to balance the next year's budget. However, City leaders are anticipating a very small cash reserve from 2004. The City has recently submitted its 2005 budget, and the declining cash reserves are evident in the reduction of services. The budgeting process resulted in the reduction of more than 100 positions throughout the City's General Fund departments, including approximately 24 and 56 positions in the police and fire departments, respectively. Given the City's current financial situation, it would not be prudent to place additional financial burden on the City and its ratepayers by implementing either the land application alternative or the RO alternative.
- The implementation of the land application alternative might not be feasible because of water rights impairments, the potential for groundwater contamination, and legal difficulties related to acquiring private land either through willing sellers or through condemnation outside of Spokane County.
- The County's financial analysis assumes that the rate stabilization portion of their monthly charge would increase for the RO alternative from $4.00 to $26.00 in one step (in year 2005). This scenario is unlikely, since elected officials are generally unwilling to place such a large burden on ratepayers over a 1-year period. A more likely scenario would include incremental increases over a period of years until the required revenue stream was achieved. This delay in increasing the rates, however, would require a larger overall rate increase than the one reflected in the analysis in order for the utility to recover the uncollected revenues from the early years. The overall higher rate would increase the residential indicator for the County higher than reported in this analysis, and would likely result in a high financial impact to the ratepayers.
- Financing mechanisms for the County to implement the projects would also be limited. The rate impact analysis for the County assumed General Obligation (GO) bonds as its source of financing for costs exceeding the current State Revolving Fund Loan from Ecology. Implementing the RO alternative would require the County to maximize its GO bond capacity. It is highly unlikely that County officials would commit the County's entire GO capacity for one project. Revenue bonds would be another financing alternative. However, because of bond financing coverage requirements, the required rate increases would be higher under this funding mechanism. These rates would place the project at a higher rate impact than that used in this analysis, going beyond financial feasibility.

7 Conclusions

The following conclusions can be derived from the economic assessment:

- The final filtration, land application, and RO alternatives achieve nearly the same results in DO improvement in Long Lake Reservoir, indicating that other sources (including nonpoint and natural sources) are significant contributors to current levels of DO. Mitigating the effects of nonpoint sources of phosphorus through aeration in combination with implementing filtration technology to reduce point source loading of phosphorus to the river may be the most cost effective way to protect existing and attainable beneficial uses of the river and meet downstream water quality standards.
- The land application and RO alternatives cost considerably more than the final filtration alternative and place a high financial burden on the ratepayers of the City, the County, and other dischargers, exceeding accepted measures of affordability.
- The land application alternative is not significantly more effective in mitigating DO, yet it is far more expensive than final filtration.
- Implementing either the land application alternative or the RO alternative would not be an effective or efficient use of resources.

This order-of-magnitude assessment of the economic impacts of the alternatives clearly documents that neither the City nor the County can affordably implement either the land application alternative or the RO alternative. Further refinement of this assessment would not appear to produce any different outcomes.

8 References

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CH2M HILL. 2004b. Conceptual Design and Cost Estimate of Reverse Osmosis System for Phosphorus Removal from Secondary Effluent. November 9, 2004. (Appendix E2 of the Spokane River UAA.)

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Report

Part 5: Appendixes

(included in Volume II)

Spokane River and Long Lake Reservoir Use Attainability Analysis

Prepared for

Spokane River UAA Sponsoring Committee

December 2004

Prepared by

CH2MHILL

Contents

Appendixes (included in Volume II of the Spokane River UAA)

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- A1 Summary of and Responses to Comments Received on Draft Spokane River UAA (Issued June 2004)
- A2 Summary of and Responses to Comments Received on Revised Advisory Committee Draft Spokane River UAA (Issued August 2004)
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B Checklist of UAA Elements

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D Results of Applying the Spokane River CE-QUAL-W2 Model in Support of Use Attainability Analyses

- D1 Results of Applying the Spokane River CE-QUAL-W2 Model in Support of Use Attainability Analyses Report
- D2 TMDL Model Parameters for Updated Next Level of Treatment Table
- D3 Additional Charts of LTI CE-QUAL-W2 Modeling Results for Year 2001

E Economic Assessment Background Materials

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- E2 Conceptual Design and Cost Estimate of Reverse Osmosis System for Phosphorus Removal from Secondary Effluent
- E3 Spokane Phosphorus Removal Costs
- E4 Spokane County Preliminary Evaluation of Land Application

F Advanced Wastewater Treatment Technology Evaluation Workshop (August 24, 2004)

G Resumes of Spokane River UAA Project Team