Snake River - Hells Canyon

Total Maximum Daily Load (TMDL)

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Abstract

The federal Clean Water Act requires that states and tribes restore and maintain the chemical, physical, and biological integrity of the nation's waters (33 USC § 1251.101). For waters identified as not meeting water quality standards and listed as impaired according to Section 303(d) of the Clean Water Act, states and tribes must develop a total maximum daily load (TMDL) for the pollutants causing impairment, set at a level to achieve water quality standards. The Snake River – Hells Canyon TMDL has been developed to comply with Idaho and Oregon's responsibilities within the Clean Water Act and state-specific TMDL schedules. This TMDL describes the physical, biological, and cultural setting; water quality status; pollutant sources; and recent pollution control actions in the Snake River – Hells Canyon Subbasin located in southwestern Idaho and eastern Oregon. This TMDL consists of three major sections: 1) subbasin assessment, 2) loading analysis and allocation, and 3) water quality management or implementation plan(s).

The scope of the this TMDL extends from where the Snake River intersects the Oregon/Idaho border near Adrian, Oregon (Snake River mile (RM) 409) to immediately upstream of the inflow of the Salmon River (RM 188) (Hydrologic Unit Codes (HUCs) 17050115, 17050201 and 17060101, and a small corner of 17050103). This includes the Hells Canyon Complex reservoirs: Brownlee, Oxbow and Hells Canyon. The overall reach has been divided into smaller segments based on similar hydrology, pollutant delivery and processing mechanisms, and operational, management or implementation strategies. These include the following: the *Upstream Snake River* segment which extends from where the river intersects the Oregon/Idaho border near Adrian, Oregon (RM 409), downstream to Farewell Bend (RM 335). The *Brownlee Reservoir segment* includes Brownlee Reservoir from Farewell Bend (RM 335) to Brownlee Dam (RM 285). The *Oxbow Reservoir* segment includes Oxbow Reservoir from the outflow of Brownlee Reservoir below Brownlee Dam (RM 285) to Oxbow Dam (RM 272.5). The *Hells Canyon Reservoir* segment includes Hells Canyon Reservoir from the outflow of Oxbow Reservoir below Oxbow Dam (RM 272.5) to Hells Canyon Dam (RM 247). The *Downstream Snake River* segment includes the Snake River from below Hells Canyon Dam (RM 247) to immediately upstream of the Salmon River inflow (RM 188). Within these segments all designated beneficial uses and all listed pollutants from both states have been addressed by the TMDL with the exception of mercury. The following summary identifies the basic findings of the assessment and analysis process.

Bacteria. The Snake River is listed from RM 409 to 347 for bacteria. Analysis has shown that bacteria 303(d) listings are not indicated given the available data. Designated uses are not impaired due to elevated bacteria levels within any of the listed segments. Based on these findings, the TMDL recommends that the mainstem Snake River from RM 409 to 347 be delisted for bacteria by the State of Idaho.

Mercury. The Snake River is listed from RM 409 to 188 for mercury. The mercury TMDL for the Snake River- Hells Canyon reach has been postponed to 2006 in a US EPA approved action due to the fact that essentially no water column data are currently available to this effort.

Nutrients, Nuisance Algae and Dissolved Oxygen. The Snake River is listed from RM 409 to 272.5 for nutrients. Available data show excessive total phosphorus concentrations in the Upstream Snake River segment (RM 409 to 335) of the SR-HC reach. Nuisance algae blooms have been observed to occur routinely in the Upstream Snake River segment and the upstream sections of Brownlee Reservoir. Site-specific chlorophyll *a* and total phosphorus targets (less than 14 ug/L and less than or equal to 0.07 mg/L respectively) were identified by the TMDL. These targets are seasonal in nature and apply from May through September. Attainment of these targets is projected to result in a reduction of roughly 50 percent in algal biomass (as measured by chlorophyll *a*) that in turn will result in improvement in dissolved oxygen concentrations in both the Upstream Snake River and Brownlee Reservoir segments. The TMDL assigns waste load allocations to direct point source dischargers to the Snake River operating mechanical treatment plants to reduce discharge concentrations by 80 percent. Lagoon discharges will assess the feasibility of changing to land application or biological nutrient removal and implementation objectives will be assessed on a case by case basis. Nonpoint source discharges will be required to reduce to the 0.07 mg/L level. Inflowing tributaries have been assigned load allocations to meet the 0.07 mg/L total phosphorus target at their inflow to the Snake River. A load allocation for the addition of 1,125 tons of dissolved oxygen per season has been assigned to Idaho Power Company to offset reduction in assimilative capacity caused by the Hells Canyon Complex impoundments.

Pesticides. The Snake River is listed for pesticides from RM 285 to 272.5 (Oxbow Reservoir). Pesticides of concern are DDT and dieldrin, both of which are banned and no longer in use in the United States. TMDL targets were identified as less than 0.024 ng/L water column concentration DDT, less than 0.83 ng/L water column concentration DDD, less than 0.59 ng/L water column concentration DDE, and less than 0.07 ng/L water column concentration dieldrin. All available samples showed t-DDT fish tissue concentrations that exceeded the EPA screening level; no samples showed dieldrin fish tissue concentrations that exceeded the EPA screening level. All water column samples exhibited levels above the TMDL targets for both DDT and dieldrin. Load allocations for new application of these banned compounds are zero. Load allocations for legacy application and transport of DDT were established at less than 0.31 kg/year for RM 409 to 335 and less than 0.33 kg/year for Brownlee and Oxbow Reservoirs. Load allocations for legacy application and transport of dieldrin were established at less than 0.88 kg/year for RM 409 to 335 and less than 1.0 kg/year for Brownlee and Oxbow Reservoirs. These load allocations represent the sum of allowable point and nonpoint source-related loading. Pesticide targets apply year-round.

pH. The Snake River is listed for pH from RM 409 to 347 and from RM 335 to 285. Analysis has shown that pH 303(d) listings are not indicated given the available data. No exceedences were observed to occur from RM 409 to 335. Less than 1 percent exceedence was observed in the Brownlee Reservoir segment data. Based on these findings, the TMDL recommends that the mainstem Snake River from RM 409 to 347 and from RM 335 to 285 be delisted for pH by the State of Idaho.

Sediment. The Snake River is listed for sediment from RM 409 to 272.5. The TMDL has established targets of no more than 50 mg/L total suspended solids (TSS) as a monthly average and less than or equal to 80 mg/L TSS for no more than 14 days to protect aquatic life uses. Load allocations to meet the TMDL targets have been established for those tributaries and nonpoint sources (drains) that exceed target values at their inflow to the Snake River.

Temperature. The Snake River is listed from RM 409 to 188 for temperature. Elevated summer water temperatures have been measured in both the Upstream Snake River segment near Weiser, Idaho (RM 351), in the Hells Canyon Complex reservoirs, and in the Downstream Snake River segment prior to the construction of the dams. To address salmonid rearing temperature exceedences, point sources discharging directly to the Snake River within the SR-HC TMDL reach have been allocated heat loads corresponding to discharge loads applied to design flows to ensure that the no-measurable-increase requirements will be met. A waste load allocation for future point sources of no-measurable-increase has been identified as part of this TMDL. A gross nonpoint source temperature load allocation has been established at no greater than 0.14 ^{o}C for nonpoint sources in the SR-HC TMDL reach. A gross nonpoint source temperature load allocation has been established at no greater than 0.14 ^{o}C for tributaries in the SR-HC TMDL reach. These allocations apply at the inflow to the Snake River in the SR-HC TMDL reach, during those periods of time that the site-potential temperature in the mainstem Snake River is greater than 17.8 ^{o}C. A temporal shift in water temperatures exiting Hells Canyon Dam is observed during the late fall and winter months; the decline in temperature in the fall is delayed from that observed immediately upstream of the Hells Canyon Complex. While the temporal distribution of this temperature shift is due to the delay in flow caused by water moving through the Hells Canyon Complex, the actual heat load (warmer water) is not. The impoundments are not a heat source. Sources of elevated water temperature include natural, non-quantifiable and anthropogenic sources upstream of the Hells Canyon Complex and similar sources on inflowing tributaries. To address elevated temperatures occurring during salmonid spawning periods below Hells Canyon Dam, a temperature load allocation in the form of a required temperature change at Hells Canyon Dam was identified such that the temperature of water released from Hells Canyon Dam is less than or equal to the water temperature at RM 345, or the maximum weekly maximum temperature target of 13 °C for salmonid spawning, plus no greater than 0.14 ^{o}C.

Total Dissolved Gas. Total dissolved gas, while not a 303(d) listed pollutant, was addressed in the TMDL due to a direct request by members of the Public Advisory Team. Spill at Brownlee and Hells Canyon Dams is the source of elevated total dissolved gas within the lower SR-HC TMDL reach. A load allocation for total dissolved gas has been assigned to the Hells Canyon Complex that applies to each location where spill occurs (i.e. a load allocation of less than 110 percent of saturation applies to Oxbow Reservoir to address the effects of spill from Brownlee Dam, a load allocation of less than 110 percent of saturation applies to Hells Canyon Reservoir to address the effects of spill from Oxbow Dam, and a load allocation of less than 110 percent maximum saturation applies to the Downstream Snake River segment to address the effects of spill from Hells Canyon Dam).

It is recognized that the SR-HC TMDL addresses an extremely complex system that includes a combination of diverse natural, point, and nonpoint pollutant sources. The system has been highly modified from its original condition through the placement and operation of impoundments; surface water diversions and drains; upstream and tributary modifications for hydropower production, irrigation storage, flood control and recreational use; and a variety of other anthropogenic activities. Data is available for some pollutants to determine whether the water quality standards are met, however, for other pollutants there is only limited data that does not conclusively show that the waters are impaired by such pollutants.

This TMDL has therefore adopted a phased approach to implementation that will identify interim, measurable milestones to determine the effectiveness of management measures or other action controls being implemented, and a process for reviewing and revising management approaches to assure effective management measures are implemented. Agencies responsible for the preparation and approval of the SR-HC TMDL (US EPA, ODEQ and IDEQ) recognize that long time-frames (potentially 50 to 70 years) may be required for water all quality standards to be consistently met.

The Implementation Plan submitted contains two separate, state-specific plans: the State of Oregon General Water Quality Management Plan and the State of Idaho General Implementation Plan. Together, these documents represent the general water quality management plan (implementation plan) for the SR-HC TMDL. In addition to the implementation plan submitted for the mainstem SR-HC TMDL reach, tributary plans will also be prepared as part of tributary TMDL processes. These plans will be prepared according to the appropriate state-specific schedules under which they are identified. It is also expected that information will continue to be collected to fill existing data gaps and allow a more accurate determination of the status of designated beneficial uses within the SR-HC TMDL reach and the influence of pollutants delivered to and processed by the system.

Executive Summary

The federal Clean Water Act (CWA) requires that states and tribes restore and maintain the chemical, physical, and biological integrity of the nation's waters (33 USC § 1251.101). States and tribes, pursuant to section 303 of the CWA are to adopt water quality standards necessary to protect fish, shellfish, and wildlife while providing for recreation in and on the waters whenever possible. Section 303(d) of the CWA establishes requirements for states and tribes to identify and prioritize water bodies that are water quality limited (i.e., water bodies that do not meet water quality standards). States and tribes must periodically publish a priority list of impaired waters, currently every two years. For waters identified on this list, states and tribes must develop a total maximum daily load (TMDL) for the pollutants causing impairment, set at a level to achieve water quality standards. This document addresses the water bodies in the Snake River – Hells Canyon (SR-HC) Subbasin that have been placed on what is known as the "303(d) list."

This subbasin assessment and SR-HC TMDL analysis is a joint effort between the Idaho Department of Environmental Quality (IDEQ) and the Oregon Department of Environmental Quality (ODEQ), with participation by the US Environmental Protection Agency (US EPA) and local stakeholders.

What is a TMDL?

A TMDL is the amount of a particular pollutant that a specific stream, lake, river or other waterbody can tolerate without violating state water quality standards.

In this framework, a TMDL can be best described as a watershed or basin-wide budget for pollutant loading to a waterbody. A TMDL, in actuality, is a planning document. The "allowable budget" is first determined by scientific study of a stream to determine the amount of pollutants that can be assimilated without causing the stream to exceed the water quality standards set to protect the stream's designated beneficial uses (e.g., fishing, domestic water supply, etc.). This amount of pollutant loading is known as the *loading capacity*. It is established taking into account seasonal variations, natural and background loading, and a margin of safety. Once the loading capacity is determined, sources of the pollutants are considered. Both *point* and *nonpoint sources* must be included (US EPA, 1991b).

POINT SOURCES

Point sources of pollution are defined as discreet conveyances (e.g. pipes) that discharge directly into waterbodies, such as discharges associated with wastewater treatment plants. A point source is simply described as a discrete discharge of pollutants as through a pipe or similar conveyance.

NONPOINT SOURCES

Nonpoint sources, such as farms, lawns, or construction sites contribute pollution diffusely through run-off. Examples are sheet flow from pastures and runoff from forest logging. Nonpoint sources may include (but are not limited to), run-off (urban, agricultural, forestry, etc.), leaking underground storage tanks, unconfined aquifers, septic systems, farms, lawns, construction sites, stream channel alteration, and damage to a riparian area.

Once all the sources are accounted for, the pollutants are then allocated or budgeted among the sources in a manner that will describe the total maximum pollutant load that can be discharged into the river without causing the water quality standards to be exceeded. Ultimately the responsibility for improving water quality lies on the shoulders of everyone who lives, works or recreates in a watershed that drains into an impaired waterbody.

LOAD ALLOCATIONS

Load allocations are simply the amounts of pollutants that can be discharged from each source or category and still ensure that the total pollutant load does not exceed the loading capacity. The TMDL does not specify how the dischargers must attain their particular load allocation. The TMDL will not set best management practices for a discharger or otherwise tell the discharger how to meet their goal; it merely sets their goal.

Nonpoint sources are grouped into a "load allocation" (LA) and point sources are grouped into a "wasteload allocation" (WLA). By federal regulation, the total load capacity “budget” must also include a "*margin of safety*" (MOS). The "MOS" accounts for uncertainty in the loading calculation. The MOS may not be the same for different waterbodies due to differences in the availability and strength of data used in the calculations. The margin of safety cannot be "traded".
All together,

Loading Capacity = **TMDL** = **WLAs** + **LAs** + **Margin of Safety**.

The (point source) waste load allocation is implemented through an existing regulatory program under the federal Clean Water Act (CWA) called the National Pollutant Discharge Elimination System (NPDES) permit program. These permits set effluent quality limitations and require implementation of best available technologies that may include specific best management practices already established by the US EPA through regulation. Provided that a viable trading framework is in place, pollutant trading is allowed between, or within, the load allocation and the wasteload allocation categories.

In most cases, pollution load data already exists for most permitted point sources through the NPDES permitting process. Similar data are seldom available for nonpoint sources. Therefore, the TMDL process must develop similar load calculations for nonpoint sources of pollution, and for natural sources of pollution. In many circumstances, nonpoint source contributions will be broken down into additional categories, such as agriculture, development, forestry, or mining. Because it is difficult to identify specific nonpoint sources of pollution, it is unlikely that data will be collected on individual nonpoint sources (or landowners) along a waterbody. Instead, most TMDLs focus on estimating the cumulative or combined contribution of all nonpoint sources along a waterbody.

TMDLs generally consist of three major sections:
1) subbasin assessment,
2) loading analysis, and
3) water quality management or implementation plan(s).

SUBBASIN ASSESSMENT

A subbasin assessment describes the affected area, the water quality concerns and status of beneficial uses of individual water bodies, nature and location of pollution sources, and a summary of past and ongoing pollution control activities.

LOADING ANALYSIS

Loading analysis provides the estimate of a waterbody's pollutant load capacity, a margin of safety, and allocations of load to pollutant sources defined as the TMDL. Allocations are required for each permitted point sources and categories of non-point sources whose sum will meet the load capacity with load to spare as a margin of safety. Minor non-point sources may receive a lumped allocation. Generally a loading analysis is required for each pollutant of concern. But it is recognized that some listed pollutants are really water quality problems that are the result of other pollutants. For example, habitat affected by sediment or dissolved oxygen affected by nutrients causing nuisance aquatic growths. In these cases one listed stressor may be addressed by the loading reduction of another.

A complete loading analysis lays out a general pollution control strategy and an expected time frame in which water quality standards will be met. Long recovery periods (greater than five years) are expected for TMDLs dealing with non-point sediment or temperature sources. Interim water quality targets are recommended in these instances. Along with the load reductions, these targets set the sideboards in which specific actions are scheduled in the subsequent implementation plan.

WATER QUALITY MANAGEMENT OR IMPLEMENTATION PLAN

The implementation plan is guided by the TMDL and provides details of actions needed to achieve load allocations, a schedule of those actions, and follow up monitoring to document progress or provide other desired data. Implementation plans specify the local actions that lead to the goal of full support of designated beneficial uses. Important elements of these plans are:

- Implementation actions based on the load allocations identified in the TMDL
- An estimated time by which water quality standards are expected to be met, including interim goals or milestones as deemed appropriate
- A schedule specifying, what, where, and when actions to reduce loads are to take place
- Identification of who will be responsible for undertaking each planned action
- A plan specifying how accomplishments of actions will be tracked
- A monitoring plan to refine the TMDL and/or document attainment of water quality standards

To fulfil the requirements of the State of Oregon TMDL process, an implementation plan will be submitted to the US EPA with the SR-HC TMDL. IDEQ guidance states that a TMDL implementation plan should be developed within eighteen months of the approval of the TMDL it is intended to support and supplement. Because of this difference in procedure, a general implementation plan is being submitted with the SR-HC TMDL and other, more specific plans will be prepared and submitted according to the appropriate IDEQ or ODEQ schedule and procedure. Together, these documents will represent the general water quality management plan (implementation plan) for the SR-HC TMDL.

Snake River - Hells Canyon TMDL General Information

This TMDL has been developed to comply with Idaho and Oregon's TMDL schedule. This assessment describes the physical, biological, and cultural setting; water quality status; pollutant sources; and recent pollution control actions in the SR-HC Subbasin located in southwestern Idaho and eastern Oregon.

The first part of SR-HC TMDL, the subbasin assessment, is an important first step leading to the TMDL. The starting point for this assessment was Idaho's and Oregon's current 303(d) lists of water quality limited water bodies. Seven Idaho segments and four Oregon segments (corresponding to the same stretch of the Snake River) of the SR-HC Subbasin were identified on this list. The subbasin assessment portion of this document examines the current status of 303(d) listed waters, and defines the extent of impairment and causes of water quality limitation throughout the subbasin. The loading analysis quantifies pollutant sources and allocates responsibility for load reductions needed to return listed waters to a condition meeting water quality standards.

PUBLIC PARTICIPATION

Throughout the SR-HC TMDL process, local experience and participation have been and will continue to be invaluable in the identification of water-quality issues and reduction strategies appropriate on a local scale. During the initial stages of the SR-HC TMDL process, a structured public involvement program was established that included both local stakeholders and technical, agency personnel. This program was established so members of the local communities could provide direction and leadership in developing and implementing this plan. The public committee created is known as the SR-HC Public Advisory Team (PAT). The SR-HC PAT provides an opportunity for concerned citizens, representing a number of stakeholder groups, to see the SR-HC TMDL process through from start to finish.

Categories for stakeholder representation were identified by IDEQ and ODEQ according to state-specific protocols. Nominations for potential seatholders in each of these interest categories were solicited from the general public through letters to local governments, organizations, stakeholder groups, individuals, and watershed councils in both Oregon and Idaho. Generally, one representative from each state was selected from the nominations received to represent each area of interest. An alphabetical listing of the final stakeholder seats within the SR-HC PAT follows:

- Hydropower Interests
- Idaho Agricultural Interests
- Idaho Environmental Interests
- Idaho Local Government Interests
- Idaho Municipal Interests
- Idaho Public at Large
- Idaho Sporting/Recreational Interests
- Idaho Timber/Forestry Interests
- Industrial Interests
- Oregon Agricultural Interests
- Oregon Environmental Interests
- Oregon Local Government Interests

- Oregon Municipal Interests
- Oregon Public at Large
- Oregon Sporting/Recreational Interests
- Oregon Timber/Forestry Interests
- Other Idaho Interests
- Other Oregon Interests
- Tribal Interests – Nez Perce
- Tribal Interests – Shoshone/Paiute

The SR-HC PAT functions as an advisory body to the DEQs on SR-HC TMDL and implementation matters within the DEQ responsibilities outlined above. SR-HC PAT members help to identify contributing pollutant sources, advise the DEQs in arriving at equitable pollutant reduction allocations, and recommend specific actions needed to effectively control sources of pollution. Additionally, SR-HC PAT seatholders represent a critical mechanism in disseminating information to their respective interest groups, and relaying concerns and advice from these interest groups to the DEQs.

At the initial meetings of the SR-HC PAT, it was determined that due to the large geographical area of the SR-HC TMDL reach and the associated watershed, and the fact that the interests represented by separate SR-HC PAT seatholders may be divergent in their consideration of, and position on, some issues, the SR-HC PAT would not operate under a consensus-based process. The seatholders and the interagency team members (ODEQ and IDEQ) decided that there should be an opportunity for the submission (formally or informally) to the public record of opinions different from that of the SR-HC PAT in general, or to the approach, philosophy or methodology used by the DEQs in the formulation of the SR-HC TMDL.

In accordance with this decision, an informal record of differences in opinion on issues discussed is available to the public in the minutes from SR-HC PAT meetings, and in the listing of informal comments by SR-HC PAT members on initial drafts of the SR-HC Subbasin Assessment (and other sections of the SR-HC TMDL document as they become available) compiled by the DEQs. This information is available on request from the Cascade Satellite Office of IDEQ, PO Box 247, Cascade, ID 83611; and from the Pendleton Office of ODEQ, 700 SE Emigrant, Pendleton, OR 97801.

Subbasin at a Glance

The scope of the SR-HC TMDL extends from where the Snake River intersects the Oregon/Idaho border near Adrian, Oregon (Snake River mile (RM) 409) to immediately upstream of the inflow of the Salmon River (RM 188) (Hydrologic Unit Codes (HUCs) 17050115, 17050201 and 17060101, and a small corner of 17050103). This includes the Hells Canyon Complex reservoirs: Brownlee, Oxbow and Hells Canyon. Figure A shows the geographical scope of this TMDL.

Because of the extensive scope of this TMDL (RM 409 to 188), the overall SR-HC TMDL reach has been divided into smaller subsections or segments based on similar hydrology, pollutant delivery and processing mechanisms, and operational, management or implementation strategies.

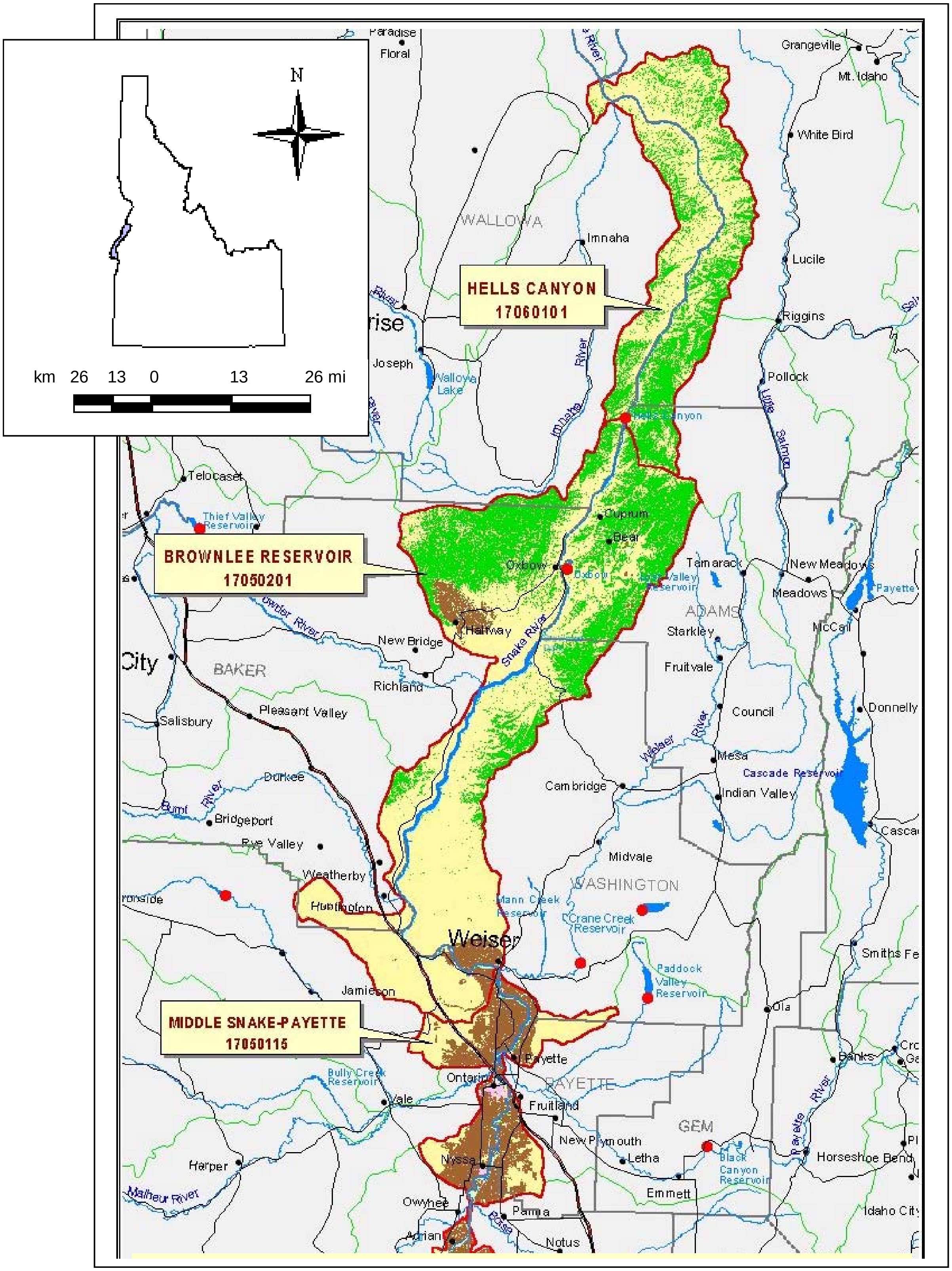


Figure A. Geographical scope of the Snake River – Hells Canyon TMDL

The five segments are:

- Upstream Snake River (RM 409 to 335, 74 miles total)
- Brownlee Reservoir (RM 335 to 285, 50 miles total)
- Oxbow Reservoir (RM 285 to 272.5, 12.5 miles total)
- Hells Canyon Reservoir (RM 272.5 to 247, 25.5 miles total)
- Downstream Snake River (RM 247 to 188, 59 miles total)

Figure B shows the separate segments as identified within the SR-HC TMDL reach.

The Upstream Snake River segment (RM 409 to 335) includes the riverine section of the Snake River upstream of the reservoir impoundments. It extends from where the river intersects the Oregon/Idaho border near Adrian, Oregon (RM 409), downstream to Farewell Bend (RM 335). All of the major tributary inflows to the SR-HC TMDL reach (with the exception of the Burnt and Powder rivers) enter the mainstem river within this segment. The vast majority of agricultural and urban/suburban land use occurs within the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach. Flow within this segment is primarily driven by snowmelt and seasonal precipitation events, upstream and tributary impoundments, and irrigation diversions and returns. The 303(d) listed pollutants in this segment include bacteria, dissolved oxygen, mercury, nutrients, pH, sediment and temperature (1998 303(d) list).

The Brownlee Reservoir segment (RM 335 to 285) includes Brownlee Reservoir from Farewell Bend through the Brownlee Dam. While Brownlee Reservoir contains three fairly distinct hydrological regions: the riverine zone near the tailwaters (roughly RM 335 to 315), the transition zone (roughly RM 315 to 305), and the lacustrine zone (RM 305 to 285); water management and water quality concerns are well correlated with the reservoir boundaries. Total reservoir volume is 1,420,000 acre-feet. Flow into Brownlee Reservoir is made up of the outflow of the Upstream Snake River segment (RM 409 to 335), and the Burnt and Powder rivers that flow into Brownlee Reservoir at RM 327.5 and RM 296 respectively. However the inflow of these two tributaries is relatively minor when compared with the inflow from the Upstream Snake River segment, representing less than 2% of the combined total. Flow and residence time within the reservoir are controlled by the outflow through Brownlee Dam. Average residence time is 34 days, however, with consideration of the additional internal processes of stratification, depth of withdrawal, flood control requirements and management for power generation, the residence time in different parts of the reservoir can vary considerably. Listed pollutants in this segment include dissolved oxygen, mercury, nutrients, pH, sediment and temperature (1998 303(d) list).

The Oxbow Reservoir segment (RM 285 to 272.5) includes Oxbow Reservoir from the outflow of Brownlee Reservoir below Brownlee Dam to Oxbow Dam. The reservoir is much smaller than Brownlee Reservoir and has an average retention time of only 1.4 days. Flow into Oxbow Reservoir is almost exclusively the outflow of Brownlee Reservoir. Wildhorse River, which flows directly into the reservoir near the Brownlee Dam, constitutes less than 1% of the total inflow. Total reservoir volume is 57,500 acre-feet. Flow and residence time within the reservoir are controlled by the releases from Brownlee Dam and the releases from Oxbow Dam. Oxbow Reservoir is not operated for flood control. Due to its relatively small size, highly controlled inflow and outflow, and short residence time, water management and water quality concerns in

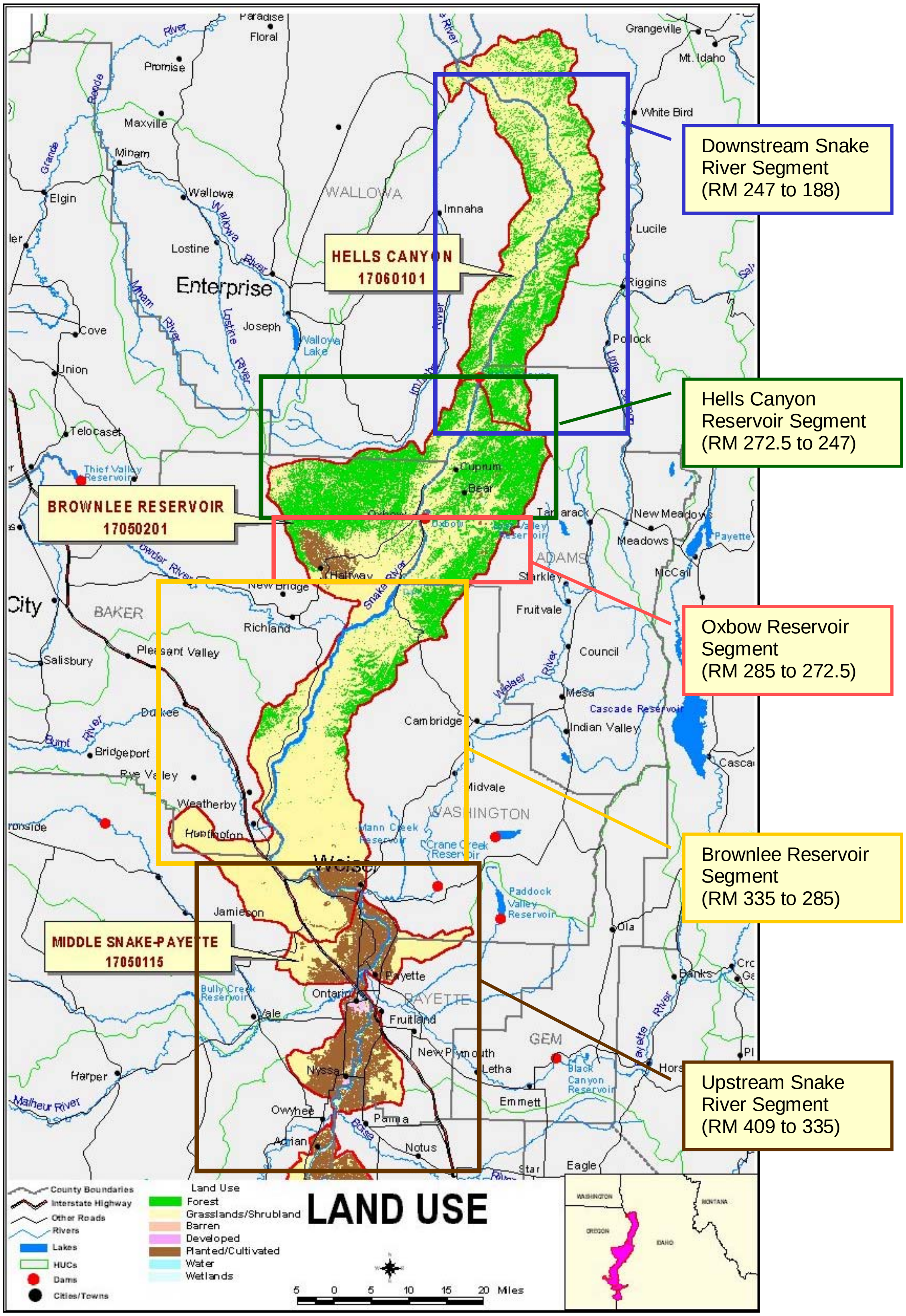


Figure B. Snake River – Hells Canyon TMDL segments.

this segment are well correlated with water quality upstream in Brownlee Reservoir. Listed pollutants in this segment include mercury, nutrients, pesticides, sediment and temperature.

The Hells Canyon Reservoir segment (RM 272.5 to 247) includes Hells Canyon Reservoir from the outflow of Oxbow Reservoir below Oxbow Dam to Hells Canyon Dam. This segment is also fairly small and fast flowing with a total volume of 170,000 acre-feet and has an average retention time of 4 days. Flow into Hells Canyon Reservoir is almost exclusively the outflow of Oxbow Dam. Pine Creek, which flows directly into the reservoir near the Oxbow Dam, constitutes less than 1% of the total inflow. The releases from Oxbow Reservoir and the releases from Hells Canyon Dam control flow and residence times within the reservoir. Hells Canyon Reservoir is not operated for flood control. Due to its relatively small size, highly controlled inflow and outflow, and short residence time, water management and water quality concerns in this segment are well correlated with water quality upstream in Brownlee and Oxbow Reservoirs. Listed pollutants in this segment include mercury and temperature (1998 303(d) list).

The Downstream Snake River segment (RM 247 to 188) includes the Snake River from below Hells Canyon Dam to immediately upstream of the Salmon River inflow. This segment is a rapid flowing, narrow river characterized by steep canyon walls and stretches of white water. The flow and volume of this segment are almost completely driven by the outflow of the Hells Canyon Complex reservoirs, and support substantial recreational uses year round. Listed pollutants in this segment include mercury and temperature (1998 303(d) list).

PARAMETERS (POLLUTANTS) OF CONCERN AND DESIGNATED BENEFICIAL USES

As this TMDL is a bi-state effort, the final document must meet the needs of both Oregon and Idaho. In order to accomplish this, all designated uses and listed pollutants from both states must be addressed by the TMDL. Therefore, the SR-HC TMDL addresses all listed pollutants from both Idaho’s 303(d) list and Oregon’s 303(d) list. These designated beneficial uses and the parameters of concern are listed in Tables A-1 and A-2.

KEY INDICATORS OF IMPAIRMENT

Designated beneficial use impairment and target exceedences have been identified to the extent possible given the available data set. Table B lists the pollutants from the 303(d) lists of Idaho and Oregon and the key indicators of impairment associated with each pollutant. Both quantitative (measured data) and qualitative (observations of system characteristics) methods were used in the evaluation of designated use support. Information on the occurrence of impairment indicators is included in Table B on a segment-specific basis. The information listed in Table B represents the current level of understanding of beneficial use impairment and system dynamics within the SR-HC TMDL reach. The phased implementation approach and iterative nature of the TMDL process will allow further refinement of the identified designated use impairment as additional data are collected and understanding of the system dynamics improves.

POLLUTANT SOURCES

Many, varied sources of pollutant loading have been identified within the SR-HC Subbasin. In some cases sources can contribute directly to exceedences of water quality targets (as in the case of excessive nutrient loading causing nuisance algae blooms. In other cases, pollutant sources

Table A-1. Idaho segment specific listing information for the Snake River - Hells Canyon TMDL reach.

Segment	Idaho 303(d) Listed Pollutants	Idaho Designated Beneficial Uses
Snake River: RM 409 to 396.4 Upstream Snake River (OR/ID border to Boise River Inflow)	(downstream from ID border) bacteria, dissolved oxygen, nutrients, pH, sediment	(downstream from ID border) cold water aquatic life primary contact recreation domestic water supply
Snake River: RM 396.4 to 351.6 Upstream Snake River (Boise River Inflow to Weiser River Inflow)	bacteria, nutrients, pH, sediment	cold water aquatic life primary contact recreation domestic water supply
Snake River: RM 351.6 to 347 Upstream Snake River (Weiser River Inflow to Scott Creek Inflow)	bacteria, nutrients, pH, sediment	cold water aquatic life primary contact recreation domestic water supply
Snake River: RM 347 to 285 Brownlee Reservoir (Scott Creek to Brownlee Dam)	dissolved oxygen, mercury, nutrients, pH, sediment	cold water aquatic life primary contact recreation domestic water supply special resource water
Snake River: RM 285 to 272.5 Oxbow Reservoir	nutrients, sediment, pesticides	cold water aquatic life primary contact recreation domestic water supply special resource water
Snake River: RM 272.5 to 247 Hells Canyon Reservoir	not listed	cold water aquatic life primary contact recreation domestic water supply special resource water
Snake River: RM 247 to 188 Downstream Snake River (Hells Canyon Dam to Salmon River Inflow)	temperature	cold water aquatic life salmonid spawning primary contact recreation domestic water supply special resource water

Table A-2. Oregon segment specific listing information for the Snake River - Hells Canyon TMDL reach.

Segment	Oregon 303(d) Listed Pollutants	Oregon Designated Beneficial Uses
Snake River: RM 409 to 395 Upstream Snake River (Owyhee Basin)	mercury, temperature	Public/private domestic water supply industrial water supply irrigation water, livestock watering salmonid rearing and spawning* (trout) resident fish (warm water) and aquatic life water contact recreation wildlife and hunting fishing, boating, aesthetics

Segment	Oregon 303(d) Listed Pollutants	Oregon Designated Beneficial Uses
Snake River: RM 395 to 335 Upstream Snake River to Farewell Bend (Malheur Basin)	mercury, temperature	Public/private domestic water supply industrial water supply irrigation water, livestock watering salmonid rearing and spawning* (trout) resident fish (warm water) and aquatic life water contact recreation wildlife and hunting fishing, boating, aesthetics
Snake River: RM 335 to 260 Brownlee Reservoir Oxbow Reservoir Upper half of Hells Canyon Reservoir (Powder Basin)	mercury, temperature	public/private domestic water supply industrial water supply irrigation water, livestock watering salmonid rearing and spawning* resident fish and aquatic life water contact recreation wildlife and hunting fishing, boating, aesthetics hydropower
Snake River: RM 260 to 188 Lower half of Hells Canyon Reservoir Downstream Snake River (Grande Ronde Basin)	mercury, temperature	public/private domestic water supply industrial water supply irrigation water, livestock watering salmonid rearing and spawning (downstream) resident fish and aquatic life water contact recreation wildlife and hunting fishing, boating, aesthetics anadromous fish passage commercial navigation and transport

Table B. Key indicators of impairment specific to listed pollutants for the Snake River - Hells Canyon TMDL.

Parameter	Indication of Impairment
Bacteria	Site-specific data showing concentrations greater than 126 *E coli* organisms per 100 mL as a 30 day log mean with a minimum of 5 samples OR samples greater than 406 *E coli* organisms per 100 mL. In the absence of site-specific data, key indicators of bacteria problems include illness in primary contact recreation users. • No segments of the SR-HC TMDL reach were found to exhibit these conditions.
Dissolved Oxygen (DO)	Site-specific data showing concentrations less than 6.5 mg/L water column where cool water aquatic life/salmonid rearing is the designated use for the State of Oregon or cold water aquatic life is the designated use for the State of Idaho. Less than 8 mg/L water column DO where cold water aquatic life is the designated use for the State of Oregon, less than 11 mg/L water column DO or intergravel DO lower than 8 mg/L when and where salmonid spawning is a designated use for either state. In the absence of site-specific dissolved oxygen data, key indicators of dissolved oxygen problems include fish kills, anaerobic sediments and lack of support for aquatic life uses. • The portions of the Snake River upstream of RM 409 were shown to exhibit dissolved oxygen concentrations below those required to support salmonid spawning and incubation. Water quality and substrate conditions in the

Parameter	Indication of Impairment
	Upstream Snake River segment (RM 409 to 335) parallel conditions upstream where dissolved oxygen violations were observed. • The Brownlee Reservoir segment (RM 335 to 285) was shown to exhibit dissolved oxygen target exceedences.
Mercury (Hg)	Site-specific data showing concentrations greater than 0.012 ug/L water column concentration total mercury and/or greater than 0.35 mg/kg methylmercury in fish tissue, and fish tissue advisories based on consumption concerns. • Fish in the Upstream Snake River segment (RM 409 to 335) were shown to exhibit exceedences of the fish tissue targets • Fish in the Brownlee Reservoir segment (RM 335 to 285) were shown to exhibit exceedences of the fish tissue targets
Nutrients Nuisance Algae	Key indicators of nutrient problems include excessive algae growth and associated dissolved oxygen and pH problems. For the State of Oregon, exceedence of 15 ug/L chlorophyll *a* (a surrogate for algae mass) indicates that there is potentially a problem with excessive nutrient loading. Chlorophyll *a* concentrations greater than 15 ug/L trigger an evaluation to determine the level of impairment. This TMDL represents that evaluation for the SR-HC TMDL reach. • Excessive algae blooms are observed to occur in the Upstream Snake River segment (RM 409 to 335) (see dissolved oxygen) • Excessive algae blooms are observed to occur in the upstream sections of Brownlee Reservoir (see dissolved oxygen)
Pesticides	Site-specific data showing water column concentrations of greater than 0.024 ng/L DDT, 0.83 ng/L DDD, 0.59 ng/L DDE, and/or 0.07 ng/L Dieldrin. • Fish in the Upstream Snake River segment (RM 409 to 335) were shown to exhibit exceedences of the fish tissue action levels. A very small data set shows water column target exceedences. Sediment concentrations are at levels of concern. • Fish in the Brownlee Reservoir segment (RM 335 to 285) were shown to exhibit exceedences of the fish tissue targets. Sediment concentrations are at levels of concern.
pH	Site-specific data showing pH measurements less than 7 and/or greater than 9 pH units In the absence of site-specific pH data, key indicators of pH problems include fish kills and lack of support for aquatic life uses. • No segments of the SR-HC TMDL reach were found to exhibit these conditions.
Sediment (Total Suspended Solids (TSS))	Site-specific data showing concentrations greater than 80 mg TSS/L for acute events lasting more than 14 days, and/or greater than 50 mg TSS/L monthly average In the absence of site-specific data, key indicators of sediment problems include lack or degradation of spawning habitat, population decline, feeding problems, gill and scale problems and reduced growth rates. • Duration data are not available to make a direct assessment of target exceedence. Habitat concerns exist in the Upstream Snake River and upstream Brownlee Reservoir segments. • The primary concern associated with sediment in this TMDL is as a transport mechanism for mercury, pesticides and nutrients. Sediment acts as an indicator of transport and delivery potential within the system.
Temperature	Cold water Aquatic Life/Salmonid Rearing: Site-specific data showing water temperatures with greater than a 0.14 ^{o}C increase

Parameter	Indication of Impairment
	from anthropogenic sources when the site potential is greater than 17.8 °C Salmonid Spawning: A maximum weekly maximum temperature of 13 °C (when and where salmonid spawning occurs) if and when the site potential is less than a maximum weekly maximum temperature of 13 °C. If and when the site potential is greater than a maximum weekly maximum temperature of 13 °C, the target is no more than a 0.14 °C increase from anthropogenic sources. Applicable to RM 247 to 188 only, from October 23rd to April 15th for fall chinook, and from November 1st to March 30th for mountain whitefish. Or site-specific data showing water temperatures with greater than a 0.14 °C increase from anthropogenic sources when aquatic species listed under the Endangered Species Act are present and a temperature increase would impair the biological integrity of the Threatened and Endangered population. In the absence of site-specific data, key indicators of temperature problems include fish kills, lack or loss of habitat, unsuccessful spawning and reduced growth rates. • Exceedences of the temperature target for cold water aquatic life and salmonid rearing occur to some degree during June, July, August and September throughout the SR-HC TMDL reach. • These exceedences were determined to be primarily due to natural and non-quantifiable conditions. Exceedences were observed historically in the Upstream Snake River segment (RM 409 to 335) and in the reservoir segments before the impoundments were in place. • Exceedences of the temperature target for salmonid spawning occur to some degree during mid-October in the Downstream Snake River segment (RM 247 to 188).
Total Dissolved Gas (TDG)	Site-specific data showing concentrations greater than 110% total dissolved gas saturation In the absence of site-specific data, key indicators of total dissolved gas problems include gas bubble disease in fish. • Exceedences of the total dissolved gas target are observed to occur in Oxbow, Hells Canyon reservoirs and in the Downstream Snake River segment during periods of spill.

can contribute indirectly to water quality target exceedences (as in the case of sediment transporting mercury within the subbasin, or algae growth leading to dissolved oxygen sags). To the extent possible, pollutant sources have been identified within the SR-HC Subbasin, however, some sources may not have been identified and, with the collection of additional data, some sources currently identified may be found to contribute less of a load than assessed. The sources listed in Table C represent the current level of understanding of pollutant loading, transport and delivery to the SR-HC TMDL reach. The phased implementation approach and iterative nature of the TMDL process will allow further refinement of the identified sources as our understanding of the system improves.

Key Findings

The SR-HC TMDL reach is a very complex system exhibiting varying hydrology, pollutant processing and transport characteristics, and anthropogenic influences. In many cases the data

Table C. Pollutant sources within the Snake River - Hells Canyon TMDL reach.

Parameter	Pollutant Source
Bacteria	No segments of the SR-HC TMDL reach were found to exceed the targets. While there may be sources of bacteria in the subbasin, they are not currently observed to be contributing to designated use impairment in the SR-HC TMDL reach.
Dissolved Oxygen (DO)	• Point sources discharging phosphorus into the Upstream Snake River segment (RM 409 to 335), including municipal, stormwater and industrial discharges • Nonpoint sources including agriculture, stormwater, and natural loading • Tributary inflows to the SR-HC TMDL reach • Reduced assimilative capacity due to impoundments
Mercury (Hg)	• Point source discharges may be sources of mercury; no measured loading is available. Point sources include municipal, stormwater and industrial discharges • Major nonpoint sources include legacy mining and natural loading. Minor nonpoint sources include legacy seed treatments, landfills, domestic sludge, air deposition, cement plants and coal fired power plants • Tributary inflows to the SR-HC TMDL reach • Existing system loading
Nutrients Nuisance Algae	• Point sources discharging phosphorus into the Upstream Snake River segment (RM 409 to 335), including municipal, stormwater and industrial discharges • Nonpoint sources including agriculture, stormwater, and natural loading • Tributary inflows to the SR-HC TMDL reach
Pesticides	• Point source discharges are not considered to be significant sources of loading • Nonpoint sources include legacy pesticide application both within the SR-HC Subbasin and from upstream application • Tributary inflows to the SR-HC TMDL reach • Existing system loading
pH	No segments of the SR-HC TMDL reach were found to exceed the targets for pH.
Sediment (TSS)	• Point source discharges, including municipal, stormwater and industrial discharges, are not considered to be significant sources of loading with the exception of stormwater discharges • Nonpoint sources include erosion from agriculture, recreation and urban/suburban sources as well as natural loading • Tributary inflows to the SR-HC TMDL reach
Temperature	• Dominant source of loading is natural temperature influences • Point source discharges, including municipal, stormwater and industrial discharges, are sources of heating but are currently operating within the no measurable increase margin • Nonpoint sources include flow and temperature influences from agriculture, water management and urban/suburban sources • Tributary inflows to the SR-HC TMDL reach
Total Dissolved Gas (TDG)	• Spill from Brownlee and Hells Canyon Reservoirs

collected to support the SR-HC TMDL effort is sufficient to determine the level of support for designated beneficial uses within the system (i.e. bacteria, nutrients, pH, temperature, total dissolved gas). In some cases, enough data are available to make a preliminary assessment, but additional data are necessary before formal load allocations based on existing loading or designated use support status can be identified (i.e. mercury, pesticides and sediment). The following summary captures the basic findings of this assessment process. All topics are discussed in greater detail within the TMDL document and the attached appendices.

BACTERIA

The SR-HC TMDL reach is listed from RM 409 to 347 for bacteria. Analysis has shown that bacteria 303(d) listings are not indicated given the available data. Designated uses are not impaired due to elevated bacteria levels within any of the listed segments. Available data (1999 and 2000) were collected in an appropriate fashion for evaluation of the 30 day log mean, with a minimum of 5 samples over an appropriate time period collected at most sampling locations. Monitoring occurred during the summer season and correlates well not only with the period of time that conditions in the river would be conducive to bacterial growth, but also to the season of greatest primary contact recreation use. No exceedences were observed. Based on these findings, the SR-HC TMDL process recommends that the mainstem Snake River from RM 409 to 347 be delisted for bacteria by the State of Idaho. The SR-HC TMDL process further recommends that monitoring of bacteria levels (*E. coli*), especially in those areas of the SR-HC TMDL reach where recreational use consistently occurs, continue to be an integral part of the water quality monitoring of the Upstream Snake River and Brownlee Reservoir segments.

MERCURY

The SR-HC TMDL reach is listed from RM 409 to 188 for mercury. To date, data available show that mercury concentrations in the SR-HC reach of the Snake River exceed the fish tissue target established by this TMDL. Water column data are not available to allow an assessment of the use support status of aquatic life uses due to mercury concentrations within the SR-HC system.

All fish tissue data available in this reach were positive for mercury. A summary of these data show that the Oregon and Idaho levels of concern were exceeded by 80% (0.35 mg/kg) and 52% (0.5 mg/kg) respectively. Both states have acted to issue fish consumption advisories based on these exceedences. Primary sources of mercury within the SR-HC TMDL reach are legacy mining and natural loading. Both are associated with geological deposits of mercury within the Owyhee and Weiser watersheds. Based on these findings, and on the concerns associated with consumption of fish by both waterfowl and wildlife within the SR-HC TMDL reach, a TMDL is considered necessary.

Due to the fact that essentially no water column data are available to this effort, a TMDL cannot be established at this time for mercury in the SR-HC TMDL reach. Therefore, IDEQ and ODEQ have determined it is in the public interest to reschedule the mercury TMDL for the SR-HC TMDL reach. IDEQ has rescheduled completion of the mercury TMDL to 2006 in order to gather additional data to better determine the sources and extent of mercury contamination. This schedule change has been approved by US EPA. ODEQ’s schedule for the mercury TMDL coincides with this date. The state of Oregon is developing capability to model site-specific bioaccumulation factors. Also, Oregon's mercury TMDL is not due until 2006. This schedule change will allow a better use of these capabilities and the opportunity to collect additional data. Both Idaho and Oregon have interim measures in place to deal with mercury contamination such as sediment controls and fish consumption advisories as described in Section 3.1. It is the opinion of the DEQs that this schedule change will not present an adverse impact to the SR-HC TMDL reach.

NUTRIENTS, NUISANCE ALGAE AND DISSOLVED OXYGEN

The SR-HC TMDL reach is listed from RM 409 to 272.5 for nutrients. Available data show excessive total phosphorus concentrations in the Upstream Snake River segment (RM 409 to 335) of the SR-HC reach. Nuisance algae blooms have been observed to occur routinely in the Upstream Snake River segment and the upstream sections of Brownlee Reservoir. It is evident from data analysis that the distribution of chlorophyll *a* and total phosphorus concentrations observed in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach are elevated when compared to those observed in the Snake River system as a whole. This elevation cannot be wholly attributable to natural sources.

A comparison of conditions in the Upstream Snake River segment (RM 409 to 335) to conditions observed in the Snake River as a whole was used to identify site-specific chlorophyll *a* and total phosphorus targets (less than 14 ug/L and less than or equal to 0.07 mg/L respectively) for the SR-HC TMDL reach. These targets are seasonal in nature and apply from May through September. The 0.07 mg/L total phosphorus target represents a substantial reduction in the current average total phosphorus concentration in the SR-HC TMDL reach. A total phosphorus concentration of 0.07 mg/L correlates to an average chlorophyll *a* concentration of approximately 14 ug/L, which is within the range defined as appropriate for protection of designated aquatic life, domestic water supply and aesthetic/recreational beneficial uses. The reduction in total phosphorus observed in meeting the target concentration also represents a reduction of roughly 50 % in algal biomass (as measured by chlorophyll *a*). The calculated reduction in organic loading is projected to result in an improvement in dissolved oxygen levels in both the Upstream Snake River and Brownlee Reservoir segments.

The 14 ug/L chlorophyll *a* and 0.07 mg/L total phosphorus targets were developed to meet water quality criteria in the Upstream Snake River segment (RM 409 to 335). To identify the change in conditions in Brownlee Reservoir resulting from attainment of these targets in the Upstream Snake River segment, water quality in the reservoir was modeled using all inflowing waters at 0.07 mg/L of total phosphorus. The model output showed dissolved oxygen improvements in the epilimnion sufficient to meet the 6.5 mg/L criteria during the summer months. Dissolved oxygen levels concentrations in the metalimnion also showed improvement, although the projected improvements did not meet water quality targets. Modeling of long-term effects of attaining the targets project that substantial improvements in the hypolimnion will be realized over time.

Load allocations assigned to the inflowing tributaries are based on inflow concentrations meeting the 0.07 mg/L total phosphorus target. Direct point source dischargers to the Snake River operating mechanical treatment plants will be required to reduce discharge concentrations by 80%. Lagoon discharges will assess the feasibility of changing to land application or biological nutrient removal and implementation objectives will be assessed on a case by case basis. Nonpoint source discharges will be required to reduce to the 0.07 mg/L level. As modeling showed that the presence of Brownlee Reservoir acts to reduce the assimilative capacity of the river, additional dissolved oxygen required to offset this reduction in assimilative capacity will be the responsibility of Idaho Power Company and has been identified as a load allocation of 1,125 tons of dissolved oxygen per season.

PESTICIDES

The SR-HC TMDL reach is listed for pesticides from RM 285 to 272.5 (Oxbow Reservoir). Pesticides of concern to this TMDL are DDT and dieldrin, both of which are banned and no longer in use in the United States. Available pesticide data identified total DDT (t-DDT) and dieldrin concentrations in fish tissues throughout the Snake River and several major tributaries in Idaho.

The data show that concentrations of both t-DDT and cyclodiene compounds (dieldrin) increased with distance downstream. Reservoir concentrations (mean = 1,261 ug/kg fish tissue) were somewhat higher overall than tributary concentrations (mean = 990 ug/kg fish tissue), but the trend was evident in both types of surface waters. The reservoir samples exhibited greater variation than the riverine samples. Of the pesticides identified in the SR-HC TMDL reach, all samples showed t-DDT fish tissue concentrations that exceeded the EPA screening level; no samples showed dieldrin fish tissue concentrations that exceeded the EPA screening level. All water column samples (four data points for each compound) exhibited levels above the SR-HC TMDL targets for both DDT and dieldrin.

The available dieldrin data show that fish tissue concentrations were relatively similar throughout the Upstream Snake River segment (RM 409 to 335), increasing slightly within the Brownlee Reservoir samples. A comparison of mean values from the Upstream Snake River segment (riverine mean = 32.4 ug/kg fish tissue) with the Brownlee Reservoir segment (RM 335 to 285) (lacustrine mean = 45 ug/kg fish tissue) shows a relatively moderate difference. The Brownlee Reservoir samples showed much greater variation than the Upstream Snake River samples. In the small data set available for dieldrin, over 73% of the fish tissue data points (n = 16) showed concentrations of dieldrin that were above the detection limits.

Load allocations for new application of these pesticides are all zero as they are banned compounds. Due to the lack of data to accurately characterize pesticide loading to the Oxbow Reservoir segment (RM 285 to 272.5), and the diffuse and widespread legacy nature of pesticide loading to the Snake River, load allocations for legacy application and transport of DDT and dieldrin were assigned on a general basis for the Upstream Snake River segment (RM 409 to 335). These load allocations represent the sum of point and nonpoint source-related loading. Insufficient data are available to further differentiate pollutant sources within the segment. Pesticide targets apply year-round.

pH

The SR-HC TMDL reach is listed for pH from RM 409 to 347 and from RM 335 to 285. Analysis has shown that pH 303(d) listings are not supported by the available data. No exceedences were observed to occur in the data available for the Upstream Snake River segment (RM 409 to 335). Less than 1% exceedence was observed in the Brownlee Reservoir segment (RM 335 to 285). Data were collected over the course of several years and represent a variety of flow and water quality conditions. Based on these findings, the SR-HC TMDL process recommends that the mainstem Snake River from RM 409 to 347 and from RM 335 to 285 be delisted for pH by the State of Idaho. The SR-HC TMDL process further recommends that monitoring of pH continue to be an integral part of the water quality monitoring of the Upstream Snake River and Brownlee Reservoir segments.

Sediment

The SR-HC TMDL reach is listed for sediment from RM 409 to 272.5. No duration data are available to assess the extent of impairment or support in these reaches. Targets of no more than 50 mg/L total suspended solids (TSS) as a monthly average and less than or equal to 80 mg/L TSS for no more than 14 days have been set in a conservative fashion so that aquatic life uses will be protected in the listed segments. These targets closely match those identified by IDEQ for the Lower Boise River (1998) and Mid-Snake River TMDLs (1997) so management of the Snake River system is consistent with previous approaches.

Sediment loading within the SR-HC TMDL reach is also of concern because of the attached pollutant loads (mercury, pesticides and nutrients) that the sediment carries. In the SR-HC TMDL, sediment targets and monitored trends will function as an indicator of changes in transport and delivery for these attached pollutants. The available data show that over 95% of the sediment loading into the SR-HC TMDL reach originates in the Upstream Snake River segment (RM 409 to 335). Sources of unmeasured load may include nonpoint source runoff from anthropogenic sources, precipitation events, unidentified small tributaries and drains. Sediment targets apply year round.

TEMPERATURE

The SR-HC TMDL reach is listed from RM 409 to 188 for temperature. Elevated summer water temperatures have been measured in both the Upstream Snake River segment near Weiser, Idaho (RM 351), in the Hells Canyon Complex reservoirs, and in the Downstream Snake River segment prior to the construction of the dams. Summertime water temperatures routinely exceed 24 ^{o}C in both the current and the historic data. Temperature loading calculations within the SR-HC TMDL reach have shown that natural sources and non-quantifiable sources were the dominant cause of temperature exceedences. (Non-quantifiable influences include the effects of upstream and tributary impoundments, water withdrawals, channel straightening and diking and removal of streamside vegetation.) Calculated natural and non-quantifiable background temperature influences to the mainstem Snake River within the SR-HC TMDL reach equal over 90% of the increase in water temperature for the critical months of June, July, August and September. It is well recognized that in hot, arid climates such as that in which the SR-HC TMDL reach is located, natural atmospheric heat sources will have a noticeable influence on water temperatures.

To address salmonid rearing temperature concerns the following point and nonpoint source load allocations have been identified. Point sources discharging directly to the Snake River within the SR-HC TMDL reach have been allocated heat loads corresponding to discharge loads applied to design flows to ensure that no measurable increase requirements will not be exceeded. A waste load allocation for future point sources of no measurable increase has been identified as part of this TMDL.

A gross nonpoint source temperature load allocation has been established at no greater than 0.14 ^{o}C for nonpoint sources in the SR-HC TMDL reach. (This applies primarily to agricultural and stormwater drains and similar inflows.) This allocation applies at discharge to the Snake River in the SR-HC TMDL reach, during those periods of time that the site-potential temperature in the mainstem Snake River is greater than 17.8 ^{o}C. It is projected that implementation associated with total phosphorus and total suspended solids reductions will result in reduced inflow temperatures in the smaller drains and tributaries to the mainstem Snake River as many of the approved methods for the reduction of total phosphorus and suspended solids are based on streambank revegetation and similar methodologies that will increase shading.

A gross nonpoint source temperature load allocation has been established at no greater than 0.14 ^oC for tributaries in the SR-HC TMDL reach. This is equal to the sum of the waste load allocation and the load allocation for anthropogenic tributary sources. This allocation applies at the inflow to the Snake River in the SR-HC TMDL reach, during those periods of time that the site-potential temperature in the mainstem Snake River is greater than 17.8 ^oC. Anthropogenic temperature influence assessments, similar to those conducted for the Lower Boise River and the SR-HC TMDL reach will be completed as part of the tributary TMDL processes. If anthropogenic sources within the drainage are observed to exceed the no measurable increase value for the tributary inflow, load allocations will be identified through the tributary TMDL process.

A temporal shift in water temperatures exiting Hells Canyon Dam is observed during the late fall and winter months; the decline in temperatures in the fall is delayed from that observed immediately upstream of the Hells Canyon Complex. While the temporal distribution of this temperature shift is due to the delay in flow caused by water moving through the Hells Canyon Complex, the actual heat load (warmer water) is not. The impoundments are not a heat source. Sources of elevated water temperature include natural, non-quantifiable and anthropogenic sources upstream of the Hells Canyon Complex and similar sources on inflowing tributaries. Because peak summer temperatures are several degrees cooler due to withdrawals from below the reservoir surface, and modeling has demonstrated that releases from Hells Canyon Dam would meet cold water aquatic life/salmonid rearing water temperature targets if waters inflowing to the reservoirs met cold water aquatic life/salmonid rearing targets, it is concluded that the Hells Canyon Complex reservoirs are not contributing to temperature exceedences specific to the cold water aquatic life/salmonid rearing designated use

However, water temperature modeling also shows that even if the inflowing water temperature met water quality targets for salmonid spawning at the onset of salmonid spawning (October 23 for fall chinook), the water exiting the Hells Canyon Complex would not meet the salmonid spawning criteria (although by only a small margin) because of the temporal shift created by the Hells Canyon Complex. It is, therefore, concluded that the responsibility for exceeding the salmonid spawning criteria is specific to the presence and operation of the Hells Canyon Complex.

To address violations of the water quality criteria for salmonid spawning temperatures, a thermal site-potential for water downstream of Hells Canyon Dam was established as the water temperature at RM 345 (approximately 10 miles upstream of Farewell Bend) using data from 1991 to 2001. A temperature load allocation in the form of a required temperature change at Hells Canyon Dam was identified as a change in water temperature such that the temperature of water released from Hells Canyon Dam is less than or equal to the water temperature at RM 345, or the maximum weekly maximum temperature target of 13 °C for salmonid spawning, plus the allowable temperature change defined as no greater than 0.14 ^oC. The entire load for the Downstream Snake River segment (RM 247 to 188) is allocated to the Hells Canyon Complex of dams owned and operated by IPCo. Specific compliance parameters for meeting this load allocation will be defined as part of the 401 Certification process.

TOTAL DISSOLVED GAS

Elevated total dissolved gas levels are the result of releasing water over spillways of dams. Gas supersaturation is caused when air becomes dissolved in water while spilling over a dam into the depth of a plunge pool. High hydrostatic pressure causes the air to be driven into solution, resulting in supersaturation. Spill at Brownlee and Hells Canyon Dams is the source of elevated total dissolved gas in the SR-HC reach. At this time, voluntary spill does not occur within the Hells Canyon Complex. Spill at dams occurs only involuntarily, usually as a result of flood control constraints. The magnitude of the exceedence (to some extent) and the total distance downstream of the dam where water was observed to exceed the less than 110% standard are observed to be directly related to the volume of the spill. Observed ranges of total dissolved gas loading to the Oxbow Reservoir, Hells Canyon Reservoir and Downstream Snake River segments are between 114% to 128% for spill from Brownlee Dam and 108% to 136% for spill from Hells Canyon Dam.

As spill over Brownlee and Hells Canyon Dams is the source of elevated total dissolved gas in the SR-HC TMDL reach, the entire load allocation is assigned to the Hells Canyon Complex. This load allocation applies to each location where spill occurs (i.e. a load allocation of less than 110% maximum saturation applies to the tailwaters of Oxbow Reservoir during spill from Brownlee Dam, and a load allocation of less than 110% maximum saturation applies to the Downstream Snake River segment during spill from Hells Canyon Dam).

Water Quality Targets

Because the Snake River from RM 409 to 188 is an interstate water body with the state boundary line described as the centerline of the river, water quality standards and particularly water quality criteria for both Oregon and Idaho must be attained. Because the state line between Oregon and Idaho is in the middle of the mainstem Snake River, the waters of both states are mixed mid-river. Therefore waters from both sides must meet the criteria of both states in the mainstem. This is accomplished by determining which standards are the most stringent and applying those criteria as targets for this TMDL.

Due to the use of different methodology for each state, it is not immediately obvious which standards represent the most stringent values. A direct calculation of stringency was therefore undertaken for standards for which numeric criteria had been established. In the case of those pollutants where numeric criteria were not available, reasonable state and federal guidelines and guidance documents have been applied in correlation with the current understanding of the system and the physical constraints imposed by naturally occurring conditions. The resulting water quality targets for the SR-HC TMDL are listed in Table D.

TMDL Summaries

TMDLs have been written for nutrients/dissolved oxygen, pesticides, sediment, temperature and total dissolved gas. The following pages represent a summary of the information specific to each of the TMDLs written for the SR-HC TMDL reach.

Table D. Water quality targets specific to the Snake River - Hells Canyon TMDL.

Parameter	Selected Target	Where Applied
Bacteria	Less than 126 *E coli* organisms per 100 mL as a 30 day log mean with a minimum of 5 samples AND no sample greater than 406 *E coli* organisms per 100 mL	Full SR-HC TMDL reach (RM 409 to 188), year-round
Dissolved Oxygen (DO) • Cold water aquatic life and salmonid rearing	8 mg/L water column dissolved oxygen as an absolute minimum, OR (where conditions of barometric pressure, altitude, and temperature preclude attainment of 8 mg/L) dissolved oxygen levels shall not be less than 90%; unless adequate, i.e. continuous monitoring, data are collected to allow assessment of the multiple criteria section in the standards.	Downstream Snake River Segment (RM 247 to 188), year-round
• Salmonid spawning, when and where it occurs	11 mg/L water column dissolved oxygen as an absolute minimum OR (where conditions of barometric pressure, altitude, and temperature preclude attainment of 11 mg/L) dissolved oxygen levels shall not be less than 95%; with intergravel dissolved oxygen not lower than 8 mg/L, unless adequate, i.e. continuous monitoring, data are collected to allow assessment of the multiple criteria section in the standards. These targets will apply only to that portion of the SR-HC TMDL reach below Hells Canyon Dam (RM 247 to 188), from October 23rd to April 15th for fall chinook, and from November 1st to March 30th for mountain whitefish.	Downstream Snake River Segment (RM 247 to 188), October 23 to April 15
• Cool water aquatic life	6.5 mg/L water column as an absolute minimum, unless adequate, i.e. continuous monitoring, data are collected to allow assessment of the multiple criteria section in the standards.	Full SR-HC TMDL reach (RM 409 to 188), year-round
Mercury (Hg)	Less than 0.012 ug/L water column concentration (total) Less than 0.35 mg/kg in fish tissue	Full SR-HC TMDL reach (RM 409 to 188), year-round
Nuisance Algae	14 ug/L mean growing season limit (nuisance threshold of 30 ug/L with exceedence threshold of no greater than 25%)	Full SR-HC TMDL reach (RM 409 to 188), May through September
Nutrients	Less than or equal to 0.07 mg/L total phosphorus	Full SR-HC TMDL reach (RM 409 to 188), May through September
Pesticides	Less than 0.024 ng/L water column concentration DDT Less than 0.83 ng/L water column concentration DDD Less than 0.59 ng/L water column concentration DDE Less than 0.07 ng/L water column concentration Dieldrin	Oxbow Reservoir Segment (RM 285 to 272.5) and upstream waters, year-round
pH	7 to 9 pH units	Full SR-HC TMDL reach (RM 409 to 188), year-round
Sediment (Turbidity)	Less than or equal to 80 mg TSS/L for acute events lasting no more than 14 days, and less than or equal to 50 mg TSS/L monthly average	Full SR-HC TMDL reach (RM 409 to 188), year-round
Temperature • Cold water aquatic life and salmonid rearing	17.8 ^{o}C (expressed in terms of a 7-day average of the maximum temperature) if and when the site potential is less than 17.8 ^{o}C. If and when the site potential is greater than 17.8 ^{o}C, the target is no more than a 0.14 ^{o}C increase from anthropogenic sources. When aquatic species listed under the Endangered Species Act are present and if a temperature increase would impair the biological integrity of the Threatened and Endangered population	Full SR-HC TMDL reach (RM 409 to 188), year-round

Parameter	Selected Target	Where Applied
	then the target is no greater than 0.14 °C increase from anthropogenic sources.	
• Salmonid spawning, when and where it occurs for specific species	A maximum weekly maximum temperature of 13 °C (when and where salmonid spawning occurs) if and when the site potential is less than a maximum weekly maximum temperature of 13 °C. If and when the site potential is greater than a maximum weekly maximum temperature of 13 °C, the target is no more than a 0.14 °C increase from anthropogenic sources. When aquatic species listed under the Endangered Species Act are present and if a temperature increase would impair the biological integrity of the Threatened and Endangered population then the target is no greater than 0.14 °C increase from anthropogenic sources. These targets will apply only to that portion of the SR-HC TMDL reach below Hells Canyon Dam (RM 247 to 188), from October 23rd to April 15th for fall chinook, and from November 1st to March 30th for mountain whitefish.	Downstream Snake River Segment (RM 247 to 188), October 23 to April 15
Total Dissolved Gases	Less than 110%	Oxbow Reservoir to the Salmon River Inflow (RM 285 to 188), year-round

TMDL summaries are not included for the bacteria and the pH listings for the Upstream Snake River and Brownlee Reservoir segments as data show that targets are being met and both are recommended for delisting by the State of Idaho. No final TMDL could be prepared for mercury due to a lack of water column data. This TMDL has been postponed to 2006. Data will be collected during the intervening time period and a full assessment completed by 2006. TMDL summaries for all other listed pollutants follow.

NUTRIENTS, NUISANCE ALGAE, DISSOLVED OXYGEN (DO)

Pollutant of Concern:	***Nutrients, Nuisance Algae, Dissolved Oxygen***
Segments Listed: (See Tables A-1 and B-1 for specific stream segments)	Idaho: Upstream Snake River, Brownlee Reservoir, Oxbow Reservoir Oregon: None
Uses Affected:	Aesthetics, Recreation, Resident Fish and Aquatic Life At Risk: Domestic Water Supply
Known Sources:	Point source discharges including municipal, stormwater and industrial discharges Nonpoint sources including agriculture, stormwater and natural loading Tributary inflows to the SR-HC TMDL reach Reduced assimilative capacity due to impoundments
Indications of Impairment:	Excessive algae growth occurring in the Upstream Snake River segment (RM 409 to 335), excessive algae growth in the upstream sections of Brownlee Reservoir and associated dissolved oxygen problems.
Target(s): (see Table 2.2.2 for further detail)	A minimum of 6.5 mg/L dissolved oxygen for listed segments upstream of Hells Canyon Dam, minimum of 8 mg/L dissolved oxygen downstream. No greater than 14 ug/L mean growing season chlorophyll *a* limit (nuisance threshold of 30 ug/L). A maximum of 0.07 mg/L total phosphorus instream.
Critical Conditions:	Dissolved oxygen requires year round application of the target Chlorophyll *a* and total phosphorus target attainment critical May through September.
Capacity: (total phosphorus, May through September)	Upstream Snake River: 2,735 kg/day Brownlee Reservoir: 2,829 kg/day Oxbow Reservoir: 2,839 kg/day
Loading: (total phosphorus, May through September)	Point Sources: 516 kg/day at design flow Nonpoint Sources: Upstream Snake River: 5,899 kg/day Brownlee Reservoir: 3,288 kg/day (calculated at Brownlee Dam) Oxbow Reservoir: 2,918 kg/day (calculated at Oxbow Dam)
TMDL:	Written for all listed segments based on the 14 ug/L mean growing season chlorophyll *a* and 0.07 mg/L total phosphorus targets.
Waste Load Allocations: (total phosphorus, May through September)	All mechanical plants discharging directly to the Snake River within the SR-HC TMDL reach will attain 80% reduction in total phosphorus loading. Lagoon system waste load allocations are set at existing design-flow loading.
Load Allocations*: (*values were determined for an average water year and include natural loading. Target is no greater than 0.07 mg/L total phosphorus instream.) (total phosphorus, May through September)	Snake River inflow: 1,379 kg/day Owyhee River inflow: 71 kg/day Boise River inflow: 242 kg/day Malheur River inflow: 58 kg/day Payette River inflow: 469 kg/day Weiser River inflow: 136 kg/day Drains: 91 kg/day Ungaged: 137 kg/day (including stormwater and overland agricultural runoff) Total Upstream Snake River (nonpoint sources): 2,735 kg/day Brownlee Reservoir: 2,829 kg/day Burnt River: 21 kg/day Powder River: 33 kg/day Oxbow Reservoir: 2,839 kg/day

Pollutant of Concern:	***Nutrients, Nuisance Algae, Dissolved Oxygen***
	Dissolved oxygen load allocation of 1,125 tons seasonally, specific to the transition zone and metalimnion of Brownlee Reservoir to offset reduction in assimilative capacity.
Margin of Safety:	Explicit 13% based on sampling and analytical error, and conservative assumptions
Implementation Time Frame:	Point source implementation within time frames identified by NPDES permit schedules. Nonpoint source implementation to begin with completion of site-specific implementation plans (18 months after approval of TMDL) and to proceed with all deliberate speed. Draft interim goals at 0.01 mg/L total phosphorus decrease in mainstem waters every 10 years Schedule specifics will be determined as part of the implementation planning process. The potential for long-term time frames (up to 70 years) for full system potential to be realized. Implementation of the dissolved oxygen load allocation to Brownlee Reservoir will be timed similar to the nonpoint source implementation schedule. If direct oxygenation is selected as the implementation mechanism, addition will be timed for those periods of low dissolved oxygen and correlated with reservoir monitoring to allow the most effective use of injected dissolved oxygen to the reservoir.
Monitoring Needs:	Point source monitoring of discharge concentrations to track progress, nonpoint/agency monitoring of mainstem concentrations to track progress.

More detail on the general points in the TMDL summary can be found in the loading analysis discussion in Section 3.0 and in the discussion of load allocations in Section 4.0.

PESTICIDES

Pollutant of Concern:	*Pesticides (DDT and Dieldrin, and degradation products)*
Segments Listed: (See Tables A-1 and B-1 for specific stream segments)	Idaho: Oxbow Reservoir Oregon: None
Uses Affected:	Fishing Additional data necessary to evaluate support status of cold water aquatic life/salmonid rearing, resident fish and aquatic life, wildlife and hunting
Known Sources:	Point source discharges are not considered to be significant sources of loading. Nonpoint sources include legacy pesticide application both within the SR-HC Subbasin and drainage area upstream, tributary inflows to the SR-HC TMDL reach and existing system loading from legacy application.
Indications of Impairment:	Fish tissue exceedences of DDT action levels (US EPA) and water column exceedences of SR-HC TMDL DDT and dieldrin targets.
Target(s): (see Table 2.2.2 for further detail)	Less than 0.024 ng/L water column concentration DDT Less than 0.83 ng/L water column concentration DDD Less than 0.59 ng/L water column concentration DDE Less than 0.07 ng/L water column concentration Dieldrin
Critical Conditions:	Year round
Capacity:	Upstream Snake River: 0.34 kg/year (t-DDT), 0.98 kg/year (dieldrin) Brownlee Reservoir: 0.37 kg/year (t-DDT), 1.1 kg/year (dieldrin) Oxbow Reservoir: 0.37 kg/year (t-DDT), 1.1 kg/year (dieldrin)
Loading:	Upstream Snake River: 42 grams/year (t-DDT), 28 kg/year (dieldrin) (Based on an extremely small data set)
TMDL:	Written for upstream and listed segment based on the water-column targets identified for DDT and dieldrin
Load Allocations:	Zero load allocation for new application. Bulk load allocation to point and nonpoint sources set at load capacity less 10% margin of safety.
Margin of Safety:	Explicit, 10%
Implementation Time Frame:	Concurrent with nonpoint source implementation as identified by sediment and nutrient TMDLs.
Monitoring Needs:	Nonpoint/agency monitoring of mainstem concentrations to determine loading, continued fish tissue monitoring to determine trends and progress monitoring.

More detail on the general points in the TMDL summary can be found in the loading analysis discussion in Section 3.0 and in the discussion of load allocations in Section 4.0.

SEDIMENT

Pollutant of Concern:	Sediment
Segments Listed: (See Tables A-1 and B-1 for specific stream segments)	Idaho: Upstream Snake River, Brownlee Reservoir, Oxbow Reservoir Oregon: None
Uses Affected:	Aesthetics, Recreation, Resident Fish and Aquatic Life, Fishing Duration data necessary to determine aquatic life use support status
Known Sources:	Point source discharges including municipal and industrial discharges. Nonpoint sources including agriculture, stormwater and natural loading, and tributary inflows to the SR-HC TMDL reach.
Indications of Impairment:	Lack or degradation of habitat, population decline. (See mercury, nutrient, and pesticide discussions for attached pollutant concerns.)
Target(s): (see Table 2.2.2 for further detail)	Less than or equal to 80 mg/L total suspended solids (TSS) for acute events lasting less than 14 days, and less than or equal to 50 mg TSS/L monthly average.
Critical Conditions:	Year round
Capacity: (TSS)	Upstream Snake River: 1,265,630 kg/day Brownlee Reservoir: 1,290,200 kg/day Oxbow Reservoir: 1,305,682 kg/day
Loading:	Point Sources: Design flow = 722 kg/day Nonpoint Sources: Upstream Snake River: 1,483,691 kg/day Brownlee Reservoir: loading cannot be calculated due to reservoir sink effect Oxbow Reservoir: loading cannot be calculated due to reservoir sink effect
TMDL:	Written for all listed segments based on the SR-HC TMDL TSS targets as protective for aquatic life and as indicators of changes in transport and delivery of attached pollutants.
Waste Load Allocations:	NPDES permits set at current limits for point source discharges.
Load Allocations and Threshold Values*: (* Threshold values are based on anti-degradation requirements established at currently measured loads)	Snake River inflow: 677,785 kg/day (threshold value) Owyhee River inflow: 48,007 kg/day Boise River inflow: 130,466 (threshold value) Malheur River inflow: 42,062 kg/day Payette River inflow: 137,887 kg/day (threshold value) Weiser River inflow: 53,617 kg/day (threshold value) Drains: 57,628 kg/day Ungaged: 118,178 kg/day, (including stormwater and overland agricultural runoff) Total Upstream Snake River (nonpoint sources): 1,265,630 kg/day Burnt River: 9,713 kg/day Powder River: 14,857 kg/day (threshold value)
Margin of Safety:	Explicit, 10%
Implementation Time Frame:	Nonpoint source implementation to begin concurrent with nutrient reduction measures. No additional implementation measures are expected based on sediment alone. If fully implemented, nutrient reduction measures should act to reduce sediment sufficient to meet load allocations. Schedule specifics will be determined as part of the implementation planning process. The potential for long-term time frames (up to 70 years) for full system potential to be realized.

Pollutant of Concern:	***Sediment***
Monitoring Needs:	Nonpoint/agency monitoring of duration-based concentrations in mainstem, and progress monitoring.

More detail on the general points in the TMDL summary can be found in the loading analysis discussion in Section 3.0 and in the discussion of load allocations in Section 4.0.

TEMPERATURE

Pollutant of Concern:	**Temperature**
Segments Listed: (See Tables A-1 and B-1 for specific stream segments)	Idaho: Downstream Snake River Oregon: Upstream Snake River, Brownlee Reservoir, Oxbow Reservoir, Hells Canyon Reservoir, Downstream Snake River
Uses Affected:	Cold Water Aquatic Life/Salmonid Rearing, Salmonid Spawning* (*below Hells Canyon Dam)
Known Sources:	Dominant source of loading is natural and non-quantifiable temperature influences. Non-quantifiable influences including the effects of upstream and tributary impoundments, water withdrawals, channel straightening and diking and removal of streamside vegetation. Point source discharges, including municipal, stormwater and industrial discharges, are sources of heating but are currently operating within the no measurable increase margin. Nonpoint sources include flow and temperature influences from agriculture, water management, geothermal (natural and urban/suburban sources, and tributary inflows to the SR-HC TMDL reach.
Indications of Impairment:	Exceedences of the temperature target for cool and cold water aquatic life and salmonid rearing occurring during June, July, August and September throughout the SR-HC TMDL reach. Exceedences were observed historically in the Upstream Snake River segment (RM 409 to 335) and in the reservoir segments before the impoundments were in place. Exceedences of the temperature target for salmonid spawning occurring during mid-October for fall chinook in the Downstream Snake River segment.
Target(s): (see Table 2.2.2 for further detail)	Cold water Aquatic Life/Salmonid Rearing: Less than 0.14 ^{o}C increase from anthropogenic sources when the site potential is greater than 17.8 ^{o}C Salmonid Spawning: A maximum weekly maximum temperature of 13 ^{o}C (when and where salmonid spawning occurs) if and when the site potential is less than a maximum weekly maximum temperature of 13 ^{o}C. If and when the site potential is greater than a maximum weekly maximum temperature of 13 ^{o}C, the target is no more than a 0.14 ^{o}C increase from anthropogenic sources. Applicable to RM 247 to 188 only, from October 23rd to April 15th for fall chinook, and from November 1st to March 30th for mountain whitefish. Less than a 0.14 ^{o}C increase from anthropogenic sources when aquatic species listed under the Endangered Species Act are present and a temperature increase would impair the biological integrity of the Threatened and Endangered population. *Please see Table D for greater detail.*
Critical Conditions:	June through September for cold water aquatic life/salmonid rearing October 23rd through April 15th for salmonid spawning (below Hells Canyon Dam).
Capacity:	No measurable increase (defined as 0.14 ^{o}C for this TMDL) Upstream Snake River: less than 0.14 ^{o}C cumulative loading Brownlee Reservoir: less than 0.14 ^{o}C cumulative loading Oxbow Reservoir: less than 0.14 ^{o}C cumulative loading Hells Canyon Reservoir: less than 0.14 ^{o}C cumulative loading

Pollutant of Concern:	***Temperature***
	Downstream Snake River: less than 0.14 ^{o}C cumulative loading
Anthropogenic Loading:	Cold water aquatic life/salmonid rearing: Upstream Snake River: less than 0.05 ^{o}C cumulative loading Brownlee Reservoir: less than 0.013 ^{o}C cumulative loading Oxbow Reservoir: less than 0.013 ^{o}C cumulative loading Hells Canyon Reservoir: less than 0.008 ^{o}C cumulative loading Downstream Snake River: less than 0.005 ^{o}C cumulative loading Salmonid Spawning: Temporal shift at the outlet of Hells Canyon Dam. Water leaving the dam is warmer in the fall than upstream water temperatures and cooler in the spring than upstream water temperatures. Some of this temporal shift occurs during the spawning period for fall chinook (starting October 23). Exceedences of the salmonid spawning temperature occur from October 23 thorough 06 November immediately below the Hells Canyon Dam.
TMDL:	Written for all listed segments
Waste Load Allocations:	Cold water aquatic life/salmonid rearing: Current discharge loads applied to design flows to ensure that no measurable increase will not be exceeded Salmonid Spawning: not applicable
Load Allocations:	Cold water aquatic life/salmonid rearing: Anthropogenic nonpoint source loading less than 0.14 ^{o}C, Temperature assessments on a tributary drainage basis. Salmonid Spawning: Idaho Power Company ΔT resulting in water temperatures at the discharge of Hells Canyon Dam of no more than 0.14 ^{o}C above those observed at RM 345 or water temperatures less than 13 ^{o}C (daily maximum) at the discharge of Hells Canyon Dam, October 23rd through 15 April.
Margin of Safety:	Point Sources: Explicit MOS of 10% Nonpoint Sources: Implicit, as defined by criteria application in target.
Implementation Time Frame:	Point source implementation within time frames identified by NPDES permit schedules. Nonpoint source actions for nutrient/sediment reduction should include those practices that can result in localized temperature improvements such as revegetation of streambanks and efficient water usage. Implementation will follow nutrient/sediment implementation schedule. Tributary assessments of anthropogenic temperature influences as defined by tributary TMDL schedules.
Monitoring Needs:	Point source monitoring of discharge temperatures as part of routine reports, tributary monitoring to assess anthropogenic temperature influences, and progress monitoring.

More detail on the general points in the TMDL summary can be found in the loading analysis discussion in Section 3.0 and in the discussion of load allocations in Section 4.0.

TOTAL DISSOLVED GAS (TDG)

Pollutant of Concern:	Total Dissolved Gas
Segments Listed: (See Tables A-1 and B-1 for specific stream segments)	Idaho: None Oregon: None Addressed through request from Public Advisory Team members
Uses Affected:	Resident Fish and Aquatic Life, Cold Water Aquatic Life/Salmonid Rearing
Known Sources:	Spill from Brownlee and Hells Canyon Reservoirs
Indications of Impairment:	Greater than 110% of total dissolved gas saturation Gas bubble disease in fish Exceedences of the total dissolved gas target are observed to occur in Oxbow, Hells Canyon reservoirs and in the Downstream Snake River segment during periods of spill.
Target(s):	Less than 110% of saturation (see Table 2.2.2 for further detail)
Critical Conditions:	Year round
Capacity:	Less than 110% of saturation
Loading:	Oxbow and Hells Canyon Reservoir segments: 114% to 128% saturation during spill from Brownlee Dam. Downstream Snake River segment: 108% to 136% saturation during spill from Hells Canyon Dam.
TMDL:	Written for the Oxbow Reservoir, Hells Canyon Reservoir and Downstream Snake River segments.
Waste Load Allocations:	No point source loading for total dissolved gas.
Load Allocations:	Less than 110% of saturation at the edge of the aerated zone below Brownlee Dam, Oxbow Dam and Hells Canyon Dam.
Margin of Safety:	Implicit, using conservative criteria established for protection of designated aquatic life uses.
Implementation Time Frame:	Appropriate to engineering and design/operation studies to identify mechanisms to reduce saturation. Commensurate with correlated FERC and 401 Certification process requirements.
Monitoring Needs:	Monitoring of discharge total dissolved gas concentrations as part of routine progress monitoring.

More detail on the general points in the TMDL summary can be found in the loading analysis discussion in Section 3.0 and in the discussion of load allocations in Section 4.0.

Reasonable Assurance

All identified point sources discharging to the Snake River within the SR-HC TMDL reach are permitted facilities administered by the US EPA (Idaho facilities) or the State of Oregon (Oregon facilities). Wasteload (WLAs) reductions can be precipitated by modification of the NPDES permit. However, the load reductions needed to achieve desired water quality and restore full support of designated beneficial uses in the SR-HC TMDL reach will not be achieved in entirety by upgrades of the point sources.

For watersheds that have a combination of point and nonpoint sources where pollution reduction goals can only be achieved by including some nonpoint source reduction, a reasonable assurance that reductions will be met must be incorporated into the TMDL. The load reductions for the SR-HC TMDL will rely on nonpoint source reductions to meet the load allocations to achieve desired water quality and to restore designated beneficial uses. To ensure that nonpoint source reduction mechanisms are operating effectively, and to give some quantitative indication of the reduction efficiency for in-place BMPs, monitoring will be conducted. The monitoring will not be carried out on a site-specific basis but rather as a suite of indicator analyses monitored at the inflow and outflow of the segments within the SR-HC TMDL reach and at other appropriate locations such as the inflow of tributaries.

The states have responsibility under Section 401 of the CWA to provide water-quality certification. Under this authority, the states review projects to determine applicability to local water-quality issues. The State of Idaho and State of Oregon water-quality standards refer to other programs whose mission is to control nonpoint pollution sources. Some of these programs and responsible agencies are listed in Table E.

Table E. State regulatory authority for nonpoint pollution sources.

Citation	Idaho responsible agency	Oregon responsible agency
Rules governing forest practices	Idaho Department of Lands	Oregon Department of Forestry
Rules governing solid waste management	Idaho Department of Environmental Quality / Health Districts	Oregon Department of Environmental Quality
Rules governing subsurface and individual sewage disposal systems	Idaho Department of Environmental Quality / Health Districts	Oregon Department of Environmental Quality
Rules and standards for stream channel alteration	Idaho Department of Water Resources	Oregon Division of State Lands
Rules governing exploration and surface mining operations	Idaho Department of Lands	Oregon Department of Geology and Mineral Industries
Rules governing placer and dredge mining	Idaho Department of Lands	Oregon Division of State Lands
Rules governing dairy waste	Idaho Department of Agriculture	Oregon Department of Agriculture

If instream monitoring indicates an increasing pollutant concentration trend (not directly attributable to environmental conditions) or a violation of standards despite use of approved

BMPs or knowledgeable and reasonable efforts, then BMPs for the nonpoint sources activity must be modified by the appropriate agency to ensure protection of beneficial uses (Subsection 350.02.b.ii). This process is known as the "feedback loop" in which BMPs or other efforts are periodically monitored and modified if necessary to ensure protection of beneficial uses. With continued instream monitoring, the TMDL will initiate the feedback loop process and will evaluate the success of BMP implementation and its effectiveness in controlling nonpoint source pollution.

If a nonpoint pollutant(s) is determined to be impacting beneficial uses and the activity already has in-place referenced BMPs, or knowledgeable and reasonable practices, the state may request the BMPs be evaluated and/or modified to determine appropriate actions. If evaluations and/or modifications do not occur, injunctive relief may be requested (IDAPA 16.01.02350.2, ii (1); OAR 46EB.025 and 46EB.050).

It is expected that a voluntary approach will be able to achieve load allocations needed. Public involvement along with the commitment of the agricultural community have demonstrated a willingness to implement BMPs and protect water quality. In the past, cost-share programs have provided the agricultural community technical assistance, information and education, and the cost share incentives to implement BMPs. The continued funding of these projects will be critical for the load allocations to be achieved in the SR-HC TMDL.

Water Quality Management Plan and General Implementation Plan

To fulfil the requirements of the State of Oregon TMDL process, a Water Quality Management Plan or Implementation Plan must be submitted to the US EPA with the SR-HC TMDL. IDEQ guidance states that a TMDL implementation plan should be developed within eighteen months of the approval of the TMDL it is intended to support and supplement. Because of this difference in procedure, a general plan will be submitted with the SR-HC TMDL.

A general document is being submitted to fulfill the requirements of the TMDL process. However, substantial differences in state procedure and policy for implementation of TMDLs exist between Oregon and Idaho. Therefore, this document contains two separate, state-specific plans: the State of Oregon General Water Quality Management plan, and the State of Idaho General Implementation Plan. Together, these documents represent the general water quality management plan (implementation plan) for the SR-HC TMDL. More detailed, site-specific implementation plans will be prepared within 18 months of the approval of the SR-HC TMDL.

Conclusions

There is a substantial amount of data available to this effort. While some parameters will require additional monitoring in order to complete the TMDL process, this robust database has made an initial assessment of system needs and designated use requirements possible. The following, general conclusions are the result of the assessment and TMDL process:

- Bacteria and pH listings were not found to be supported by the data and have been recommended for delisting.

- Mercury concentrations were observed to be in excess of the SR-HC TMDL fish tissue targets in over 85% of the data and fish tissue consumption advisories remain in place, but no final TMDL could be prepared due to a lack of water column data. This TMDL has been postponed to 2006. Data will be collected during the intervening time period and a full assessment completed by 2006.

- The assessment of water quality conditions within the SR-HC TMDL reach identified designated beneficial use impairment from excessive nutrient loading in the Upstream Snake River (RM 409 to 335) and Brownlee Reservoir (RM 335 to 285) segments.

- While little data were available for pesticides within the SR-HC TMDL reach, and no data were available for the listed segment (Oxbow Reservoir), the data available indicate that pesticide transport within the SR-HC TMDL reach should be minimized. Implementation of concurrent pollutant reductions for total phosphorus is projected to result in reductions in pesticide transport and delivery within the SR-HC TMDL reach.

- Similarly, the influence of sediment, listed as a pollutant in the Upstream Snake River, Brownlee and Oxbow Reservoir segments, on aquatic life uses could not be fully assessed due to lack of duration data. However, excessive concentrations of sediment were identified based on monthly averages from some tributary and drain inflows. Additionally, sediment was identified as a transport mechanism for mercury, pesticides and nutrients within the SR-HC TMDL reach.

- Atmospheric and non-quantifiable influences were identified as the primary source of temperature exceedences and an in-depth evaluation of cold water refugia in the reservoirs demonstrated the critical nature of such habitat to the arid SR-HC TMDL reach.

- Total dissolved gas was identified as a pollutant of concern by SR-HC PAT members and an assessment of exceedences and impairment was completed. Exceedences of the total dissolved gas target were observed to be the result of spill over Brownlee and Hells Canyon Dams. Load allocations to meet the water quality targets were assigned to the Brownlee and Hells Canyon Dams.

As demonstrated by the size and diversity of the issues addressed in this document, the SR-HC TMDL reach is a highly complex system and will no doubt yield unexpected results as implementation and further data collection proceeds. The challenges encountered in determining designated beneficial use support and system impairment are an outgrowth of this complexity and will require additional assessment and revisitation as our understanding of the system evolves. Additionally, due to the complexity encountered and the enormous geographic scope of this effort, an extended time period for implementation and system response will be required. Generally, TMDL processes are expected to be completed within ten to 15 years of approval, this system, with its sequential tributary TMDL processes, wide diversity of land use and staggering size will not doubt require several decades to respond completely to implementation projects and changes in management.

Because of the complex nature and the extended time frame required, it is absolutely critical that the SR-HC TMDL remain a truly iterative process whereby our improved understanding of the system can be re-applied to the initial targets and goals as time passes, and that these targets and goals can be updated to better reflect system needs and appropriate management.

3.0 Loading Analyses

3.0.1 General Information

A TMDL prescribes an upper limit on discharge of a pollutant from all sources so as to assure water quality standards are met. It further allocates load capacity (LC) among the various sources of the pollutant. Pollutant sources fall into two broad classes: point sources, each of which receives a waste load allocation (WLA); and nonpoint sources, which receive a load allocation (LA). Natural background (NB), when present, is considered part of the load allocation, but is often identified separately because it represents a part of the load not subject to control. Because of uncertainties regarding quantification of loads and the relation of specific loads to attainment of water quality standards, the rules regarding TMDLs (40 CFR § 130) require a margin of safety (MOS) be a part of the TMDL.

Practically, the margin of safety is a reduction in the load capacity (LC) that is available for allocation to pollutant sources. The natural background load is also effectively a reduction in the load capacity available for allocation to human-caused pollutant sources. This can be summarized as the equation:

LC = MOS + NB + LA + WLA = TMDL.

The equation is written in this order because it represents the logical order in which a loading analysis is conducted. First the loading capacity is determined. Then the loading capacity is broken down into its components: the necessary margin of safety is determined and subtracted; then natural background, if relevant, is quantified and subtracted; and then the remainder is allocated among pollutant sources. When the breakdown and allocation is completed, the TMDL must equal the loading capacity.

Another step in a loading analysis is the quantification of current pollutant loads by source. This allows the specification of load reductions as percentages from current conditions, considers equities in load reduction responsibility, and is necessary in order for pollutant trading to occur. Also a required part of the loading analysis is that the load capacity be based on critical conditions – the conditions when water quality standards are most likely to be violated. If protective under critical conditions, a TMDL will be more than protective under other conditions. Because both load capacity and pollutant source loads vary, and not necessarily in concert, determination of critical conditions can be more complicated than it may appear on the surface.

A load is fundamentally a quantity of a pollutant discharged over some period of time, and is the product of concentration and flow. Due to the diverse nature of various pollutants, and the difficulty of strictly dealing with loads, the federal rules allow for “other appropriate measures” to be used when necessary. These “other measures” must still be quantifiable, and relate to water quality standards, but they allow flexibility to deal with pollutant loading in more practical and tangible ways. The rules also recognize the particular difficulty of quantifying nonpoint loads, and allow “gross allotment” as a load allocation where available data or appropriate predictive techniques limit more accurate estimates. For certain pollutants whose effects are long term, such as sediment and nutrients, EPA allows for seasonal or annual loads.

This document represents the loading analyses for the pollutants addressed by the Snake River - Hells Canyon (SR-HC) Total Maximum Daily Load (TMDL). These include the pollutants listed in Table 3.0.1.

Table 3.0.1 Segment specific listing information for the Snake River - Hells Canyon TMDL reach

Segment	Idaho 303(d) Listed Pollutants	Oregon 303(d) Listed Pollutants
Snake River: RM 409 to 396.4 Upstream Snake River (OR/ID border to Boise River Inflow)	(downstream from ID border) bacteria, dissolved oxygen, nutrients, pH, sediment	mercury, temperature
Snake River: RM 396.4 to 351.6 Upstream Snake River (Boise River Inflow to Weiser River Inflow)	bacteria, nutrients, pH, sediment	mercury, temperature
Snake River: RM 351.6 to 347 Upstream Snake River (Weiser River Inflow to Scott Creek Inflow)	bacteria, nutrients, pH, sediment	mercury, temperature
Snake River: RM 347 to 285 Brownlee Reservoir (Scott Creek to Brownlee Dam)	dissolved oxygen, mercury, nutrients, pH, sediment	mercury, temperature
Snake River: RM 285 to 272.5 Oxbow Reservoir	nutrients, sediment, pesticides	mercury, temperature
Snake River: RM 272.5 to 247 Hells Canyon Reservoir	not listed	mercury, temperature
Snake River: RM 247 to 188 Downstream Snake River (Hells Canyon Dam to Salmon River Inflow)	temperature	mercury, temperature

Because of the extensive scope of this TMDL, the SR-HC TMDL process has divided the SR-HC reach into five separate segments based on similar hydrology, pollutant delivery and processing mechanisms, and operational, management or implementation strategies. The five segments are:

- The Upstream Snake River segment (RM 409 to 335)
- The Brownlee Reservoir segment (RM 335 to 285)
- The Oxbow Reservoir segment (RM 285 below Brownlee Dam to RM 272.5)
- The Hells Canyon Reservoir segment (RM 272.5 below Oxbow Dam to RM 247)
- The Downstream Snake River Segment (RM 247 below Hells Canyon Dam to RM 188)

Pollutant sources within the SR-HC TMDL reach include point sources, nonpoint sources and tributary inflows. These sources will each be discussed in the context of the segment to which they discharge.

Permitted point sources are listed in Table 2.5.0. This category includes those sources that discharge from a discrete point under the requirements of a discharge permit. For the SR-HC TMDL reach there are 9 permitted point sources, some of which have multiple discharges. For example, until recently IPCo had cooling water, sump water, and wastewater discharges associated with the Oxbow Dam and hydropower facility. The majority of the facilities in Table 2.5.0 are wastewater treatment facilities and industries with wastewater, process water, cooling water and permitted stormwater discharges.

Nonpoint sources are generally those sources that discharge over a diffuse area. They are generally not permitted and are more difficult to quantify than point sources due to the disperse nature of their discharges. Nonpoint source discharge occurs in all segments of the SR-HC TMDL reach and includes agriculture, forestry, urban/suburban, stormwater, groundwater and natural loading.

Tributary inflows to the SR-HC TMDL reach include the mainstem Snake River upstream of RM 409, the Owyhee, Boise, Malheur, Payette and Weiser rivers and numerous small streams. For the purposes of this TMDL, the tributary inflows have been treated as discrete nonpoint sources. Although it is recognized that pollutant loads to the tributaries stem from a variety of point and nonpoint sources within the tributary drainage, the mixed loading that reaches the Snake River is considered to be nonpoint source in nature.

A general discussion of methods available for the determination of pollutant loading, and a general water balance determination and hydrology assessment is available in Appendix G.

3.1 Mercury Loading Analysis

Due to the fact that essentially no water column data are available to this effort, a TMDL cannot be established for mercury for the SR-HC TMDL reach. Therefore, IDEQ and ODEQ have determined it is in the public interest to reschedule the mercury TMDL for the SR-HC TMDL reach. IDEQ will reschedule the mercury TMDL to 2006 in order to gather additional data to better determine the sources and extent of mercury contamination. ODEQ's schedule for the mercury TMDL coincides with this date.

The state of Oregon is developing capability to model site-specific bioaccumulation factors. Also, Oregon's mercury TMDL is not due until 2006. This schedule change will allow a better use of these capabilities and the opportunity to collect additional data.

Both Idaho and Oregon have interim measures in place to deal with mercury contamination such as sediment controls and fish consumption advisories as described in Section 3.1. It is the opinion of the DEQs that this schedule change will not present an adverse impact to the SR-HC TMDL reach.

The discussion of mercury loading presented below is a preliminary assessment only. This assessment will be augmented with additional data and evaluation tools as monitoring and modeling efforts progress. A final loading analysis and load allocation will be completed by December 2006. The final assessment will replace the preliminary assessment presented below.

3.1.1 Water Quality Targets and Guidelines: Current and Pending

The purpose of TMDL development is to meet applicable water quality standards. As a bi-state TMDL addressing interstate waters, the applicable targets for this effort have been identified as the most stringent of each state's water quality standards. In this way the attainment of these targets will ensure that the water quality requirements of both states will be met. The water quality standards and guidance values appropriate to mercury in the SR-HC TMDL are discussed below.

3.1.1.1 FEDERAL.

The US Food and Drug Administration (US FDA) has established a criterion of 1 part-per-million (mg/kg) methylmercury in fish tissue (US FDA, 1984) as an action level to protect against potential health risks for human consumption of fish. Recently (US FDA, 9 March 2001), the US FDA also announced an advisory on methylmercury in fish, specifically recommending that pregnant women, women of childbearing age who may become pregnant, nursing mothers and young children not eat certain types of ocean fish that may contain high levels of methylmercury.

Mercury criteria promulgated by the US EPA identify a water column concentration of 0.051 ug/L as a maximum for waters where fish are being harvested for human consumption, and a water column concentration of 0.050 ug/L, for waters where fish harvest occurs in combination with water being used as a domestic water supply (Federal Register 63, No 237, 68357, 1998). In response to further study and assessment nationwide, the US EPA has recently released new guidance under section 304(a) of the Clean Water Act (US EPA, 2001a) that identifies a criterion for methylmercury in fish tissue of 0.3 parts-per-million (mg/kg) to protect the health of consumers. This criterion has been developed to address the consumption of larger fish portions (17.5 grams as opposed to 6.5 grams previously) by the general public. The US EPA expects this criterion to be used as guidance by states when in establishing or updating water quality standards and fish consumption advisories.

3.1.1.2 STATE OF OREGON.

The State of Oregon has adopted an action level of 0.35 parts-per-million (mg/kg) for methylmercury in fish tissue for Oregon waters. This level is used as a screening factor in determining the need for establishing fish consumption advisories to protect human health. The State of Oregon has also adopted a water column criterion of 0.144 ug/L for methylmercury (OAR 340-41-725, 765, 805, 845 (2) (p)(B) which references an earlier version of EPA Table 20).

3.1.1.3 STATE OF IDAHO.

The State of Idaho has adopted an action level of 0.5 parts-per-million (mg/kg) for methylmercury in fish tissue for Idaho waters. This level is used as a screening factor in determining the need for establishing fish consumption advisories for the protection of human health. The State of Idaho has also adopted a water column criterion of 0.012 ug/L for methylmercury based on extrapolation of the US FDA target of 1.0 parts-per-million (mg/kg) methylmercury in fish tissue using a US EPA report documenting the use of bioconcentration factors for the determination of water column criteria (US EPA, 1984). In response to recent advances in analytical technology and better understanding of methylmercury transport and uptake in living systems, the State of Idaho action level for methylmercury in fish tissue, and the associated guidelines for issuing fish consumption advisories are currently undergoing review. New action levels and guidelines are expected to be identified late in 2003 (personal communication, M. Wen, IDHW-EHS, May 2001).

The most stringent applicable water quality standards for mercury in the SR-HC TMDL area are the 0.012 ug/L water column methylmercury adopted by the State of Idaho, and the 0.35 parts-per-million (mg/kg) fish tissue concentration criteria established by the State of Oregon. These represent preliminary targets for mercury for the SR-HC TMDL. The final TMDL, to be completed in 2006, will identify final targets for mercury in the SR-HC TMDL reach.

3.1.2 Designated Beneficial Use Impairment

The SR-HC reach is listed from RM 409 to RM 188 for mercury. To date, data available show that mercury concentrations in the SR-HC reach of the Snake River exceed the fish tissue target established by this TMDL. Water column data is not available to allow an assessment of the use support status of aquatic life uses due to mercury concentrations within the SR-HC system.

All fish tissue data available in this reach were positive for mercury. A summary of these data show that the Oregon and Idaho levels of concern were exceeded by 80% (0.35 mg/kg) and 52% (0.5 mg/kg) respectively. Both states have acted to issue fish consumption advisories based on these exceedences. The US FDA action level for fish tissue (1.0 mg/kg) was exceeded in less than 10% of the fish tissue samples taken from the Upstream Snake River segment, and less than

3% of the fish tissue samples taken from the Brownlee Reservoir segment. The very limited data set available show no (0%) measured exceedences of the 0.050 ug/L US EPA water column criteria, however, detection limits were above this value by almost an order of magnitude in most cases.

The two samples in the Upstream Snake River segment exceeding the US FDA criteria occurred in channel catfish collected from the Snake River near the mouth of the Owyhee River and near Nyssa, Oregon. The three samples exceeding the US FDA criteria in Brownlee Reservoir occurred in channel catfish, crappie and smallmouth bass collected from Brownlee Reservoir near the mouth of the Burnt River.

Although there are no data available that show direct impairment of aquatic life uses due to mercury concentrations within the SR-HC system, the designated beneficial use of fishing is not fully supported due to fish consumption advisories for methylmercury established by the states of Oregon and Idaho. Therefore, the 303(d) listing of non-support is based on the presence of fish consumption advisories rather than the violation of water quality standards for mercury. Because of this, an appropriate initial target by which to evaluate the support status of the designated fishing use is the fish tissue target of 0.35 parts-per-million (mg/kg) identified by the SR-HC TMDL. There is insufficient data to determine the use support for aquatic life uses or for the wildlife and hunting use designation.

3.1.3 Mercury in Surface Waters

Mercury is a naturally occurring element, present in the environment in three principal forms: elemental, inorganic and methylated (or organic) mercury. Geologic deposits of mercury occur naturally in an inorganic form as the mineral cinnabar (HgS) in several areas of the SR-HC watershed, mainly the Owyhee and Weiser River drainages (Koerber, 1995; Gebhards *et al.*, 1971).

Air deposition and sediment transport and deposition processes (erosion) can result in mercury entering surface water systems. Once in the water, mercury can be converted from one form to another. Particle-bound mercury can be concentrated in areas of sediment deposition through particle settling, and then later released by diffusion or re-suspension. Much of the inorganic mercury entering surface water systems attaches to particles and sinks to the bottom. While inorganic or sediment-bound mercury can be absorbed by aquatic organisms, the rate and efficiency of the uptake is much lower than that for methylated or organic mercury. Inorganic forms of mercury can be converted to organic forms by microbial action. In an organic form (commonly methylmercury), mercury can easily enter the food chain, or it can be released back to the atmosphere by volatilization (USGS, 1995). Many factors influence the form, concentration and transport of mercury in the environment, these include the concentration of dissolved organic carbon (DOC), the pH of the water system, and the concentration of dissolved oxygen in the water (Hurley, 2001).

In aquatic systems, the majority of mercury binds to organic matter and fine particulates, the transport of mercury bound to larger, bed-sediment particles in rivers and lakes is generally less substantial than that observed for smaller, finer sediment fractions (US EPA, 2001a and 2001e).

Particulate-bound mercury has been shown to move through the food chain through ingestion by filter feeding organisms and through conversion to dissolved forms. Mercury-bound particle sizes range from colloidal materials (diameters less than a micron) to particles with diameters of tens of microns (MASCO, 2001).

In the bottom sediments, the most important conversion is the bacterially mediated methylation of mercury involving the addition of methyl groups to the mercuric ion (Hg^{2+}) by means of enzymatic activity (Agostino, 2001; MASCO, 2001; NWF, 2001). This conversion of inorganic to organic mercury occurs at different rates in different waterbodies. That is why some waterbodies with high levels of total mercury, but low rates of conversion to methylmercury, may not carry fish advisories while others do.

The exact mechanism(s) by which mercury is converted to methylmercury and readily enters the food chain remain largely unknown, and probably vary among ecosystems. It is known however, that certain bacteria play an important initial role. Many anaerobic bacteria, living at the sediment/water interface, including many strains of *Staphylococci*, *Streptococci*, yeasts and *Escherichia coli* (present in human intestines), are able to convert inorganic or elemental mercury into methylmercury (Ely, 1970; MASCO, 2001; NWF, 2001).

Studies have shown that bacteria that process sulfate (SO_4^{2-}) in the environment take up mercury in its inorganic form, and through metabolic processes convert it to methylmercury. According to current understanding, some of the "right" ingredients for producing methylmercury are found in systems that are rich in carbon, and low in dissolved oxygen (Hurley, 2001). The conversion of inorganic mercury to methylmercury is important for two reasons: (1) methylmercury is much more toxic than inorganic mercury, and (2) organisms require considerably longer to eliminate methylmercury (USGS, 1995). Methylmercury has low aqueous solubility and tends to accumulate in the lipid-rich tissues of aquatic organisms.

While most people and wildlife can generally tolerate extremely low levels of mercury. When mercury enters the body it becomes concentrated in tissue, an effect known as bioaccumulation. Since this element is toxic at very low concentrations, even slight increases in the minute concentrations naturally present in the environment can have serious effects on humans and wildlife (NWF, 1997).

Methylmercury is absorbed by tiny aquatic organisms such as phytoplankton and then zooplankton, which are in turn eaten by small fish. The chemical is stored in the fish tissue and is passed on at increasing concentrations to larger predator fish. People and wildlife at the top of the food chain are consequently exposed to elevated amounts of methylmercury through the contaminated fish they consume (NWF, 1997). Additionally, methylmercury is not eliminated effectively by metabolic systems and will continue to accumulate in fish as they age (Allen-Gil *et al.*, 1995; Allen and Curtis, 1991; Benson *et al.* 1976), creating the greatest risk for bioaccumulation in older, predatory fish species (Agostino, 2001). Bioconcentration factors of 63,000 for freshwater fish, 10,000 for salt-water fish, 100,000 for marine invertebrates, and 1,000 for freshwater and marine plants have been observed (US EPA, 2001b).

Studies have shown that for the same species of fish taken from the same region, increasing the acidity of the water (decreasing pH) and/or the dissolved organic carbon content generally results in higher body burdens in fish, possibly because lower pH increases ventilation rate and membrane permeability, accelerates the rates of methylation and uptake, affects partitioning between sediment and water, or reduces growth or reproduction of fish (US EPA, 2001e; USGS, 1995). However, many of the details of the aquatic mercury cycle are still unknown, and remain areas of active research.

While many factors are known to influence the accumulation of mercury in aquatic organisms (pH, water temperature, the amount of dissolved organic material present, etc.), how these factors relate to each other and to the bioaccumulation of methylmercury is still poorly understood. No single factor has been generally correlated with level of mercury accumulation in aquatic organisms. Therefore, even though two water bodies may be very similar in physical characteristics, the measured concentrations of methylmercury in fish may be very different between the two (US EPA Mercury Web Site and 2001b).

In addition, the transformation of inorganic mercury to methylmercury is not well defined. It is currently linked to both chemical and microbial processes and often occurs in a cyclic fashion within surface water systems. Thus, inorganic mercury in a surface water system represents a potential source of methylmercury if appropriate conditions exist (US EPA Mercury Web Site and 2001b).

The evaluation of mercury within aquatic systems is still an evolving science. Analytical methods have improved dramatically over the last few years as evidenced by increased accuracy and lower detection limits, and state and federal policy and guidance have undergone many changes.

3.1.4 Sources

Both natural and anthropogenic sources of mercury are known to occur in the SR-HC TMDL drainage. External sources of mercury loading to this reach include natural and background loads from the watershed and air deposition from point and nonpoint sources.

3.1.4.1 NATURAL GEOLOGICAL SOURCES.

Natural sources of mercury include volcanic rocks and mineral deposits in the rocks and soils in several areas of the SR-HC drainage. Cinnabar, the most commonly occurring ore of mercury, contains 86.2% mercury and can occur as impregnations and vein fillings in near-surface environments from solutions associated with volcanic activity and hot springs. Cinnabar can also occur as placer type concentrations produced with the erosion of mercury-bearing rocks (ADEQ, 1999a and 1999b). Natural weathering and erosive processes can increase the transport and mobility of the mercury associated with these deposits. Concentrations of mercury identified in various rocks and soils are shown in Table 3.1.1.

Mercury concentrations identified in the Owyhee River drainage are notably higher than those identified in other areas. Some of these deposits contain enough mercury that they have been mined profitably. These deposits represent potential sources of natural loading to the SR-HC reach. Additionally, given the high level of geothermal activity in the Owyhee River drainage, natural, geothermal releases may also be a significant and persistent source of mercury in the

Table 3.1.1. Identified concentrations of mercury in different rock and soil types.

Type or location	Mercury (ppm)	Reference
Igneous rocks (international)	0.01 to 0.1	Fleischer *et al.*, 1970; ATSDR, 1994a
Sedimentary rocks	0.01 to 0.05	ATSDR, 1994a
Owyhee River Basin rocks	<0.1 to 6.2	Koerber, 1995
Background rocks	0.01 to 0.05	Andersson, 1979
Western soils	0.5	Hill, 1973
Average of all soils	0.02 to 0.625	ATSDR, 1994a
SE Oregon and N Nevada soils	0.032 to 0.051	Schacklette and Boerngen, 1984
Owyhee River Basin soils	0.1 to 565.0	Koerber, 1995

area (Allen and Curtis, 1991). Mercury deposits have also been identified in the Weiser River drainage (IDEQ, 1985), although mining activities in this drainage were more limited in scope.

Anthropogenic sources of mercury in the SR-HC area include historic use of fungicides and seed treatments in the Snake River Basin, sewage sludge and compost, landfills and industrial processes, legacy mining activities, current mining activities, air deposition from sources both inside and outside the area, cement plants and coal-fired power plants. Tributary flows to the Snake River also potentially deliver mercury from both natural and anthropogenic sources within tributary drainage areas.

3.1.4.2 SEED TREATMENTS.

From the 1950's to the 1980's, chemical treatments containing mercury were used on seed grains in the US. During 1970, mercurial seed treatment on winter and spring wheat in Idaho was estimated to be equivalent to 720 pounds (327 kg) of mercury annually (Gebhards *et al.*, 1971). The use of these seed treatments was discontinued in the 1980's. Historically, the mercury in these treatments may have contributed to water contamination due to field drainage and irrigation water return in some areas. While the use of these treatments has primarily been discontinued in the US, residual mercury in agricultural soils may still be contributing a small amount of mercury to the SR-HC system through sediment transport and erosion.

Assuming the usage estimated for 1970 is representative of the average usage during the time that seed grains treated with these compounds were used in Idaho, a total of 25,200 pounds (11,454 kgs) of mercury would have been applied in the form of seed treatments in Idaho. The majority of the upstream drainage for the SR-HC TMDL is contained in the state of Idaho. Approximately 67% of the total grain grown in Idaho in 1970 was produced in the Snake River Basin upstream of Hells Canyon Dam (USDA-NASS, 2001). Assuming that the 1970 distribution of agricultural land devoted to grain production throughout the state is representative of the distribution during the time when mercury-containing seed treatments were used (roughly 1950 to 1985), 67% of the total mercury from seed treatments (16,884 pounds, 7,675 kgs) would have been applied in the Snake River Basin. In Oregon, assuming that use of seed treatments in the southeastern portion of the state was similar to that in Idaho, 1,077 pounds of mercury (489 kgs) in the form of seed treatments was applied during this same 35-year period. Total mercury from usage of seed treatments in the drainage above Hells Canyon Dam is estimated at 17,961 pounds (8,164 kgs) over the 35 year time period (513 pounds/year, 233 kgs/year).

While a percentage of this total could leach, over time, to the Snake River system and be transported downstream, treated seed grains were planted over a very large area (roughly 642,000 acres). Assuming that all acres were planted with the same density of seed, the calculated mercury loading is 0.013 kg per acre. Not all land on which mercury-treated seeds were planted is still in agricultural use, however, irrigation and cropping practices on current agricultural lands are much improved from those used previously. Flood and furrow irrigation has been replaced in many areas with sprinkler or drip irrigation systems that result in substantially lower erosion and sediment transport. Management techniques currently in use such as straw mulching and PAM application have also been reported to reduce sediment transport. With reduced erosion and sediment transport probability, and the cessation of use in the mid 1980's, the mercury from legacy seed treatments in the Snake River Basin is not identified as a substantial source of current mercury loading to the SR-HC reach.

3.1.4.3 Sewage Sludge (or Biosolids) and Wastewater Treatment Plants.

Mercury concentrations in domestic wastewater sludge range from 0 to 2.2 mg/L. The average concentration defined by the US EPA is 0.28 mg/L (US EPA, 1984b). The application of sewage sludge to croplands can result in increased levels of mercury in soil. However, land application operations are permitted activities and are generally monitored for heavy metals accumulation in soils. They are also sited and managed such that the risk of discharge of either runoff water or eroded materials into surface water systems is low. Under general circumstances, therefore, these facilities are not identified as a substantial source of mercury loading to the SR-HC system.

Wastewater treatment plants have been observed to discharge elevated concentrations of mercury due to the waste from dental offices and medical waste disposal. Four wastewater treatment plants currently discharge to the Snake River in the SR-HC TMDL reach. Industrial discharges can also carry substantial concentrations of mercury depending on what is being manufactured. Battery and florescent light-bulb manufacturers have been documented to elevate mercury levels in their waste-streams. No such manufacturing facilities discharge directly to the Snake River within the SR-HC TMDL reach.

No mercury monitoring is currently available to determine the loading to the SR-HC TMDL reach that these sources represent.

3.1.4.4 Landfills.

A number of landfills are sited in the SR-HC drainage basin. The US EPA has identified the greatest source of mercury loading in landfills to be associated with the disposal of batteries (the primary source), and other items such as broken florescent bulbs and thermometers. However, due to their relative sparseness and general locations in the area (away from surface and ground water influences), these facilities are not identified as a substantial source of mercury loading to the SR-HC system.

3.1.4.5 MINING.

Gold, silver and mercury mining has occurred historically in the SR-HC drainage area between 1860 and 1920, primarily in the area of the Owyhee River watershed. Mercury ore (cinnabar) deposits have been identified in the Owyhee and Weiser drainages (Koerber, 1995; Gebhards *et al.*, 1971). Transport and deposition of mercury from these sources may contribute to the soil and water concentrations within the SR-HC drainage area (Koerber, 1995). The Weiser River drainage also experienced mining in the early to mid 1900's. The Idaho-Almmaden mine located about 11 miles east of the City of Weiser, produced over 600 tons of liquid mercury in a process where ore is roasted and then mercury vapors are condensed and collected. The mine operated between 1939 and 1942 (152 tons), then reopened and operated between 1955 and 1961 (456 tons) (Alt and Hyndman, 1989).

Mercury was used historically in the extraction process to remove gold from raw ore. Before the beginning of the 20th century, mercury amalgamation of gold ores was a common practice throughout the Western US (Hill, 1973; Allen-Gil *et al.*, 1995; Allen and Curtis, 1991; ADEQ, 1999a and 1999b). Most of the mercury in the amalgam was recovered, but some washed out with the fines. Amalgam furnaces may also have resulted in soil contamination through short-range deposition (ADEQ, 1999a and 1999b). Mercury in mine tailings is commonly in the elemental form. However, stream sediments in the area of tailings piles are often enriched in elemental and exchangeable forms of mercury (ADEQ, 1999a and 1999b). Observed mercury concentrations in legacy gold and silver tailing piles can range up to 5 mg/kg at various sites throughout North America (Lacerda, *1990*; Allen-Gil *et al.*, 1995; Allen and Curtis, 1991). Additionally, while gold and silver mining do not directly increase the availability of mercury within the watershed, rock-crushing activities associated with the extraction process that reduce the particle size of mercury-containing rock and increase the amount of mercury available in a readily erodable form (ADEQ, 1999a and 1999b).

A study conducted jointly by IDHW and IDFG in 1970 showed that bottom fish collected from areas in the Snake River Basin with substantial legacy mining activities exhibited mercury concentrations in muscle tissue that averaged 0.520 mg/kg. Rainbow trout in the same area averaged muscle tissue mercury concentrations of 0.231 mg/kg. Bottom fish and rainbow trout from an area outside the influence of mining activities averaged muscle tissue mercury concentrations of 0.275 mg/kg and 0.102 mg/kg respectively. While the date of this study indicates that the analytical technology used is not as robust and accurate as that available today, a relative comparison of values remains valid. The data indicate that the levels of mercury in fish tissue in fish exposed to mining wastes is nearly double that of fish in the same geologic area (e.g. exposed to natural sources of mercury) but not exposed to mining wastes (Gebhards *et al.*, 1971).

The Owyhee River flows into the Snake River in the Upstream Snake River segment of the SR-HC TMDL at RM 396.7. Mercury concentrations in bed sediments of Owyhee Reservoir average 1.4 ug/g, with most of the mercury (92%) being associated with sediment particles greater than 1 mm in diameter. Water column mercury measured in the Owyhee Reservoir averaged 0.37 ug/L (range 0.07 to 0.67 ug/L) (Allen-Gil et al., 1995; Allen and Curtis, 1991). Given the 715,000 acre-foot volume of the reservoir, this represents a total mass of 327 kg of mercury in a dissolved and therefore fairly mobile form. The mean mercury concentration in sediment reported for Owyhee Reservoir was higher than that reported for numerous other lakes in the Northwest (Allen-Gil et al., 1995; Allen and Curtis, 1991).

Mercury loading in Owyhee Reservoir is most likely derived from natural deposits exacerbated by legacy mercury, gold and silver mining in the area. It is estimated that more than 76 pounds of mercury were lost daily during mining years in Idaho (Hill, 1973; Allen-Gil *et al.*, 1995; Allen and Curtis, 1991). The Idaho Historical Society reported that one mill in the Owyhee River drainage (Silver City) "lost" 2.5 tons of mercury between 1866 and 1888. Free mercury was visible in the soil and rock crevices at a mill site in the same area as late as 1971 (Gebhards *et al.*, 1971).

Mercury concentrations in sediments from the Weiser River were also evaluated (Buhler *et al.*, 1984). The mean sediment mercury concentration in the mainstem Weiser River was 0.054 mg/kg (dry weight). The mean sediment mercury concentration in tributaries to the Weiser River was 1.30 mg/kg (dry weight).

Little information is available to determine the mercury loading to the Snake River from the Owyhee River drainage or from any of the other tributaries to the Snake River in the SR-HC reach. One of the major problems encountered is the lack of water column data. The majority of water column data available was collected prior to 1990 and is therefore not easily correlated with current analytical technology. In addition, this data, and that collected in the 1990's show no measurable concentrations above the detection limits. The elevated concentrations of mercury in the soils and water of the Owyhee River drainage indicate that it represents a substantial source of potential loading from both natural and anthropogenic sources. Anthropogenic loading is assumed to be primarily the result of legacy mining activities.

3.1.4.6 AIR DEPOSITION.

Air deposition of mercury has recently been identified as a substantial source of mercury loading in the US (US EPA, 1997a and 1997b). The anthropogenic air deposition rate for the SR-HC reach estimated by this report is 1 to 3 ug/m^2/yr (US EPA, 1997a and 1997b). Using a mean value of 2 ug/m^2/yr, this yields a potential deposition of 13 kg/year of mercury to the land area directly discharging to the SR-HC TMDL reach and 380 kg/year of mercury to the land area in the Snake River drainage area above Hells Canyon Dam. The primary source of atmospheric mercury identified by this report is the combustion of fossil fuels. Current emissions of mercury from manufacturing sources are low compared to combustion sources, with the exception of chlor-alkali plants and portland cement manufacturing plants.

Recent guidance on mercury deposition released by US EPA in 2001 report a "typical low level air deposition load" as 10 ug/m^2. A study of the San Francisco area measuring wet and dry deposition rates for the San Francisco estuary at 4.2 ug/m^2/year and 19 ug/m^2/year, respectively (Tsai, 2001). Adjustment of the original calculated loading from air deposition to reflect the updated UP EPA deposition loads increases the original estimate to a potential deposition of 65 kg/year of mercury to the land area directly discharging to the SR-HC TMDL reach and 1,900 kg/year of mercury to the land area in the Snake River drainage area above Hells Canyon Dam.

Even without site-specific data, assuming that actual deposition loads are bracketed by these two estimates gives a strong indication that air deposition represents a substantial source of mercury loading to the SR-HC TMDL reach.

3.1.4.7 PORTLAND-PROCESS CEMENT PLANTS.

There is currently one operating cement plant in the immediate SR-HC drainage, the Ash Grove plant at Durkee, OR. Monitoring indicates that this plant produces emissions containing approximately 109 pounds (49.5 kg) of mercury per year.

3.1.4.8 COAL-FIRED POWER PLANTS.

There is only one coal-fired power plant operating in the Snake River region. The power plant at Boardman, OR is located in the Willow Creek subbasin in Oregon, near the Oregon/Washington border, approximately 100 miles northwest of the northern extent of the SR-HC TMDL reach. This plant produces emissions containing approximately 186 pounds (84.5 kg) of mercury per year when operating at full capacity.

The prevailing wind direction in the SR-HC watershed is from west to east. As both of these facilities are located west of the SR-HC area, there is a potential for at least some of the mercury loading from these plants to reach the SR-HC TMDL drainage. Probability is higher that the Ash Grove cement plant will be a greater contributor however as it is located nearly due west of the SR-HC reach while the Boardman plant is located to the northwest of the SR-HC TMDL area. Mercury emitted from these types of sources can travel for long distances depending on the chemical form it is in and the climate. Areas of relatively low precipitation offer less chance for the mercury to be deposited close to the source, as wet deposition will not occur regularly. Dry deposition, where mercury adsorbs to suspended particles usually results in longer-range transport than wet-deposition where mercury is captured in rain or snow and falls down with the drops. Dry deposition is expected to be the most common form of air deposition for mercury in the SR-HC reach.

3.1.5 Transport and Delivery

Sediment transport of mercury is expected to be highest in drainages where steep slopes, relatively sparse vegetation and precipitation occurring primarily in the form of snowfall combine. Sparse vegetation and timing of snowmelt in the Owyhee and Weiser River drainage, and in much of the rest of the SR-HC drainage where geologic deposits of mercury occur, produce conditions favoring high surface runoff and sediment transport.

Flooding can also enhance mercury transport and bioaccumulation. Flooding results in a surge of mercury and other materials into local reservoirs where methylation occurring in flooded shorelines and near shore sediments may result in higher rates of bioaccumulation. This mechanism has been documented (Phillips *et al.*, 1987) in the Upper Missouri River Basin where northern pike were observed to exhibit higher mercury concentrations in the year following significant flooding than in previous or succeeding years.

Additionally, land use patterns may play a role in determining the behavior of mercury in reservoir systems (Allen-Gil *et al.*, 1995; Allen and Curtis, 1991; Sorensen *et al.* 1990). Land use patterns may act to influence mercury transport within a drainage area to surface water systems and within reservoir systems. Unfortunately, the relative impact of land use practices is not quantifiable with the available data for the SR-HC system.

A report prepared by CH2MHill for IPCo (IPCo, 2000d) identified sediment mercury levels and associated particle sizes within the SR-HC reach. As discussed in more detail in Section 3.1.6, the samples containing the greatest concentrations of mercury in the Upstream Snake River segment (RM 409 to 335) contained larger-size sediment particles, suggesting that the mercury is present in either its native form or as cinnabar (HgS) (IPCo, 2000d) and is most likely deposited in this stretch through erosion and transport processes.

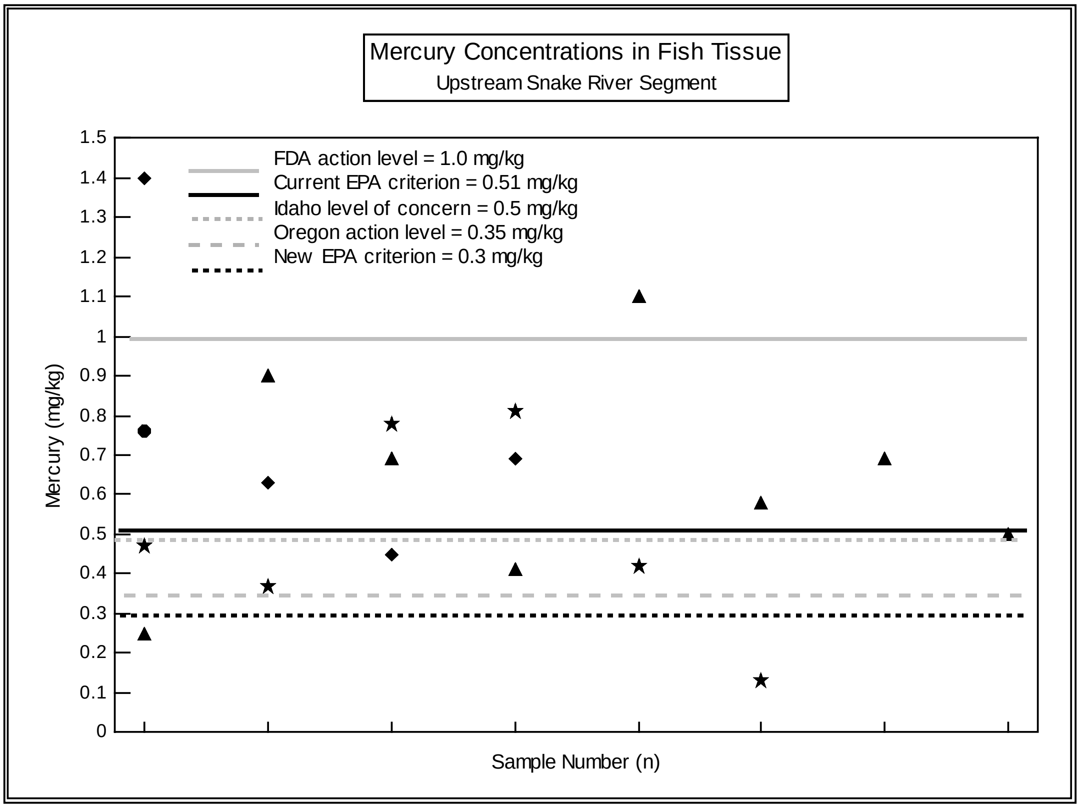
3.1.6 Data Available for the Snake River - Hells Canyon Reach

Mercury data available to this TMDL effort are almost exclusively in the form of fish tissue concentrations. Few data points identifying water column concentrations of mercury are available. Water column data are reported as <0.1 ug/L (Rinella *et al.*, 1994) or are reported as "below the detection limit" of 0.5 (the majority of the data set) or 0.2 ug/L, and were collected before 1990. There are 23 water column samples collected in 1990 that reported concentrations below detection limits of 0.2 ug/L mercury (US EPA STORET). Additionally, information collected by the City of Fruitland as part of the monitoring associated with the City's wastewater treatment plant show three data points for the Snake River (near the discharge point of RM 373). All samples were taken early in 2002 and show water column mercury concentrations in the Snake River to be less than the detection limit of 0.010 ug/L. These values are below the preliminary water column target of 0.012 ug/L established by the SR-HC TMDL.

Mercury data is available from the 1970's and the 1990's. However, due to substantial changes land management, sampling and analytical techniques and dramatic improvements in detection limits, the data collected in the 1990's is assumed to be more representative of actual conditions than that collected in the 1970's. Data collected in the 1970's are discussed in a general fashion within this section. Data from the 1990's are used as a basis for determining designated beneficial use impairment and management/control measures appropriate for the system. Data are shown in Figure 3.1.1 and Table 3.1.2.

Studies conducted in the 1970's (Benson *et al.,* 1976; Maret, 1995) characterized mercury concentrations in fish populations in Brownlee Reservoir (76 samples) and the Downstream Snake River (18 samples) segment as compared to upstream populations in the Snake River (31 samples).

The data collected in the 1990's contain a small fish tissue methylmercury data set for the Upstream Snake River segment (21 data points), a larger fish tissue methylmercury data for the Brownlee Reservoir segment (129 data points), and a single data point for the Downstream Snake River segment. There are no known fish tissue methylmercury data available for the Oxbow Reservoir or Hells Canyon Reservoir segments. No measured water column and little sediment mercury data are available to this effort. Water column data indicate only that concentrations were below the below detection limits, they do not give quantitative, measured concentration values.



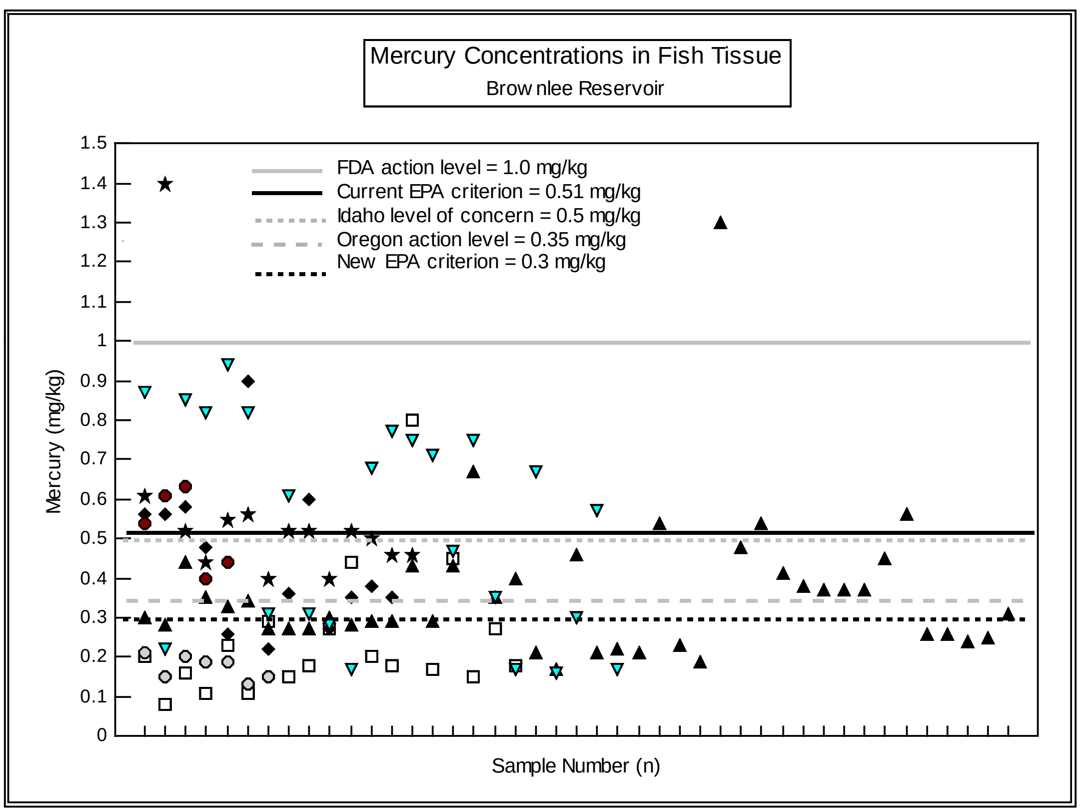


Figure 3.1.1. Mercury concentrations in fish tissue samples from the Upstream Snake River (RM 409 to 335) and Brownlee Reservoir Segments of the Snake River - Hells Canyon TMDL reach.

Table 3.1.2. Mercury data available for the Snake River - Hells Canyon TMDL (1970 through 1997).

Sample Site	Sample Group	Fish species	Year*	Average Hg (mg/kg wet weight)	n
Upstream	OSU	Channel Catfish	1970	0.61	11
Brownlee Res.	OSU	Channel Catfish	1970	0.97	5
Brownlee Res.	IDFG	Largemouth Bass	1970	0.37	3
Brownlee Res.	IDFG	Smallmouth Bass	1970	0.53	2
Brownlee Res.	IDFG	Bluegill	1970	0.60	1
Brownlee Res.	IDFG	Channel Catfish	1970	0.37	16
Brownlee Res.	IDFG	Carp	1970	0.24	1
Brownlee Res.	IDFG	Pike Minnow	1970	0.73	1
Brownlee Res.	IDFG	Sucker	1970	0.30	9
			Average	**0.51**	**38**
Upstream	IDFG/IDHW	Catfish	1975	0.33	20
Upstream	IDFG & Others	Water	1975 to 1977	<0.5 ug/L	72
Upstream	IDFG & Others	Water	1977 to 1987	<0.5 to <0.2 ug/L	67
Upstream	IDFG & Others	Water	1987 to 1989	<0.2 ug/L	19
Brownlee Res.	IDFG/IDHW	Idaho Catfish	1975	0.50	20
Brownlee Res.	IDFG/IDHW	Idaho Bass	1975	0.64	18
			Average	**0.57**	**38**
Hells Canyon	IDFG/IDHW	Idaho Bass	1975	0.79	18
Upstream	USGS	Carp	1990	0.79	4
Upstream	USGS	Channel Catfish	1990	0.64	8
Upstream	USGS	Smallmouth Bass	1990	0.50	6
Upstream	USGS	Crappie	1990	0.24	1
			Average	**0.62**	**19**
Upstream	USGS	Whole Water	1990	<0.1 ug/L	2
Upstream	USGS	Whole water	1989	<0.5 ug/L	3
Upstream	USGS	Whole water	1989	<0.2 ug/L	6
Upstream	USGS	Sediment	1990	0.02 ug/g	2
Brownlee Res.	IDEQ	Smallmouth Bass	1994	0.56	14
Brownlee Res.	IDEQ	Carp	1994	0.60	13
Brownlee Res.	IDEQ	Catfish	1994	0.34	42
Brownlee Res.	IDEQ	Black Crappie	1994	0.24	19
Brownlee Res.	IDEQ	White Crappie	1994	0.53	24
Brownlee Res.	IDEQ	Yellow Perch	1994	0.54	5
Brownlee Res.	IDEQ	Rainbow Trout	1994	0.19	7
			Average	**0.39**	**124**

Sample Site	Sample Group	Fish species	Year*	Average Hg (mg/kg wet weight)	n
Brownlee Res.	USGS & others	Whole water	1990 to 1996	< 0.2 ug/L	23
Upstream	USGS	Sediment	1997	0.04 ug/g	1
Brownlee Res.	USGS & IPCo	Largescale Sucker	1997	0.11	1
Brownlee Res.	USGS & IPCo	Carp	1997	0.32	1
Brownlee Res.	USGS & IPCo	Smallmouth Bass	1997	0.29	1
Brownlee Res.	USGS & IPCo	Crappie	1997	0.27	1
Brownlee Res.	USGS & IPCo	Channel Catfish	1997	0.33	1
			Average	**0.26**	**5**
Brownlee Res.	USGS	Sediment	1997	0.10 ug/g	2
Hells Canyon	USGS & IPCo	Largescale Sucker	1997	0.03	1
Upstream	USGS & IPCo	Channel Catfish	1997	0.21	1
Upstream	USGS & IPCo	Largescale Sucker	1997	0.07	1
			Average	**0.14**	**2**

(*****NOTE: Data collected prior to 1989 to 1990 may show higher levels of error due to differences in sampling and analysis as compared to current technology. Data in this table are from Benson, 1976; Gebhards *et al.*, 1971; Maret, 1995; Rinella *et al.*, 1994; Clark and Maret, 1998; IDEQ, 1994; IDFG-IDHW, 1971 to 1979; IPCo, 2000d; Buhler, 1971; Buhler *et al.*, 1971.)

All fish tissue samples collected from this reach were positive for mercury. A summary of the data show that the Oregon and Idaho levels of concern were exceeded by 80% (0.35 mg/kg) and 52% (0.5 mg/kg) respectively. Both states have acted to issue fish consumption advisories based on these exceedences. The US FDA action level for fish tissue (1.0 mg/kg) was exceeded in less than 10% of the fish tissue samples taken from the Upstream Snake River segment, and less than 3% of the fish tissue samples taken from the Brownlee Reservoir segment. The very limited data set available show no (0%) measured exceedences of the 0.050 ug/L US EPA water column criteria, however, detection limits were above this value by almost an order of magnitude in most cases.

Fish tissue methylmercury data collected in the Upstream Snake River (n = 20) segment show the highest fish tissue methylmercury concentrations in fish taken from the area of the mouth of the Owyhee River (0.73 mg/kg, n = 3), followed by the fish taken from the area of the mouth of the Weiser River (0.64 mg/kg, n = 3). These findings correlate well with the relative levels of natural geological mercury deposits identified and mining activities within these drainages, as compared to the SR-HC reach in general.

Elevated mercury concentrations in fish tissue from the Upper Snake River Basin were identified by Maret (USGS, Maret, 1995) in an intensive evaluation of existing data (1970 to 1990). Mercury concentrations from most sites exceeded the US Fish and Wildlife National Contaminant Biomonitoring Program (NCBP) baseline concentration of 0.11 ug/g, but did not exceed the US FDA action level of 1.0 mg/kg for fish consumption. All fish tissue data from the Snake River show concentrations above the detection limits in all cases except samples from the

Snake River at Flagg Ranch (< 0.05 mg/kg wet weight (Maret, 1995)), the Snake River at Minidoka (< 0.1 mg/kg wet weight (Clark and Maret, 1998)) and the Snake River at Kimberly (< 0.1 mg/kg wet weight (Clark and Maret, 1998)). The areas where fish tissue mercury concentrations were below detection limits correlate well with sediment mercury concentrations, which were below the detection limits only in the Minidoka and Blackfoot areas (both < 0.02 mg/kg (Clark and Maret, 1998)).

Warmwater and nongame species in Idaho were found to contain approximately twice the concentration of mercury as found in coldwater game fish species (Gebhards *et al.*, 1971). This indicates a relationship between diet and age, and mercury accumulation. Fish that are piscivorous (eat other fish) generally contain higher levels of mercury than fish that eat mainly plankton and insects. Some fish (such as rainbow and cutthroat trout) convert from a plankton/insect diet to a small fish diet after reaching a certain age or weight. Therefore older fish, and fish whose diets consist mainly of other fish should be avoided. Fish populations, in association with those human populations most at risk for injury due to mercury consumption, are targeted by the fish consumption advisories in place.

Gebhards (1971) states that geological sources of mercury are probably the major contributors to mercury residues in fish in the SR-HC area where anthropogenic activity is limited. The Oregon fish consumption advisory states that “the mercury in fish is thought to be from natural volcanic and geothermal sources in the upper drainage areas, possibly influenced by historical mining practices”. This statement is substantiated by the evaluation of proportional source loads within the SR-HC system.

Some bed sediment mercury information is available for several sites in the Upstream Snake River and Brownlee Reservoir segments. Mercury concentrations in bed sediments of the Snake River upstream of CJ Strike Reservoir range from 0.035 parts-per-million (ug/g) near Blackfoot to 0.09 parts-per-million (ug/g) near Buhl (Maret, 1995).

Mercury in bed sediments sampled by the USGS in Brownlee Reservoir near the inflow of the Burnt River and at Mountain Man Lodge (RM 310) (Clark and Maret, 1998) in 1997 were less than 0.174 parts-per-million (mg/kg), the threshold effects level (TEL) and 0.486 parts-per-million (mg/kg), the probable effects level (PEL) in all cases. The TEL and PEL are concentrations levels published by the National Oceanic and Atmospheric Association (NOAA) for the protection of benthic life.

The CH2MHill report (IPCo, 2000d) identified sediment mercury levels and associated particle sizes within the SR-HC reach. Particle size is an important factor in evaluating the distribution of mercury in sediments as smaller particle sizes have exponentially greater surface areas and are therefore likely to carry much larger adsorbed loads of trace metals and organic compounds. Clays and silts, commonly made up of very fine particles, generally have much higher concentrations of adsorbed constituents than coarser-grained sediments (IPCo, 2000d). Samples were taken from RM 397, downstream to Brownlee Dam (RM 285) including the mouth of the Owyhee, Boise, Malheur, Payette, Weiser, Burnt and Powder rivers. Samples were taken approximately every five miles from RM 340 to RM 285. Three deep core samples were extracted between RM 320 and RM 325 (within Brownlee Reservoir). Samples were collected from December 1998 to January 2000. Deep core samples included materials from approximately 10 feet below the 1952-surveyed water-surface elevation, which represents pre-impoundment conditions.

Data collected in this study showed a generally increasing trend in mercury concentration upstream to downstream. In the lower reservoir (RM 285 through 310) where the percentage of fine particles was the highest (6 samples), no concentrations exceeded the mercury PEL of 0.486 parts-per-million (mg/kg). The TEL (0.174 parts-per-million (mg/kg)) was exceeded for all samples.

In the upper reservoir (RM 312 through 336, 7 samples) the highest concentrations of mercury were observed at RM 335. The TEL was exceeded at this location, but not the PEL. The sediment collected at this location contained essentially no fine particles. This suggests that the mercury is present in either its native form or as cinnabar (HgS) (IPCo, 2000d) and is most likely deposited in this stretch through erosion and transport processes.

In the Upstream Snake River segment (RM 340 to 397, 11 samples), the TEL was exceeded at RM 340 only. This sample, located close to the one discussed at RM 335 above, contained both fine and coarse particle sizes but was analyzed as a composite. Therefore, the higher mercury levels may be due to the coarse grain sizes as at RM 335. The TEL for mercury was not exceeded in any of the tributary samples (IPCo, 2000d).

In the deep core samples (RM 320 to 325, 36 samples from 3 separate cores), none of the samples exceeded the TEL or PEL for mercury, indicating that the majority of mercury loading is probably associated with sediment erosion, transport and deposition within the SR-HC drainage rather than with strata associated directly with the SR-HC channel in Brownlee Reservoir.

Differences between this study and that undertaken by the USGS (Clark and Maret, 1998) are not necessarily indicative of reduced levels of mercury in the bed sediments within the SR-HC reach due to differences in the analytical technique applied. The digestion procedure used to prepare solids for trace metal analysis by the USGS was a more aggressive technique than that used by the CH2MHill study (IPCo, 2000d). A more aggressive digestion step can result in the dissolution of a greater proportion of the inorganic mercury in a sediment sample than that dissolved by a less aggressive digestion procedure. Therefore, reported concentrations would be expected to be higher for the analysis employing the more aggressive dissolution technique.

3.1.7 Determination of Mercury Loading

Determination of pollutant loading to a surface water system is generally accomplished through an association of concentration and flow values. Without the availability of measured water column concentration data for the SR-HC system, alternative methods of assessing mercury loading have been investigated. Without measured data for water column concentrations in the system, relative loading estimates and frequency of fish tissue target exceedences have been used as general indicators of the level of concern and actions necessary. Table 3.1.3 shows the identified sources of mercury to the SR-HC system and the relative contribution, measured or calculated of each. It should be noted that this information is preliminary, based on data and information currently available and may not be representative of the trends identified in the final SR-HC mercury TMDL.

Table 3.1.3. Identified sources of mercury loading to the Snake River - Hells Canyon reach and the relative contribution to total loading.

Source	Timeline	Data Type	Concentration or Potential Load	Relative Proportion of Measured Total
Seed treatments	Historical	Calculated	Estimated 8,164 kg total (0.013 kg/acre)	Unknown – assumed very small
Mercury in land applied domestic wastewater sludges	Current	EPA guidance	Negligible	Negligible
Landfills	Current	EPA guidance	Negligible	Negligible
Industrial processes	Current	EPA guidance	Negligible	Negligible
Mining	Legacy	Literature value	Up to 5 mg/kg tailings	Unknown – assumed moderate to high
Mining	Current	Monitored	No direct discharge	Unknown
Air Deposition - SR-HC direct drainage	Current	EPA guidance	380 to 5,110 kg/year	Unknown – estimated to be substantial
Air Deposition - Snake River Basin	Current	EPA guidance	380 kg/year	Unknown – estimated to be substantial
Ash Grove Cement Plant	Current	Monitored	49.5 kg/year	Small
Coal-Fired Power Plant	Current	Monitored	84.5 kg/year (at 100% capacity)	Small
Tributary loading (non-mining anthropogenic)	Current	Monitored – Water Column	Below detection limits	Unknown – assumed small
Natural loading – Owyhee basin	Historic and current	Monitored rock/soil concentrations	0.1 to 565.0 mg/kg in geologic deposits	Assumed moderate to high given richness of mineral deposits identified
Sediment loading – In channel values	Historic and current	Monitored rock/soil concentrations	0.02 to 0.05 mg/kg from measured data	Unknown – assumed moderate to high
Natural loading – In channel values	Historic and current	Monitored US rock/soil concentrations	0.02 to 0.625 mg/kg	Unknown – assumed moderate to high

Where sufficient data is available, bioaccumulation factors can be calculated for fish species in a mercury-enriched system. Preliminary bioaccumulation factors were developed by US EPA for application on a nationwide basis. However, under peer review, it was determined that these factors contained sufficient variability that they should not be applied in a generalized fashion (US EPA, 2001b). Peer review yielded the following findings and recommendations:

1. Bioaccumulation of methylmercury is highly site-specific in nature in aquatic environments
2. The peer reviewers recommended "developing methylmercury BAFs on a more local or regional scale if not on a site-specific basis…"
3. "After considering various issues about mercury fate in the environment…and the BAF peer review comments, EPA concluded that it is more appropriate at this time to derive a fish tissue…residue water-quality criterion for methylmercury than a water column based water quality criterion."

The recommendation was made that site-specific bioaccumulation factors be developed for systems of concern. Unfortunately, the data available at this time is not sufficient to develop site-specific methylmercury bioaccumulation factors for the SR-HC reach. Therefore, water column concentrations cannot be calculated directly from the available fish tissue data.

Similarly, in response to recent advances in analytical technology and better understanding of methylmercury transport and uptake in living systems, the State of Idaho is initiating a review and potential revision of the current action level for methylmercury in fish tissue. Oregon is willing to participate in this review. The associated guidelines for issuing fish consumption advisories are also currently undergoing review. New action levels and guidelines are expected to be identified late in 2003 (personal communication, M. Wen, IDHW-EHS, May 2001).

Known designated beneficial use impairment due to mercury concentrations within the SR-HC reach is related to the designated use of fishing. This use is not fully supported due to elevated concentrations of mercury identified in fish tissue in the Upstream Snake River and Brownlee Reservoir segments. Elevated mercury concentrations in fish tissue represent a risk for both humans and wildlife consuming fish tissue.

3.1.8 Load Allocations and Other Appropriate Actions

Using the target water column concentration of 0.012 ug/L, a load capacity can be calculated (Table 3.1.5). However, calculation of an existing load or load allocation is not possible due to lack of water column data. Additionally, while relative load comparisons can be estimated, there are not sufficient data available to quantify the loading from legacy mining activities relative to natural loading within the SR-HC system. These assessments will be accomplished as part of the 2006 mercury TMDL.

3.1.9 Determination of the TMDL

Due to the uncertainty of back calculation from fish tissue methylmercury data, and the lack of water column mercury data for the SR-HC reach, a TMDL load cannot be calculated at this time.

The DEQs have assessed the data available (primarily fish tissue data) and do not feel that a load can be accurately back calculated. Current EPA guidance for calculating air deposition-based loading alone would constitute 92% of the allowable calculated capacity. The DEQs do not believe that this accurately characterizes the system. More data is needed to make an accurate assessment.

Due to the magnitude of these concerns, IDEQ and ODEQ have determined it is in the public interest to reschedule the mercury TMDL for Brownlee Reservoir. IDEQ has rescheduled this mercury TMDL to 2006 in order to gather additional data to better determine the sources and extent of mercury contamination. This change has been approved by the US EPA. This timeline is in compliance with ODEQ’s existing schedule.

The state of Oregon is developing capability to model site-specific bioaccumulation factors. Also, Oregon's mercury TMDL is not due until 2006. This schedule change will allow a better use of these capabilities and the opportunity to collect additional data.

Both Idaho and Oregon have interim measures in place to deal with mercury contamination such as sediment controls and fish consumption advisories. It is the opinion of the DEQs that this schedule change will not present an adverse impact to the SR-HC TMDL reach.

3.2 Nutrient Loading Analysis

3.2.1 Water Quality Targets and Guidelines

The purpose of TMDL development is to meet applicable water quality standards. Because the SR-HC TMDL is a bi-state effort, the most stringent of each state's water quality standards have been identified as the targets for this TMDL. In this way the attainment of these targets will ensure that the water quality requirements of both states will be met.

The Upstream Snake River segment (RM 409 to 335), the Brownlee Reservoir segment (RM 335 to 285) and the Oxbow Reservoir segment (RM 285 to 272.5) of the SR-HC TMDL reach are listed for nutrients on the state 303(d) lists for this TMDL. The water quality standards and guidance values identified for excess nutrients in the SR-HC TMDL are narrative criteria that address both the direct effects of elevated nutrient concentrations and the indirect effects of increased algal growth. These criteria require that nutrients shall not exceed quantities that impair designated beneficial uses, or cause visible slime growths or other nuisance aquatic growths that impair designated beneficial uses. Designated beneficial use impairment by excess nutrients is also linked to low dissolved oxygen concentrations through the growth and decay of algae, other aquatic plants and organic material resulting from elevated nutrient concentrations and loading.

A narrative standard for nutrients is appropriate given that the associated problems (excessive growth, low dissolved oxygen, etc.) can occur under a range of concentrations and are related to system characteristics such as flow, temperature, water column mixing, light penetration and water depth. Interpretation of the narrative standard on a site-specific basis is necessary to identify targets that will be protective of designated beneficial uses within the listed segment. The designated beneficial uses determined to be most at risk from excess nutrients were those associated with recreation and aquatic life. Direct effects on aesthetics and recreational use and indirect effects on aquatic life in the SR-HC TMDL reach are linked to excessive nutrient loading. A more detailed discussion of these concerns is included in the Subbasin Assessment for the SR-HC TMDL.

US EPA previously established guidelines for nutrient concentrations in surface waters specific to those waters discharging into lakes or reservoirs (0.05 mg/L total phosphorus) and those waters not discharging into lakes or reservoirs (0.10 mg/L total phosphorus). These guidelines have since been updated by US EPA with the release of ecoregional guidance values, and nutrient criteria establishment guidance (US EPA, 2000d). Additional methodology is available from other regions of the United States for the identification of algal biomass and chlorophyll *a* targets protective of designated beneficial uses. (Chlorophyll *a* can be used as a surrogate for algal biomass determination.) This guidance was used as an initial starting point for the identification of target concentrations for nutrients in the SR-HC TMDL. Available data from the SR-HC reach and other appropriate segments of the Snake River were evaluated to determine what instream concentrations would result in attainment of water quality standards and support of designated beneficial uses. Both the riverine and the reservoir segments were evaluated.

3.2.1.1 Snake River - Hells Canyon TMDL Water Quality Chlorophyll *a* and Nutrient Targets.

A chlorophyll *a* target of 14 ug/L mean growing season concentration and a nuisance threshold of 30 ug/L chlorophyll *a* with exceedence threshold of no greater than 25 percent has been established as the chlorophyll *a* target for this TMDL. The associated nutrient concentration target established for the SR-HC TMDL is a water column concentration of total phosphorus no greater than 0.07 mg/L. These are seasonal targets that apply from May through September. A more detailed discussion of target determination is included in the following sections.

It is the opinion of IDEQ and ODEQ that:

- These targets represent a valid interpretation of narrative standards.
- These targets will be protective of both recreation and aquatic life uses and water quality, and will thus meet the requirements of the CWA.
- Attainment of these targets, in coordination with the other water quality targets identified by this TMDL will result in full support of the designated beneficial uses within the system.

There has been a substantial amount of discussion within this TMDL process regarding the application of total phosphorus targets as opposed to ortho-phosphate targets. While it is recognized that dissolved ortho-phosphate represents the phosphorus fraction that is the most readily available for growth, it is also understood that ortho-phosphate is not a conservative parameter instream. Ortho-phosphate is a dynamic component of the water column and concentrations can change dramatically in a short distance or time due to growth or die-off of algal blooms and variation in dissolved oxygen concentrations. Ortho-phosphate can convert between forms readily under favorable water column conditions and may not be an accurate representation of the pool of phosphorus available for biological uptake.

3.2.2 Designated Beneficial Use Impairment

The designated beneficial uses determined to be most at risk from excess nutrients were those associated with aesthetics, recreation and aquatic life. Additional concerns related to excessive nutrient loading include risks associated with public drinking water supplies in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach.

3.2.2.1 Recreational Use and Aesthetics.

Direct effects associated with recreational uses include decreased utilization of the SR-HC system or portions thereof due to unfavorable water color, low water clarity and unpleasant odor. Indirect effects associated with aquatic life uses in the SR-HC reach include low dissolved oxygen levels deep in the water column due to the decomposition of algae and other aquatic plant materials and high in the water column due to diurnal effects associated with substantial algae blooms. High pH levels often associated with low dissolved oxygen due to decomposing organic matter have not been observed to occur in the SR-HC TMDL reach, most probably due to the buffering effect of natural mineral compounds dissolved in the water.

A review of concerns related to excess nutrient levels in the SR-HC reach shows that excessive aquatic growth (mostly algae blooms) is commonly observed in the Upstream Snake River segment (RM 409 to 335) and sections of the Brownlee Reservoir segment (RM 335 to 285) during late spring and early summer.

IDEQ has received a number of personal accounts and complaint calls regarding the condition of the Upstream Snake River segment (RM 409 to 335), particularly between the inflow of the Boise River (RM 396.4) and Farewell Bend (RM 335). The majority of the information was received as personal communication associated with recruitment for public participation in the SR-HC TMDL process and during public meetings for the Subbasin Assessment for the SR-HC TMDL. Additional comments were associated with posted public notices for SR-HC PAT meetings. Several complaint calls unrelated to the SR-HC TMDL effort have been received by IDEQ in regards to perceived poor water quality and unpleasant odor.

The majority of people offering information stated that the level of algal growth in the river has been increasing over the last 20 years and is now at a point where they will not swim or allow members of their families to swim in the water over the summer season. Several individuals specifically stated that they had previously used the Snake River near Weiser and Brownlee Reservoir for recreation but that during the last 10 to 15 years they have recreated in the Oxbow and Hells Canyon reservoirs instead as the amount of algal growth was less and their general impression of water quality in the downstream reservoirs was more favorable.

References to unfavorable water quality in regards to boating were fewer in number than those regarding swimming. In general complainants indicated that while they still use the river for boating, they have reduced the number of visits (usually during summer months) because of the added maintenance and cleaning required due to algal growth, and a general perception of poor water quality.

Additionally, several individuals referred to unfavorable odors associated with the water in this section of the Snake River and several referred to a decline in fishing success and quantity.

While the decrease in recreational-use hours described in these comments is difficult to quantify, and acknowledging that the complaints received do not necessarily constitute a representative sampling of recreational users on the SR-HC TMDL reach of the Snake River; they do indicate that there has been a negative effect on recreational use within the SR-HC TMDL reach.

An overall assessment of water quality was conducted by IDEQ during July and August of 2001 (a low water year). The Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir were surveyed visually at several different locations for aesthetic water quality conditions and general perception of visual water quality. A general increase in turbidity and coloration intensity is apparent from upstream to downstream in the Upstream Snake River segment (RM 409 to 335) as documented in the series of photos in Figure 2.3.1. These photos (taken June 2001) illustrate the change in water clarity and color in the mainstem Snake River from Marsing (RM 425) immediately upstream of the SR-HC TMDL reach, to Nyssa (RM 385), midway through the Upstream Snake River segment of the SR-HC TMDL reach, to Weiser (RM 351.2), approximately 16 miles upstream of the headwaters of Brownlee Reservoir. A decrease in aesthetic water quality is evident in these photos. The increase in turbidity and coloration, as

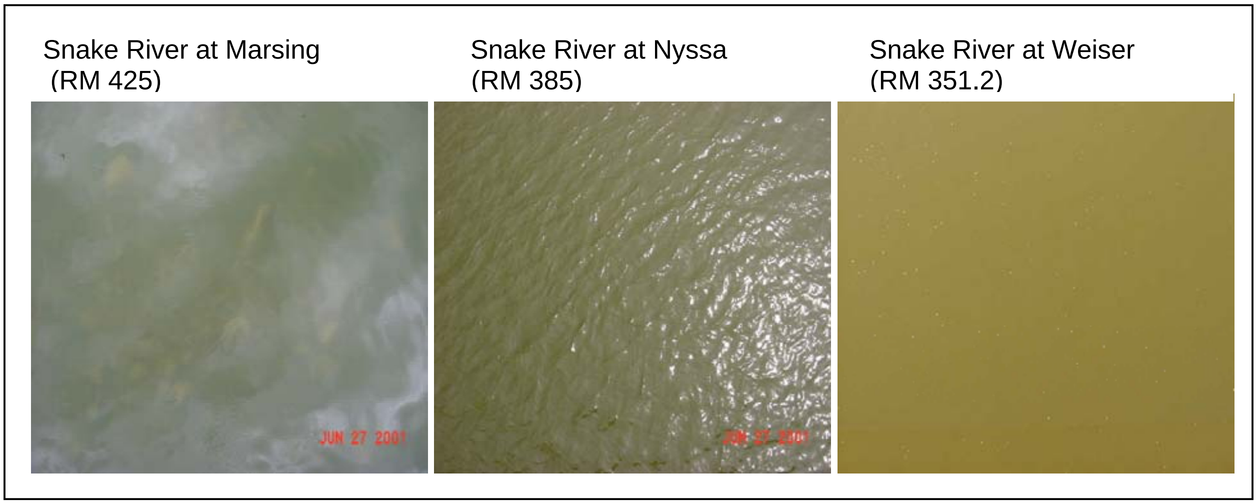


Figure 3.2.1. Photos illustrating change in water clarity and color in the mainstem Snake River from Marsing (RM 425) to Nyssa (RM 385) to Weiser (RM 351.2).

well as odor are most likely due to a combination of algae and other suspended sediment in the water column.

As aesthetic water quality and public perception are difficult to measure directly, those characteristics of water that are generally considered unappealing were evaluated. Dominant factors in the perception of water quality are coloration, odor and level of aquatic growth. Because it is correlated with all of these factors, algae was identified as a good indicator of aesthetic water quality. A commonly employed surrogate measure of algal growth is chlorophyll *a*. Chlorophyll *a* was used as a mechanism or surrogate measure of aesthetic water quality for the purposes of this assessment.

Chlorophyll is the green pigment in plants associated with photosynthesis (the process where-by plants combine light energy, nutrients and carbon to generate organic matter). A measure of chlorophyll gives information on the relative amount of photosynthesizing plants that are in the water column. Traditional methods of chlorophyll analysis give a measure of all green pigments in plants whether they are alive or dead. More current technology allows chlorophyll measurements to be corrected to remove the byproducts of chlorophyll degradation. Thus pheophytin-corrected chlorophyll *a* concentrations can be measured that report only that portion of the total chlorophyll that was actively photosynthesizing when the sample was collected, therefore, corrected chlorophyll *a* can be used to determine the amount of living algae (and other living plant material) in the water column. The chlorophyll *a* data utilized in this loading analysis was (to the extent possible) pheophytin-corrected chlorophyll *a*.

Other sources of chlorophyll *a* in the SR-HC TMDL reach may include sloughed periphyton and entrained plant materials (aquatic plants, tree leaves, etc.). Chlorophyll *a* is very labile (unstable) and does not last long once the plant materials have become detached (senescent). Algae (planktonic algae and periphyton) are presumed to be the dominant source of chlorophyll *a* in the water column during the summer months. In this manner, corrected chlorophyll *a* measurements have been used as a surrogate measure for algal biomass in the SR-HC TMDL reach. Sloughing of periphyton during spring and late fall time periods has not yet been quantified so the relative chlorophyll *a* and biomass concentrations related to this occurrence is unknown.

In order to better evaluate what concentration of chlorophyll *a* (algae) was acceptable through public perception for recreational purposes, a review of literature references to chlorophyll *a* targets based on aesthetics was conducted. Several targets were identified (Table 3.2.1), covering a range of maximum allowable chlorophyll *a* concentrations from 15 ug/L to 50 ug/L.

While Table 3.2.1 does not represent an exhaustive list, it serves to illustrate a range of chlorophyll *a* values identified to be appropriate to support of aesthetic and recreational needs. It is important to note that these values represent maximum acceptable concentrations, not averages. Individuals recreating on surface water systems do not perceive "average" water quality, they see the instantaneous conditions and use these characteristics as the basis for their perception of water quality. Therefore, these guidance values were established as maximum concentrations to support aesthetic and recreation designated uses.

Table 3.2.1 Chlorophyll *a* guidance from other states and British Columbia for aesthetic and primary contact recreation.

Location	Chlorophyll *a*
Colorado	< 15 ug/L
New Hampshire	< 15 ug/L
Minnesota	< 20 ug/L
South Dakota	< 33 ug/L
North Carolina	< 40 ug/L
British Columbia	< 50 ug/L
New Mexico	< 50 ug/L

Mean chlorophyll *a* concentrations in the mainstem Snake River between Weiser (RM 351) and RM 325 (in the upstream portion of Brownlee Reservoir) are routinely greater than 50 ug/L. These target values were identified as appropriate by several states and British Columbia. These values were (for the most part) specific to primary contact recreation and aesthetic uses. They were developed to act as a numeric representation of the maximum chlorophyll *a* concentrations that recreational users of a water system would judge to be acceptable; or as values below which algae concentrations would not result in reduced recreational usage. These values were used as a general range in determining what appropriate levels of chlorophyll *a* may be within the SR-HC TMDL reach. They are not, however, the sole driver, as other designated beneficial use concerns are associated with excessive nutrient loading.

3.2.2.2 AQUATIC LIFE.

Data available show indirect negative effects on aquatic life in the form of low dissolved oxygen (in the reservoir complex) and high productivity levels (in both the Upstream Snake River segment (RM 409 to 335) and the upstream portion of Brownlee Reservoir).

Low dissolved oxygen concentrations have been documented in Brownlee Reservoir from as early as 1968 (IPCo, 1998a and 1998b) to the present. A major fish kill occurred in Brownlee Reservoir in July of 1990, involving all fish species, including sturgeon. Dissolved oxygen concentrations observed during this event indicate that anoxia in the upper end of Brownlee

Reservoir was the dominant cause of fish mortality (IPCo, 1999c). These data indicate that the designated uses of cold water aquatic life/salmonid rearing and related aquatic life uses are not being fully supported in the downstream portion of the Upstream Snake River segment and in Brownlee Reservoir.

Organic material (algae, detritus, etc.) produced and transported within the upper SR-HC TMDL reach is the primary cause of low dissolved oxygen in Brownlee Reservoir (IPCo, 1999d, 2000a, 2000e; IDEQ, 1993b), and potentially in the lower sections of the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach as well. 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. The metalimnion (volume near the thermocline) and epilimnion (volume above the thermocline), however, experience greater turnover throughout the summer season. The metalimnion may occupy the lower depths of the photic zone and may experience some mixing due to reservoir releases and, to a lesser degree, wind action at the surface. The epilimnion occupies the upper reaches of the photic zone and experiences more surface-driven mixing.

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 coldwater species living in the reservoir (Section 3.6). 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 are known to experience low dissolved oxygen as a result of chemical and biological processes associated with stratification. This phenomenon is recognized by Idaho State standards (IAC 250.02.a). Due to this occurrence, and the fact that they are located well below the photic zone of the reservoir, 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.

3.2.2.3 ANOXIA AT THE SEDIMENT/WATER INTERFACE AND IN THE SUBSTRATE.

In addition to concerns centering on low dissolved oxygen concentrations in the water column, anoxia in the substrate represents a concern to aquatic life within the system. Many fish species, including white sturgeon and mountain whitefish deposit eggs at the sediment/water interface. Low dissolved oxygen from decaying algae and other organic matter presents a harmful or potentially lethal condition for these young fish. White sturgeon populations in the Upstream

Snake River (from Swan Falls to Brownlee Dam) are below the expected values (personal communication, J. Chandler, IPCo, August 2002). Low dissolved oxygen levels at the sediment/water interface may play a role in the reduced populations and low recruitment observed.

Elevated concentrations of chlorophyll *a* have been observed in the Upstream Snake River segment (RM 409 to 335) and the headwaters of Brownlee Reservoir (BCPW, 2001; IPCo, 1999d, 2000a, 2000e; IDEQ, 1993b). These levels indicate that substantial algal blooms occur consistently in this area. Additionally, excessive levels of periphyton have been observed in the Snake River at the USGS gage near the inflow of the Weiser River (personal communication, P. Woods, USGS, 2001). Decomposition of organic material from these algal blooms and other nutrient-induced growth deposited within the SR-HC TMDL system has been suspected to result in low dissolved oxygen levels within the sediments and at the sediment/water interface within the Upstream Snake River segment (RM 409 to 335) and the headwaters of Brownlee Reservoir.

As discussed previously, low dissolved oxygen associated with depositional areas in Brownlee Reservoir has been well documented (IPCo, 1999d, 1999g, 2000c; BCPW, 2001). Investigation of similar conditions in the Upstream Snake River segment (RM 409 to 335) is currently in progress.

No sediment/water interface or substrate dissolved oxygen data from the Upstream Snake River segment (RM 409 to 335) is available to this TMDL process at this time, however, data from artificial redd studies conducted upstream of RM 409 by IPCo in 1999 to 2000 and 2000 to 2001 (IPCo, 2001c) show that dissolved oxygen concentrations drop to very low levels (less than 2.0 mg/L) during the late spring and summer months at the sediment/water interface. Artificial redds were constructed at RM 450.4, 447.8 and 441.8. These locations are between Swan Falls and the upstream portion of the SR-HC TMDL reach.

Intergravel dissolved oxygen measurements collected in the artificial redds in 1999 to 2000 showed concentrations below 6 mg/L at RM 450.4 and 441.8 by late February, 2000. Dissolved oxygen concentrations at these two sites were below 4.0 mg/L by April 2000 and below 2.0 mg/L May through June of 2000 (data are not available for the summer months). Intergravel dissolved oxygen measurements in the artificial redd at RM 447.8 showed concentrations above 6 mg/L December 1999 through early May 2000. Dissolved oxygen concentrations below 6.0 mg/L were observed late May through June 2000 at this site (IPCo, 2001c).

Intergravel dissolved oxygen measurements were collected in the artificial redds at RM 450.4 and 447.8 during 2000 to 2001. These data showed concentrations below 6 mg/L at both sites by late March 2001. Dissolved oxygen concentrations at both sites were below 4.0 mg/L by April 2001 and below 2.0 mg/L May through June of 2001 (IPCo, 2001c).

Initial, qualitative assessments of the Upstream Snake River segment of the SR-HC TMDL reach (RM 409 to 335), have identified conditions similar to those observed in the Snake River at the location of these artificial redds (e.g. similar flow and temperature conditions combined with a thick layer of decomposing organic material located at the sediment/water interface). These initial, qualitative investigations, combined with the data collected by IPCo upstream, suggest that low dissolved oxygen concentrations similar to those observed in the artificial redds occurs at the sediment/water interface in the Upstream Snake River segment (RM 409 to 335). This is likely one of the factors contributing to the decline in white sturgeon populations in this segment of the Snake River.

3.2.2.4 PRODUCTION OF METHYLMERCURY.

Of additional concern to this TMDL is the conversion of inorganic or elemental mercury within the SR-HC TMDL reach to methylmercury. While inorganic or sediment-bound mercury can be absorbed by aquatic organisms, the rate and efficiency of the uptake is much lower than that for methylated or organic mercury, which can easily enter the food chain (USGS, 1995). Many factors influence the form, concentration and transport of mercury in the environment, these include the concentration of dissolved organic carbon (DOC), the pH of the water system, and the concentration of dissolved oxygen in the water (Hurley, 1995).

Sediment samples collected and analyzed for mercury content in both the Upstream Snake River segment (RM 409 to 335) and the Brownlee Reservoir segment (RM 335 to 285) show that the highest concentrations of sediment-associated mercury are at RM 335 and RM 340. Both samples exceeded the threshold effects level (TEL) of 0.174 parts-per-million (mg/kg), the concentration level published by the National Oceanic and Atmospheric Association (NOAA) for the protection of benthic life. These elevated levels of mercury, when combined with organic material resulting from excessive algal growth and the associated organic matter in this area, represent a substantial potential for methylmercury production.

There is a relationship between mercury concentrations observed in bed sediments and those observed in the tissue of resident fish. Methylmercury produced in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285), has the potential to affect not only local aquatic life but also downstream species as well, as the methylmercury produced will be carried downstream by flowing water. Organic matter accumulating from algal growth and nutrient enrichment in the Upstream Snake River segment (RM 409 to 335) is of particular concern as it accumulates in the area between RM 340 and RM 320, the location identified as exhibiting the highest concentrations of sediment-associated mercury within the TMDL reach. This condition has the potential to exacerbate the conversion of inorganic mercury to methylmercury within this reach and contribute to higher methyl-mercury concentrations in the Hells Canyon Complex reservoirs and further downstream.

Low dissolved oxygen conditions in Brownlee Reservoir also have the potential to contribute to higher methyl-mercury concentrations in downstream waters.

All fish tissue data available in the SR-HC TMDL reach were positive for mercury. Water column data available were below the 0.050 ug/L concentration value established by the US EPA, however, detection limits were greater than the threshold limit by almost an order of magnitude in most cases so violations of the criteria could occur within these samples even though concentrations are reported as below the detection limit. The Oregon and Idaho levels of concern for methylmercury in fish tissue were exceeded by 80 percent (0.35 mg/kg) and 52 percent (0.5 mg/kg) respectively. Based on these data, both states have fish consumption advisories in place.

An evaluation of sediment and fish tissue data from the Snake River mainstem as a whole showed that in areas where sediment-associated mercury concentrations were below the detection limits, fish tissue concentrations were also (Section 3.1). All fish tissue data collected from the mainstem Snake River show concentrations above the detection limits except samples from the Snake River at Flagg Ranch (< 0.05 mg/kg wet weight (Maret, 1995a and 1995b)), the Snake River at Minidoka (< 0.1 mg/kg wet weight (Clark and Maret, 1998)) and the Snake River at Kimberly (< 0.1 mg/kg wet weight (Clark and Maret, 1998)), areas well upstream of the SR-HC TMDL reach. The areas where fish tissue mercury concentrations were below detection limits correlate well with sediment mercury concentrations. Sediment mercury concentrations below the detection limits were observed in the Minidoka and Blackfoot areas (both < 0.02 mg/kg (Clark and Maret, 1998)) only.

Warmwater and nongame species in Idaho were found to contain approximately twice the levels of methylmercury as found in coldwater game fish species (Gebhards et. al., 1971). This finding is of concern as the majority of fish species within the SR-HC TMDL reach are warm water fishes. Fish populations, in association with those human populations most at risk for injury due to mercury consumption, are targeted by the fish consumption advisories in place for both Oregon and Idaho within the SR-HC TMDL reach.

Deposition of organic matter on the surface of the river channel occurs throughout the Snake River system. Deposition within the Upstream Snake River segment (RM 409 to 335) occurs most efficiently in areas of reduced flow velocity (eddies, backwaters, pools, etc). Deposition within Brownlee Reservoir has been observed to occur in the upstream sections of the reservoir (RM 325 to 310). Both organic and inorganic materials are deposited in these areas. Decomposition of organic matter removes oxygen from the water column. This results in anaerobic conditions at the sediment/water interface. Under these conditions the conversion of inorganic mercury to methylmercury has been observed to occur more readily. Therefore, increased availability of methylmercury in the SR-HC TMDL reach can be directly related to the production and deposition of organic material (algae, periphyton, etc.), and associated anoxic or low oxygen conditions.

While data available to the SR-HC TMDL indicate that the dominant source of mercury is naturally occurring geological deposits which are (at best) difficult to control, the conversion of the inorganic mercury contained within these sediments to methylmercury (the form most related to health concerns for both aquatic life and humans) is related to available organic material and anoxic substrate conditions. Given the current understanding of the methylation process, reductions in organic matter within the SR-HC TMDL reach are possible, and are projected to result in reductions in the amount of methylmercury produced. Reductions in algal growth have a high priority in this TMDL as they represent one of the most effect mechanisms for control of mercury already within the SR-HC TMDL system in addition to the direct benefits to water quality that would result.

3.2.2.5 Domestic Water Supply.

The US EPA identifies nutrient enrichment as a serious health problem in the context of drinking water supplies. Trihalomethanes are carcinogenic (cancer causing) compounds that can be produced when water containing organic compounds is chlorinated or brominated as part of the treatment and disinfection processes in drinking water facilities. The organic compounds commonly associated with the trihalomethane formation process are humic substances, algal metabolites and algal decomposition products (US EPA, 2000d). According to references in the recent US EPA nutrient guidance document for rivers and streams, the density of algae and the level of eutrophication in raw water supplies have been correlated with the production of trihalomethanes in drinking water (US EPA, 2000d).

In addition to the human health concerns associated with eutrophic drinking water supplies, taste and odor problems associated with algal growth have been reported nationwide. Many of the chemical compounds that algae secrete can result in unpleasant tastes and odors. These compounds are difficult to remove with standard equipment or treatment processes. They often require activated carbon treatment, direct, in-river treatment of the water supply or other such mechanism. Additionally, increased treatment costs from clogged filters, corrosion of intake pipes, increase in the amount of chemicals necessary to treat the water, increased back-flushing of filters and additional settling times to attain acceptable water quality can result from nutrient impairment of domestic water supplies (US EPA, 2000d).

Two cities within the SR-HC TMDL reach use the Snake River as a source of drinking water, the City of Ontario, Oregon (RM 369) and the City of Weiser, Idaho (RM 352). The designation of the SR-HC TMDL reach as a domestic water supply requires that the needs of this beneficial use be considered in the management of the SR-HC TMDL reach, namely, decreased total biomass to decrease the potential for trihalomethane production, decreased total biomass for reduction of filter clogging, reduction of nutrient concentrations to reduce pipe corrosion, and etc.

Finally, the production of neuro- and hepato-toxins by cyanobacteria (blue-green algae) blooms is of concern. When present at excessive concentrations cyanobacteria often produce toxins that can result in skin irritation to swimmers, and illness or even death in animals ingesting the water. The deaths of 23 cattle in Cascade Reservoir (located on the Payette River) were reported in 1993 due to excessive cyanobacteria blooms. This phenomenon is not confined to lake and reservoir systems, however, and has occurred previously in the Snake River. Two canine deaths due to ingestion of blue-green algal toxins were confirmed (November, 2000) and several others suspected (Fall 1999) below the Minidoka Dam along the Snake River between Rupert and Burley, Idaho (Eyre, 2001), approximately 265 miles upstream from the SR-HC TMDL reach.

3.2.2.6 Endangered and Threatened Species.

The portion of the SR-HC TMDL reach listed for excessive nutrients provides habitat for the Idaho spring snail, (*Pyrgulopsis idahoensis,* formerly *Fontelicella idahoensis* (Frest and Johannes, 2001)). Distribution includes the mainstem Snake River from RM 422 to 393 and from RM 372 to 340 (IPCo, 2001a). This snail species is listed as threatened under the Federal Endangered Species Act (ESA). It requires cold, clear, well-oxygenated water for full support. These snails have been observed to live on rocks and sediment at the sediment/water interface within the Snake River channel.

Given the information discussed above, and the current understanding of the SR-HC TMDL reach, it is the professional opinion of IDEQ and ODEQ that excessive nutrient levels are impairing designated beneficial uses in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. Data available show impairment of aesthetic and recreational uses, and indicate a level of concern for cold water aquatic life/salmonid rearing, resident fish and aquatic life, domestic water supply designated beneficial uses within the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285). Impairment of the Oxbow Reservoir segment (RM 285 to 272.5) cannot be determined at this time but will be directly related to the water quality in Brownlee Reservoir due to inflow and retention characteristics. It is also the professional opinion of IDEQ and ODEQ that attainment of the SR-HC TMDL chlorophyll *a* target of 14 ug/L mean growing season concentration and a nuisance threshold of 30 ug/L chlorophyll *a* with exceedence threshold of no greater than 25 percent, combined with the nutrient target of less than or equal to 0.070 mg/L total phosphorus, in combination with other SR-HC TMDL pollutant targets will result in full support of the designated beneficial uses within the system.

3.2.3 Sources

Both natural and anthropogenic sources of phosphorus are known to be present in the SR-HC TMDL drainage. Anthropogenic loading includes both point and nonpoint sources. A brief overview of nutrient sources is discussed below. A more detailed description is available in the Subbasin Assessment for the SR-HC TMDL.

3.2.3.1 Natural Sources.

A general discussion of natural sources of nutrient loading is available in Section 2.2.4.3. Natural sources of nutrients include erosion of phosphorus-containing rock and soils through wind, precipitation, temperature extremes and other weathering events. Natural deposits of phosphorus (Hovland and Moore, 1987) have been identified in the Snake River drainage near Pocatello, Idaho (RM 731.2). Geological deposits in the Blackfoot River watershed (inflow at RM 750.6) contain phosphorus in sufficient concentrations that they have been mined. The Snake River flows through this area some distance upstream of the SR-HC TMDL reach.

In an effort to assess the potential magnitude of natural phosphorus concentrations in the mainstem Snake River due to these geological deposits, total phosphorus concentrations occurring in the mainstem near the Blackfoot and Portneuf River inflows (RM 750.6 and 731.2 respectively) were evaluated. Data was available for the Snake River near Blackfoot, Idaho (USGS gage # 13069500, RM 750.1) and for the Blackfoot and Portneuf Rivers (USGS, 2001a). The mainstem Snake River and these tributary river systems, where they flow through the natural mineral deposits represent a worst-case scenario for evaluation of natural phosphorus loading and were identified as potential sources of naturally occurring phosphorus to the SR-HC reach. USGS gaged flow data and water quality data from the 1970’s to the late 1990’s is available for the Blackfoot and Portneuf Rivers ((USGS gage # 13068500, and #13075500 respectively). Because both the mainstem and tributary watersheds have been settled for some time, and land and water management has occurred extensively, the data compiled represent both natural and anthropogenic loading.

Total phosphorus concentrations in the Snake River mainstem, measured near Blackfoot, Idaho (RM 750.1), from 1990 to 1998 averaged 0.035 mg/L (range = <0.01 to 0.11 mg/L, median =

0.03 mg/L, mode = 0.02 mg/L) (USGS, 2001a). Nearly 40 percent (23 samples) of the total data set showed total phosphorus concentrations less than or equal to 0.02 mg/L. Data represents year-round sampling. Winter sampling was slightly less frequent (approximately 19% of the total) than spring, summer or fall.

Natural phosphorus concentrations were not assessed as part of the Blackfoot River TMDL (IDEQ, 2001b). Total phosphorus concentrations in the Blackfoot River, measured near the mouth, from 1990 to 1999 averaged 0.069 mg/L (range = <0.01 to 0.43 mg/L, median = 0.04 mg/L, mode = 0.03 mg/L) (USGS, 2001a). Nearly 23 percent (12 samples) of the total data set showed total phosphorus concentrations less than or equal to 0.02 mg/L. Data represents year-round sampling. Winter sampling was less frequent (approximately 13% of the total) than spring, summer or fall.

Natural phosphorus concentrations were not assessed for the Portneuf River TMDL (IDEQ, 1999d). Total phosphorus concentrations in the Portneuf River, measured near the mouth, from 1990 to 1998 averaged 0.085 mg/L (range = <0.01 to 0.28 mg/L, median = 0.069 mg/L, mode = 0.03 mg/L) (USGS, 2001a). Nearly 21 percent (6 samples) of the total data set showed total phosphorus concentrations less than or equal to 0.02 mg/L. Data represents year-round sampling. Winter sampling represented approximately 22 percent of the total.

The fact that very low total phosphorus concentrations were observed routinely (more than 20% of the time) in the mainstem Snake River, the Blackfoot River and the Portneuf River, all watersheds with a high level of use and management show that the natural loading levels are likely below detection limit concentrations. The additional fact that these low concentrations were observed in watersheds in much closer proximity to the rich geological phosphorus deposits indicates that these deposits likely do not represent a significant source of high, natural loading to the SR-HC TMDL reach, located well downstream from the mineral deposits identified.

Given the above discussion, the natural background concentration for total phosphorus in the mainstem Snake River has been estimated as at or below 0.02 mg/L for the SR-HC TMDL reach. This value is based on the available data set. Data from the Snake River upstream of RM 409 was included in this data set to address the concern of enrichment of surface waters by the phosphoric deposits located in central and eastern Idaho (Hovland and Moore, 1987). Due to the fact that there are substantial anthropogenic influences in Snake River Basin, the lower 15th percentile value for total phosphorus concentration was selected as a conservative estimate of natural phosphorus concentration. In this manner, natural concentration levels for the mainstem Snake River were calculated conservatively. This initial estimate will be reviewed as additional data become available and revisions will be made as appropriate.

The estimated natural background loading concentration for the mainstem Snake River (0.02 mg/L) is most likely an overestimation of the natural loading but represents a conservative estimate for the purposes of load calculation. In addition, this concentration correlates well with other studies that have been completed and closely approximates the total phosphorus concentration identified for a reference system (relatively un-impacted) by the US EPA (US EPA, 2000d; Dunne and Leopold, 1978).

A necessary set of data to establish natural loading or concentration values for the tributary streams is not currently available. Therefore, natural background concentrations for all tributaries will be determined as part of upcoming TMDL development on the Weiser, Owyhee, and Malheur Rivers, and tributary implementation plans for the Payette and Boise Rivers.

3.2.3.2 ANTHROPOGENIC SOURCES.

Anthropogenic nutrient sources to the SR-HC TMDL reach include permitted point sources that discharge directly to the Snake River within the SR-HC TMDL reach (as listed in Table 2.5.0), nonpoint source discharges in the direct drainage, and man-made sources that discharge to tributaries of the SR-HC TMDL reach. Point source discharges to tributary systems are a recognized component of overall loading to the SR-HC reach, but are identified as nonpoint source tributary loading in this TMDL. Load calculations and load allocations will be made to the mouth of the tributaries and the tributary-specific TMDL process will determine point and nonpoint source load allocation mechanisms. Those point sources that discharge to tributary systems are not included in the point source loading calculations for the SR-HC TMDL.

Anthropogenic nonpoint sources of phosphorus in the SR-HC area include (among others) agricultural sources such as runoff from fertilized fields, sediment-bound transport from plowing, and flood and furrow irrigation, as well as organic enrichment; sediment-bound transport and organic enrichment from forestry sources such as logging and streambank disturbance; and urban/suburban sources including stormwater runoff, improperly functioning septic and sewer systems and lawn fertilizers.

Elevated phosphorus concentrations have been observed in the Upstream Snake River segment (RM 409 to 335), in the inflowing tributaries and in many of the agricultural drains where they enter the Snake River (US EPA, 1974; IDEQ, 1998a; IPCo, 1998a and 1998b; BCPW, 2001) as shown in Figure 3.2.2 plots a through j (multiple pages).

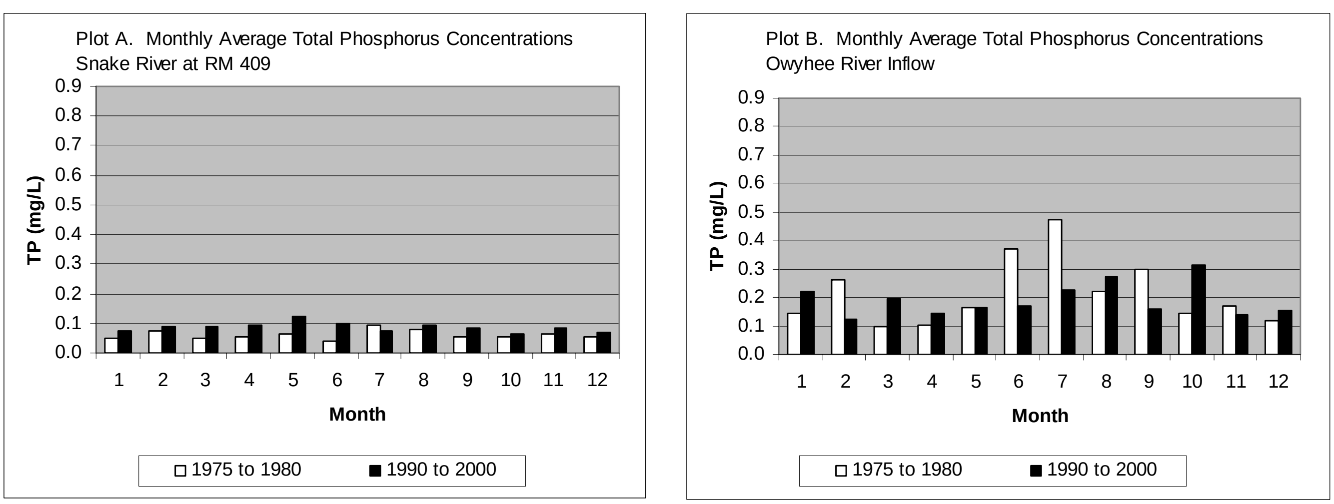


Figure 3.2.2. Mean monthly total phosphorus concentrations for locations on the mainstem Snake River and at the mouths of the major tributary inflows within the Snake River - Hells Canyon TMDL reach. The data sets displayed do not necessarily contain equal numbers of data points.

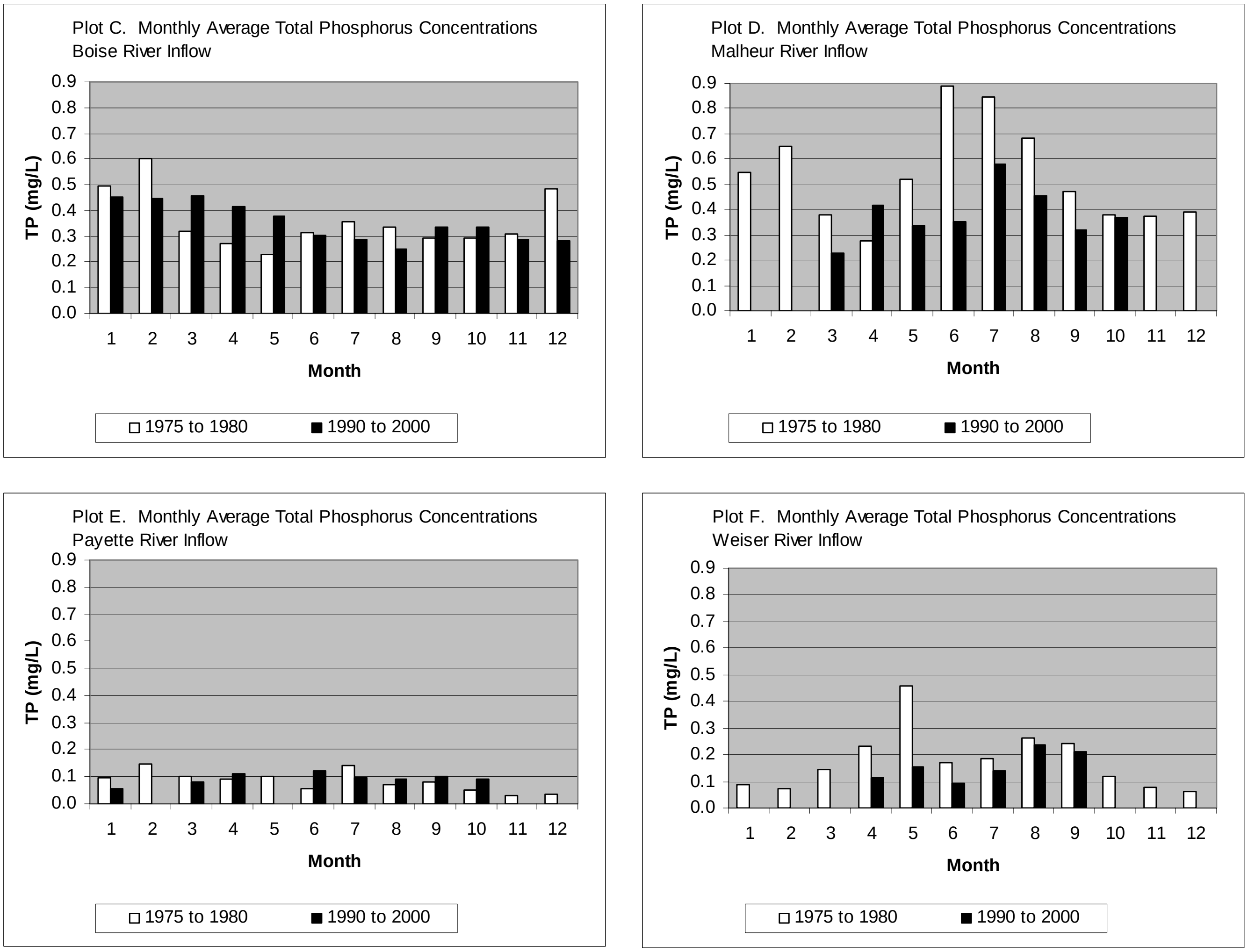


Figure 3.2.2. (cont.) Mean monthly total phosphorus concentrations for locations on the mainstem Snake River and at the mouths of the major tributary inflows within the Snake River - Hells Canyon TMDL reach. The data sets displayed do not necessarily contain equal numbers of data points.

Concentrations tend to increase in correlation with the summer growing and irrigation season. The concentration data available represent the sum of natural and anthropogenic loading from the identified tributaries and mainstem locations. Data from 1975 to 1980 and data from 1990 to 2000 are summarized.

The Malheur River (plot D) shows substantial reduction in total phosphorus concentrations between 1975 to 1980 and 1990 to 2000. In most other cases, a level trend or a slight increase in concentration is observed between the two data sets. The data sets displayed do not contain equal numbers of data points for the 1975 to 1980 and 1990 to 2000 time periods.

In most cases, more data was available in the 1990 to 2000 time period than in the 1975 to 1980 time period. Lack of data or smaller than average data sets occurred in some years and at some locations. These limited data may not be representative of average conditions. Scales on all plots were normalized to allow for an easier comparison of relative concentration differences.

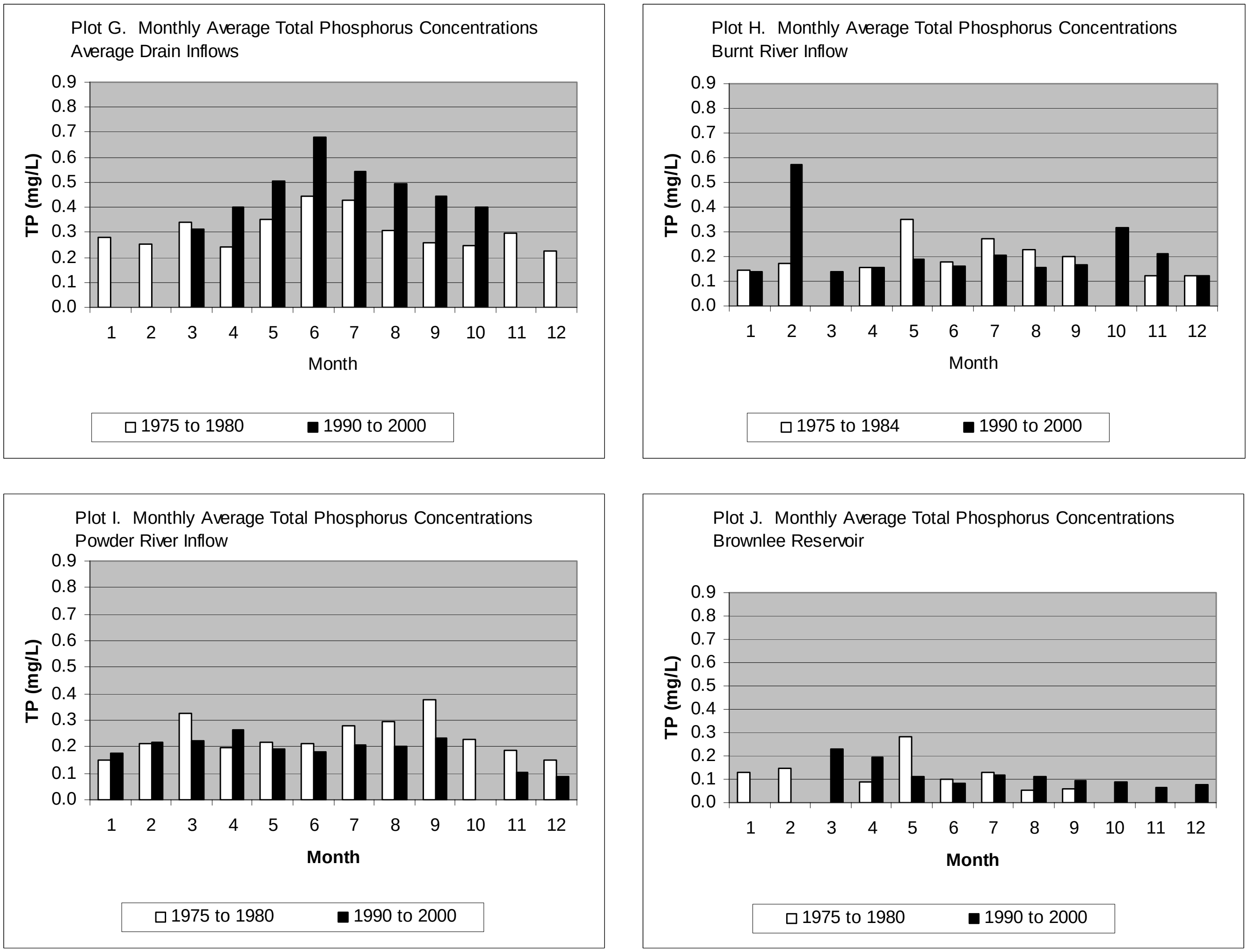


Figure 3.2.2. (cont.) Mean monthly total phosphorus concentrations for locations on the mainstem Snake River and at the mouths of the major tributary inflows within the Snake River - Hells Canyon TMDL reach. The data sets displayed do not necessarily contain equal numbers of data points.

Studies performed throughout the United States have shown that "conditions that allow periphyton/plankton biomass to accumulate (i.e. adequate light, optimum current velocity for periphyton, sufficient water detention for plankton, as well as low loss to aquatic grazers) will not result in high biomass without sufficient nutrient supply. Nutrients, especially phosphorus, are the key stimulus to increased and high algal biomass" (US EPA, 2000d). This is supported by data collected in the Snake River system as shown in Figure 3.2.3. It is observed that lower phosphorus concentrations within the Snake River system correlate with lower concentrations of chlorophyll *a* than those observed at higher total phosphorus concentrations.

Conditions resulting in high water temperatures, elevated nutrient loading and low flow conditions are favorable to cyanobacteria species. Control of two of these three conditions is not feasible for the SR-HC TMDL. First, elevated water temperatures within the SR-HC TMDL

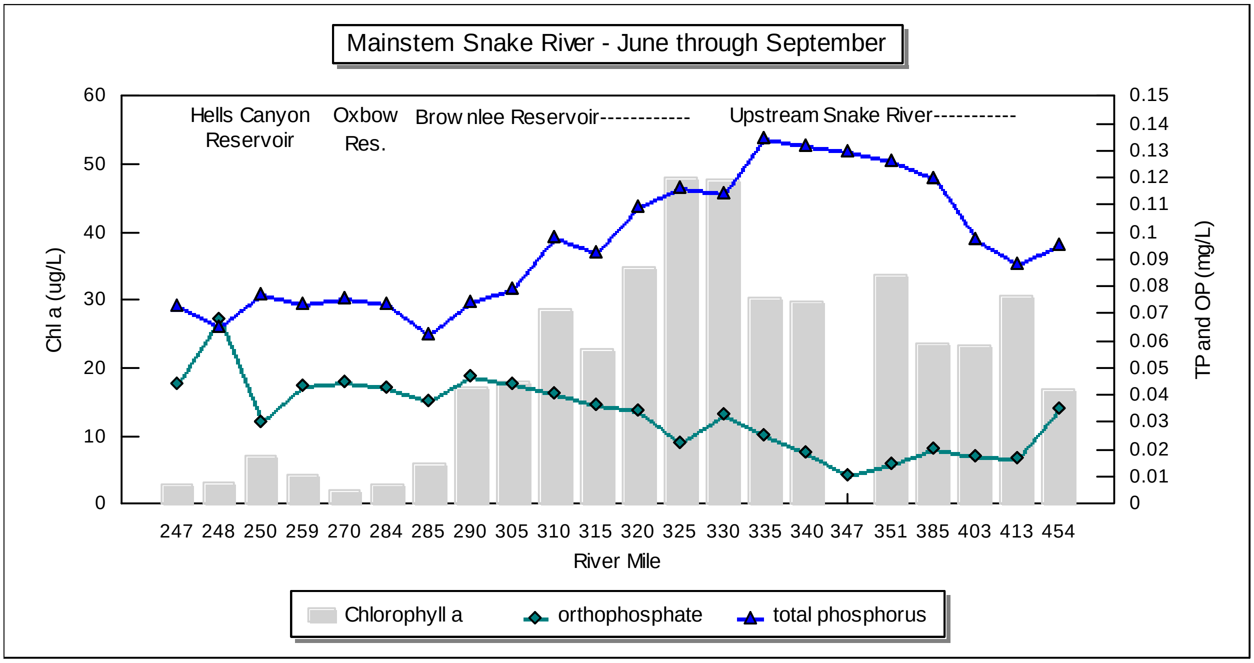


Figure 3.2.3. Spatial distribution of mean phosphorus and chlorophyll *a* concentration data within the Snake River - Hells Canyon TMDL reach (June through September, 1990 to 2000).

reach have been shown to be predominantly the result of natural atmospheric and non-quantifiable thermal loading. Second, changes to flow conditions are outside of the scope of this TMDL. The third condition, elevated nutrient loading, can be controlled under the auspices of the TMDL and implementation processes.

3.2.4 Transport and Delivery

The primary mechanism for nutrient transport in the SR-HC reach is surface and subsurface water flow. Nutrients can be dissolved in the water column or adsorbed onto the surface of soil and sediment particles, and organic matter. The sediment fractions most commonly associated with the greatest nutrient loading are the fine and very fine particles that have the largest surface area to volume ratio and therefore the largest adsorption capacity. These particles can be transported long distances before they drop out of the water column. Once deposited, these particles can act as a source of phosphorus enrichment in two ways: through direct re-entrainment of solid particles with an increase in flow, and through desorption of attached nutrients to the water column. This cycle is discussed in greater detail in the sediment loading analysis (Section 3.5) and the Subbasin Assessment (Section 2.2).

As with sediment loading, land use and management may influence nutrient transport and delivery within the watershed. Long-term saturation of soils can result in anoxic conditions that cause the release of adsorbed phosphorus. This can occur in flooded soils in the watershed, from intentional flooding as is used in some irrigation practices, or unintentional flooding such as in a poorly drained lawn or garden area. It also occurs at the sediment/water interface in anoxic areas of a reservoir system. This type of de-sorption results in a form of phosphorus that is much more readily available for uptake by aquatic plants.

3.2.5 Data Available for the Snake River - Hells Canyon TMDL Reach

As discussed in the general loading assessment, a fairly robust data set for phosphorus (total and ortho) was available to the SR-HC TMDL effort. The data available for a nitrogen loading assessment was more limited. However, the nitrogen data available show trends similar to those observed for phosphorus within the SR-HC system.

Nutrient data has been collected over the time period from 1975 to current for both the mainstem Snake River and tributary sites. Mean values, concentration ranges and number of data points available are shown in Table 3.2.2 a through c.

Table 3.2.2 a. Distribution of total phosphorus (TP) data available for the Snake River - Hells Canyon TMDL (1975 through 2000).

Sample Site	Number of Samples	Mean TP concentration (mg/L)	Maximum (mg/L)	Minimum (mg/L)
Snake River Inflow (RM 425 to 403)	96	0.081	0.550	0.007
Tributary Mouths				
Owyhee (RM 396.7)	161	0.195	1.46	0.082
Boise (RM 396.4)	255	0.362	2.00	0.07
Malheur (RM 368.5)	80	0.444	1.46	0.06
Payette (RM 365.6)	115	0.101	0.57	0.02
Weiser (RM 351.6)	120	0.172	1.43	0.03
Drains	205	0.340	1.58	0.06
Upstream Snake River Mainstem (RM 409 to 335)	490	0.112	0.885	0.01
Brownlee Reservoir	199	0.110	0.610	0.019
RM 335 to 319		0.148		
RM 320 to 304		0.109		
RM 305 to 285		0.076		
Burnt River (RM 327.5)	92	0.203	2.33	0.081
Powder River (RM 296)	170	0.214	0.694	0.02
Oxbow Reservoir (RM 285 to 272.5)	179	0.087	0.154	0.02
Hells Canyon Reservoir (RM 272.5 to 247)	128	0.083	0.36	0.016
Downstream Snake River Segment (RM 247 to 188)	201	0.079	0.39	0.005

Data in this table are from US EPA STORET, 1998a; IPCo, 1999d and 2000a; USGS, 1999, and Boise City Public Works, 2001.

Table 3.2.2 b. Distribution of dissolved ortho-phosphate (DOP) data available for the Snake River - Hells Canyon TMDL (1975 through 2000).

Sample Site	Number of Samples	Mean DOP concentration (mg/L)	Maximum (mg/L)	Minimum (mg/L)
Snake River Inflow (RM 425 to 403)	22	0.01	0.08	0.001
Tributary Mouths				
Owyhee (RM 396.7)	148	0.070	0.65	0.021
Boise (RM 396.4)	160	0.287	0.58	0.051
Malheur (RM 368.5)	76	0.251	0.39	0.053
Payette (RM 365.6)	103	0.036	0.12	0.005
Weiser (RM 351.6)	13	0.07	0.15	0.02
Drains	nd	nd	nd	nd
Upstream Snake River Mainstem	394	0.027	0.12	0.002
Brownlee Reservoir	184	0.037	0.18	0.005
RM 335 to 319		0.035		
RM 320 to 304		0.034		
RM 305 to 285		0.043		
Burnt River (RM 327.5)	90	0.120	0.40	0.052
Powder River (RM 296)	163	0.149	0.13	0.008
Oxbow Reservoir (RM 285 to 272.5)	179	0.0465	0.13	0.005
Hells Canyon Reservoir (RM 272.5 to 247)	125	0.0426	0.16	0.005
Downstream Snake River Segment (RM 247 to 188)	109	0.054	0.11	0.004

Data in this table are from US EPA STORET, 1998a; IPCo, 1999d and 2000a; USGS, 1999, and Boise City Public Works, 2001. (nd = no data available)

Data has been collected in the form of total phosphorus, ortho-phosphate, and numerous other unique analytical methodologies. Data sets for total phosphorus (n = 2,494) and dissolved ortho-phosphate (dissolved ortho-phosphate (DOP) concentrations and soluble reactive phosphorus (SRP) data, total n = 1,766) were the most robust and were selected for use with the SR-HC TMDL.

Within the available data set, total phosphorus and chlorophyll *a* concentrations are observed to increase markedly from upstream to downstream within the Upstream Snake River segment (RM 409 to 335) (Figure 3.2.3). The total phosphorus concentration in the Upstream Snake River segment is nearly 40 percent higher than that observed at the inflow to this reach (RM 409). Several tributaries discharge water with notably elevated total phosphorus concentrations in this reach.

Table 3.2.2 c. Distribution of chlorophyll *a* (Chl *a*) data available for the Snake River - Hells Canyon TMDL (1975 through 2000).

Sample Site	Number of Samples	Mean Chl *a* concentration (ug/L)	Maximum (ug/L)	Minimum (ug/L)
Snake River Inflow (RM 413 to 403)	115	20.3	115	0.9
Tributary Mouths				
Owyhee (RM 396.7)	34	6.3	14.6	0.3
Boise (RM 396.4)	8	7.6	38.5	0.8
Malheur (RM 368.5)	52	12.6	56.7	0.8
Payette (RM 365.6)	16	8.8	22.1	0.8
Weiser (RM 351.6)	3	2.8	3.4	2.2
Drains	nd	nd	nd	nd
Upstream Snake River Mainstem	316	30.7	179	1
Brownlee Reservoir	1012	28.4	727	0
RM 335 to 319		56.2	727	19
RM 320 to 304		9.0	19	3
RM 305 to 285		1.3	3	0
Burnt River (RM 327.5)	76	9.2	136	0.5
Powder River (RM 296)	117	8.8	74	0
Oxbow Reservoir (RM 285 to 272.5)	354	6.0	117	0
Hells Canyon Reservoir (RM 272.5 to 247)	425	5.6	65	0
Downstream Snake River Segment (RM 247 to 188)	145	4.4	28	0

Data in this table are from US EPA STORET, 1998a; IPCo, 1999d and 2000a; USGS, 1999, and Boise City Public Works, 2001. (nd = no data available)

These tributary inflows are the primary source of phosphorus enrichment in the SR-HC reach. Average total phosphorus concentrations in the Boise and Malheur rivers are greater than four times the concentration in the inflowing Snake River (at RM 409). Average total phosphorus concentrations measured in agricultural drains discharging to the Snake River are only slightly less, still more than four times greater than the mainstem Snake River. All inflowing tributaries contribute water that is higher in average total phosphorus concentration than the mainstem Snake River at RM 409.

A marked decrease in total phosphorus and chlorophyll *a* concentration is observed between where the Snake River enters Brownlee Reservoir (RM 335) and where it exits Hells Canyon Reservoir (RM 247) as show in Figure 3.2.3. The Hells Canyon Complex acts as a phosphorus sink, reducing the average total phosphorus concentration by approximately 33 percent by the time the Snake exits the complex at Hells Canyon Dam. The majority of concentration decrease occurs in Brownlee Reservoir. The decreasing trend in phosphorus concentration is evident from the inflow at approximately RM 335 to the outlet of the dam at RM 285. The overall concentration decrease within Brownlee Reservoir averages approximately 30 percent. Several differences and similarities are evident in the data displayed in Tables 3.2.2 a through c. The average total phosphorus concentrations and the range of concentration values for the Boise and Malheur rivers, and for the averaged agricultural drains are very closely correlated. This same relationship holds for the Boise and Malheur Rivers for ortho-phosphate concentrations as well. In all cases, the Payette River presents a unique set of characteristics quite unlike any of the other tributary systems to the SR-HC reach.

Similar to total phosphorus, dissolved ortho-phosphate concentrations are observed to increase from upstream to downstream (Figure 3.2.3). The dissolved ortho-phosphate concentration at the downstream end of the Upstream Snake River segment (RM 330 to 335) is higher than that observed at the inflow to this reach (RM 409). Ortho-phosphate concentration is notably influenced by uptake from algal growth within the system however, and therefore is not a conservative constituent. Also similar to total phosphorus, tributary dissolved ortho-phosphate concentrations are notably elevated above those observed in the Snake River inflow (Table 3.2.2 b). Tributary inflows are the primary source of dissolved ortho-phosphate enrichment in the SR-HC reach. Average dissolved ortho-phosphate concentrations in the Boise and Malheur rivers are greater than 25 times the concentration in the inflowing Snake River. Dissolved ortho-phosphate concentrations measured in the other tributaries discharging to the Snake River are lower but still several times greater than the mainstem Snake River. All inflowing tributaries contribute water that is higher in dissolved ortho-phosphate than the mainstem Snake River at RM 409. This enrichment of mainstem waters leads to the potential for greater productivity during the summer season.

An increase in dissolved ortho-phosphate concentration is observed as the Snake River moves through the Hells Canyon Complex. The complex acts as a sink for total phosphorus, but internal processing converts a portion of the sediment and/or biota-related phosphorus to dissolved ortho-phosphate (Figure 3.2.4). (This is also evident in the data displayed in a monthly time step in Figures 2.3.17 and 2.3.18.) The relative proportion of ortho-phosphate increases from upstream to downstream within Brownlee Reservoir. This conversion results in an overall increase from the inflowing concentrations at Farewell Bend (RM 335) of nearly 100 percent by the time the Snake exits the complex at Hells Canyon Dam (RM 247). The majority of concentration increase (74%) occurs in Brownlee Reservoir (0.027 mg/L to 0.047 mg/L). However, this increase in available dissolved ortho-phosphate does not result in an increase in algal growth within the reservoir complex and algal blooms are not observed within Oxbow and Hells Canyon Reservoirs or downstream at the same magnitude or intensity with which they occur in the Upstream Snake River segment (RM 409 to 335).

The relationship of total phosphorus, chlorophyll *a* and total suspended solids within the SR-HC TMDL reach provides understanding of transport and processing mechanisms in the riverine and reservoir sections. Figure 3.2.5 shows total suspended solids concentrations decreasing precipitously at the inflow of Brownlee Reservoir (RM 335 to 330). The decrease in chlorophyll *a* describes a less steeply-sloped curve, indicating that algae are among the lighter sediment particles and are therefore transported farther downstream than the more dense (presumably inorganic) solids, which drop out more abruptly. The data available indicate that sediment in this

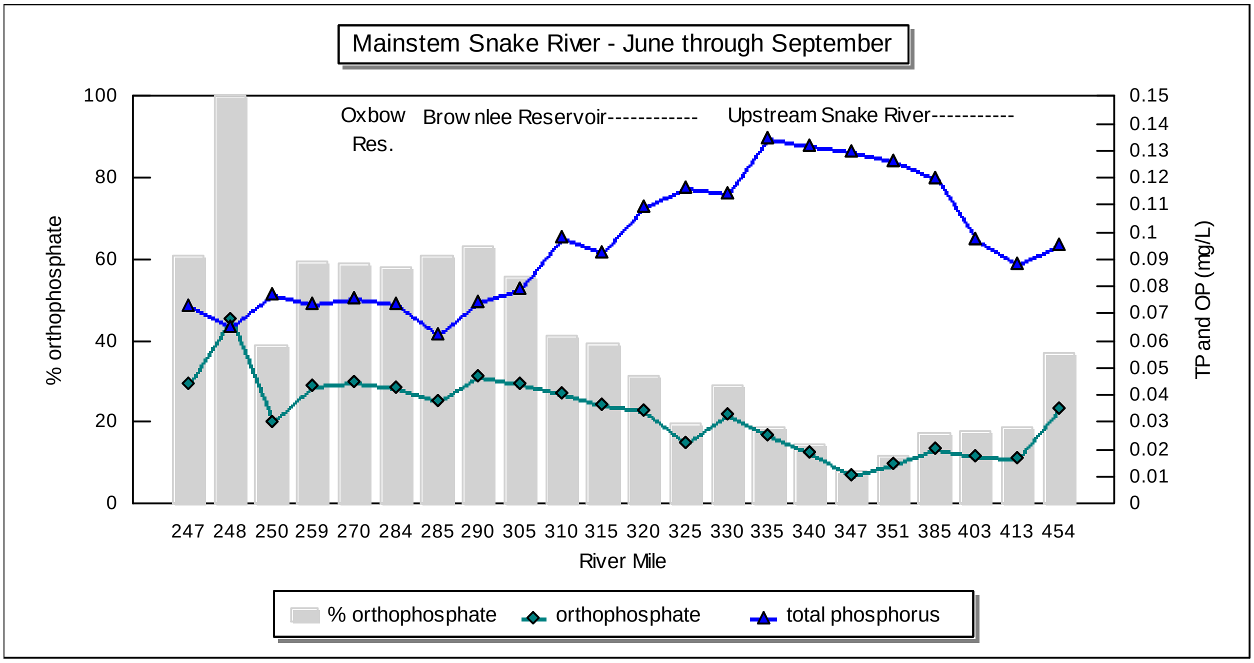


Figure 3.2.4. Spatial distribution of mean phosphorus and chlorophyll *a* concentration data within the Snake River - Hells Canyon TMDL reach (June through September, 1990 to 2000).

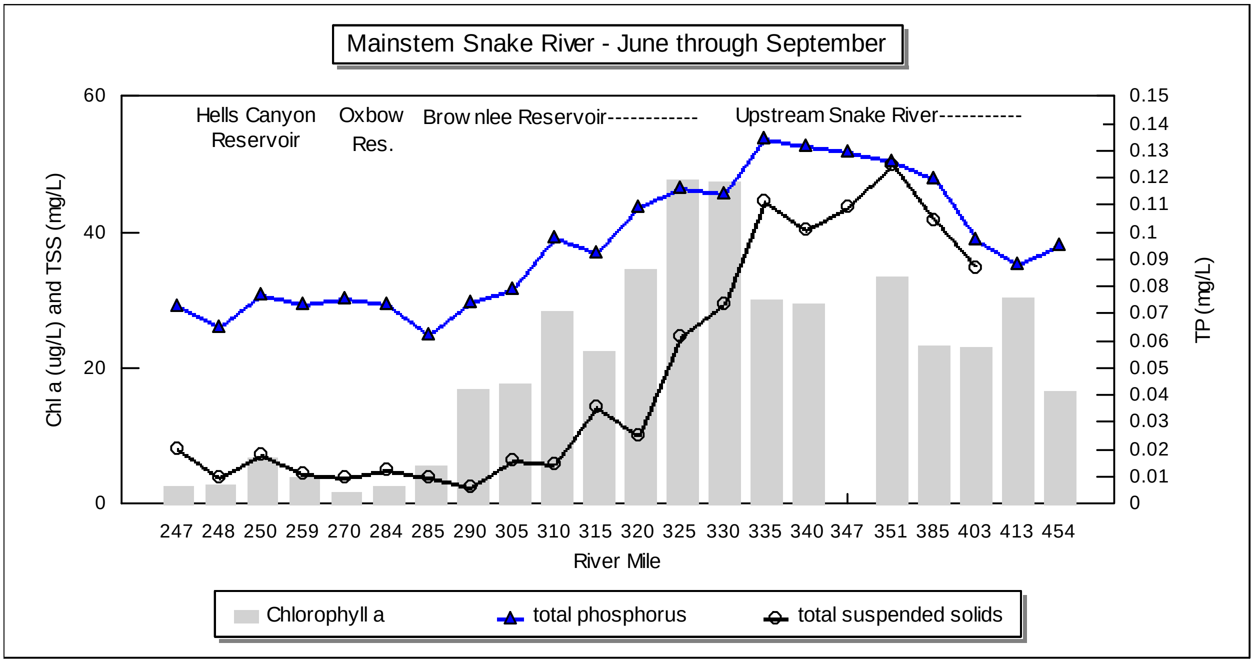


Figure 3.2.5. Spatial distribution of mean total suspended solids, phosphorus and chlorophyll *a* concentration data within the Snake River - Hells Canyon TMDL reach (June through September, 1990 to 2000).

depositional area is predominantly associated with coarser particle sizes, while the smaller, lighter particles are deposited somewhat further downstream.

Total suspended solids concentrations show the most marked decrease between RM 335 and RM 320. Chlorophyll *a* concentrations show the most marked decrease between RM 325 and RM 315. Total phosphorus concentrations show a sustained decrease between RM 335 and RM 285. This indicates that total phosphorus concentrations are the result of both that phosphorus associated directly with the heavier sediment particles (probably inorganic in nature) and that phosphorus originally in the water column that was taken up by algae and incorporated into the biomass moving into the Hells Canyon Complex. A portion of the total phosphorus within the system is also associated with the smaller, lighter inorganic particles (silts and clays) that are transported farther downstream within the system. A portion of this phosphorus, along with that portion associated with the algal biomass is processed within the Hells Canyon Complex and discharged as dissolved ortho-phosphate, as evidenced by the nearly flat curve described by the total phosphorus concentrations in the Oxbow and Hells Canyon Reservoirs.

Chlorophyll *a* concentrations in the inflowing tributaries are relatively moderate, averaging less than 15 ug/L overall. Chlorophyll *a* concentrations are greatest in the Owyhee and Malheur rivers, and least in the Weiser River, but all are relatively low, falling below the action level of 15 ug/L identified by the State of Oregon as a trigger for water quality investigations. All inflowing tributary waters are lower in chlorophyll *a* concentration than the average concentration in the Upstream Snake River segment (RM 409 to 335).

Chlorophyll *a* concentrations were used in this load assessment as a measurement of algae production. The data presented in Table 3.2.2 c show that both the Snake River and the reservoir complex provide an environment suitable for the high levels of algal production. Algal dynamics investigated by IPCo (1998a and 1998b) identified blooms in the lower section of the Upstream Snake River segment (RM 409 to 335) and in the upstream portion of Brownlee Reservoir. Blooms occurred in early May and late June. Concurrent nutrient monitoring indicated that during these blooms, phosphorus was the limiting factor to algal growth. A significant die-off was observed in this study between the two blooms, occurring in mid-May. This trend has been documented to occur with slight variations for a number of years.

The identification of algal populations in major blooms contributing to poor water quality is critical in defining appropriate targets for this TMDL. Several studies have been undertaken to identify algal species in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285). According to work done by Falter in 1999 (reported in IPCo, 1999d), diatoms are the dominant population in the spring and fall in the Snake River. Both green and blue-green algae species are present in the summer.

Algae blooms in the SR-HC reach are observed to be inversely correlated with dissolved ortho-phosphate concentration. During periods of high productivity, chlorophyll *a* concentrations increase while dissolved ortho-phosphate concentrations drop precipitously. With die-off or drop in productivity, dissolved ortho-phosphate concentrations increase, due in part to both lack of uptake and release of dissolved ortho-phosphate from dead and decaying algal materials.

Figure 3.2.6 shows the cyclic relationship observed between chlorophyll *a* and dissolved ortho-phosphate during the course of this bloom.

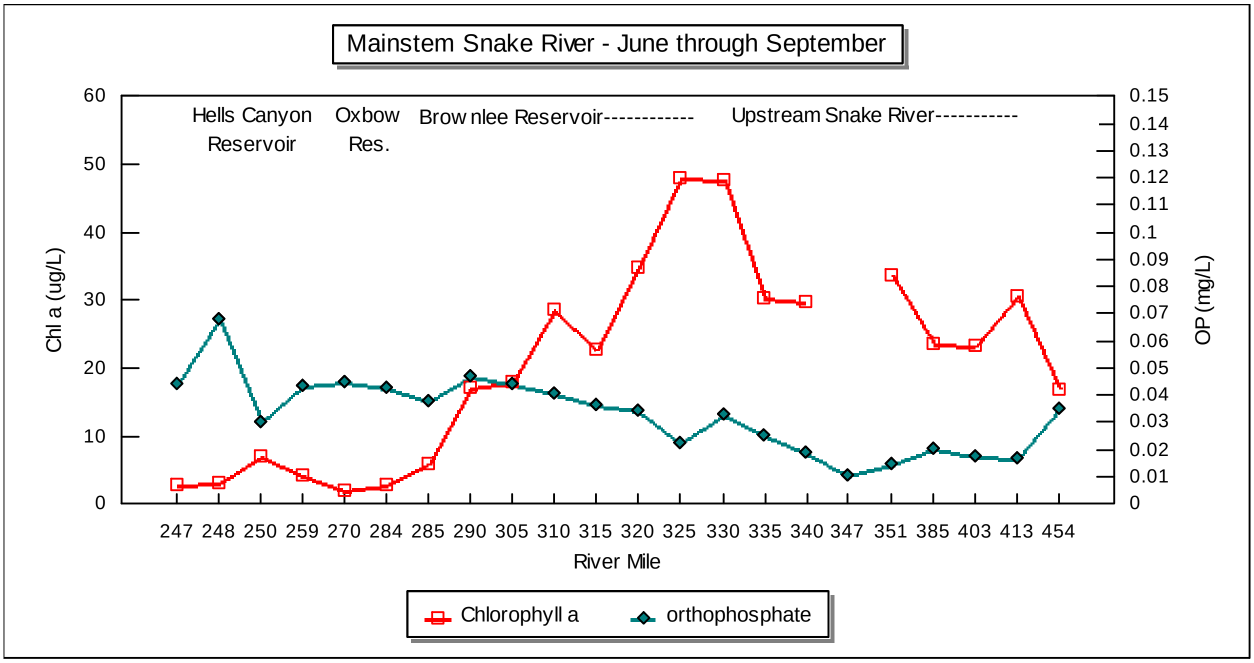


Figure 3.2.6. Algae mass (chlorophyll *a*) vs. dissolved phosphorus concentration for the mainstem Snake River in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285).

The plotted data show relatively low ortho-phosphate concentrations throughout the sections of the SR-HC TMDL reach where chlorophyll *a* concentrations are high. When chlorophyll *a* concentrations start to decrease however, ortho-phosphate concentrations increase. Where chlorophyll *a* concentrations are elevated, a general decrease is observed in the ortho-phosphate concentration.

Relatively low levels of algal production (as identified by chlorophyll *a* measurements) occur in the segment of the Snake River upstream of RM 396. Total phosphorus concentrations in the area of Celebration Park (RM 449) and Adrian, Oregon (RM 403) average approximately 0.08 mg/L over the years for which data are available.

Relatively low levels of chlorophyll *a* are observed in this location, indicating low algal populations in the water column. A visual inspection of the water at Celebration Park shows relatively clear, transparent conditions throughout the summer season, even when the river downstream supports a large algal population.

Several studies of the trophic status of the reservoir complex have been completed (IDEQ, 1993b; IPCo, 1999d), and the reservoirs were identified as being eutrophic. Mechanisms for the determination of trophic status range from relatively simple classifications based on nutrient concentrations to very complex classifications based on a number of interrelated variables. A moderately simple scheme of classification developed by Horne and Goldman (1994) includes four basic characteristics: concentration and supply rates of nutrients, substantial variation in oxygen saturation (supersaturation in the epilimnion and depression of dissolved oxygen concentrations in the hypolimnion), high primary productivity, and cloudy water with relatively low light penetration (Secchi depths 0.1 to 2 m).

Low dissolved oxygen concentrations in the water column have not been documented in the Upstream Snake River segment (RM 409 to 335). During the summer months when low dissolved oxygen concentrations are most likely to occur in areas of slow flow, high algal productivity results in supersaturation of the water column. While low dissolved oxygen is not expected to occur in the river to the degree that it does in the reservoir, due to mixing and shallow water aeration, it is expected that low dissolved oxygen concentrations would occur in areas of slow flow or in places where eddies and backwaters result in sluggish waters, and as a result of diurnal variations in the immediate vicinity of large algal blooms during periods when photosynthesis is not occurring.

As discussed in Section 3.2.2.3, violations of the dissolved oxygen criteria have been documented in data from artificial redd studies conducted upstream of RM 409 by IPCo in 1999 to 2000 and 2000 to 2001 (IPCo, 2001c). These data show dissolved oxygen concentrations of less than 2.0 mg/L during the late spring and summer months at the sediment/water interface between Swan Falls and the upstream portion of the SR-HC TMDL reach. Due to the fact conditions similar to those that occur in the region between Swan Falls and RM 409, also occur in the Upstream Snake River segment (RM 409 to 335), low dissolved oxygen concentrations are likely to occur in areas of the Upstream Snake River segment. Data available on white sturgeon in the Upstream Snake River segment (RM 409 to 335) show that this population is not being supported. Water quality degradation, including low dissolved oxygen at the sediment/water interface is most likely contributing to this lack of support.

3.2.6 Determination of Nutrient Loading

The method used for determination of nutrient loading for the SR-HC TMDL reach is discussed in the general hydrology and loading analysis, and in the sections above.

The available data show that total phosphorus loading into the SR-HC reach originates almost exclusively from the Upstream Snake River segment (RM 409 to 335).

No point source discharge permits in the SR-HC TMDL reach contain phosphorus limitations. One treated wastewater discharger currently monitors for total phosphorus concentrations on a quarterly basis (City of Fruitland). One industrial point source discharger currently monitors for total phosphorus concentrations (Heinz Frozen Foods). The reported concentrations from these monitoring efforts, and estimates available for average discharge concentrations are above the 0.070 mg/L instream target for the SR-HC TMDL. Using available data and estimated discharge concentrations for wastewater treatment plants of 3.5 mg/L, the total phosphorus loading from point source discharges was calculated at 516 kg/year. For facilities discharging part time, only that time when discharge occurred was assessed. Therefore, the calculated point source load for the summer growing season does not include loading from the City of Ontario as this facility utilizes land application in the summer and there is no discharge during the critical period. Point source loading represents approximately 8 percent of the total calculated load to the SR-HC reach. As all point sources discharging directly to the SR-HC TMDL reach do not monitor total phosphorus discharge concentrations, additional data would be necessary to determine actual total phosphorus loading from each permitted point source discharge and the concentration observed at the edge of the mixing zone.

Measured tributary total phosphorus loading to this segment accounts for the majority of the phosphorus load to the SR-HC TMDL reach (76%), with ungaged (estimated) drain flows accounting for 10 percent of the total system load and unmeasured sources accounting for approximately 6 percent of the total. Measured tributary dissolved ortho-phosphate loading to this segment also accounts for the majority of the dissolved ortho-phosphate load to the SR-HC reach (approximately 80%), with ungaged (estimated) drain flows accounting for approximately 7 percent of the total system load and unmeasured sources accounting for approximately 4 percent of the total. Care should be taken in the interpretation of dissolved ortho-phosphate values however, as ortho-phosphate is not a conservative parameter throughout the system.

Sources of unmeasured load may include nonpoint source runoff from anthropogenic sources, precipitation events, unidentified small tributaries and drains, ground-water sources and ground-water sources. As ungaged flows were calculated by subtraction, this may also include error in gaged flow measurements.

Nutrient loads from agricultural drains discharging to the SR-HC reach were determined using concentration and flow data where available. Flow data was not plentiful however, and most flows were estimated using general descriptions and the calculated return flow information by area supplied by the USBR (USBR, 2001). Calculated averages were used in place of concentration values where data were not available. These values therefore should be viewed as best estimates. If additional, drain-specific data become available during the implementation of this TMDL, it will be used in place of these estimates. Land area associated with the drains was calculated at 249,100 acres total (USBR, 2001). A listing of drain names and locations is included in Appendix J.

The relative nutrient loads shown in Table 3.2.3 a and b are calculated for the SR-HC reach using average summer flows (Table 2.1.1).

3.2.7 TMDL Determination

Nutrient standards for both the State of Idaho and the State of Oregon are narrative in nature, identifying that nutrient concentrations that result in the impairment of designated beneficial uses or the production of visible slime growths or other nuisance aquatic growths that impair designated beneficial uses are in violation of the standard.

Given the water quality concerns that can result from excessive nutrient concentrations and the range of concentrations and related system characteristics such as flow, temperature, water column mixing, light penetration and water depth under which these conditions can occur throughout the Pacific Northwest, a narrative nutrient standard is appropriate. Interpretation of

Table 3.2.3 a. Relative point source total phosphorus loads calculated for the Snake River - Hells Canyon TMDL (May through September, 1995, 2000).

Waste Load Type	Location	Design Flow Load (kg/day)	NPDES[1] or other Permit Number
City of Nyssa	RM 385	11	101943 OR0022411
Amalgamated Sugar	RM 385	50	101174 OR2002526
City of Fruitland	RM 373	5.5	ID0020907
Heinz Frozen Foods	RM 370	412	63810 OR0002402
City of Ontario	RM 369	0[1]	63631 OR0020621
City of Weiser	RM 352	32	ID0020290
City of Weiser	RM 352	5.5	ID0001155
Brownlee Dam (IPCo)	RM 285	Unmeasured, assumed minimal[2]	ID0020907
Oxbow Dam (IPCo)	RM 272.5	Unmeasured, assumed minimal[2]	101275 OR0027286
Hells Canyon Dam (IPCo)	RM 247	Unmeasured, assumed minimal[2]	101287 OR0027278
Total Point Source Loading	SR-HC TMDL reach	516	

[1] None of the summer loading produced by the City of Ontario is discharged to the Snake River as land application is employed during the critical months (May through September).
[2] Facilities sump discharge and turbine cooling water, not a phosphorus or waste treatment source.

the narrative standard on a site-specific basis is necessary to identify targets that will protect all designated beneficial uses within the listed segment. The designated beneficial uses determined to be most at risk from excess nutrients were those associated with recreation, aquatic life and domestic water supply. Therefore, establishment of a nutrient target for the SR-HC TMDL reach had to take into account both the concerns associated with the support of designated beneficial uses and the system characteristics that lead to violation of the standard. The process followed to identify nutrient targets for the SR-HC TMDL had two major goals:

1. To identify targets for nutrient loading such that their attainment would result in full support of designated beneficial uses and achievement of water quality standards.
2. To identify the assimilative capacity of the SR-HC reach.

The first goal is directly related to the establishment of a TMDL for nutrients and associated water quality concerns. The second goal is specific to the development of an accurate and equitable load allocation process. Both goals are discussed in greater detail in the following sections.

Table 3.2.3 b. Relative total phosphorus loads calculated for tributaries and other nonpoint sources (NPS) to the Snake River - Hells Canyon TMDL (May through September, based on concentration data from 1995, 1996 and 2000, and mean flow values).

Load Type	Location	Load (kg/day)	Percent of Total NPS Loading
Snake River Inflow	RM 409	1,912	31.5
Owyhee River	RM 396.7	265	4.4
Boise River	RM 396.4	1,114	18.3
Malheur River	RM 368.5	461	7.6
Payette River	RM 365.6	710	11.7
Weiser River	RM 351.6	392	6.5
Drains	Upstream Snake River Segment	660	10.9
Ungaged flows	Upstream Snake River Segment	385	6.3
Agriculture, Stormwater and Forestry	Upstream Snake River Segment (RM 409 to 335)	Included in the ungaged flow loading	
Nonpoint Source Total for the Upstream Snake River Segment (RM 409 to 335)		5,899	97.1
Burnt River	RM 327.5	52	0.9
Powder River	RM 296	126	2.1
Agriculture, Stormwater and Forestry	Brownlee Reservoir segment (RM 335 to 285)	Cannot be calculated, assumed small	
Nonpoint Source Total for the Brownlee Reservoir Segment (RM 409 to 335)			2.9
Agriculture, Stormwater and Forestry	Oxbow Reservoir segment (RM 285 to 272.5)	Cannot be calculated, assumed small	

* NOTE: The values in this column represent the load in the Snake River or tributary at the end of the listed section. For example, the load listed for Brownlee Reservoir is the load that is passed to Oxbow Reservoir at Brownlee Dam. The load listed for the Owyhee River is the load that is transported to the Snake River at the location where the Owyhee joins the Snake. Data in this table are from US EPA STORET, 1998a; IPCo, 1999d and 2000a; USGS, 1999 and Boise City Public Works, 2001.

3.2.8 Identification of Nutrient Targets

Several different processes for identification of nutrient targets have been outlined in the guidance documents for nutrient criteria recently released by the US EPA (US EPA, 2000d). These documents provide information and strategy for establishing nutrient criteria for both rivers and streams, and lakes and reservoirs. The goal of this process was to identify a numeric nutrient target specific to the support of designated beneficial uses in the SR-HC TMDL reach. These documents provided valuable guidance in the establishment of the target. The numeric target was identified to support the narrative criteria already in place for both states.

A first step undertaken in this process was the identification of limiting factors within the SR-HC TMDL system. Two major indicators of limiting factors were evaluated: Nitrogen to phosphorus ratios and algal population dynamics.

3.2.8.1 NITROGEN TO PHOSPHORUS RATIO.

The nitrogen to phosphorus ratio (N:P ratio) and its correlation with algal growth has been the subject of a large body of research. Freshwater systems tend to be phosphorus limited. A general rule often applied to N:P ratios in freshwater systems is that if the N:P ratio is greater than ten, the limiting agent is phosphorus and excessive algal growth will usually not occur if phosphorus is reduced appropriately. If the N:P ratio is less than ten, the limiting agent is nitrogen and excessive algal growth will usually not occur if nitrogen is reduced appropriately.

This has been applied using both soluble and total nutrient measurements. However, care must be taken in using soluble nutrient measurements during an algal bloom to identify this ratio as soluble nutrient concentrations can drop to nearly unmeasurable levels due to rapid uptake. Differences and errors in analytical procedures are more marked at very low concentrations and thus represent a greater relative error. The threshold of ten is commonly applied, and was selected in this analysis as a cutoff value between limiting agents, however, a range of N:P ratios over which nitrogen and phosphorus may be co-limiting agents has been identified as from 7 to 15 (US EPA, 2000d).

Where N:P ratios greater than 10:1 occur in a freshwater system, incidence of algal blooms will likely be controlled by total phosphorus concentrations. Bloom severity will be in relation to the excess phosphorus available (Schindler, 1978; Jaworski, 1981). Generally, a phosphate concentration of 0.01 mg/l will support plankton, while concentrations of 0.05 to 0.1 mg/l phosphate or higher are likely to result in nuisance blooms (Dunne and Leopold, 1978; US EPA, 1986b), depending on site specific conditions.

The data available to the SR-HC TMDL reach was evaluated on a monthly average basis to determine the nitrogen to phosphorus ratio (Figure 3.2.7 and 3.2.8). Total nitrogen (as N) and total phosphorus (as P) measurements were used. Soluble nitrogen and soluble phosphorus data sets were not as plentiful and did not cover the same time frames as well as the total nutrient data sets. Not all data sets included the same number of data points. Where there was a substantial discrepancy in the number of data points within compared data sets an average monthly value was calculated.

The N:P ratios for RM 385 and RM 351.2 were all greater than ten with the exception of the July average at RM 385. This is a good indication that phosphorus acts as a limiting agent in the Upstream Snake River segment (RM 409 to 335). In the months immediately preceding algae blooms, April and May, the N:P ratios are substantially above the threshold value of ten, and are also above the range (7 to 15) where nitrogen and phosphorus have been observed to act as co-limiting agents. During this time period, phosphorus acts as the limiting agent.

In the SR-HC TMDL reach, and in the Mid-Snake TMDL reach (RM 547), both segments where nutrient TMDLs have been prepared, the N:P ratios are substantially higher than those observed in the Snake River sections in-between (Figure 3.2.8). This may be due to the relative differences in water quality within the Snake River system, but may also be influenced by the differences in timing and total number of data points in each of the available data sets. The data evaluation involved in the CJ Strike (2004) and Mid-Snake Succor (2002) TMDL efforts will be helpful in refining upstream contributions to the SR-HC TMDL effort.

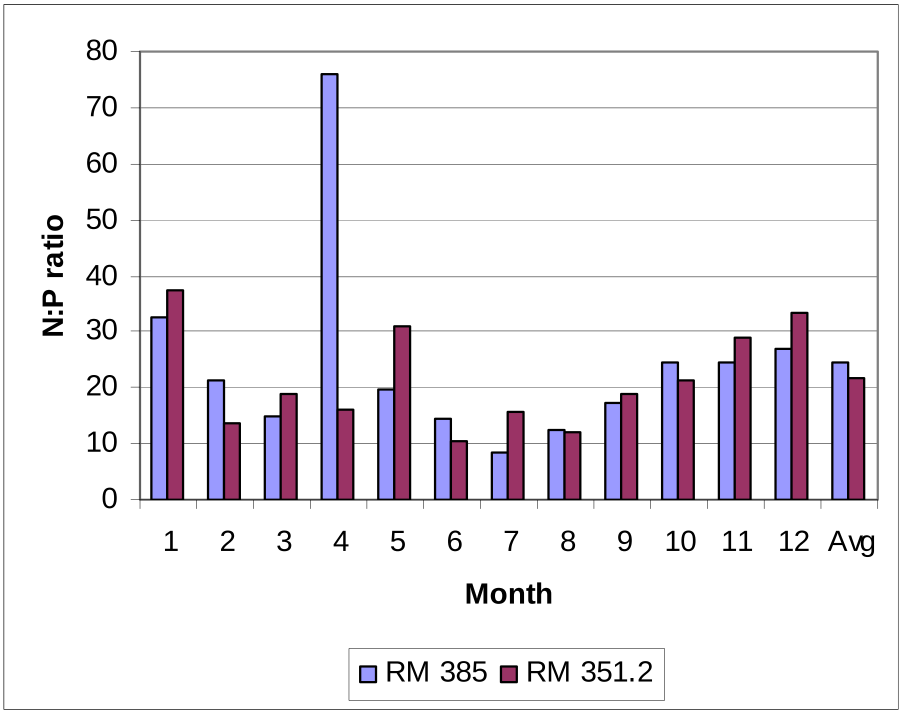


Figure 3.2.7. Nitrogen to phosphorus ratios in the Snake River - Hells Canyon TMDL reach for RM 385 (near Nyssa, Oregon) and RM 351.2 (near Weiser, Idaho).

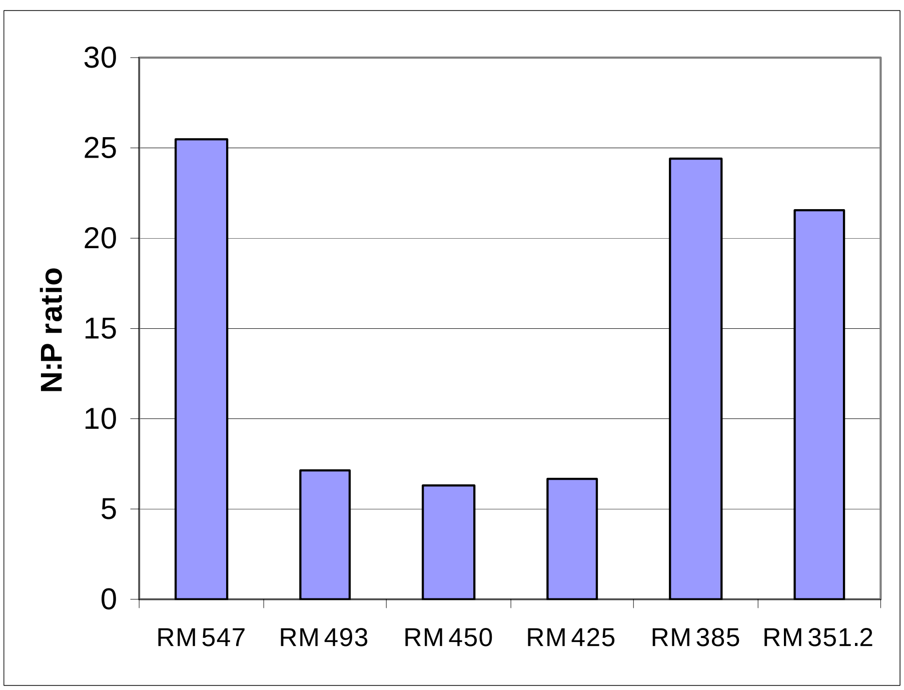


Figure 3.2.8. Nitrogen to phosphorus ratios for different segments of the Snake River. River mile 547 and river mile 385 to 351.2 have been identified as impaired due to excessive nutrient loading on the Idaho State 303(d) list for 1998.

3.2.8.2 Algal Populations.

The identification of algal taxa in major blooms contributing to poor water quality is critical to the identification of limiting agents. The work above shows that throughout the year, phosphorus is the limiting agent in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach. During the months of June and August the N:P ratios near the lower end of the Upstream Snake River segment are within the range where nitrogen and phosphorus have been observed to act as co-limiting agents (based on N:P ratios). An identification of the different populations of observed growth in the river is necessary in order to determine with more specificity which nutrient acts as the limiting agent during these time periods.

Several studies have been undertaken to identify algal species in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285). According to work done by Falter in 1999 (reported in IPCo, 1999d), diatoms are the dominant population in the spring and fall in the Upstream Snake River segment (RM 409 to 335). Green and blue-green algae species are present in the summer. Blue-green species dominate where excessive blooms have been identified.

Data collected during a major algal bloom in 1992 in the Snake River between RM 396 and RM 310 showed that the major types of algae present in the Upstream Snake River segment (RM 409 to 335) were cyanobacteria species (*Microcystis aeruginosa*, and *Aphanizomenon flos-aquae*). The algal population in the lower sections of the river were almost exclusively *Anabaena spiroides* (99%), also a cyanobacteria (IDEQ, 1992 to 1993, unpublished data).

A similar study conducted by IPCo in the reservoir complex in 1991, 1993 and 1994 (relatively low flow years) showed the upper end of Brownlee Reservoir dominated by green algae. The middle segment of Brownlee Reservoir showed a mixture of blue-green and green species. Phytoplankton species in the lower segment of Brownlee Reservoir, and the Oxbow and Hells Canyon reservoirs were dominated by cyanobacteria species (IPCo, 1999c).

This information indicates that cyanobacteria species are prominent population types in major algae blooms in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. Some cyanobacteria are able to fix nitrogen out of the water both within the water column and at the air/water interface and are therefore difficult if not impossible to control with nitrogen reductions. Phosphorus is therefore the limiting factor in these blooms. Based on this analysis, targets for the SR-HC TMDL reach identify water column concentrations of phosphorus rather than nitrogen. Reductions of phosphorus will likely have the most benefit in reducing blooms composed of these algal species.

3.2.8.3 Target Determination – Scope and Reasoning.

The reasoning behind the determination of a phosphorus target for the SR-HC TMDL reach is outlined in the following sections. This determination was made based on the requirements of the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach.

The SR-HC TMDL is a complex system including both river and reservoir segments. In order to determine the assimilative capacity of the SR-HC TMDL reach, the system was divided into manageable sections. The Upstream Snake River segment (RM 409 to 335) represents the dominant inflow to the Hells Canyon Complex reservoirs and the Downstream Snake River segment (RM 247 to 188). If the Upstream Snake River segment (RM 409 to 335) meets water quality standards in river, the water quality in Brownlee Reservoir will be improved. Only that portion of water quality impairment directly attributable to the reservoir systems, and independent of the inflowing water quality, can be identified as the responsibility of the construction and operation of the reservoirs. Therefore, determination of water quality needs in the Upstream Snake River segment (RM 409 to 335) separate from the Hells Canyon Complex segments is critical to the equitable allocation of load and responsibility within the SR-HC TMDL reach.

The identification of the phosphorus target described in the following sections is based on the needs of the Upstream Snake River segment (RM 409 to 335). The additional needs of the reservoir segments are addressed in the allocation of dissolved oxygen improvements discussed in the sections following the target determination discussion. While upstream water quality is not the sole source of water quality exceedences downstream, it is the dominant source of pollutant loading to downstream segments. (Over 95% of the total phosphorus loading to the SR-HC TMDL reach is delivered by the Upstream Snake River segment (RM 409 to 335)). Therefore, improvements in water quality in the Upstream Snake River segment will result in improvements throughout the SR-HC TMDL reach just as degraded water quality in the Upstream Snake River segment now results in degraded water quality downstream.

3.2.8.4 Definition of Reference Conditions.

A definition of reference conditions for determination of appropriate nutrient targets for the SR-HC TMDL was undertaken as part of this TMDL process. In the US EPA nutrient guidance document (US EPA, 2000d) the use of reference reaches is discussed as a mechanism to determine appropriate nutrient criteria. This same approach was utilized in the identification of nutrient targets for the SR-HC TMDL. The size, complexity and use-patterns of the Snake River preclude the use of a reference system to determine appropriate phosphorus targets for the SR-HC TMDL reach.

Data available to this assessment included total phosphorus, dissolved ortho-phosphate, total nitrogen and chlorophyll *a* concentrations from 1975 to 2000. A fairly even distribution of spring and summer conditions in high, medium and low water years were available within this data set. Initially, a database of nutrient and chlorophyll *a* information was assembled for various segments of the Snake River. These sections were selected for climate and flow conditions similar to those observed in the SR-HC TMDL reach. The assessment included three general sections of the Snake River: the mainstem above RM 600, the mainstem between RM 400 and 600, and the mainstem between RM 400 and 335. All of these sections are listed as impaired to some degree. No portion of the Snake River mainstem, where characteristics are similar to those observed in the SR-HC TMDL reach, is identified as un-impaired, therefore no true reference condition exists within the mainstem Snake River.

The mainstem Snake River above RM 600 is a section of the river well upstream of the SR-HC TMDL reach. Some reaches of this section are listed in the State of Idaho 1998 303(d) list as being impaired due to excess sediment (HUC #17040212, #17040209, and #17040206), low dissolved oxygen and excess nutrients (HUC #17040206). For the majority of its length however, this section is not listed for nutrient or dissolved oxygen related concerns. It is therefore, by definition, the "least impaired section" evaluated as part of this assessment.

The mainstem Snake River between RM 400 and 550 is the section of the river immediately upstream of the SR-HC TMDL reach. This section is listed in the State of Idaho 1998 303(d) list as being impaired due to excess sediment and nutrients (HUC #17050101 and part of HUC #17050103), low dissolved oxygen, bacteria, and pH (part of HUC #17050103), and pesticides (HUC #17050101). For the majority of its length this section is listed for nutrient and/or dissolved oxygen related concerns. It is therefore, by definition, "the moderately impaired section" evaluated as part of this assessment.

The mainstem Snake River between RM 400 and 335 is a section of the river included in the Upstream Snake River segment of the SR-HC TMDL reach. This section is listed in the State of Idaho 1998 303(d) list as being impaired due to excess sediment, nutrients, low dissolved oxygen, bacteria, pH (part of HUC #17050103 and HUC #17050115). For the entire length this section is listed for nutrients related concerns. It is therefore, by definition, "the heavily impaired section" evaluated as part of this assessment.

As stated above, data from 1975 to 2000 was utilized in this assessment. Data from single years were not compared to other years; rather, direct correlations between total phosphorus concentrations and chlorophyll *a* concentrations existing within the system at any one time were compared with each other. The identification of the relationship of total phosphorus concentrations to chlorophyll *a* concentrations was the main object of this assessment. Therefore, although the older data may not represent current conditions, they do represent the relationship between total phosphorus and chlorophyll *a* existing within the system at that time.

Many sections of the Snake River where climate and flow conditions were similar to those in the SR-HC TMDL reach did not have data available for use in this TMDL. The sections utilized, therefore, represent those sections where data was available, and where climate and flow conditions are comparable to the SR-HC TMDL reach. It is recognized that the flow volume in portions of the Snake River upstream of the SR-HC TMDL reach is less than the flow volume in the SR-HC TMDL reach, however, this data set represents the best available information and has been used to establish general targets.

A general distribution of concentration values for chlorophyll *a* and total phosphorus is displayed in the box and whisker plots shown in Figures 3.2.9 and 3.2.10. A *box-and-whisker* plot is a visual representation of how data is spread out and how much variation there is within the data set. The "box" shows the data included in the second and third quartiles, with the median marked as a solid line across the box. The "whiskers" show the range of the data (highest and lowest value).

Figure 3.2.9 contains concentration and range information for chlorophyll *a* in the mainstem Snake River. Mean chlorophyll *a* concentrations observed upstream of RM 400 are between 12 ug/L and 15 ug/L. Between RM 350 and 330 a substantial increase is observed to occur, with

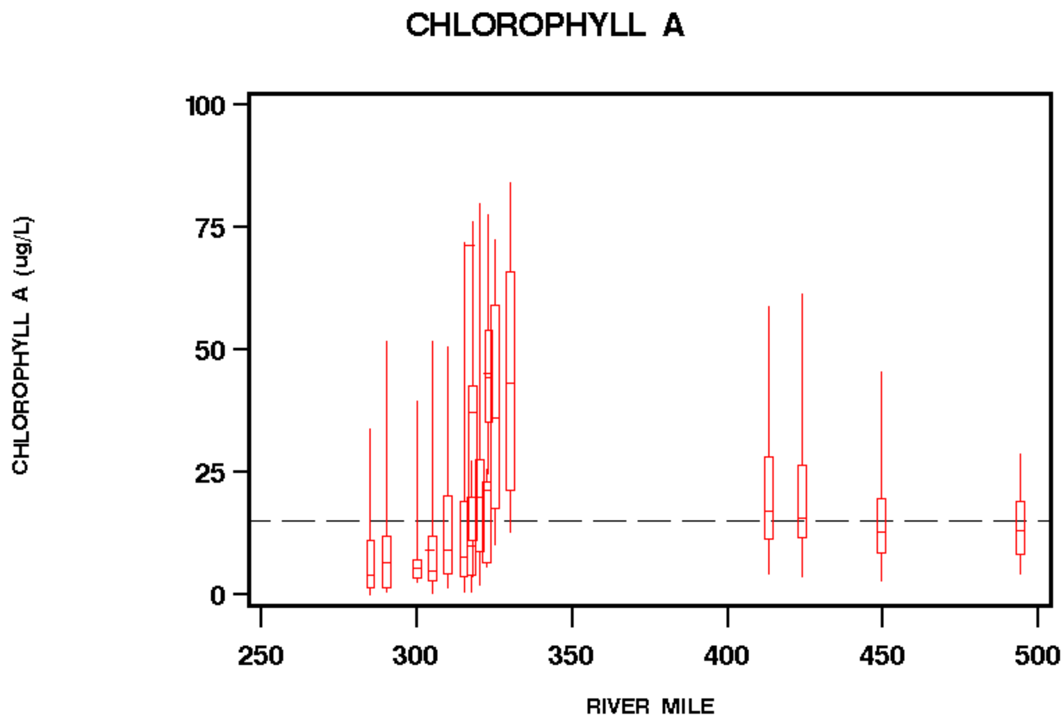


Figure 3.2.9. Box and whisker plot for chlorophyll *a* concentrations within the Snake River system.

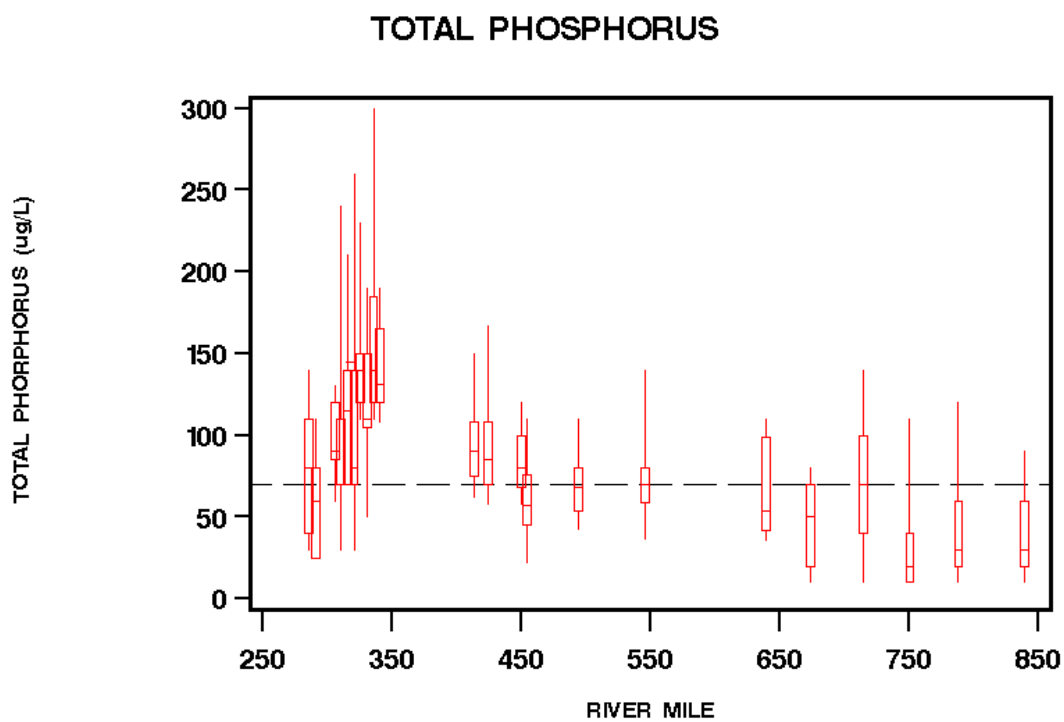


Figure 3.2.10. Box and whisker plot for total phosphorus concentrations within the Snake River system.

mean chlorophyll *a* concentrations between 25 ug/L and 40 ug/L, followed by a substantial decrease downstream of RM 330 (Brownlee Reservoir) to between 7 ug/L and 12 ug/L.

Total phosphorus concentrations displayed in Figure 3.2.10 follow a similar trend. Mean total phosphorus concentrations observed upstream of RM 600 are between 0.03 and 0.07 mg/L. Between RM 400 and RM 600 a slight increase is noted, with mean concentrations between 0.04 and 0.07 mg/L. Between RM 350 and 330 a substantial increase is again observed to occur, with mean total phosphorus concentrations increasing to between 0.09 and 0.14 mg/L, followed by a substantial decrease downstream of RM 330 to approximately 0.06 mg/L.

The concentration data plotted for the Upstream Snake River segment (RM 409 to 335) in Figures 3.2.9 and 3.2.10 show that chlorophyll *a* concentrations observed in the Upstream Snake River segment (RM 409 to 335) are generally 10 ug/L to 15 ug/L higher than those observed in the Snake River upstream of RM 400. Total phosphorus concentrations in this segment are generally 0.05 mg/L to 0.07mg/L higher than those observed in the Snake River upstream of RM 400. This suggests that the Upstream Snake River segment (RM 409 to 335) has a higher loading of both chlorophyll *a* and total phosphorus than the upstream sections of the Snake River as a whole. This relationship is also evident in the data plotted in Figures 3.2.11 and 3.2.12.

Cumulative distribution function (cdf) plots for chlorophyll *a* and total phosphorus for the sections described previously are shown in Figures 3.2.11 and 3.2.12. Cumulative distribution

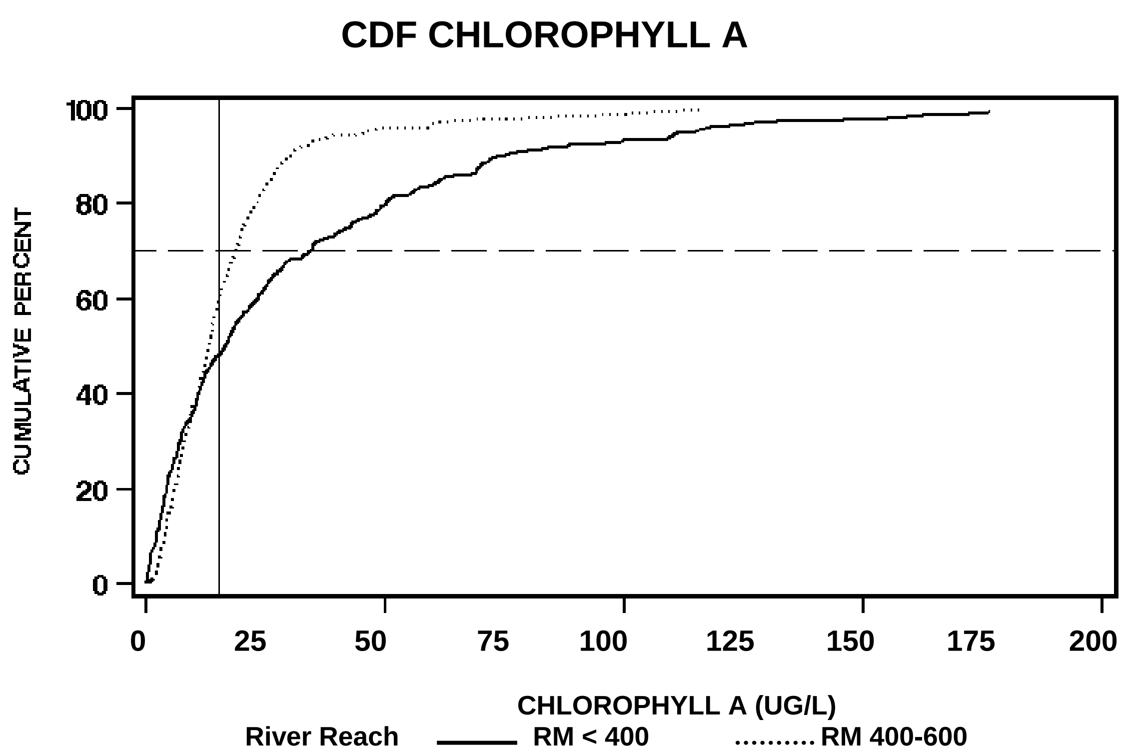


Figure 3.2.11. Cumulative distribution function (cdf) plot of chlorophyll *a* concentrations for two separate sections of the Snake River.

function plots represent the probability that the parameter of concern (in this case the chlorophyll *a* or total phosphorus concentration on the horizontal axis) is less than or equal to a certain percentage (identified on the vertical axis).

The plots for both chlorophyll *a* and total phosphorus show a similar trend in that the downstream section (RM 400 to 335) exhibits notably higher concentrations a greater portion of the time than the upstream sections (RM 400 to 600, or upstream of RM 600). This suggests greater overall loading and greater overall impact to water quality is occurring in the Upstream Snake River segment (RM 409 to 335). For this reason, the Snake River sections upstream of the SR-HC TMDL reach were used in the determination of reference conditions for the SR-HC TMDL reach.

US EPA (2001d) guidance suggests the identification of three concentration ranges based on a frequency distribution as a starting point for determining reference conditions, at risk conditions, and impaired conditions. In order to ensure representative ranges, and minimize the potential that outliers in the data would create a bias, the lowest and highest measured values (5%) were eliminated from consideration. The assessment was accomplished using the data distributed between the 5th and 95th percentiles. This data distribution was then divided evenly into three categories with the 35th percentile concentration defining the threshold below which reference conditions would be defined, and the 65th percentile defining the threshold above which

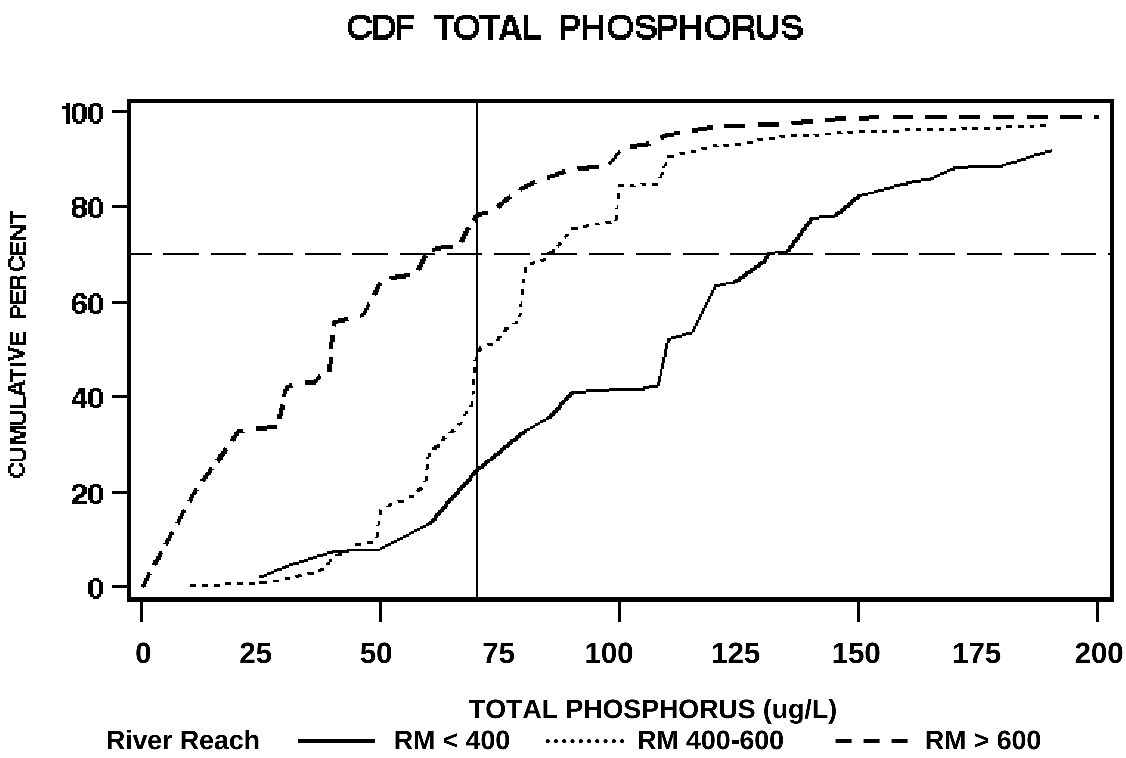


Figure 3.2.12. Cumulative distribution function (cdf) plot of total phosphorus concentrations for three separate sections of the Snake River.

impairment was projected to occur. The concentration range described between the 35th and the 65th percentiles was recommended as a definition of allowable conditions, with lower values tending toward better water quality conditions and higher concentration values being defined as more at risk for impairment. The results of this analysis are tabulated in Table 3.2.4.

Table 3.2.4. Distribution of total phosphorus and chlorophyll *a* data for the Snake River system (1992 through 1995, May through September data).

Data Reach	Data Range	35th Percentile Value	65th Percentile Value
Total Phosphorus (mg/L)			
Snake River System upstream of RM 600	0.01 to 0.28	0.025 mg/L	0.053 mg/l
Snake River between (RM 400 and 600)	0.022 to 0.411	0.065 mg/L	0.077 mg/L
Upstream Snake River segment (RM 409 to 335)	0.01 to 2	0.080 mg/L	0.125 mg/L
Chlorophyll a (ug/L)			
Snake River between (RM 400 and 600)	1 to 115	9 ug/L	16 ug/L
Upstream Snake River segment (RM 409 to 335)	1 to 95	9 ug/L	25 ug/L

Using the general guidance from the US EPA (2000d), the 35th percentile data from the section of the Snake River upstream of RM 600 was used to identify concentration values appropriate to reference conditions for the Snake River system. Using this method, total phosphorus concentrations equal to or less than 0.025 mg/L would represent high quality “reference” conditions. This correlates well with the calculated natural background concentration of 0.02 mg/L based on available data. Applying the 65th percentile concentration value as the threshold concentration above which impairment would be projected to occur would establish an upper concentration limit of 0.053 mg/L for total phosphorus.

The same analysis was performed using the data available from RM 400 to RM 600. Within this data set, total phosphorus concentrations equal to or less than 0.065 mg/L would represent high quality “reference” conditions. Applying the 65th percentile concentration value as the threshold concentration above which impairment would be projected to occur would establish an upper concentration limit of 0.077 mg/L for total phosphorus. This correlates well with the calculated target concentration identified by the Mid-Snake TMDL (IDEQ, 1997c) of 0.075 mg/L for the support of designated beneficial uses and attainment of water quality standards.

To maintain consistency between the total phosphorus and chlorophyll *a* data sets, the 65th percentile values from both the data set collected upstream of RM 600 and the data set from RM 400 to RM 600 were used to establish a range of concentration values (0.053 mg/L to 0.077 mg/L) as a starting point for total phosphorus target determination.

As no chlorophyll *a* data were available from the Snake River upstream of RM 600, data from RM 400 to RM 600 were evaluated using the same methodology to identify preliminary chlorophyll *a* targets for the SR-HC TMDL reach. Based on this analysis, chlorophyll *a* concentrations equal to or less than 9 ug/L would represent high quality “reference” conditions for the SR-HC TMDL, and the threshold concentration above which impairment would be projected to occur would establish an upper concentration limit of 16 ug/L for chlorophyll *a* concentrations in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach.

These values (chlorophyll *a* threshold concentrations of 16 ug/L or less and a total phosphorus threshold target range of 0.053 mg/L to 0.077 mg/L) were used as an initial starting point for identification of targets to attain water quality standards and meet the needs of the designated beneficial uses defined in Section 3.2.2.

Figures 3.2.9 through 3.2.12 and Table 3.2.4 provide evidence that the distribution of chlorophyll *a* and total phosphorus concentrations observed in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach are elevated when compared to those observed upstream of the SR-HC TMDL reach (upstream of RM 409) in the Snake River system.

The 65^{th} percentile value for chlorophyll *a* in the Upstream Snake River segment (RM 409 to 335) is 63 percent higher than the 65^{th} percentile value observed in the Snake River between RM 400 and RM 600. Similarly, the 65^{th} percentile value for total phosphorus observed in the Upstream Snake River segment is 49 percent over the 65^{th} percentile value observed in the Snake River between RM 400 and RM 600. This value is more than two times greater than the 65^{th} percentile value observed in the Snake River upstream of RM 600.

3.2.8.5 CHLOROPHYLL *A* AND TOTAL PHOSPHORUS TARGET IDENTIFICATION.

The statistical determination of reference conditions discussed above supplied a valid range of values for reference and threshold target determination. This range was then related to the unique characteristics of the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach to “ground truth” the general characteristics described by using information specific to this segment and identify a specific numeric target for this reach.

Excessive algal growth is the dominant factor in the impairment of designated beneficial uses in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL. Excessive algal growth has both direct and indirect effects on designated beneficial uses. Direct effects include degradation of aesthetic and recreational opportunities, and the concerns associated with excessive organic loading in domestic water supplies. Indirect effects include low dissolved oxygen resulting from the decomposition of decaying algae, and the associated chemical changes that result. Controlling algal growth in the Upstream Snake River segment (RM 409 to 335) will act to improve water quality and address these impacts to designated beneficial use support.

The identification of a target specific to algal growth or biomass is at best cumbersome and difficult to define. Therefore, chlorophyll *a* (commonly used as a surrogate measure for algae biomass) will be used as a target for the Upstream Snake River segment (RM 409 to 335). The chlorophyll *a* target selected has been identified as appropriate to attain water quality standards and be protective of all designated beneficial uses. Designated beneficial uses in the Upstream Snake River segment that were evaluated in this assessment include: aquatic life, domestic water supply, aesthetics and recreation.

Aquatic life:

As the target identified must be protective of all designated beneficial uses, and as aquatic life uses are generally more sensitive than recreational or aesthetic uses, the support of aquatic species is an important consideration. Mountain whitefish, a salmonid species, are known to inhabit the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach. However, this TMDL acknowledges that a mixed fishery is present in this segment, made up of warm, cool and cold water species. A review of existing literature regarding nuisance thresholds and chlorophyll *a* standards by Pilgrim et al. (2001) reported chlorophyll *a* standards for waters likely inhabited by salmonids at 10 to 15 ug/L, and for waters not inhabited by salmonids at 25 to 40 ug/L. The 65th percentile threshold target of 16 ug/L is close to the upper range defined for salmonid-supporting waters and below the range defined for non-salmonid supporting waters.

Domestic water supply:

To be protective of domestic drinking water supplies, Rashke (1994) proposed a mean growing season chlorophyll *a* limit of 15 ug/L for surface water bodies utilized as water supplies. The 65th percentile threshold target of 16 ug/L is close to this limit.

Aesthetics and recreation:

In the acknowledgement that of information specific to the local perception of acceptable chlorophyll *a* concentrations was limited, information available from other studies (discussed in Section 3.2.2.1) was also utilized. This information provides a range of between 15 and 50 ug/L for maximum chlorophyll *a* concentrations for the support of aesthetics and recreation in North America (Table 3.2.1). These values are maximum concentrations; mean concentrations observed would therefore be expected to be lower, depending on the allowable level of exceedence. Additional data on water discoloration (Table 3.2.5) shows that an acceptable level of discoloration commonly occurs at chlorophyll *a* concentrations between 10 and 15 ug/L. Above this, deep discoloration is observed to occur, along with the formation of algal scum. The 65th percentile threshold target of 16 ug/L is within the lower end of the range defined for maximum allowable concentrations, and near the upper end of the range defined for allowable water discoloration.

Table 3.2.5 Water discoloration linked to chlorophyll *a* concentrations for water bodies in the southeastern United States (from Raschke, 1993).

Chlorophyll *a* (ug/L)	Degree of Water Discoloration
> 10	No water discoloration
10 to 15	Some discoloration, some development of algal scums
20 to 30	Deep discoloration, frequent algal scum formation
> 30	Very deep discoloration, intense matting of algal scum

The ranges identified above as being protective of designated beneficial uses extend from 10 ug/L to 50 ug/L. The 16 ug/L target identified previously as the threshold above which impairment is likely to occur falls at the low end of the range presented for protection of aesthetics and recreation. This value is near the high end of the range presented for the protection of salmonids but below the range presented for the protection of non-salmonids. This value is very close to that defined as being protective of domestic water supply uses. Therefore, a chlorophyll *a* target of less than or equal to 16 ug/L mean growing season concentration appears to be protective of the more sensitive designated uses for the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach. Because this assessment evaluated the relationship between total phosphorus and chlorophyll *a* throughout the system as a whole, recommended associated error included over/underestimation of overall concentration by grab sampling (10% to 25%), and analytical error (3% to 5%). Error ranges were recommended by Dr. Paul Woods of the USGS (sample error) and certified federal and state analytical laboratories (analytical error). Sampling and analytical protocol information is available for USGS, US EPA, and IPCo data utilized in this assessment. These data represent the primary data sources for this evaluation. As all sample collection and analytical work for these data were performed under rigorous, well defined protocols, conservative error estimates were used for all sources. This resulted in an overall MOS of 13 percent. Applying this MOS to the initial 16 ug/L threshold value yields a target of 14 ug/L chlorophyll *a*.

The allowable level of exceedence for this target is recognized as critical factor in the support of designated beneficial uses. Frequency exceedence levels of up to 25 percent were found to be protective for recreational uses by Smeltzer and Heiskary (1990) and have been applied in this assessment. Given the existing data set, based on summer growing season chlorophyll *a* concentrations, this exceedence level, combined with the 14 ug/L mean growing season concentration target results in a nuisance threshold of 30 ug/L chlorophyll *a*.

A 14 ug/L mean growing season chlorophyll *a* concentration and a nuisance threshold of 30 ug/L chlorophyll *a* is projected to be protective of all designated beneficial uses, and to result in the attainment of appropriate water quality within the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach, it has been established as the chlorophyll *a* target for this TMDL.

In order to attain the chlorophyll *a* target identified for the Upstream Snake River segment of the SR-HC TMDL reach, reductions in total phosphorus concentrations in the mainstem Snake River must be accomplished. In a ranked, paired distribution of data (Figure 3.2.13 a), the nuisance threshold of 30 ug/L chlorophyll *a*, combined with the 14 ug/L mean growing season concentration target corresponds to total phosphorus concentrations between 0.053 mg/L and 0.077 mg/L. In order to define the appropriate numeric total phosphorus target for the Upstream Snake River segment (RM 409 to 335), several issues were considered.

An inflection point is apparent in the plotted data (Figure 3.2.13a), occurring between 0.065 and 0.072 mg/L total phosphorus. The difference in trend between total phosphorus concentrations below 0.065 mg/L and concentrations above 0.072 mg/L indicates that greater chlorophyll *a* concentrations (and therefore greater total biomass) occur at higher concentrations of total phosphorus. This correlation is somewhat intuitive, but variation in natural systems often makes it difficult to define quantitatively.

While the chlorophyll *a* values at and below the inflection point in Figure 3.2.13 a are very similar, chlorophyll *a* concentrations associated with total phosphorus concentrations greater than 0.072 mg/L, especially maximum concentrations, are substantially greater than those associated with total phosphorus concentrations less than 0.072 mg/L. As shown in Table 3.2.6,

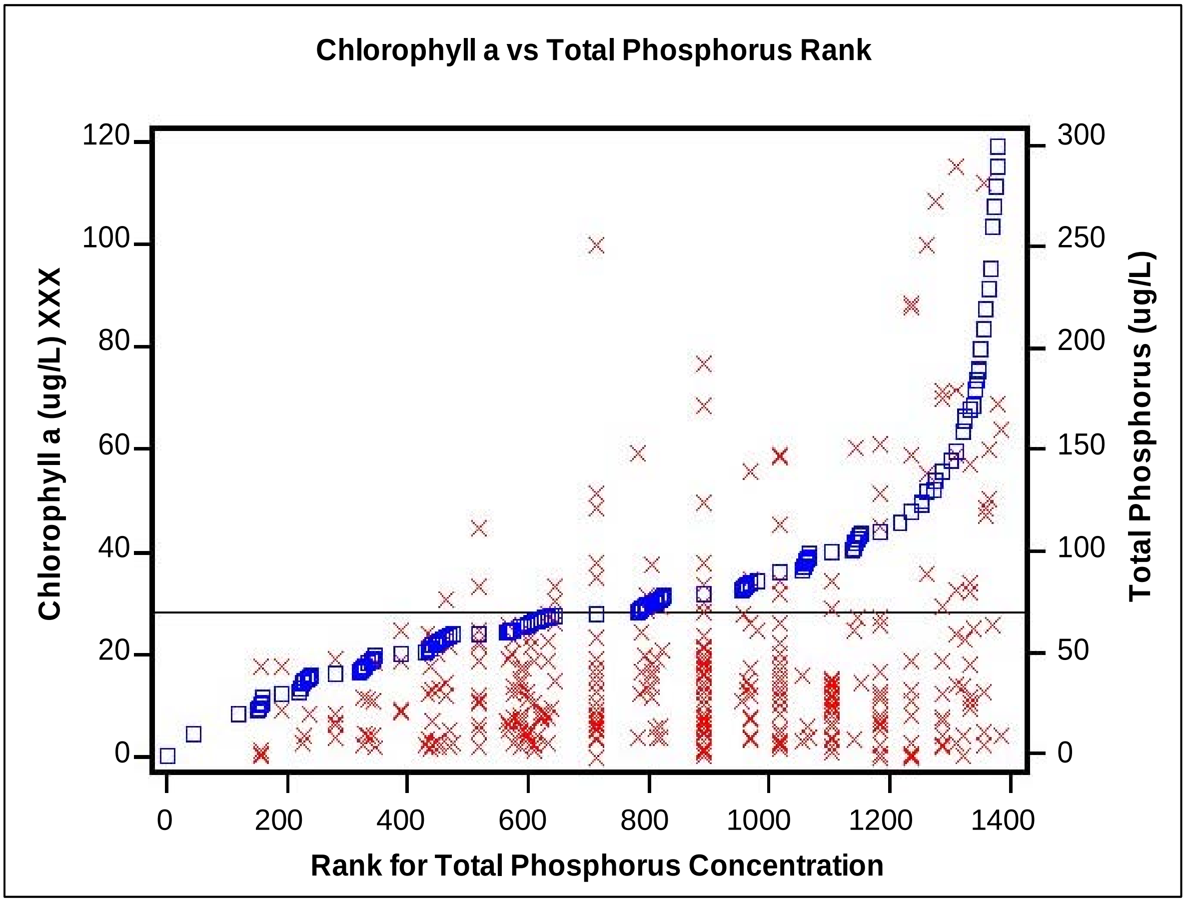


Figure 3.2.13 a. Chlorophyll *a* concentration data as correlated with increasing total phosphorus concentration for the Upstream Snake River segment (RM 409 to 335) of the Snake River - Hells Canyon TMDL.

Table 3.2.6. Correlated total phosphorus and chlorophyll *a* values for Upstream Snake River segment (RM 409 to 335) data.

Total Phosphorus Range	Chlorophyll *a* Range	Chlorophyll *a* mean	Chlorophyll *a* 65th Percentile
0.01 mg/L to 0.065 mg/L	0 ug/L to 44 ug/L	11.8 ug/L	14.6 ug/L
0.065 mg/L to 0.072 mg/L	0 ug/L to 45 ug/L	11.8 ug/L	16.0 ug/L
0.072 mg/L to 2.0 mg/L	0 ug/L to 95 ug/L	24.8 ug/L	30.8 ug/L

the maximum, average chlorophyll *a* values associated with total phosphorus concentrations greater than 0.072 mg/L are double those observed at or below this value. When these values are compared to those observed in the analysis of the larger Snake River system data set, upstream of RM 400, they supply additional information on water quality improvements. The total phosphorus concentrations at the inflection point are within the range described by the previous analysis of the Snake River data, namely 0.053 mg/L to 0.077 mg/L. Additionally, these data show that measurable reductions in algal biomass can be achieved by attaining the 0.072 to 0.065

mg/L concentration, but that reductions below 0.065 mg/L will probably not result in substantially greater improvements than those achieved at 0.065 mg/L. This is important in the consideration of the economic costs of implementation. For this reason, the lower threshold value identified by the data set from upstream of RM 600 (0.053 mg/L) was considered inappropriate to the SR-HC TMDL reach and will not be applied.

The remaining threshold value (0.077 mg/L) was assessed using best professional judgement and estimates of associated error. Because this assessment evaluated the relationship between total phosphorus and chlorophyll *a* throughout the system as a whole, recommended associated error included over/underestimation of overall concentration by grab sampling (10% to 25%), and analytical error (3% to 5%). Error ranges were recommended by Dr. Paul Woods of the USGS (sample error) and certified federal and state analytical laboratories (analytical error). Sampling and analytical protocol information is available for USGS, US EPA, and IPCo data utilized in this assessment. These data represent the primary data sources for this evaluation. As all sample collection and analytical work for these data were performed under rigorous, well defined protocols, conservative error estimates were used for all sources. This resulted in an overall margin of safety of 13 percent. When applied to the threshold values generated by the data set from RM 400 to RM 600 (0.077 mg/L total phosphorus), a target value of 0.067 mg/L total phosphorus was identified, 0.07 mg/L (after rounding). These target concentrations were then evaluated for designated use support within the SR-HC TMDL reach.

3.2.8.6 Target Evaluation for Designated Use Support.

Within the ranked data set it was observed that a general increasing trend in maximum chlorophyll *a* concentration occurred with increasing total phosphorus concentration (Figure 3.2.13a). Although there is variation within the data set, a general correlation of increasing maximum chlorophyll *a* values with increasing total phosphorus concentration was observed in the data.

The target of 0.07 mg/L total P (over the growing season) is projected to result in a median chlorophyll *a* concentration of about 12 ug/L (Figure 3.2.13 a). When median total P concentrations are at 0.07 mg/L, maximum chlorophyll *a* concentrations rarely exceed 30 ug/L in this system (this is because to a first approximation about one-half of the total P in a system is available to the algae). Therefore maximum total P concentrations of 0.07 mg/L will result in substantially lower median seasonal chlorophyll *a* concentrations, probably around 15 ug/L.

This is corroborated when comparing the Snake to other lakes and reservoirs in the Pacific Northwest (Figure 3.2.13 b). Median total P concentrations during the growing season below 0.07 mg/L typically produce median chlorophyll *a* concentrations less than 15 ug/L. If the target of 0.07 mg/L total P in the Snake is realized, median total P will be much less than 0.07 mg/L and the chlorophyll *a* concentrations correspondingly lower. Thus the “average” of 14 ug/L chlorophyll *a* corresponding to a maximum total P of 0.07 mg/L appears to be reasonable. Moreover, the 0.07 mg/L target will eliminate the large peaks in chlorophyll *a* observed in the upper part of the reservoir (Figure 3.2.13 a).

Chlorophyll *a* concentrations correlated with total phosphorus concentrations between 0.02 mg/L and 0.065 mg/L ranged from a minimum of 0 ug/L to a maximum of 44 ug/L (Table 3.2.6). The average chlorophyll *a* concentration over this range was 11.8 ug/L. Chlorophyll *a* concentrations correlated with total phosphorus concentrations between 0.065 mg/L and 0.072 mg/L, ranged from a minimum of 0 ug/L to a maximum of 45 ug/L. The average chlorophyll *a* concentration over this range was 11.8 ug/L. Chlorophyll *a* concentrations correlated with total phosphorus concentrations above 0.072 mg/L ranged from a minimum of 0 ug/L to a maximum of 95 ug/L. The average chlorophyll *a* concentration over this range was 24.8 ug/L.

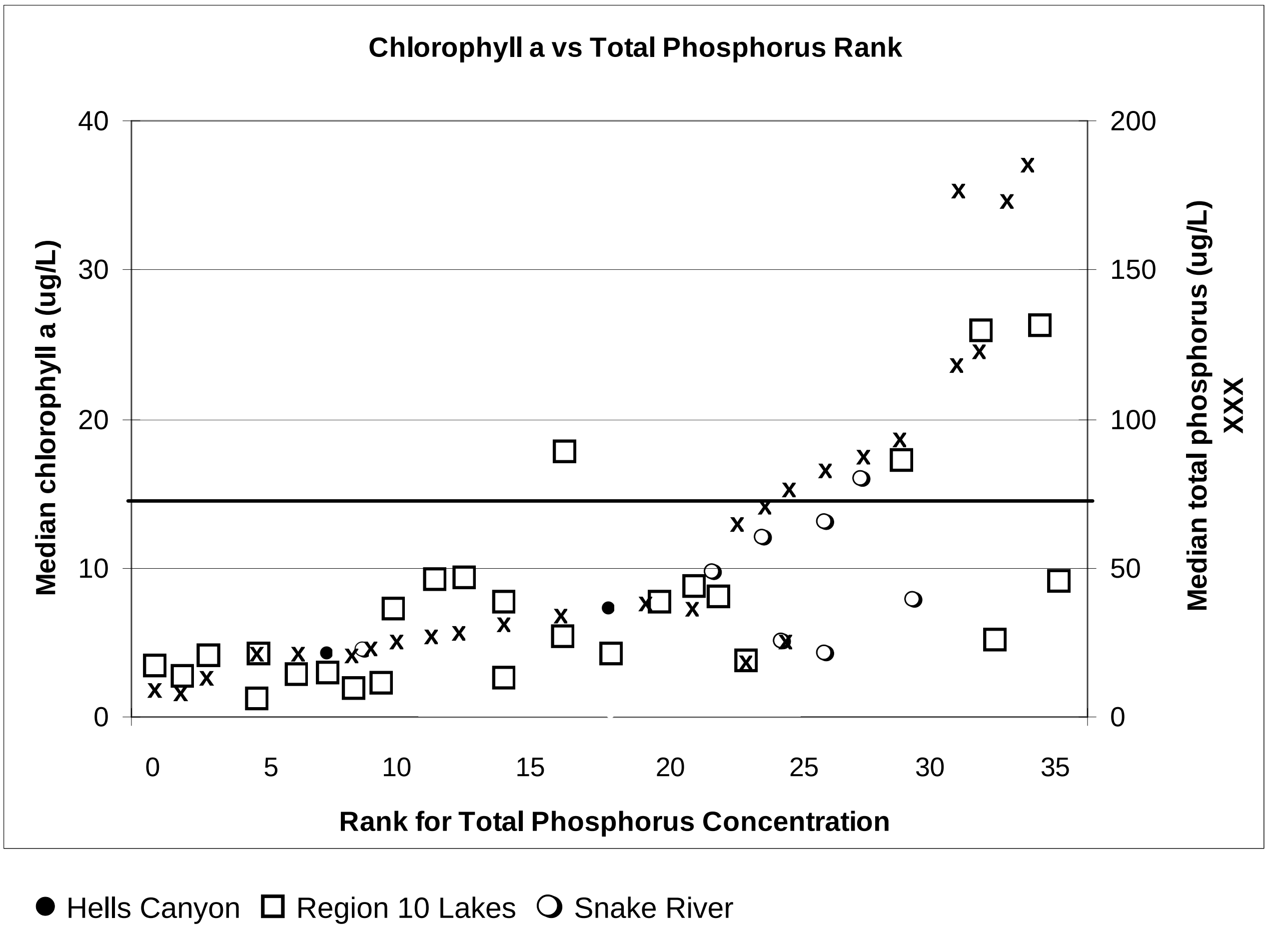


Figure 3.2.13 b. Comparison of median chlorophyll *a* concentration data as correlated with median total phosphorus concentration data for lakes and reservoirs in the Pacific Northwest.

If the 14 ug/L mean growing season chlorophyll *a* target is achieved through attainment of the 0.07 mg/L total phosphorus target, then designated beneficial uses in the Upstream Snake River segment (RM 409 to 335) directly linked to algal growth will be supported. These include domestic water supply, aesthetics and recreation. Full support of the aquatic life designated beneficial uses is dependent on the level of improvement in dissolved oxygen that occurs as a result of reduced algal growth. While algal blooms are expected to occur even with attainment of the 0.07 mg/L total phosphorus target, the frequency of occurrence will be reduced and the peak chlorophyll *a* concentrations should generally remain less than 30 ug/L. This is projected to result in full support of aesthetics and recreational designated beneficial uses and improved dissolved oxygen concentrations.

Attainment of the 0.07 mg/L target value represents a substantial reduction in the current average total phosphorus concentration in the SR-HC TMDL reach. Mainstem total phosphorus concentrations in the Snake River near Weiser average 0.13 mg/L to 0.14 mg/L total phosphorus annually (1999 to 2000 data set). The 0.07 mg/L target will require an overall reduction of 54 percent in total phosphorus concentration in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach. When natural loading is accounted for (0.02 mg/L) the anthropogenic-related concentration is calculated at 0.11 mg/L to 0.12 mg/L. Using this concentration, to decrease total phosphorus concentration to 0.07 mg/L will require a 62 percent reduction in overall anthropogenic loading.

Attainment of the 14 ug/L mean growing season chlorophyll *a* target represents a reduction of roughly 44 percent in chlorophyll *a* and associated algal biomass. Approximately 1.5 percent of algal organic matter is chlorophyll *a* (Raschke, 1993). The average chlorophyll *a* concentration in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach during the summer season is 24.8 ug/L (103 ug/L maximum). Translated to algal biomass using the relationship above, in conjunction with 1995 (July average) flows at the Weiser gage of 15,000 cfs, this represents an algal biomass loading of approximately 61,000 kg/day (67 tons/day) near the Weiser gage station in the mainstem Snake River.

The average calculated chlorophyll *a* concentration resulting from attainment of the 0.07 mg/L total phosphorus target is 14 ug/L. This translates to an algal biomass loading of approximately 34,000 kg/day (37 tons/day) near the Weiser gage station. The reduction realized in total algal biomass is 27,000 kg/day (30 tons/day). This calculation does not account for additional reductions in biomass (periphyton and other organic growth) that can be directly influenced by reductions in nutrient concentrations.

In order to evaluate the influence of this reduced biomass on dissolved oxygen in the downstream river and reservoirs, several assumptions were made. It was assumed that the algae-related organic material was 50 percent labile (easily decomposed) and 50 percent refractory (more stable). It was also assumed that the decay of the labile fraction would occur in a day's time. Both of these assumptions are somewhat conservative, but still allow a relative evaluation of the influence of reduced organic loading to the system. Using a conservative organic matter/O_2 demand coefficient of 0.8 (Newbold and Liggett, 1974; Cole and Buchak, 1995), the reduction in organic matter from the 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets results in a savings of 16,500 kg/day (18.2 tons/day) of oxygen in the water column. This equates to an approximately 0.3 mg/L dissolved oxygen increase in the water column as a whole or, perhaps more appropriately, 2 mg/L improvement in dissolved oxygen in 20 percent of the water column (improvements in dissolved oxygen would most likely be associated with depositional areas in the river system). The savings in water column oxygen due to reduced organic loading is expected to be of most benefit in those areas currently at risk for low sediment/water interface dissolved oxygen concentrations.

The projected 44 percent reduction in organic mater is conservative as accounts only for reductions in algal growth within the system. It does not account for any corresponding reduction in attached growth (periphyton, attached macrophytes, etc.) resulting from reductions in nutrient loading. Additionally, it does not account for reduced sediment-oxygen demands from erosion-based sediment reductions occurring with implementation progress.

If substrate dissolved oxygen levels require greater improvements than those identified by nutrient reductions, the TMDL will be re-evaluated. It is recognized that improvement in substrate dissolved oxygen levels will not be instantaneous as there is already a substantial store of organic material available within the SR-HC TMDL system. However, sustained reductions in incoming loads of organic material combined with transport and recycling within the system will, over time, result in decrease in the amount of organic material available within the SR-HC TMDL reach, this will improve substrate dissolved oxygen levels and benefit aquatic life using the sediment/water interface

Modeled Evaluation of Total Phosphorus Target Attainment.

A modeling effort using the USACOE CE-QUAL-W2 model has been undertaken by IPCo for the purposes of improving understanding of the Hells Canyon Complex system as part of the FERC re-licensing effort for the Hells Canyon Complex hydropower facilities (IPCo, 1999d). Because of its potential application to the SR-HC TMDL process, this model was evaluated extensively by the DEQs. The IPCo model has been reviewed and evaluated by modeling experts at IPCo and their contractors, and has been peer reviewed by a panel of modeling experts from several different state and federal agencies that were assembled by IPCo. In addition, the DEQs have evaluated this model and its application to the SR-HC TMDL effort and have conducted a separate peer review through a panel of modeling experts assembled by the DEQs in response to requests voiced by some members of the SR-HC PAT.

Although it was recognized in all peer reviews that no model will ever be a perfect fit for any system, all reviewers from all of the peer review efforts indicated that they felt confident with the manner in which the model had been validated and applied to the Hells Canyon Complex. (For more information on this peer review process please contact the IDEQ Boise Regional Office, 1445 North Orchard, Boise, Idaho 83706.) Because of the outcome of the peer reviews conducted, it is the opinion of the DEQs that the IPCo model represents a valid tool for evaluation of water quality conditions within the SR-HC TMDL reach.

The IPCo model was utilized to simulate the water quality response to the 0.07 mg/L total phosphorus target in the Upstream Snake River segment (RM 409 to 335) and the Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. Modeling work was accomplished by IPCo and contract personnel. Simulations included a projection of both short-term (benefits that would be realized quickly) and long-term (benefits that would take a more extended period of time to occur) water quality improvements based on the attainment of the 0.07 mg/L total phosphorus target. The following section contains a summary of the information provided by IPCo regarding this modeling effort. The full memorandum is attached as Appendix F.

The changes in water quality in the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir were evaluated. The 1995 baseline boundary condition in the Brownlee Reservoir Model is based on the 1995 Southwest Snake River Model (IPCo, 2000a) results calibrated to measured data from Porters Island. The model includes soluble reactive phosphorus and phosphorus tied to organic matter (based on a coefficient for the stoichiometric equivalent between organic matter and phosphorus) (Cole and Wells, 2000; IPCo, 1999d). Thus, organic matter in the boundary condition multiplied by the coefficient represent organic phosphorus in the model.

To evaluate total phosphorus in the model and the reduction to meet the target, total organic matter was calculated as the sum of algae and dissolved and particulate organic matter. Total organic matter was converted to organic phosphorus using a ratio of 100:1 (total organic matter: organic phosphorus) (IPCo, 2000a). Total phosphorus was calculated as the sum of organic phosphorus and soluble reactive phosphorus. The model does not account for inorganic (mineral) phosphorus attached to sediment. The date when total phosphorus exceeded the criteria by the greatest amount was identified in the boundary condition and the difference between the maximum value and the target was calculated. This difference was then used to reduce the algae, organic matter, and soluble reactive phosphorus boundary conditions for the entire year. Model output is displayed in Figure 3.2.14.

As can be seen in Figure 3.2.14, the average modeled chlorophyll *a* concentration in the Upstream Snake River segment (RM 409 to 335) decreases by greater than the calculated 44 percent (estimated ~70%). This is reasonable as the original calculated value focuses on annual average chlorophyll *a* and does not account for other organic matter loads generated instream. Modeled chlorophyll *a* concentrations resulting from the attainment of the 0.07 mg/L total phosphorus target are within the range described in Table 3.2.1 as representing valid maxima for support of aesthetic and recreational designated uses, and match those identified in Table 3.2.6 associated with the 0.07 mg/L total phosphorus target.

To simulate the short term improvements, dissolved phosphorus and organic phosphorus (i.e. organic matter, including algae) were reduced from the 1995 baseline boundary conditions such that inflowing phosphorus levels did not exceed 0.07 mg/L. Long-term phosphorus improvements related to changes in sediment oxygen demand were simulated by replacing baseline sediment oxygen demand values estimated during model optimization with more typical values.

Changes in dissolved oxygen concentrations from each of the simulations were compared to baseline conditions by calculating the percent of volume where dissolved oxygen levels were below dissolved oxygen criteria. Baseline conditions were represented by the peer-reviewed Brownlee Model using 1995 measured boundary conditions, optimized to measured in-reservoir water quality data (IPCo, 1999d).

The simulation results demonstrate improving conditions from short-term conditions without sediment oxygen demand improvements to long-term conditions with sediment oxygen demand improvements. In general, the simulations show an increase in dissolved oxygen in all zones except the riverine zone, where dissolved oxygen is already at super saturated levels as a result

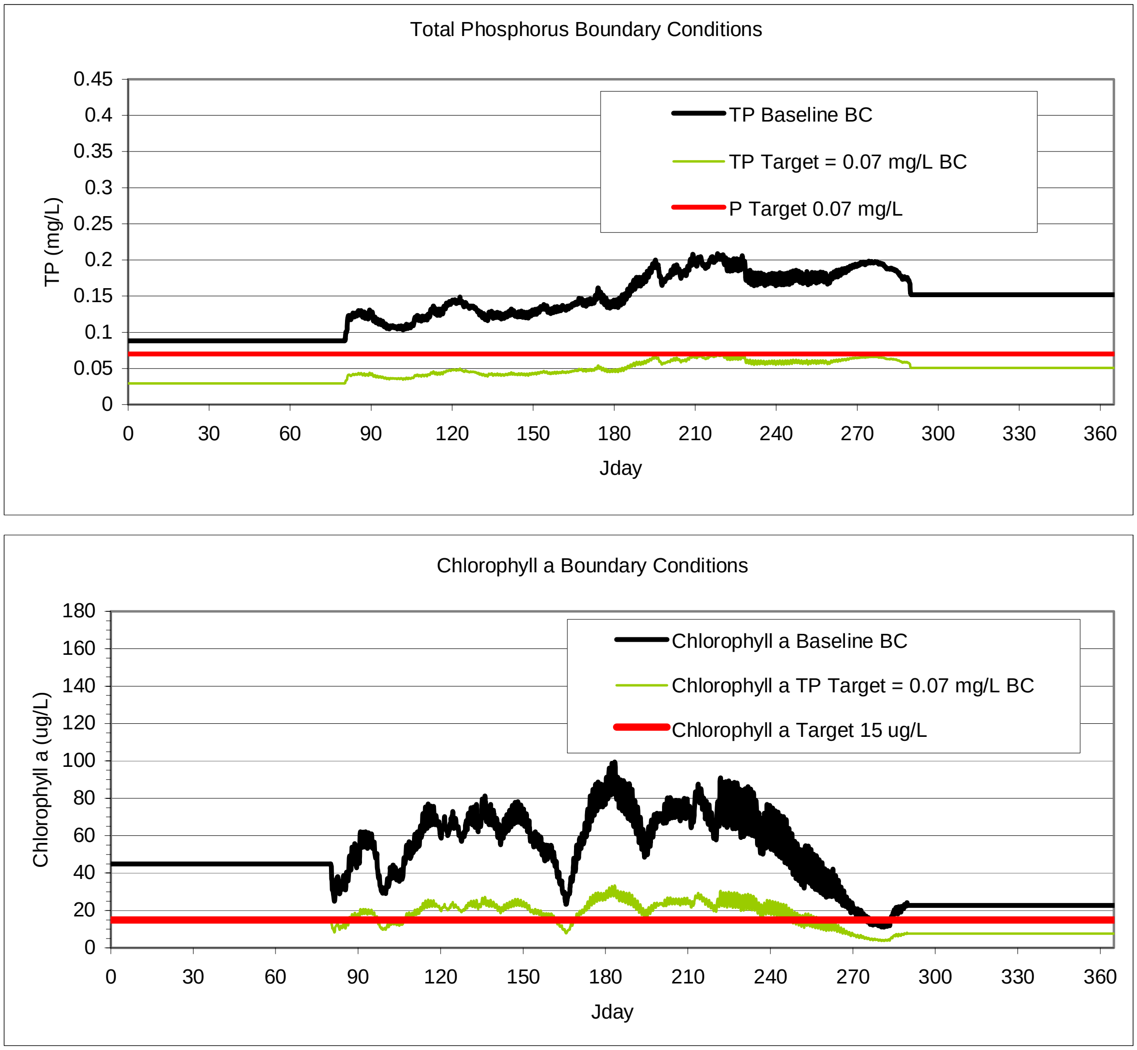


Figure 3.2.14. 1995 Boundary conditions, baseline and modeled total phosphorus target reductions.

of the algal bloom. In general, the dissolved oxygen improvement is greatest in the summer, especially in the metalimnion.

The simulation in Figure 3.2.15 a shows Brownlee Reservoir's initial response to reductions in total phosphorus and organic matter loads based on the total phosphorus target of 0.07 mg/L. When the TMDL is first implemented, sediment oxygen demand will be unchanged from baseline conditions. This limits the initial level of improvement (i.e., increase in dissolved oxygen) in the downstream end of the transition zone and in the lacustrine zone where sediment oxygen demand levels are highest.

The response to these long-term improvements was simulated by reducing sediment oxygen demand to 0.1 gm oxygen m^{-2} day^{-1} throughout the Brownlee Reservoir (Figure 3.2.15 b). This sediment oxygen demand is more typical of naturally occurring sediment oxygen demand levels

(Cole and Wells, 2000). The inflowing boundary conditions are unchanged from the previous simulation.

These simulations show that substantial improvements in water quality in Brownlee Reservoir will occur through implementation of the 0.07 mg/L total phosphorus target proposed for the SR-HC TMDL. While substantial improvements in dissolved oxygen are projected to occur as a result of the attainment of the 0.07 mg/L total phosphorus target, additional improvements are needed to meet dissolved oxygen criteria in Brownlee Reservoir. This is discussed in more detail in Section 3.2.8.7.

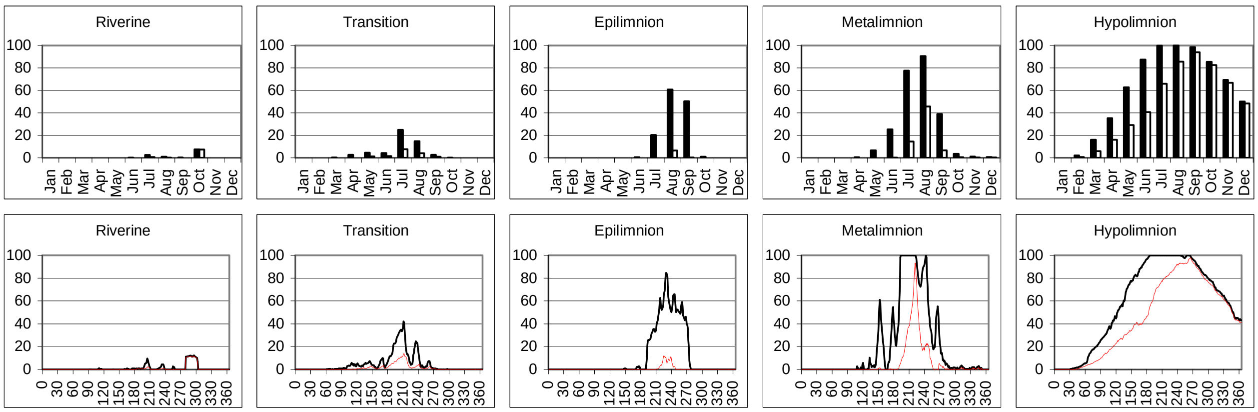


Figure 3.2.15 a. Simulation results showing short-term improvement resulting from implementation of the 0.07 mg/L total phosphorus target. Dark line shows percent dissolved oxygen below criteria (6.5 mg/L) for baseline and light line shows total phosphorus target.

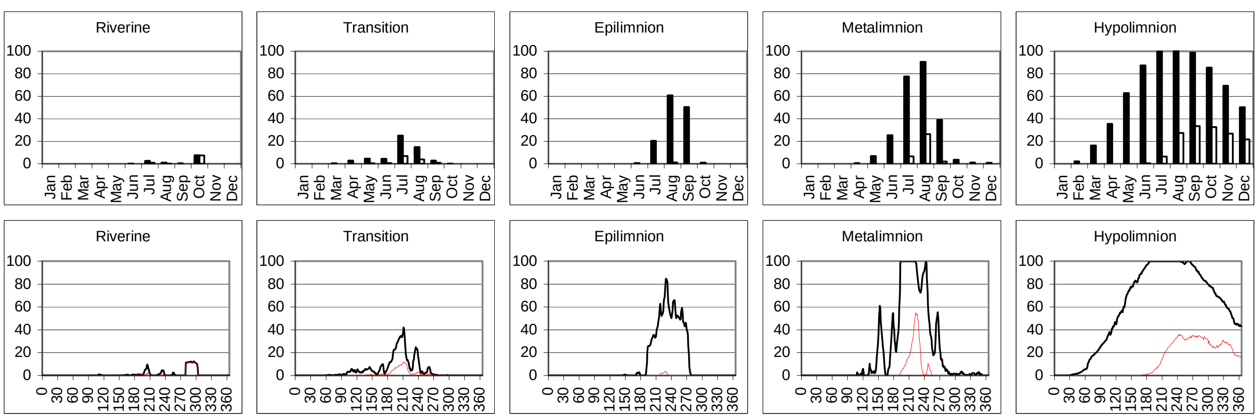


Figure 3.2.15 b. Simulation results showing long-term improvement resulting from implementation of the 0.07 mg/L total phosphorus target and resulting decrease in sediment oxygen demand. Dark line shows percent dissolved oxygen below criteria (6.5 mg/L) for baseline and light line shows total phosphorus target with sediment oxygen demand improvement.

Both calculated and modeled results showed similar increases in water quality through reduced algae (chlorophyll *a*) concentrations and improved dissolved oxygen. Because these evaluations were undertaken using very different methodologies and associated assumptions, the agreement between the two acts to substantiate the predicted outcome.

Other Benefits Projected from Meeting the Total Phosphorus Target.

The reduction in organic matter will also decrease the potential for methylmercury production within the SR-HC TMDL reach. A roughly 44 percent reduction in algae-related organic loading to the SR-HC TMDL reach, and the associated reductions in other aquatic growth through nutrient management will reduce the available organic material and thus reduce the opportunity for of the conversion process. The lack of understanding of the time frame over which it occurs precludes quantification of the actual reduction in methylmercury expected. It is also recognized that this improvement will not be instantaneous as there is already a substantial store of organic material available within the SR-HC TMDL system. However, as incoming loads of organic material decrease over time, and transport and recycling within the system proceeds, the amount of organic material available within the SR-HC TMDL reach will decrease, thus leading to decreased methylmercury concentrations. This in turn will reduce the concerns related to aquatic life and fish consumption by humans and animals.

The reduced growth resulting from a 44 percent reduction in total algal biomass will improve water quality conditions related to domestic water intakes as well, as reduced organic matter will lead to reduced potential for trihalomethane production, fewer filter concerns, and lower corrosive potential as nutrient concentrations decrease.

Finally, the US EPA guidance (US EPA, 2000d) illustrates a water quality continuum where systems exhibiting reference conditions are displayed on the left (lower percentile) of the plotted scale and systems identified as impaired are shifted toward the right (higher percentile) of the plotted scale. Waters in between fall on a continuum that blends gradually from impaired conditions to reference conditions with those on the impaired side of the continuum listed as *at risk*. In attaining this target value, the SR-HC TMDL reach will more closely reflect the most frequently occurring total phosphorus concentrations observed in the Snake River system as a whole, rather than the higher total phosphorus concentrations that currently result in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach being shifted toward the impaired end of the scale.

The target of 0.07 mg/L total phosphorus is slightly higher than that projected statistically for the Snake River upstream of RM 600 (0.065 mg/L total phosphorus), a less impacted system; but represents substantial reductions in total phosphorus loading, nuisance algal growth, and similar reductions in the associated water quality problems identified by this assessment.

As outlined above, the 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets are supported by data analysis for the Snake River and the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach. They are also supported by the guidance on determining nutrient criteria recommended by US EPA. The data analysis and modeled reductions show that attainment of the target will result in substantial reduction in algal growth (as determined by chlorophyll *a* data) and improved dissolved oxygen concentrations within the Upstream Snake River segment (RM 409 to 335).

Therefore, it is the opinion of IDEQ and ODEQ that attainment of less than or equal to 14 ug/L mean growing season chlorophyll *a* concentration through attainment of the less than or equal to 0.07 mg/L mainstem total phosphorus target will result in reductions in algal growth sufficient to support aquatic life, domestic water supply, recreational and aesthetic uses within the Upstream Snake River segment of the SR-HC TMDL reach and attainment of the water quality standards for both Oregon and Idaho.

3.2.8.7 Identification of Difference in Assimilative Capacity for The Reservoir Segments.

While targets were evaluated separately for the Upstream Snake River segment (RM 409 to 335) and reservoir segments (RM 335 to 247), the Snake River system operates very much as a complete whole. Water quality within the SR-HC TMDL reach moves as a continuous chain, improvements in water quality in one segment will have a positive effect on downstream segments as degraded water quality in upstream segments will result in poor water quality downstream. This is especially true of the relationship between water quality in Brownlee Reservoir and that in Oxbow and Hells Canyon Reservoirs. Improvements in water quality in Brownlee Reservoir will have an immediate and positive effect on water quality in Oxbow and Hells Canyon Reservoirs. For this reason, the 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets were evaluated for water quality improvements primarily in Brownlee Reservoir.

As stated previously, the initial strategy for nutrient target identification in the SR-HC TMDL reach was to establish a target appropriate for the Upstream Snake River segment (RM 409 to 335) which represents the dominant inflow to both the Hells Canyon Complex reservoirs and the Downstream Snake River segment (RM 247 to 188). It was theorized that if the Upstream Snake River segment met water quality standards in river, the water quality in Brownlee Reservoir (and the downstream reservoirs) would be improved. The level of improvement realized in the reservoir complex is a function of (1) the dependence of reservoir water quality on inflowing water quality, and (2) the change in assimilative capacity of the system as it moves through the impoundments. Impairment due to the latter is attributable to the reservoir systems; impairment due to the former is attributable to upstream sources.

The 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets described in the preceding sections are based on the needs of the Upstream Snake River segment (RM 409 to 335). These targets were then applied to the reservoir complex (primarily Brownlee Reservoir as it is located the farthest upstream, has the largest volume, and exhibits the greatest occurrence of water quality degradation of the three and therefore is the most sensitive to inflowing water quality).

The loading analysis (Section 3.2.6) clearly demonstrated that the reservoirs act as a sink for pollutants within the SR-HC TMDL system, removing approximately 44 percent of the total phosphorus and 77 percent of the sediment from the water before it reaches the Downstream Snake River segment (RM 247 to 188).

There are no activities associated directly with the reservoirs that act as phosphorus sources such as those identified in the Upstream Snake River segment (RM 409 to 335). However, the reservoirs do change the way the water moves through the system. This in turn can have an influence on how pollutants are processed and transported within the SR-HC TMDL reach.

The influence of the 0.07 mg/L target was investigated by applying the target phosphorus concentration and the reduced algae load to the inflowing waters of Brownlee Reservoir. For the purposes of this analysis it was assumed that all of the inflowing mainstem met the target concentration and showed the same 44 percent reduction in algae mass calculated to occur in the Upstream Snake River segment (RM 409 to 335).

The same assumptions for algae-related organic material, decay of the labile fraction, and organic matter/O_2 demand coefficients were applied in this evaluation as were applied in the evaluation of the Upstream Snake River segment (Section 3.2.8.6). Oxygen savings in the water column (from reduced algae decomposition) were calculated using 1995 flow data as they represented the most complete set and a reasonably average flow year (90% of the 30-year average). Average monthly flows were calculated, as were average monthly dissolved oxygen concentrations for each of the reservoir sections (RM 335 to 285) using information supplied by IPCo on the size and general volume of the reservoir segments (RM 335 to 247). Daily variations in dissolved oxygen were not tracked. Because they process pollutants differently, have somewhat different flow characteristics during stratification, and represent different levels of priority in designated beneficial use support, the sections of Brownlee Reservoir were evaluated separately for dissolved oxygen influences with the identified 0.07 mg/L total phosphorus target.

Brownlee Reservoir was divided into five separate sections (Figure 3.2.16):

- The riverine section (RM 340 to 325)
- The transition zone (RM 325 to 308)
- The lacustrine zone – epiliminion (RM 308 to 285) from surface elevation to 35 m below the surface.
- The lacustrine zone – metalimnion (RM 308 to 285) from 35 m below the surface to 45 m below the surface.
- The lacustrine zone – hypolimnion (RM 308 to 285) from 45 m below the surface to depth.

The volumes of these sections were calculated using information supplied by IPCo (IPCo, 1999d and personal communication, R. Myers and J. Harrison, IPCo, 2001). The values utilized are shown in Table 3.2.7.

Table 3.2.7. Volume information by section for Brownlee Reservoir. (Data provided by Idaho Power Company.)

Reservoir Section	Section Volume (acre-feet)	% of total reservoir
Riverine	179,382	14%
Transition	341,288	27%
Epilimnion	476,410	37%
Metalimnion	153,565	12%
Hypolimnion	122,696	10%
Total	1,273,341	100%

The influence on water quality was evaluated for the summer months when low dissolved oxygen levels most frequently occur. Each reservoir section was evaluated separately to assess the influence of improved dissolved oxygen and reduced phosphorus and algae loading in the inflowing waters. Each section was evaluated as a whole. It was assumed that the dissolved oxygen improvements within each segment were fully mixed, laterally and vertically. The information generated for the existing conditions (pre-target attainment) is shown in Figure 3.2.17.

Calculated dissolved oxygen curves for the transition zone and epilimnion show dissolved oxygen levels dropping below 6.5 mg/L in July, August and September. Minimum concentration values calculated are approximately 5.25 mg/L and 5.5 mg/L respectively. Calculated dissolved oxygen curves for the metalimnion show a more marked and extensive decrease with dissolved oxygen levels dropping below 6.5 mg/L in June, July, August and September. Minimum concentration values calculated are approximately 2.25 mg/L, occurring during the month of August. Calculated dissolved oxygen curves for the hypolimnion show a substantial decrease in dissolved oxygen concentration starting in June and continuing through the fall. Dissolved oxygen levels calculated dropped well below 3.0 mg/L (a situation lethal to most fish) in July and continue to decrease through the fall. Minimum concentration values calculated are approximately 1.25 mg/L, occurring during the month of September.

The curves shown in Figure 3.2.18 are calculated dissolved oxygen concentrations post-target attainment, showing the response of Brownlee Reservoir waters to improved water quality in the inflowing Snake River at RM 335. In all sections of the reservoir, attainment of water quality targets upstream resulted in a dramatic improvement in dissolved oxygen concentrations in the reservoir waters.

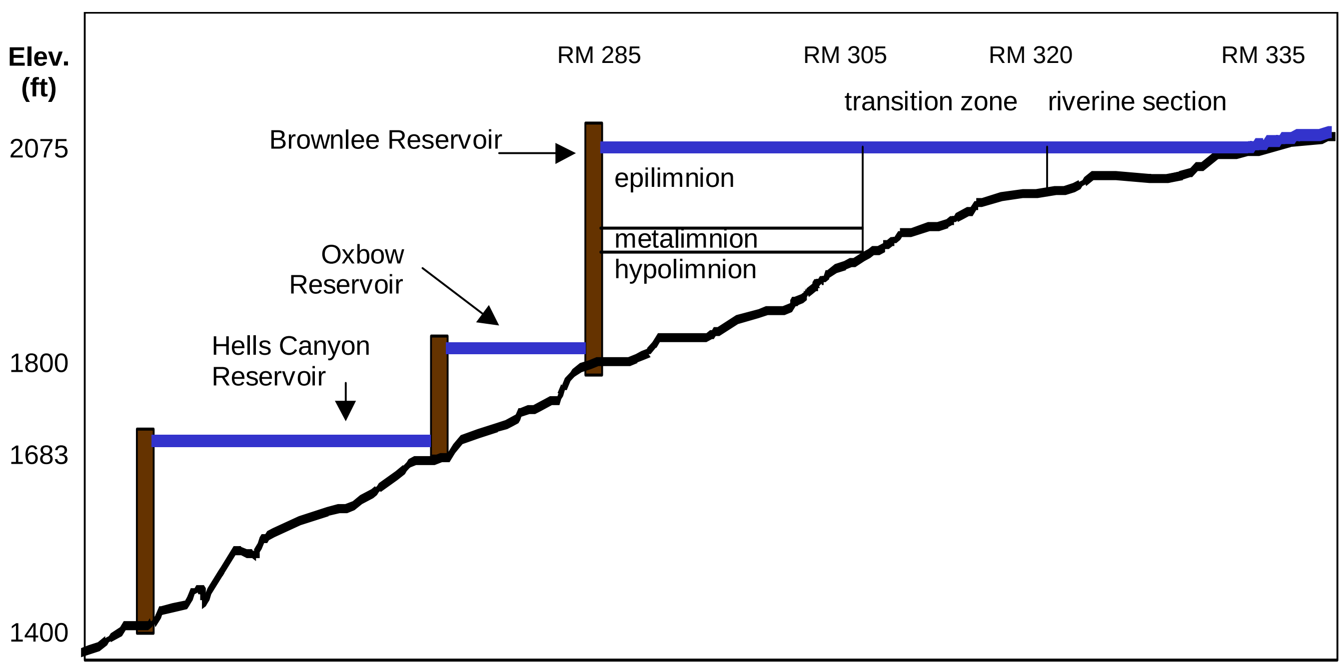


Figure 3.2.16. Diagram of the Hells Canyon Complex showing the dams and the reservoirs and diagramming the separate Brownlee Reservoir sections.

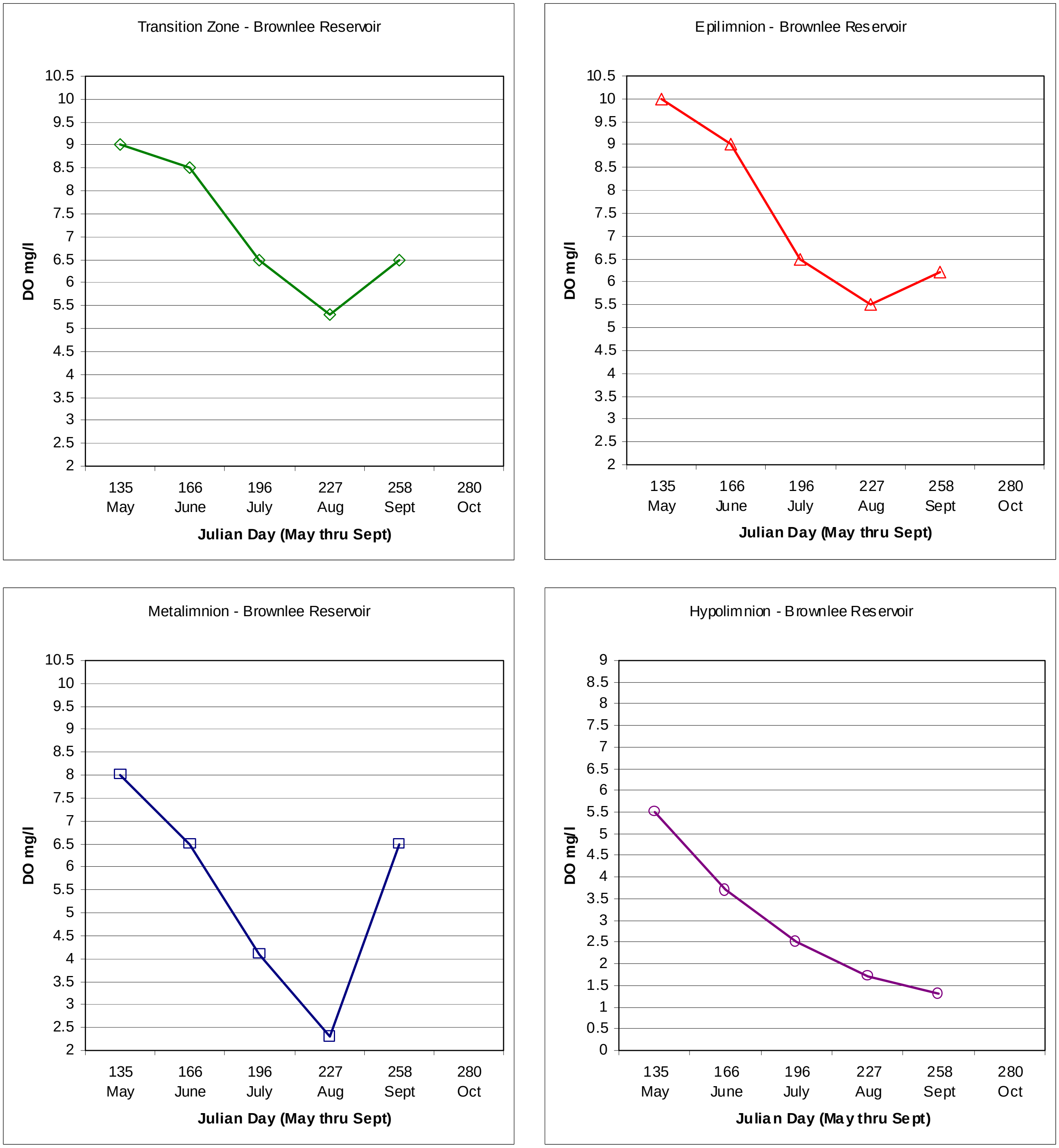


Figure 3.2.17. Calculated dissolved oxygen curves for distinct zones in Brownlee Reservoir (RM 335 to 285) under existing conditions.

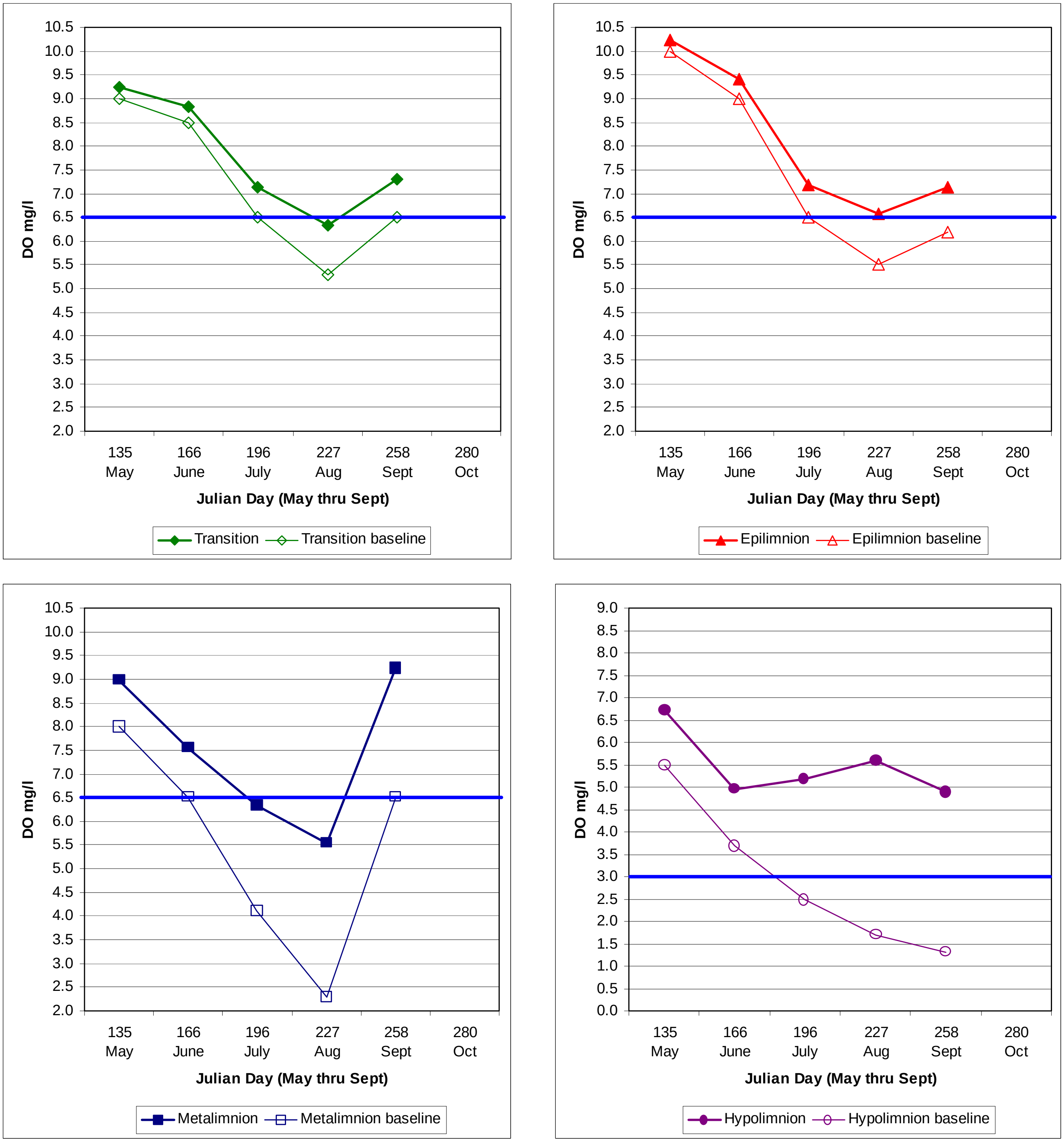


Figure 3.2.18. Calculated effect of improved dissolved oxygen in Brownlee Reservoir (RM 335 to 285) as an effect of attaining the 14 ug/L chlorophyll *a* and 0.07 mg/L total phosphorus concentration targets in the Upstream Snake River segment (RM 409 to 335).

In all cases, low dissolved oxygen conditions were projected to occur to a lesser extent and for a shorter duration under the target conditions than calculated for existing conditions. Dissolved oxygen concentrations were not calculated for the riverine section of Brownlee as the methodology used would result in overestimates due to substantially shorter residence times than those in the transition or lacustrine zones. The curves calculated for existing conditions are also included in the plots for comparison, and are labeled "baseline" conditions for each section.

Calculated post-attainment dissolved oxygen curves for the transition zone show concentrations dropping to or below 6.5 mg/L for approximately 16 days, and *below* 6.5 mg/L for approximately 10 days in early August. Minimum concentration values calculated are approximately 6.3 mg/L. Calculated post-attainment dissolved oxygen curves for the epilimnion show concentrations dropping to but not below 6.5 mg/L for two days in early August. Minimum concentration values calculated are approximately 6.5 mg/L. Calculated dissolved oxygen concentrations for the metalimnion were at or below 6.5 mg/L for approximately 45 days and *below* 6.5 mg/L for approximately 41 days during late July and much of August. Minimum concentration values calculated are approximately 5.5 mg/L, occurring during the month of August.

Calculated dissolved oxygen curves for the hypolimnion show a decrease in dissolved oxygen concentration starting in June and continuing through the fall. Dissolved oxygen levels calculated never dropped below 3.0 mg/L (a situation lethal to most fish). Minimum concentration values calculated are approximately 5.0 mg/L, occurring for approximately two days during the month of June, and approximately 4.9 mg/L, occurring for approximately three days during the month September.

As can be seen from Figure 3.2.18, dissolved oxygen improvements are realized in all sections of the reservoir from application of the 0.07 mg/L total phosphorus target. The improvements calculated for the metalimnion section are the greatest while the increases calculated for the transition zone and epilimnion are the smallest in magnitude. The improvements observed in most cases allow the reservoir sections to meet the water quality target of 6.5 mg/L dissolved oxygen. 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.

Direct calculation of the dissolved oxygen improvements and additional oxygen necessary to meet the water quality target of 6.5 mg/L were completed using the information plotted in Figure 3.2.18 and the reduction in biomass discussed previously. Because of the lack of continuous dissolved oxygen data, linear transitions between dissolved oxygen concentrations were used.

Transitions occurring in the reservoir most certainly do not follow a linear pattern. It is likely that such transitions occurring in the reservoir would describe a more rounded shape with greater temporal variation than described by the calculated curves. The straight-line effects of the calculated dissolved oxygen transitions potentially masks the shoulders of the curves and is a source of error (most probably underestimation) to this analysis. For this reason, an additional margin of safety has been identified.

The identified margin of safety has two purposes in this calculation, to correct for the errors introduced by the linear transitions discussed above, and to be protective over a wide range of water years. Data used in these calculations were from 1995, a relatively average water year (90% of the 30-year average). The identified margin of safety recognizes that dissolved oxygen concentrations in the reservoir will have wider variability than that described by the 1995 data, and seeks to be protective of aquatic life uses.

The calculated time period when post-attainment metalimnetic waters do not meet the 6.5 mg/L target occurs during the months of July and August, a total time period of 45 days where metalimnetic waters are at or below the 6.5 mg/L dissolved oxygen target. Because of the linear transition mechanism used to calculate the change in dissolved oxygen concentration, some exceedences of the target may also occur during the last part of June and the first part of September but are masked by the monthly time step. For this reason, a 65 day period (10 days before and 10 days after the calculated 45 day period of exceedence) was used to calculate the required improvements in dissolved oxygen specific to the metalimnion. This calculation represents a margin of safety of 44 percent. Although it may be an overestimate in some years, this period represents a more protective time frame than the 45 day period calculated directly.

The calculated time period when post-attainment transition zone waters do not meet the 6.5 mg/L target occurs during the months of July and August, a total time period of 16 days where metalimnetic waters are at or below the 6.5 mg/L dissolved oxygen target. Because the same concern regarding the linear transition mechanism used to calculate the change in dissolved oxygen concentration, a 24 day period (4 days before and 4 days after the calculated 16 day period of exceedence) was used to calculate the required improvements in dissolved oxygen specific to the metalimnion. This calculation represents a margin of safety of 50 percent. The time period in which transition zone exceedences occur lies within the exceedence time frame described for the metalimnion. Therefore, while these exceedences will require additional dissolved oxygen be added to the reservoir, they will not necessarily increase the total timeframe over which oxygenation is necessary.

Using the volume of 153,565 acre-feet (Table 3.2.7) and retention times generated for the metalimnion by IPCo, (5 days in July and 8 days in August under full pool (1995) conditions), approximately 1,540 billion liters of water pass through the transition zone and metalimnion during the 65 day period described above.

The total dissolved oxygen mass required to address the loss of assimilative capacity in the metalimnion alone over this time frame is 1,053 tons (957,272 kg). This is equivalent to an even distribution of 16.2 tons/day (14,727 kg/day) over 65 days.

The total dissolved oxygen mass required to address the loss of assimilative capacity in the transition zone alone over this time frame is 72 tons (65,454 kg). This is equivalent to an even distribution of 3.0 tons/day (2,727 kg/day) over 24 days.

Together, these separate loads will require the addition of a calculated 1,125 tons of oxygen (1.02×10^6 kg). When applied in an even distribution, this translates to approximately 17.3 tons/day (15,727 kg/day) for 65 days.

The calculated time period when exceedences occurred in the metalimnion of Brownlee Reservoir is between Julian days 182 and 247 (the first of July through the first week of September) when dissolved oxygen sags are observed to occur to a greater degree than those identified as the result of poor water quality inflowing from the upstream sources. However, this time frame is not a requirement for timing of oxygen addition or other equivalent implementation measures. Timing of oxygen addition or other equivalent implementation measures should be such that it coincides with those real-time periods where dissolved oxygen sags occur and where it will be the most effective in improving aquatic life habitat and support of designated beneficial uses.

To achieve this improvement in dissolved oxygen does not require direct oxygenation of the metalimnetic and transition zone waters. Improvements in dissolved oxygen concentrations can be accomplished through equivalent reductions in total phosphorus or organic matter upstream, or other appropriate mechanism that can be shown to result in the required improvement of dissolved oxygen in the metalimnion and transition zones to the extent required. A reduction of 1.7 million kg total of organic matter/algal biomass would equate to the identified dissolved oxygen mass. This translates to approximately 11,000 kg/day over the critical period (May through September) or 26,000 kg/day over the 65 day period identified in the calculations for reduced assimilative capacity. The total phosphorus load reduction required to achieve this reduction in organic loading is approximately 1,487 kg/day over the critical period (May through September) or 3,500 kg/day over the 65 period identified in the calculations for reduced assimilative capacity. Direct oxygenation is one method by which the additional dissolved oxygen required can be delivered, but it should not be interpreted as the only mechanism available. Cost effectiveness of both reservoir and upstream BMP implementation should be considered in all implementation projects.

Because this requirement for additional dissolved oxygen is specific to Brownlee Reservoir, IPCo (as operator of the Hells Canyon Complex) will be responsible for implementation of these improvements. There are both total phosphorus and dissolved oxygen improvements required within the different segments of the SR-HC TMDL reach. It should be clarified that Upstream Snake River segment (RM 409 to 335) pollutant sources are responsible for those water quality problems occurring in the Upstream Snake River segment (RM 409 to 335). They are not responsible 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, IPCo (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.

Restoring viable concentrations of dissolved oxygen throughout the reservoirs is of highest priority. In the case of the epilimnion and metalimnion, these waters represent primary fish habitat. In the case of the hypolimnion, these waters do not represent the same level of habitat as the metalimnion and epilimnion (IPCo, 2001d). They also represent waters that are more difficult to treat due to low circulation and flushing during stratification. 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 (Speece, 1970, 1994, 1996).

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. This represents an initial benefit that, combined with the long-term benefits of phosphorus and algae reduction, will result in attainment of non-lethal conditions in the short-term and of water quality standards in the longer-term future.

An additional benefit of the improved dissolved oxygen levels in the transition zone is in the reduced desorption and transformation processes due to the absence of anoxic conditions. The majority of deposition observed in the Hells Canyon Complex occurs in the transition zone of Brownlee Reservoir, which coincides with the area of highest observed sediment-mercury concentrations. By providing sustained dissolved oxygen levels at or above 6.5 mg/L, the pollutant loading associated with this deposition presents a much smaller threat to water quality within the SR-HC TMDL reach and downstream.

Modeled dissolved oxygen improvements provided by IPCo, show a smaller reduction in assimilative capacity than that calculated as discussed above. The total mass of additional dissolved oxygen need projected by the IPCo model was 880 tons total (22 percent difference from the 1,125 tons calculated). The difference may be attributed to the fact that the calculated value (1,125 tons) focuses on annual average chlorophyll *a* and does not account for reductions in other organic matter loads generated instream, or attempt to quantify long-term improvements from reduced loading. The chlorophyll *a* concentrations modeled by IPCo account for reductions in other organic loading to the system and for the reduction in sediment oxygen demand resulting from long-term improvements.

3.2.8.8 Identification of the Critical Period for Target Application.

Because most of the negative effects in the SR-HC TMDL reach associated with elevated nutrient levels stem from excessive algal growth, which is a seasonal occurrence, an evaluation of the critical time period for phosphorus reductions was included as part of the target determination for this TMDL.

Total algal growth and temporal distribution of phosphorus loading was evaluated. Within the mainstem Snake River two general periods of elevated chlorophyll *a* concentration are observed

(Figure 3.2.19). Blooms occur in the mainstem Snake River and in the upstream end of Brownlee Reservoir in the spring (April at RM 385 and May to June at RM 340) and summer (June to July at RM 385 and Aug at RM 340). These periods of growth represent the dominant source of algal biomass to the SR-HC TMDL reach. Other sources of organic material, such as periphyton sloughing, are not well understood. Further investigation of such sources will be carried out as part of the phased implementation process.

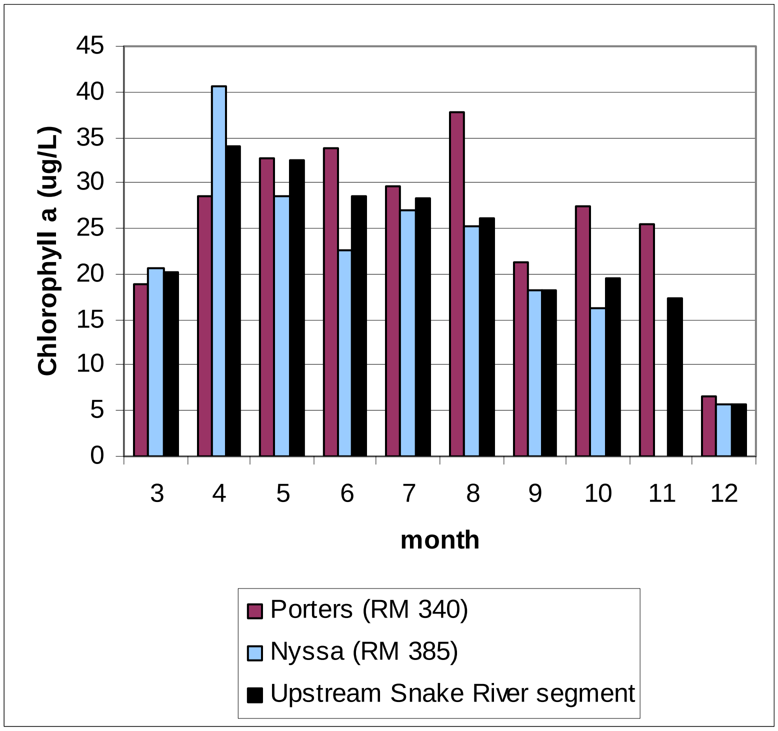


Figure 3.2.19. Temporal distribution of chlorophyll *a* in the Upstream Snake River segment (RM 409 to 335).

Winter conditions do not encourage algal growth as water temperatures are lower and available sunlight is both less intense and of shorter duration. Nuisance level blooms have not been observed to occur during winter months in the SR-HC TMDL reach. Both total phosphorus and chlorophyll *a* concentrations measured in the mainstem Snake River decrease substantially during the late fall and winter months (see Figure 3.2.2 and 3.2.19).

The fact that algae blooms are generally a summer occurrence, and that summer growth appears to be most directly related to the designated use support concerns discussed previously, is an indication that seasonal targets would be appropriate if sufficient reductions could occur during the critical period of algae growth to result in improved water quality and support of designated beneficial uses.

To assess the applicability of a seasonal target, total algal biomass loading was calculated using measured chlorophyll *a* concentrations. The annual distribution of loading was evaluated as shown in Figure 3.2.20.

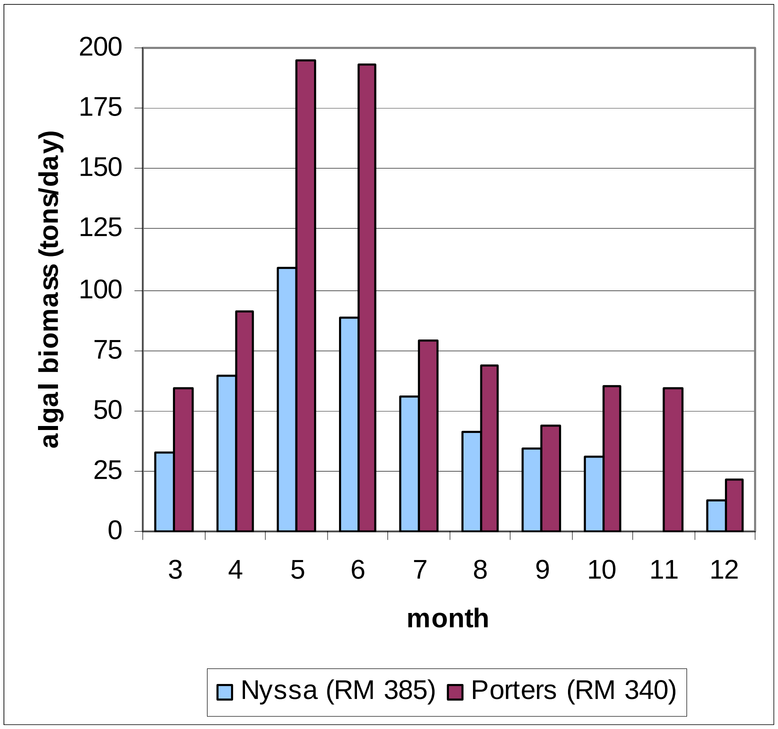


Figure 3.2.20. Temporal distribution of algae biomass loading in the Snake River - Hells Canyon TMDL reach as calculated from measured chlorophyll *a* concentrations.

Several considerations were recognized in the establishment of an appropriate critical period for nutrient reductions.

1. Impairment of the designated recreational and aesthetic use occurred primarily due to algal growth. All complaints received were specific to the summer and early fall months.

2. Concerns related to the potential of non or only partial support of aquatic life uses due to low substrate dissolved oxygen centered primarily on organic matter deposition and decomposition in the river and reservoir headwater areas. This decomposition will occur at a much slower rate in cool water temperatures and is therefore less of a concern in winter and early spring months than in summer and fall months. Nutrient controls will reduce the total amount of algae related growth and deposition overall so that less oxygen depletion occurs as a result of decomposition.

3. Concerns related to increased methylation of mercury due to excessive organic loading are specific to both the organic load and the anoxic conditions documented in Brownlee Reservoir and qualitatively identified in the Upstream Snake River segment (RM 409 to 335). Low dissolved oxygen in these areas is most likely to occur during summer and early fall months. Nutrient controls will reduce the total amount of algae related growth and deposition overall so that less oxygen depletion occurs. Initial calculations show that the areas of greatest

deposition in Brownlee Reservoir and in the Upstream Snake River segment (RM 409 to 335) will benefit from improved dissolved oxygen levels.

4. Domestic water supply concerns regarding trihalomethane production are specific to those time periods when greatest algal biomass is produced (early summer through fall). Filtration concerns are also specific to this time period. Corrosion concerns are specific to time periods with elevated nutrient concentrations. These occur most commonly in the summer and early fall months (Figure 3.2.2).

5. Establishment of critical period should be specific to the needs of the system in supporting designated beneficial uses, but should also recognize naturally occurring exceedences. In the SR-HC TMDL, natural runoff patterns generally occur during the months of March and April. Individual tributary systems may experience earlier or later snowmelt and runoff patterns. BMP-based treatment of snowmelt induced spring flows is not always effective. Both stormwater and agricultural BMPs, if properly installed and operated, will function to reduce this runoff-induced loading, but will function less efficiently in times of substantially increased flow volume, especially if it occurs during a time period when vegetation has not re-established after a winter die-off. Therefore, the highest treatment efficiencies will most likely occur during the summer and fall seasons when vegetation is well established and flows are less than spring runoff volumes.

Given this information, it has been determined that the total phosphorus target identified should be applied in a seasonal fashion that will allow direct management of the water quality concerns associated with nutrient loading. Application of this target over the time frame when conditions favoring algal growth are known to occur (May through September) will result in the reduction of dominant sources of phosphorus in the water shed and system loading in general. With a target application of May through September, it is calculated that approximately 70 percent of the total algal biomass loading can be addressed. The remaining 30 percent of the biomass loading occurs during spring flows, where treatment can occur with stormwater and agricultural BMPs but at reduced efficiency) and during winter months where total loading is minimal and retention within the reservoirs is not slowed by stratification.

This seasonal target will act to reduce both those forms of phosphorus most responsible for algal growth within the system, and algal growth itself. Dissolved phosphorus loading is generally highest during the summer irrigation season in both the mainstem Snake River and the majority of the inflowing tributaries (the Boise River is one exception to this trend as dissolved phosphate concentrations remain relatively steady throughout the year). Thus, application of this target will result in the reduction of the majority of the dissolved phosphate load attributable to anthropogenic sources within the watershed. Dissolved phosphate concentrations throughout the remainder of the year do not pose a substantial concern to water quality as water temperatures are not conducive to excessive growth, and the rapid movement of water through the SR-HC TMDL reach does not result in much retention of this dissolved fraction of the phosphate loading. Additionally, seasonal application of the target will directly address the sediment bound fraction of the total phosphorus loading as it will be in place over the course of the growing and irrigation season.

3.2.9 Reductions Necessary to Meet Nutrient Targets

The specific level of reduction realized by attainment of this target is dependent on the type of water year and the tributary. Setting a concentration-based target means that in high flows, the loading delivered at the target value will be greater than the load delivered at the target value during medium or low flow years. However, the load delivered during high flow years will still be reduced from the load delivered without TMDL-based reductions. Low and average flow years may show a larger relative percentage reduction in nutrient loading by meeting the 14 ug/L mean growing season chlorophyll *a* concentration and 0.07 mg/L total phosphorus targets as loading is based on instream flow (load = flow x concentration). High flow years will also see a reduced nutrient load, but the overall relative magnitude of reduction will be smaller due to the higher flows.

Additionally, research performed by both IPCo and Boise City Public Works (Brown and Caldwell) show that some of the most pronounced water quality problems in Brownlee Reservoir have occurred during the longer retention times resulting from low water years. It is theorized that these longer retention times can allow the development of more severe hypoxic and anoxic conditions. Therefore, both flow and retention time, in correlation with pollutant loads and concentrations have the potential to influence water quality in the SR-HC TMDL reach. All of these factors should therefore be considered in the development of the monitoring plans that will be included in the site specific implementation plans prepared following the approval of this TMDL. They will also be considered in the assessment of progress as implementation proceeds.

3.2.10 Load Allocations

Load allocations are discussed in greater detail in Section 4.0. Total phosphorus allocation mechanisms were determined as a result of discussions within the public process and PAT work group products (Appendix I).

3.3 Pesticide Loading Analysis

3.3.1 Water Quality Targets and Guidelines

The purpose of TMDL development is to meet applicable water quality standards. Because the SRHC TMDL is a bi-state effort, the most stringent of each state's water quality standards have been identified as the targets for this TMDL. In this way the attainment of these targets will ensure that the water quality requirements of both states will be met.

The Oxbow Reservoir segment (RM 285 to 272.5) of the SR-HC TMDL reach is listed for pesticides. An evaluation of available data has shown the pesticides of concern specific to the SR-HC TMDL effort to be DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl) ethane, CAS #50-29-3), and its metabolites DDD (1,1-dichloro-2,2-bis(p-chlorophenyl) ethane, CAS #72-54-8) and DDE (1,1-dichloro-2,2-bis(chlorophenyl) ethylene, CAS #72-55-9) and dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo,exo-1,4:5,8-dimethanonaphthalene, CAS #60-57-1). The water quality standards and guidance values appropriate to pesticides in the SR-HC TMDL are those that apply to DDT and its metabolites and dieldrin. The water quality targets established for the SR-HC TMDL are based on standards from both Idaho and Oregon. The standards adopted by both states are based on US EPA guidance values (National Toxics Rule and Table 20) (EPA FRL-OW-6186-6a).

DDT: less than 0.024 ng/L water column concentration
DDD: less than 0.83 ng/L water column concentration
DDE: less than 0.59 ng/L water column concentration
Dieldrin: less than 0.07 ng/L water column concentration

These represent the applicable targets for pesticides for the SR-HC TMDL.

3.3.2 Designated Beneficial Use Impairment

There are no data available documenting pesticide concentrations in water, fish tissue or sediment in Oxbow Reservoir. There are no indications of impairment of the designated beneficial uses due to pesticide concentrations in Oxbow Reservoir. No fish consumption advisories for pesticides are currently in place. However, over 95% of the inflow to Oxbow Reservoir is from Brownlee Reservoir, therefore, available data from upstream segments (Upstream Snake River and Brownlee Reservoir) were evaluated. These data show elevated concentrations of fish tissue t-DDT and dieldrin. The US EPA action level for fish tissue DDT was established to address the combination of DDT and its metabolites (known as total or t-DDT). This action level, set at 1.0 mg/kg, was exceeded in 44% of the data. None of the available data showed exceedences of the US EPA action levels for fish tissue concentrations of dieldrin (1.0 mg/kg).

Fish containing high concentrations of pesticides pose a health threat to humans and predatory wildlife that ingest fish tissue. Predatory wildlife most at risk are those predators of older, larger fish such as bald and golden eagles, both of which inhabit areas of the SR-HC TMDL reach.

Water column data from upstream segments is very limited. Only a very small data set was available for water column concentration. All water column samples exceeded the SR-HC TMDL water column targets for DDT and dieldrin. All fish tissue samples exhibited concentrations of DDT and dieldrin above the US EPA screening level. None of the samples exceeded the US FDA action level for DDT and dieldrin in edible fish (Clark and Maret, 1998; Rinella *et al.*, 1994). Only t-DDT (four Snake River sites and five samples in Brownlee Reservoir), and Dieldrin (one sample in Brownlee Reservoir) showed fish tissue concentrations that exceeded the National Academy of Science, National Academy of Engineering (NAS/NAE) criteria. All fish tissue samples collected in this reach were positive for t-DDT. These data do not yield a clear answer on the support status of designated beneficial uses but do indicate that sufficient concern exists to justify the collection of additional water column data in both the Oxbow Reservoir segment (RM 285 to 272.5) and the segments upstream.

3.3.3 Pesticides in Surface Waters

3.3.3.1 DDT.

DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane) is a man-made chemical that was widely used historically to control both insects that could damage agricultural crops and those that carry diseases like malaria and typhus. DDT was discovered in 1873, but was not identified as an insecticide until 1939 when Paul Muller of Geigy Pharmaceutical in Switzerland discovered its effectiveness. He was awarded the Nobel Prize in medicine and physiology in 1948 for this discovery.

The use of DDT increased substantially on a global scale after World War II. It was particularly effective against the mosquito that spreads malaria and lice that carry typhus. The World Health Organization (WHO) estimates that during the period of its use approximately 25 million lives were saved by reducing the spread of these diseases. DDT seemed to be the ideal insecticide as it was cheap and of relatively low toxicity to mammals (oral LD50 is 300 to 500 mg/kg). However, concern over environmental effects began to appear in the late 1940s. Many species of insects were able to develop a resistance to DDT so it was no longer as efficacious a control mechanism. In addition, DDT was also discovered to be highly toxic to fish (ATSDR, 1994b, 2001; Harrison, 2001), and was linked to eggshell thinning in several families of birds (NAS/NAE, 1973; US EPA, 1992c).

Because of the risk it presented to wildlife and the potential human health concerns being raised, the use of DDT was banned (except for public health emergencies), in the United States in 1972 (USFWS, 2002). DDT is however still used in some other countries.

The remarkable chemical stability of DDT and its tendency to bio-concentrate in fatty tissues add to the complexity of the problem of legacy application and current water quality concerns. DDT is not metabolized rapidly; rather, it is stored in fatty tissues within the body. As an average, about eight years are required for an animal to metabolize half of the DDT it assimilates (this eight years is known as the biological half-life). Therefore, if an animal continues to ingest DDT at a steady rate, it will build up over time (Harrison, 2001). The buildup of DDT in natural waters is however, a reversible process. The US EPA reported a 90% reduction of DDT in Lake Michigan fish by 1978 as a result of the ban (Harrison, 2001).

Two similar chemicals (breakdown products of DDT) that are often associated with the presence of DDT in environmental systems are DDE (1,1-dichloro-2,2-bis(chlorophenyl) ethylene) and DDD (1,1-dichloro-2,2-bis(p-chlorophenyl) ethane). While these compounds are breakdown products or metabolites of DDT, DDD was also manufactured to kill pests. Its use has also been banned. DDE has no known commercial use (Harrison, 2001).

3.3.3.2 Dieldrin.

Dieldrin is also a man-made, chlorinated insecticide; popular for crops like corn and cotton from 1950 to 1970. Dieldrin does not occur naturally in the environment. Because of concerns about damage to the environment and the potential harm to human health, US EPA banned all uses of dieldrin except to control termites in 1974. In 1987, US EPA banned all uses of dieldrin (ATSDR, 2001; NTP, 2001).

In the environment, dieldrin binds tightly to soil. The disappearance of 95% of the original insecticide after application has been shown to require from 5 to 25 years (from references in PMEP, 2001). Volatilization or evaporation to the air is responsible for most of the dieldrin lost from the soil surface. The persistence of dieldrin in the soil is influenced by soil type, where soils with a high organic matter content show higher dieldrin persistence than sandy soils (from references in PMEP, 2001).

Plants take in and store dieldrin from the soil. As with DDT, dieldrin is a very stable chemical and tends to bio-concentrate in fatty tissues. Dieldrin is not metabolized very rapidly and leaves the body very slowly (ATSDR, 2001). Because dieldrin is bioaccumulative, it does not break down easily in the environment and becomes more concentrated as it moves up the food chain to humans and other wildlife (US EPA, 2001f). Dieldrin is a persistent, bioaccumulative, and toxic (PBT) pollutant targeted by US EPA.

As stated above, the Oxbow Reservoir segment (RM 285 to 272.5) of the SR-HC TMDL reach is listed for pesticides. No data is available to support this listing. However, pesticide data is available for some sites upstream of Oxbow Reservoir, including Brownlee Reservoir, which represents the largest source of inflow to Oxbow Reservoir.

Therefore, existing pesticide data for the SR-HC TMDL reach in total was evaluated. Although several pesticides have been identified in the SR-HC TMDL reach, those pesticides observed to occur at elevated concentrations within this data set were the organochlorine insecticides DDT (and its metabolites), and dieldrin. These compounds were identified as pesticides that should be evaluated within the SR-HC TMDL.

While a state standard-based fish tissue target is not available to this TMDL effort, data collected show these compounds occur in concentrations exceeding the established US EPA screening level for contaminants in edible fish (t-DDT). Concentrations of DDT and dieldrin were also observed to exceed the NAS/NAE criteria to protect fish and wildlife that consume fish within the Upstream Snake River (RM 409 to 335) and Brownlee Reservoir segment (RM 335 to 285) of the SR-HC TMDL reach. However, none of the data collected show pesticide concentrations in fish tissue that exceed the US FDA action level for contaminants in edible fish.

Neither t-DDT nor dieldrin is highly water-soluble. However, these compounds commonly adsorb onto suspended particles within the water system where they can be deposited on stream, lake and reservoir bottoms and then become re-suspended and transported in a cyclic fashion dependant on flow volume and velocity. Aquatic organisms, especially bottom-feeding species such as suckers, are vulnerable to the bioaccumulation of these compounds.

Both t-DDT and dieldrin are persistent, long lived contaminants. The half-lives (the time it takes for one half of the total mass to degrade) for these compounds have been estimated in the range of hundreds of years. Therefore, even though their use has been discontinued, they are expected to remain in the environment for the foreseeable future (US EPA, 1992a, 1992b and 1992c). This problem is evident throughout the United States. In a national US EPA study (US EPA, 1992a, 1992b and 1992c), over 90 percent of 388 sites sampled nationwide in 1986 and 1989 showed concentrations of DDE (a metabolite of DDT) and PCBs.

3.3.4 Sources

Neither DDT nor dieldrin occur naturally to any appreciable extent in the environment (Harrison, 2001). All sources of these compounds are therefore anthropogenic. Both DDT and dieldrin were used extensively in the United States prior to the 1970's. Their use was discontinued due to their potential negative effects on humans and wildlife. DDT and dieldrin are considered probable carcinogens in humans (US EPA, 1991a, 1992c, 1994c). The use of DDT in the US has been banned since 1972, and the use of dieldrin was phased out between 1974 and 1987 (US EPA, 1992c).

These compounds entered surface water systems primarily from agricultural nonpoint source runoff and atmospheric deposition. Currently, the primary sources of these compounds in surface waters are legacy deposition and continued agricultural runoff from previously treated areas.

3.3.5 Transport and Delivery

Organochlorine pesticide transport and deposition are, in most cases, directly correlated with the transport and deposition of sediment and organic matter (Clark and Maret, 1998; Maret, 1995a and 1995b; Maret and Ott, 1997; Rinella *et al.*, 1994). As these compounds are no longer in use today, the transport and delivery of pesticides adsorbed to entrained sediment and organic material in the SR-HC drainage is the most likely source of continued loading to the mainstem Snake River within the SR-HC TMDL reach.

3.3.6 Data Available for the Snake River - Hells Canyon TMDL Reach

A pesticide monitoring effort by the USGS from 1992 through 1997 (Clark and Maret, 1998) identified t-DDT and dieldrin concentrations in fish tissues throughout the Snake River and several major tributaries in Idaho. The data showed that concentrations of both t-DDT and organochlorine compounds increased with distance downstream. Reservoir concentrations were somewhat higher overall than tributary concentrations, but the trend was evident in both types of surface waters (Table 3.3.1). Only a very small data set was available for water column concentrations. All eight water column samples, four each for DDT and dieldrin, located in the Upstream Snake River segment (RM 409 to 335) exceeded the SR-HC TMDL water column targets. Over 44% of the fish tissue samples exhibited concentrations of t-DDT above the US EPA screening level. None of the fish tissue samples exhibited concentrations of dieldrin above the US EPA screening level. None of the samples exceeded the US FDA action level for DDT and dieldrin in edible fish (Clark and Maret, 1998; Rinella *et al.*, 1994). Only t-DDT (four Snake River sites and five samples in Brownlee Reservoir), and Dieldrin (one sample in Brownlee Reservoir) showed fish tissue concentrations that exceeded the NAS/NAE criteria. All fish tissue data available in this reach (RM 409 to 285, and 247 to 188) were positive for t-DDT (where t-DDT was calculated as the sum of DDT and all metabolite and degradation compounds if not directly measured.

The available t-DDT data show that total concentrations are highest in fish tissue taken from Brownlee Reservoir, followed by samples taken from the Snake River at Jump Creek (upstream of RM 409). Fish tissue samples taken from the Snake River near the Weiser and Malheur river inflows show concentrations slightly higher than those observed in fish tissue samples taken from the Snake River near the Boise and Owyhee river inflows upstream. A general comparison of the Upstream Snake River segment (RM 409 to 335) data (riverine) to the Brownlee Reservoir segment (RM 308 to 285) (lacustrine) data show an increase in observed t-DDT concentrations in reservoir samples. The mean fish tissue concentration in the Upstream Snake River segment was 990 ug/kg (range = 230 ug/kg to 1,700 ug/kg, median = 964 ug/kg). The mean for the Brownlee Reservoir segment samples was 1,261 ug/kg (range = 96 ug/kg to 3,633 ug/kg, median = 1,099 ug/kg). The Brownlee Reservoir samples showed much greater variation than the Upstream Snake River samples.

Rigorous interpretation of these data for site-specific concentration assessment is not possible, however, as fish tissue data are not necessarily indicative of the conditions of the waters in which they were harvested. Additionally, fish tissue concentrations are dependent on size, age, species, habitat conditions and other factors. Fish often move repeatedly between mainstem and tributary sites. The amount of time spent in any one location, and the life stage and season during which this time was spent, can influence the level of pesticide accumulation dramatically.

Data evaluated show that fish tissue t-DDT concentrations are generally higher in the reservoir system than in the Upstream Snake River segment (RM 409 to 335). These same data show that all of the tributary drainages monitored exhibited some level of fish tissue t-DDT contamination. All sites monitored also showed relatively low concentrations of sediment and water t-DDT concentrations as compared to the observed fish tissue concentrations, indicating the occurrence of bioaccumulation within the aquatic species sampled.

Based on the small data set available, water column t-DDT concentration data exhibit only moderate variation within the Upstream Snake River segment (RM 409 to 335). No water column data are available for the Brownlee Reservoir segment (RM 335 to 285). However, all

Table 3.3.1. Data available showing detectable t-DDT distribution in fish tissue, water and sediment in the Lower Snake River Basin.

Location	Species/ Sample	Pesticide	Conc. (ug/kg)*	Action Level Exceeded?		
				US EPA	SRHC TMDL	US FDA
Snake River at Swan Falls	sucker	t-DDT	230	No	NA	No
Snake River at Jump Creek	catfish	t-DDT	1700	Yes	NA	No
Owyhee River mouth	catfish	t-DDT	1040	Yes	NA	No
Owyhee River mouth	sediment	DDE	10.5	NA	NA	NA
Boise River at Parma	sucker	t-DDT	888	No	NA	No
Boise River at Parma	water	t-DDT	0.003	Yes	Yes	NA
Boise River at Parma	sediment	t-DDT	1.4	NA	NA	NA
Snake River at Nyssa	catfish	t-DDT	776	No	NA	No
Snake River at Nyssa	sucker	t-DDT	593	No	NA	No
Payette River 10 km upstream of mouth	bullhead	t-DDT	120	No	NA	No
Malheur River mouth	catfish	t-DDT	1270	Yes	NA	No
Malheur River mouth	water	t-DDT	0.012	Yes	Yes	NA
Malheur River mouth	sediment	t-DDT	42.3	NA	NA	NA
Malheur River mouth	sediment	DDE	5.8	NA	NA	NA
Payette River mouth	water	t-DDT	0.007	Yes	Yes	NA
Payette River mouth	sediment	t-DDT	23.1	NA	NA	NA
Snake River at Weiser	catfish	t-DDT	1420	Yes	NA	No
Snake River at Weiser	water	t-DDT	0.003	Yes	Yes	NA
Snake River at Weiser	sediment	t-DDT	8.9		NA	NA
Brownlee Reservoir	carp	t-DDT	3633	Yes	NA	No
Brownlee Reservoir	sucker	t-DDT	1505	Yes	NA	No
Brownlee Reservoir	catfish	t-DDT	1099	Yes	NA	No
Brownlee Reservoir	catfish	t-DDT	1080	Yes	NA	No
Brownlee Reservoir	catfish	t-DDT	1300	Yes	NA	No
Brownlee Reservoir	bass	t-DDT	113	No	NA	No
Brownlee Reservoir	crappie	t-DDT	96	No	NA	No
Brownlee at Burnt River	sediment	t-DDT	24	NA	NA	NA
Brownlee at Mountain Man Lodge	sediment	t-DDT	7.5	NA	NA	NA
Downstream Snake River at Pittsburgh Landing	sucker	t-DDT	191.1	No	NA	No
Downstream Snake River at Pittsburgh Landing	sucker	t-DDT	95.2	No	NA	No

* Water samples are whole water reported in ug/L
(Data presented is from Clark and Maret, 1998, Rinella *et al.*, 1994; IPCo, 200d).
US EPA = US Environmental Protection Agency screening level of 10^{-6} for contaminants in edible fish (Nowell and Resek, 1994) for fish tissue samples and 0.001 ug/L DDT water column concentration for chronic exposure (EPA FRL-OW-6186-6a).
SR-HC TMDL = Snake River – Hells Canyon DDT target of 0.000024 ug/L.
US FDA = US Food and Drug Administration action level for contaminants in edible fish (Nowell and Resek, 1994).

water column concentrations measured in the Upstream Snake River segment (n = 4) exceeded the SR-HC TMDL target value for DDT (0.024 ng/L).

Sediment t-DDT data however show greater variation and moderately higher concentrations overall in the Upstream Snake River segment (mean = 19 ug/kg, range = 1.4 ug/kg to 42.3 ug/kg, n = 6) as compared to those observed in the Brownlee Reservoir segment (mean = 16 ug/kg, range = 7.5 ug/kg to 24 ug/kg, n = 2). Bed sediment from Brownlee Reservoir at the Burnt River inflow contained the largest concentrations of organochlorine compounds in the Snake River Basin (Clark and Maret, 1998). The data set for sediment t-DDT concentrations is very small however, and may not be representative of the overall distribution of t-DDT within the SR-HC TMDL reach.

The US Department of the Interior (US DOI) conducted a study in 1990 (Rinella *et al.*, 1994) that included bed sediment data from 14 sites in the Owyhee and Malheur drainages and the Snake River from approximately RM 425 to Brownlee Reservoir. Measurable concentrations of DDE were detected at all 14 sites, and dieldrin was detected at 13 sites. Those sites appropriate to this TMDL effort and the concentrations measured are listed in Table 3.3.1 and Table 3.3.2.

A more recent sediment study (IPCo, 200d) included 42 samples taken from the mainstem Snake River from RM 397 downstream to Brownlee Dam (RM 285). Samples were collected from December 1998 to January 2000. In Brownlee Reservoir, samples were taken approximately every five miles from RM 340 to RM 285. Snake River samples included the mouth of the Owyhee, Boise, Malheur, Payette, Weiser, Burnt and Powder rivers.

This sampling effort detected only one organochlorine compound, DDE. Two Snake River samples, one at the mouth of the Owyhee River and one at the mouth of the Malheur River, exhibited measurable sediment concentrations, 10.5 ug/kg and 5.8 ug/kg DDE respectively. None of the mainstem river samples, in Brownlee Reservoir or the upstream channel, showed detectable concentrations of dieldrin. This study, based on sampling and analytical techniques very similar to those used by Rinella (Rinella *et al.*, 1994), contained a much larger sample set than the 1990 work, but showed dramatically different concentration distributions although detection limits, particle distributions and total organic carbon concentrations were similar in both studies (IPCo, 200d). Additional, long-term data collection is necessary to determine if the lower concentrations observed in the 2000 study are an indication of water quality trends in the SR-HC TMDL reach. If these values were indicative of a trend in water quality, fish tissue concentrations would also be expected to decline over time.

The available dieldrin data from the 1990 study show that fish tissue concentrations were relatively similar throughout the Upstream Snake River segment (RM 409 to 335), increasing slightly within the Brownlee Reservoir samples. A comparison of mean values from the Upstream Snake River segment (riverine) with the Brownlee Reservoir segment (lacustrine) shows only a relatively moderate difference. The mean fish tissue concentration in the Upstream Snake River segment was 32.4 ug/kg (range = 12 ug/kg to 50 ug/kg, median = 30 ug/kg). The mean for the Brownlee Reservoir segment samples was 45 ug/kg (range = 19 ug/kg to 100 ug/kg, median = 37 ug/kg). The Brownlee Reservoir samples showed much greater variation than the

Table 3.3.2. Data available on Dieldrin distribution in fish tissue, water and sediment in the Lower Snake River Basin.

Location	Species/ Sample	Pesticide	Conc. (ug/kg)*	Action Level Exceeded?		
				US EPA	SRHC TMDL	US FDA
Snake River at Jump Creek	catfish	Dieldrin	30	No	NA	No
Owyhee River mouth	catfish	Dieldrin	50	No	NA	No
Boise River at Parma	water	Dieldrin	0.002	No	Yes	NA
Boise River at Parma	sediment	Dieldrin	0.1	NA	NA	NA
Snake River at Nyssa	catfish	Dieldrin	12	No	NA	No
Snake River at Nyssa	sucker	Dieldrin	< 5.0	-	-	-
Malheur River mouth	catfish	Dieldrin	50	No	NA	No
Malheur River mouth	water	Dieldrin	0.007	No	Yes	NA
Malheur River mouth	sediment	Dieldrin	4.1	NA	NA	NA
Payette River mouth	water	Dieldrin	0.001	No	Yes	NA
Payette River mouth	sediment	Dieldrin	0.4	NA	NA	NA
Snake River at Weiser	catfish	Dieldrin	20	No	NA	No
Snake River at Weiser	water	Dieldrin	0.002	No	Yes	NA
Snake River at Weiser	sediment	Dieldrin	0.2	NA	NA	NA
Brownlee Reservoir	sucker	Dieldrin	19	No	NA	No
Brownlee Reservoir	carp	Dieldrin	37	No	NA	No
Brownlee Reservoir	catfish	Dieldrin	20	No	NA	No
Brownlee Reservoir	catfish	Dieldrin	100	No	NA	No
Brownlee Reservoir	catfish	Dieldrin	50	No	NA	No
Brownlee Reservoir	sm bass	Dieldrin	< 5.0	-	-	-
Brownlee Reservoir	white crappie	Dieldrin	< 5.0	-	-	-
Brownlee at Burnt River	sediment	Dieldrin	7	NA	NA	NA
Downstream Snake River at Pittsburgh Landing	sucker	Dieldrin	< 5.0	-	-	-
Downstream Snake River at Pittsburgh Landing	sucker	Dieldrin	3.8	No	NA	No

* Water samples are whole water reported in ug/L
(Data presented is from Clark and Maret, 1998, Rinella *et al.*, 1994; IPCo, 200d).
US EPA = US Environmental Protection Agency screening level of 10^{-6} for contaminants in edible fish (Nowell and Resek, 1994) for fish tissue data and 0.056 ug/L water column concentration for chronic exposure (EPA FRL-OW-6186-6a).
SR-HC TMDL = Snake River – Hells Canyon dieldrin target of 0.00007 ug/L.
US FDA = US Food and Drug Administration action level for contaminants in edible fish (Nowell and Resek, 1994).

Upstream Snake River samples. In the small data set available for dieldrin, over 73% of the fish tissue data points (n = 16) showed concentrations of dieldrin that were above the detection limits.

As with t-DDT data discussed above, it should be kept in mind that fish tissue data are not necessarily indicative of the conditions of the waters in which they were harvested as move back and forth between mainstem and tributary sites. The size, type and age of the fish, environmental conditions, the amount of time spent in any one location, and the life stage and season during which this time was spent, can influence the level of pesticide accumulation dramatically.

Data available show that fish tissue dieldrin concentrations in the 1990 study were generally higher in the reservoir system than in the Upstream Snake River segment (RM 409 to 335). These same data show that all of the tributary drainages monitored exhibited some level of fish tissue dieldrin contamination. All also showed relatively low concentrations of sediment and water column dieldrin concentrations as compared to the observed fish tissue concentrations, indicating substantial bioaccumulation within the aquatic species sampled.

No water column dieldrin data is available for the Brownlee Reservoir segment (RM 335 to 285), and only a single sediment dieldrin data point is available for Brownlee Reservoir. Therefore, a comparison of upstream to reservoir segments is not possible. However, all water column concentrations measured in the Upstream Snake River segment (n = 4) exceeded the SR-HC TMDL target value for dieldrin (0.07 ng/L).

The relative amount of t-DDT in fish tissue within the SR-HC TMDL reach is over 30 times that of dieldrin in the Upstream Snake River segment (RM 409 to 335) and over 28 times that of dieldrin in the Brownlee Reservoir segment (RM 335 to 285) for the 1990 study data. This is influenced by the difference in water column and lipid solubility of these compounds and the relative efficiency of uptake and excretion processes within aquatic species. It may also be influenced to a small extent by the relative differences in sediment concentration observed. (The mean t-DDT concentration in sediments is nearly 8 times that of dieldrin.)

From the data in the tables and studies discussed above it is evident that t-DDT and dieldrin are present in the Upstream Snake River and Brownlee Reservoir segments of the SR-HC TMDL, although it is not clear to what extent they still occur, as detectable sediment concentrations were generally observed only in the 1990 study, not the more extensive 2000 study.

It was also observed that tributary drainages to the SR-HC system exhibit similar pesticide pollutant loading concerns. Given the fact that the vast majority of water entering Oxbow Reservoir (greater than 99%) comes directly from Brownlee Reservoir, it is assumed that a portion of the organochlorine insecticide load in Brownlee Reservoir is transferred to Oxbow Reservoir. The relative proportion of this loading however, is unknown. It is assumed that the sediment trapping characteristics of Brownlee Reservoir act to inhibit the direct transport of sediment bound organochlorine insecticides between the two reservoirs. The validity of the pesticide listing in Oxbow cannot be directly assessed without further data collection. The presence of a general concern associated with t-DDT and dieldrin in the Upstream Snake River and Brownlee Reservoir segments however, is clearly demonstrated by the available data.

3.3.7 Determination of Pesticide Loading

Given the available data set, a rough approximation of pesticide loading to the SR-HC TMDL reach has been calculated. Since data are available for the Upstream Snake River segment (RM 409 to 335) only, loading at the USGS gage at Weiser (mainstem Snake River) is calculated to be approximately 42 kg/year (mean) for t-DDT and approximately 28 kg/year for dieldrin for an average water year. The calculated load capacity of the SR-HC TMDL reach at RM 351 (Weiser, Idaho) is approximately 0.34 kg/year t-DDT and 0.98 kg/year for dieldrin. Assuming that the data collected were representative of the average annual concentrations in the water column, this shows that the current pesticide loading is between 30 and 100 times greater in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach than the targets would allow.

All of this loading is the result of legacy application and transport. None of the load is from natural sources. None of the load is assumed to be from current application as both of these compounds are no longer in use.

While this serves to determine a relative loading value, these calculations are very approximate due to the small data set, and cannot be used to specify localized loading to an appropriate level of accuracy. Concentrations were measured only one time, and do not cover the variability of flow or transport conditions that occur over the course of the year. Additionally, load allocations for t-DDT and dieldrin are already established at zero levels within the basin by previous bans on usage (US EPA, 1992c). Therefore, even if sufficient data were available to calculate loading, no allocation mechanism exists to more stringently address the reduction of t-DDT and dieldrin.

The majority of the pesticide load associated with these compounds is accepted to be associated with sediment transport from areas of legacy application. While some legacy application undoubtedly occurred within the direct drainage of the SR-HC TMDL reach, it is most probable that the majority of the application occurred in the tributary and upstream drainages as they represent a larger proportion of the overall agricultural land surface than the direct drainage. Indirect mechanisms will therefore be the primary means for reducing the loading of these pollutants within the SR-HC TMDL reach.

Determination of pollutant loading to a surface water system is generally accomplished through an association of concentration and flow values. Without sufficient water column concentration data for the SR-HC system, calculated loading can only be used as a general indicator of level of concern. Therefore, alternative methods of assessing pesticide loading have been investigated.

3.3.8 Load Allocations and Other Appropriate Actions

Load allocations for t-DDT and dieldrin are discussed in Section 4.0 of this document. All current loading of these pesticides is considered background from legacy sources.

3.3.8.1 Data Collection

Additional data will be collected as part of the phased implementation process to assess the extent of pesticide pollutant loading to Oxbow Reservoir. The data collected during the first phases of the Implementation Plan will be assessed using the current water quality parameters, and the approach and implementation measures outlined here (and in greater detail in the source specific implementation plans) and will be assessed for appropriateness and applicability. In correlation with this effort, reasonable and prudent measures will be identified and implemented to reduce the loading to the Upstream Snake River and Brownlee Reservoir segments, therefore reducing the loading to Oxbow Reservoir. If measures identified herein are determined to be adequate to meet the target criteria, implementation efforts will continue as outlined. If new information identifies additional measures that need to be taken, these will be incorporated into the TMDL and Implementation Plan outline.

3.3.8.2 Pesticide Reduction through Direct Sediment Removal.

Direct removal of pesticides deposited in sediments is not feasible in most areas of the SR-HC TMDL reach. Most sources of legacy pesticides in the area are diffuse in nature and do not stem from a discreet source, but rather from historical application on agricultural lands or deposition from surface water transport. Removal of the sediments and organic material associated with these compounds would potentially result in degradation of other habitat parameters.

3.3.8.3 Pesticide Reduction through Sediment Control/Reduction.

While direct removal of pesticide pollutants is not feasible in the SR-HC TMDL reach, management practices can be targeted to reduce further transport to surface water systems. As identified previously, pesticide transport and deposition are, in most cases, directly correlated with the transport and deposition of sediment and organic matter (Clark and Maret, 1998; Maret, 1995a and 1995b; Maret and Ott, 1997; Rinella *et al.*, 1994). Reductions in the amount of these materials entering the SR-HC system will therefore result in reduction of pesticide pollutant transport and loading to the system. Reduction of such transport will be directly linked to the sediment reduction measures identified within this and other, related TMDLs in the Snake River Basin.

It should be clearly stated that this strategy of legacy pesticide management in no way is intended to require direct monitoring of loading or load reductions. Such monitoring for nonpoint source loading is not feasible and will therefore not be required as part of this TMDL process. Rather, appropriate management techniques specific to proper stewardship will be employed as part of the overall TMDL implementation process. These management techniques are projected to result in reduction of overall DDT and dieldrin loading related to nonpoint source discharge to the mainstem Snake River.

3.3.8.4 Pesticide and Sediment TMDLs in Tributary Systems.

TMDLs directly addressing pesticides will be written for the Owyhee and Malheur rivers by the State of Oregon in 2006 and 2003 respectively. The efforts associated with implementation of these TMDLs will also help to reduce the amount of t-DDT and dieldrin loading to the system by addressing erosive processes.

Indirect reductions in pesticide loading to the SR-HC TMDL reach will also be realized from sediment control measures on inflowing drainages as much of the pesticide loading to the system is thought to occur from pesticides bound to sediment and organic material (Maret, 1995a and 1995b; Maret and Ott, 1997; Clark and Maret, 1998; Rinella *et al.*, 1994). Sediment TMDLs will be written for tributaries to the Owyhee River, Burnt River and tributaries and Powder River and tributaries in 2005 and 2006 by the State of Oregon. Sediment TMDLs have been written for the Mid-Snake and Lower Boise rivers and will be written for the Weiser River and the tributaries to the Weiser and Payette Rivers in 2003 and 2006 by the State of Idaho. The efforts associated with implementation of these TMDLs will also help to reduce the amount of t-DDT and dieldrin loading the system by addressing erosive processes.

3.3.8.5 Reductions Due to Discontinued Use.

Maret (1995a and 1995b), in an intensive study of available data on pesticides in fish tissues observed DDT and its metabolites and PCBs in most of the fish tissue sampled from the Upper

Snake River Basin between 1970 and 1990. His analysis identified a general trend of decreasing concentrations for DDT, its metabolites and dieldrin in the Upper Snake River Basin over time during this period. This decline is assumed to be the result of a combination of discontinued use, improved land management practices, and, to a smaller extent, degradation of existing loads. A similar decline is expected to be occurring in the Lower Snake River Basin. This decline will be enhanced by the implementation of appropriate sediment control measures within this and other TMDLs in the Lower Snake River Basin.

3.3.8.6 OTHER PROTECTIVE MEASURES.

In addition to the sediment control measures implemented through the TMDL processes in the Snake River Basin, existing fish consumption advisories for mercury in the SR-HC TMDL reach target the same populations that would be at risk from bioaccumulation of pesticides in fish tissue. These advisories will act, in an indirect fashion, to protect the designated beneficial use of fishing.

3.4 Bacteria and pH Loading Analyses

3.4.1 Bacteria Loading Analysis

The Upstream Snake River segment (RM 409 to RM 335) is listed for bacteria. Previously, both Oregon and Idaho bacteria criteria were based on fecal coliform bacteria levels. Currently, criteria of both Oregon and Idaho require waterbodies where primary contact recreation occurs to contain less than 126 *E. coli* organisms/100 mL water, and less than 406 *E. coli* organisms/100 mL of water in areas where secondary contact recreation occurs (Table 2.2.1 and Table 2.2.2).

Elevated concentrations of bacteria in surface waters can result in health risks to individuals who are swimming, water skiing or skin diving (primary contact recreation) or other activities that carry the risk of ingestion of small quantities of water. This is of particular concern to the SR-HC TMDL reach as recreation is a significant use of the waterbody.

Common sources of bacteria in surface water include improperly treated sewage and septic systems as well as wastes from warm-blooded animals.

A more detailed discussion of concerns and sources of bacterial loading is available in Section 2.3.1.2.

3.4.1.1 DATA ANALYSIS.

Both *E. coli* and fecal coliform data have been used in the assessment of current and historical bacteria violations in the SR-HC TMDL reach. Current data collection allowed *E. coli* levels to be evaluated in the Upstream Snake River segment (RM 409 to 285) of the SR-HC TMDL reach. More detailed information including monitoring dates and sources is available in Section 2.3.1.2.

This listing has been evaluated using available data collected from within this segment from 1978 until present, particularly with available recent data correlated with areas and periods of recreation use. The data show that bacteria counts (*E. coli* and fecal coliform) have not exceeded water quality criteria for primary or secondary contact recreation within the Upstream Snake River segment (RM 409 to 285) of the SR-HC TMDL reach over this time period.

Table 3.4.1 shows summary bacteria data for the 1999 season. These data were collected in an appropriate fashion for evaluation of the 30-day log mean, with a minimum of 5 samples over an appropriate time period collected at most sampling locations. This monitoring was undertaken during the summer season and correlates well not only with the period of time that conditions in the river would be conducive to bacterial growth, but also to the season of greatest primary contact recreation use. Thus, they represent the critical time period for violations within the segment.

3.4.1.2 APPROPRIATE ACTIONS.

Based on these data, the SR-HC TMDL process recommends that the mainstem Snake River (RM 409 to RM 347, OR/ID border to Scott Creek inflow) be delisted for bacteria by the State of Idaho as part of the first 303(d) list submitted by the State of Idaho subsequent to the approval of the SR-HC TMDL (Table 3.4.2). The SR-HC TMDL process further recommends that

Table 3.4.1. Summary bacteria data for the 1999 season in the Upstream Snake River segment (RM 409 to 285) of the Snake River - Hells Canyon TMDL reach.

RM	Number of Samples	E. coli (#/100 mL)	
		Mean	Maximum
335	3	13	22
340	15	11	53
385	7	18	37
403	8	19	91

Table 3.4.2. Appropriate actions for bacteria in the Snake River - Hells Canyon TMDL reach.

Segment	Point Source Allocations/Appropriate Actions	Nonpoint Source Allocations/Appropriate Actions
Upstream Snake River (RM 409 to 335)	data support delisting recommend delisting	data support delisting recommend delisting
Brownlee Reservoir (RM 335 to 285)	not listed	not listed
Oxbow Reservoir (RM 285 to 272.5)	not listed	not listed
Hells Canyon Reservoir (RM 272.5 to 247)	not listed	not listed
Downstream Snake River (RM 247 to 188)	not listed	not listed

monitoring of bacteria levels (*E. coli*), especially in those areas of the SR-HC TMDL reach where recreational use consistently occurs, continue to be an integral part of the water quality monitoring of the Upstream Snake River segment (RM 409 to 285).

It should be noted that this recommended delisting is based only upon the assessment of what is required to attain water quality standards in the mainstem Snake River. No assessment of tributary water quality has been attempted in this TMDL, and conditions specific to bacteria occurring in the mainstem may not reflect conditions occurring in the tributaries. Thus, it is possible that bacteria concentrations in the tributaries to the mainstem Snake River exceed state water quality criteria. Tributary TMDLs could require reductions and could find conditions different from those assumed herein.

In addition, this TMDL does not address bacterial reductions currently required in the Lower Payette River TMDL (IDEQ, 1999b) to meet water quality standards in that tributary.

3.4.2 pH Exceedence Analysis

pH is an indicator of the acidity or alkalinity of a system. Extreme levels of pH can be directly toxic to aquatic life. Even at less extreme levels either acid or alkaline conditions can cause chemical shifts in a system that can result in the release of metallic compounds from sediments in acid conditions or increased ammonia toxicity and release of sorbed phosphorus at high pH levels.

In order to meet the water quality criteria of both states, a pH range of 7 to 9 units has been established as a target for the SR-HC TMDL process to support designated aquatic life beneficial uses within the SR-HC reach. This target has been identified to provide appropriate habitat for fish (including salmonids) and other aquatic life.

Sources of possible pH modification include discharge of acidic or alkaline industrial or municipal wastes, ammonia production during organic matter decomposition, agricultural runoff, and excessive algal growth. However, in this reach, pH is buffered by naturally occurring mineral salts so changes, when they occur, are usually small.

A more detailed discussion of concerns related to and sources of pH modifications is available in Section 2.3.1.2.

3.4.2.1 DATA ANALYSIS.

Upstream Snake River Segment (RM 409 to 285). Data collected from 1968 to 1974 in the Upstream Snake River segment show pH values ranging from 7.5 to 9.0 at RM 361 (near Weiser, Idaho) and between 7.7 and 8.5 slightly upstream from RM 409 (near Marsing, Idaho). These data were collected over a variety of seasonal variations, but do not represent continuous monitoring (US EPA, 1974 and 1975). Data collected from 1975 to 1991 show pH values ranging from 7.5 to 9.1 at RM 361 (near Weiser, Idaho). Exceedences of the pH target for the SR-HC TMDL occurred less than 1% of the time. A study over a similar time period but with less frequent sampling slightly upstream from RM 409 (near Marsing, Idaho) showed a range of pH values from 7.5 to 8.9. These data were collected over a variety of seasonal variations, but do not represent continuous monitoring (US EPA, 1974 and 1975). Data collected by IPCo during 1995 at three locations in the Upstream Snake River segment of the SR-HC TMDL reach show pH levels that range from 8.2 to 8.9 near RM 409, Adrian, Oregon; from 7.1 to 8.9 near RM 385, Nyssa, Oregon; and from 8.3 to 9.0 at RM 340, near Weiser, Idaho. An evaluation of all available pH data for the Upstream Snake River segment of the SR-HC TMDL reach shows less than 1% exceedence of the 7.0 to 9.0 pH target (greater than 300 data points). Data ranges for the Upstream Snake River segment are shown in Figure 2.3.9.

Brownlee Reservoir. Data collected from 1968 to 1974 near Brownlee Dam show pH values that average 8.0. No depth information is available with these data so location and water column variations are not known. These data were collected over a variety of seasonal variations, but do not represent continuous monitoring (US EPA, 1974 and 1975). An evaluation of all recent (1992, 1995, 1997) inflowing and mainstem pH data showed the lowest pH observed in the Brownlee Reservoir to be 7.4. The highest pH observed was 9.6 (IPCo, 1999d, 2000a, 2000c). Less than 5 % of the data were outside of the pH target established for this TMDL process (out of 529 data points, 25 data points showed exceedences, 4.7%). Figure 2.3.17 shows a summary of pH data for 1992, 1995, and 1997.

A more detailed discussion of data available is included in Section 2.3.1.2 and Section 2.3.2.2.

3.4.2.2 Appropriate Actions.

Based on these data, the SR-HC TMDL process recommends that the mainstem Snake River from RM 409 to RM 347 (OR/ID border to Scott Creek inflow) and from RM 335 to RM 285 (Brownlee Reservoir) be delisted for pH by the State of Idaho as part of the first 303(d) list submitted by the State of Idaho subsequent to the approval of the SR-HC TMDL (Table 3.4.3). The SR-HC TMDL process further recommends that monitoring of pH continue to be an integral part of the water quality monitoring of the Upstream Snake River segment (RM 409 to 285).

Table 3.4.3. Appropriate actions for pH in the Snake River - Hells Canyon TMDL reach.

Segment	Point Source Allocations/Appropriate Actions	Nonpoint Source Allocations/Appropriate Actions
Upstream Snake River (RM 409 to 335)	data support delisting recommend delisting	data support delisting recommend delisting
Brownlee Reservoir (RM 335 to 285)	data support delisting recommend delisting	data support delisting recommend delisting
Oxbow Reservoir (RM 285 to 272.5)	not listed	not listed
Hells Canyon Reservoir (RM 272.5 to 247)	not listed	not listed
Downstream Snake River (RM 247 to 188)	not listed	not listed

It should be noted that this recommended delisting is based only upon an assessment of what is required to attain water quality standards in the mainstem Snake River. No assessment of tributary water quality has been attempted in this TMDL, and conditions specific to pH occurring in the mainstem may not reflect conditions occurring in the tributaries. Thus, it is possible that pH levels in the tributaries to the mainstem Snake River exceed state water quality criteria. Tributary TMDLs could require implementation and could find conditions different from those assumed herein.

3.5 Sediment Loading Analysis

3.5.1 Water Quality Targets and Guidelines

The purpose of TMDL development is to meet applicable water quality standards. Because the SR-HC TMDL is a bi-state effort, the most stringent of each state's water quality standards have been identified as the targets for this TMDL. In this way the attainment of these targets will ensure that the water quality requirements of both states will be met.

The Upstream Snake River segment (RM 409 to 335), the Brownlee Reservoir segment (RM 335 to 285) and the Oxbow Reservoir segment (RM 285 to 272.5) of the SR-HC TMDL reach are listed for sediment on the state 303(d) lists for this TMDL. The water quality standards and guidance values identified for sediment by the states are narrative criteria that require that sediment shall not exceed quantities that impair designated beneficial uses. These criteria are linked to turbidity and state that turbidity should be less than 50 nephelometric turbidity units (NTU) above background for any given sample and less than 25 NTU for any ten consecutive days. This latter discussion was originally developed to address point sources and incorporates mixing zones in the evaluation of violations.

A narrative standard for sediment is appropriate given that wide ranges of sediment concentration and duration occur in surface waters. Interpretation of the narrative standard on a site-specific basis is necessary to identify targets that will protect designated beneficial uses within the listed segment. The designated beneficial uses within the SR-HC TMDL reach determined to be most at risk from excess sediment were those associated with aquatic life. Because sediment includes both organic and inorganic materials, direct and indirect impacts to aquatic life are possible.

Direct effects such as scale erosion, sight impairment and gill clogging are commonly associated with the duration of occurrence of a specified sediment concentration. Newcombe and Jensen (1996), in a review of 80 published reports on suspended sediment in streams and estuaries reported that lethal effects in rainbow trout begin to be observed at concentrations of 50 mg/L to 100 mg/L when those concentrations are maintained for 14 to 60 days. Similar effects are observed for other species (CH2MHill, 1998).

Indirect impacts associated with sediment in the SR-HC TMDL reach include low dissolved oxygen concentrations due to the decomposition of organic sediment materials, and water column enrichment by adsorbed pollutants. A more detailed discussion of these concerns is included in the Subbasin Assessment for the SR-HC TMDL.

Therefore, sediment loading within the SR-HC TMDL reach is of concern for aquatic life designated beneficial use support, and also because of the attached pollutant loads (nutrients, pesticides and mercury) that the sediment carries. In the SR-HC TMDL, sediment targets and monitored trends will function as an indicator of changes in transport and delivery for these attached pollutants.

3.5.1.1 SNAKE RIVER - HELLS CANYON TMDL WATER QUALITY SEDIMENT TARGETS.

Specific to direct negative effects on aquatic life, and indirect negative effects to the system linked to the transport of adsorbed pollutants, the sediment target for the SR-HC TMDL has been set at less than or equal to 80 mg total suspended solids/L for acute events lasting no more than 14 days, and less than or equal to 50 mg total suspended solids/L as a monthly average. Available information utilized in the determination of this target included both site-specific data and literature values. A more detailed discussion of the reasoning behind this target is outlined in the following sections of this document.

It is the professional opinion of IDEQ and ODEQ that these targets will be protective of both aquatic life (EIFAC, 1964; NAS/NAE, 1973; IDEQ, 1991; CH2MHill, 1998; Newcombe and Jensen, 1996) and water quality, and will meet the requirements of the CWA. The identification of the short term 80 mg/L target will allow natural runoff and storm events (for which aquatic life in the SR-HC TMDL reach are adapted) to be accommodated for by the TMDL. It is the professional opinion of IDEQ and ODEQ that attainment of these targets represent a valid interpretation of narrative standards and will result in support of the designated beneficial uses within the system.

3.5.2 Designated Beneficial Use Impairment

Duration data is critical in determining direct effects to aquatic life within the SR-HC TMDL reach. No such duration data is available to this TMDL effort. It will be collected as appropriate as part of the monitoring undertaken in the first phase of implementation following approval of this TMDL. The data collected will be assessed to determine effects on aquatic life within the SR-HC. This information will be incorporated into the TMDL as part of the iterative process.

Data is available that show indirect negative effects on aquatic life in the form of low dissolved oxygen (in the reservoir complex) and high productivity levels (in both the Upstream Snake River segment (RM 409 to 335) and Brownlee Reservoir). (This data is discussed in more detail in the Subbasin Assessment for the SR-HC TMDL and in Section 3.2.) High suspended sediment concentrations have been observed in many of the agricultural drains and several tributaries where they enter the Snake River (US EPA, 1974 and 1975; personal observations, Upstream Snake River segment (RM 409 to 335), July 1999, July and August 2000, June 2001). A substantial increase in turbidity is visually obvious as an observer moves downstream from the Marsing Bridge to the Weiser Bridge during spring and summer months. This visual trend is supported by data available for the Upstream Snake River segment (RM 409 to 335).

3.5.2.1 ENDANGERED AND THREATENED SPECIES.

The SR-HC TMDL reach provides habitat for the Idaho spring snail (*Pyrgulopsis idahoensis*, formerly *Fontelicella idahoensis* (Frest and Johannes, 2001)). The identified distribution in the mainstem Snake River is from RM 422 to 393 and from RM 372 to 40 (IPCo, 2001a). This snail species is listed as threatened under the Federal Endangered Species Act (ESA), and requires cold, clear, well-oxygenated water for full support.

3.5.3 Sources

Both natural and anthropogenic sources of sediment are known to occur in the SR-HC TMDL drainage. Sources of sediment loading to this reach include natural loading and anthropogenic loading from both point and nonpoint sources. A brief overview of sediment sources is available below. A more detailed description is available in the Subbasin Assessment for the SR-HC TMDL (Section 2.2.4.5).

3.5.3.1 Natural Sources.

Natural sources of sediment include erosion of rock and soils through wind, precipitation, temperature extremes and other weathering events. Erosion from surface water flow is substantial under average conditions, and erosion from high flow events such as flash floods and snowmelt events can result in greater sediment transport and deposition in a single large event than occurs all year from average flows. Additionally, landslides and debris flows can contribute sediment to surface water systems.

The Bonneville Flood, a catastrophic flood event that occurred approximately 14,500 years ago as the result of the failure of one of the natural dams at Red Rock Pass of Pleistocene Lake Bonneville, deposited fine-grained silty soils over much of the region. The results of this event and the associated erosive processes are visible today in the large bar complexes, fine-grained, easily re-suspended slack water deposits, scoured and eroded basalt and scabland topography in the SR-HC TMDL reach (Link *et al.*, 1999).

As there are no undeveloped watersheds in the SR-HC TMDL reach to use as a reference system for determining natural loading, a rough estimate was derived using the data available for spring runoff in the SR-HC TMDL reach. It was assumed that the majority of the natural sediment loading is delivered during spring runoff-induced flows primarily within the tributary systems. The hydrographs for all major tributaries to the SR-HC TMDL reach were evaluated, peak monthly average flows were identified and available water column concentrations used to calculate total load during spring runoff. Nearly all tributaries to the Snake had the highest flows in April. The exceptions were the Payette River, which had a broader peak of high flows (April and May loading) and the Weiser, which had the highest flow in February. The average relative loading delivered during the high flow month was 23 percent (range = 15% to 36%). This figure was applied as an estimate of natural loading to the mainstem Snake River in the SR-HC TMDL reach.

A necessary set of data for the tributary streams is not currently available. Therefore, natural background concentrations for all tributaries will be determined as part of upcoming TMDL development on the Weiser, Owyhee, and Malheur Rivers, and tributary implementation plans for the Payette and Boise Rivers.

3.5.3.2 Anthropogenic Sources.

All permitted point sources discharging to the mainstem Snake River within the SR-HC TMDL reach (Section 3.0) include maximum total suspended solids discharge limits in their NPDES permits. Most measured total suspended solids concentrations from these point sources are well below the maximum allowable concentrations identified by their NPDES permits. These permit requirements meet or exceed the SR-HC TMDL targets.

Anthropogenic nonpoint sources of sediment in the SR-HC area include agricultural sources such as plowing and flood and furrow irrigation; forestry sources such as logging and streambank disturbance; and urban/suburban sources including construction, stormwater runoff and irrigation.

3.5.4 Transport and Delivery

The primary mechanism of sediment transport in the SR-HC TMDL reach is surface water flow. High flows can transport large amounts of sediment in a wide range of particle sizes and weights. Lower flows preferentially transport lighter, smaller particle fractions. Sediment particles are deposited in areas of streams and rivers where flows decrease and sediments fall out proportionately with size and weight distributions. Sediments deposited in this manner accumulate in areas of the channel where flows are reduced. They can be re-suspended due to increasing flow and carried further downstream. This deposition and transport pattern is evident in the evaluation of suspended sediment data from 1995, an average flow year following a series of lower flow years (Appendix E). In the months of May and June, spring flows transported nearly 200 million kilograms of sediment in the Upstream Snake River segment (RM 409 to 335); the result of several years of in-channel deposition. This mass of transport was nearly three times as large as any other monthly loading that year. Sparse vegetation and timing of snowmelt in areas of the SR-HC TMDL reach and many of the tributary drainages produce conditions favoring high surface runoff and sediment transport.

Additionally, land use patterns may influence sediment transport and delivery within the watershed. Flood and furrow irrigation ditches, if they are aligned and sloped toward streams and rivers, act to direct snowmelt runoff to surface water systems. In contrast, sediment basins and settling ponds or other treatment mechanisms on agricultural lands can help to contain snowmelt and stormwater runoff and reduce or remove suspended sediments from both agricultural flows and precipitation events. Similarly, a high density of impervious surface (commonly associated with urban development) increases the volume of runoff from storm events. If properly managed, this stormwater can be diverted to catchbasins or other mechanisms where velocity is decreased and entrained materials are allowed to settle out before water enters surface or ground water systems. Unfortunately, the relative impact of land use practices is not quantifiable with the available data for the SR-HC system.

3.5.5 Data Available for the Snake River - Hells Canyon TMDL Reach

As discussed in the general loading assessment, a fairly robust data set for sediment was available to the SR-HC TMDL effort. Sediment data has been collected over the time period from 1975 to current for both the mainstem Snake River and tributary sites. Data has been collected in the form of suspended sediment concentration (SSC) measurements (n = 344), total residue measurements (equivalent to total suspended solids measurement)(n = 1,754) and turbidity measured by a Hach turbidimeter (n = 1,099). The most robust data set available was the total residue measurement data. As the total residue and total suspended solids methods are considered essentially equivalent, this data will be referred to as total suspended solids (TSS) throughout the remainder of this document. To preserve consistency in the analysis, this data set was compared with the other available data sets in an effort to determine if it was representative of the other data collected and could therefore stand alone. The largest possible number of paired data sets available for each method were compared, and the total suspended solids measurements were found to be well correlated with the turbidity measurements and moderately correlated with the suspended sediment concentration values. The lower level of correlation with the suspended sediment concentration data is not unexpected as the suspended sediment concentration data represented a much smaller and somewhat spatially limited data set (there were much fewer correlated pairs); and studies on a variety of other systems have shown that suspended sediment concentrations often are not well correlated with total suspended solids measurements (Gray *et al.*, 2000; WDOE, 1997). Table 3.5.1 and Figure 3.5.1 show the correlation observed between total suspended solids measurements and the other data sets available.

Table 3.5.1. Comparison of total suspended solids (total residue analysis) data to other sediment data available for the Snake River - Hells Canyon TMDL reach.

Method compared	Correlation coefficient (R^2)	Y-Intercept	Number of data pairs
Turbidity (Hach)	0.825	5.4	705
SSC	0.671	8.3	14

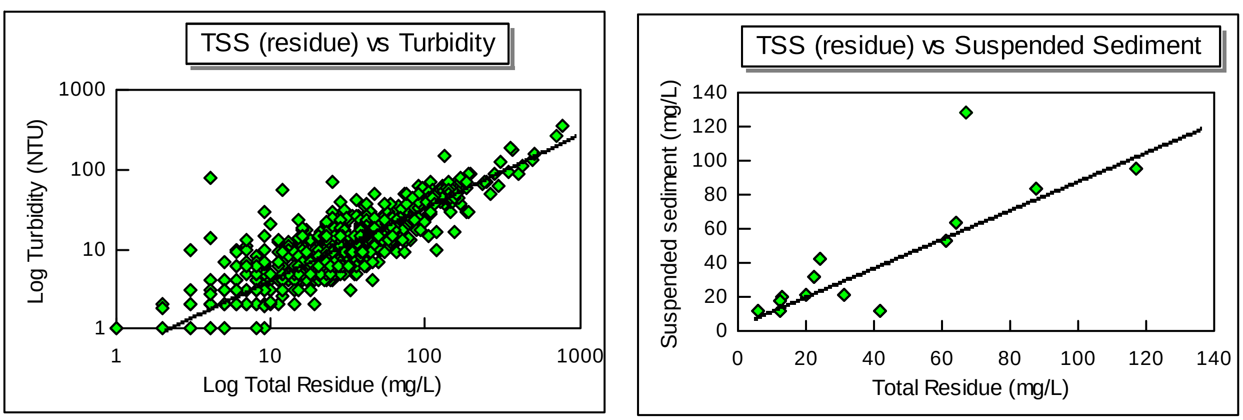


Figure 3.5.1. Linear correlation plots of total suspended solids (TSS (residue)) vs. turbidity measurements and TSS (residue) vs. suspended sediment concentrations (SSC) in the Snake River - Hells Canyon TMDL data set.

There has been a substantial amount of discussion within this TMDL process regarding the appropriateness and inherent biases of total suspended solids and suspended sediment concentration data. Both methods measure organic and inorganic sediment fractions. The analytical method used to determine total suspended solids involves filtration of an aliquot of a water sample that has been swirled to re-suspend sediment particles that may have settled to the bottom of the container. Because the entire sample is not filtered, total suspended solids data carries a slight bias toward the lighter sediment particles. The total suspended solids measurement is therefore somewhat more conservative in estimating algae, silt and clay particles, but would underestimate sand and larger, denser particles to a degree. The analytical method used to determine suspended sediment concentration filters the entire water sample and is therefore not biased toward a particular weight or density class.

While the analytical methods used are similar for both methods, the procedures used to obtain sample aliquots differ and can produce results that differ considerably when larger particle sizes (sand) represents a substantial portion of the suspended material. When fine or very fine particles make up a substantial portion of the suspended material, a higher correlation can be achieved between the two methods (WDOE, 1997).

In the SR-HC TMDL reach, the organic, clay and silt fractions of the suspended sediment are commonly observed to carry the majority of the adsorbed pollutants of concern. In addition, the effect of the organic sediments on dissolved oxygen concentrations within the water column is of concern. As total suspended solids data offers a reasonable correlation with other data sets, and represents a conservative mechanism to assess the sediment load of greatest concern, total suspended solids data were selected as the measure for sediment within this system. In addition, total suspended solids values were found to correlate well with turbidity measurements taken at the same time and place (R2 = 0.825, n = 705). This indicates that total suspended solids measurements will allow a fairly straightforward correlation of TMDL targets and point, nonpoint and direct water column measurement techniques.

Adequate data were available to calculate loading for the SR-HC TMDL reach and inflowing tributaries. Data were also available to calculate point source loading to the SR-HC TMDL reach. Flow and concentration data, average and maximum allowable, were used to determine point source loads. Nonpoint source loading data were not available to this effort.

Duration data to determine direct sediment impacts on aquatic life were not available to this effort. Distribution of the total suspended solids data utilized is shown in Table 3.5.2. A total data set is available in the Appendix E.

It should be noted that often the terms total suspended solids (TSS) and suspended sediment concentration (SSC) are used interchangeably in the literature (usually under the acronym TSS) to indicate the measurement of solids suspended in a water matrix (Gray *et al.*, 2000). This has been the case in the literature review of sediment studies for this TMDL effort. Every attempt has been made to determine the specific analytical method utilized by each study and the acronyms applied in this document are, to the extent possible, consistent with those identified previously.

3.5.6 Determination of Sediment Loading

The available data show that sediment loading to the SR-HC TMDL reach originates almost exclusively from the Upstream Snake River segment (RM 409 to 335). Point source loading represents less than 1 percent of the total sediment loading to the SR-HC TMDL reach. Measured tributary loading to this segment accounts for the majority of the sediment loading to the entire SR-HC TMDL reach, 76 percent, with ungaged (estimated) drain flows accounting for 10 percent of the total system load and unmeasured sources accounting for approximately 12 percent of the total. Sources of this unmeasured load include nonpoint source runoff from both

Table 3.5.2. Distribution of sediment data available for the Snake River - Hells Canyon TMDL reach (1970 through 1997).

Sample Site	Number of Samples	Mean TSS concentration (mg/L)	Maximum (mg/L)	Minimum (mg/L)
Snake River at Marsing	44	21.2	42	2
Tributary Mouths				
Owyhee	169	65.2	562	7
Boise	144	41.1	295	1
Malheur	93	109.2	787	2
Payette	98	36.5	406	3
Weiser	59	27.5	117	2
Drains	194	151.4	1,320	2
Upstream Snake River Mainstem	304	38.3	685	1
Brownlee Reservoir	147	21.1	411	1
Oxbow Reservoir	113	7.8	215	1
Hells Canyon Reservoir	58	9.4	116	1
Downstream Snake River Segment	69	6.9	24	1

Data in this table are from US EPA STORET, 1998a; IPCo, 1999d, 2000a, 2000c, 2000d and USGS, 1999.

anthropogenic sources and precipitation events, unidentified small tributaries and drains, error in gauged flow measurements and in-channel erosion sources.

Sediment loading to the SR-HC system shows a marked increase starting in the month of March and continuing through July and August. The months of April, May and June show the highest overall sediment loading to the system (Figure 2-29 in Appendix G), averaging over 1.5 million kg/day. July through October flow volumes and associated sediment loads are much reduced from the peaks in the previous months. These loads are smaller and relatively steady, averaging about 500,000 kg/day. Because of their direct association to irrigation and summer stormwater runoff activities, these loads are expected to carry the highest fraction of adsorbed nutrient and pesticide loading. Winter loads (November through January) average approximately 300,000 kg/day. Total suspended solids data collected by Boise City Public Works during the year 2000 show a similar trend in temporal distribution (BCPW, 2001). The relative percent sediment loading contribution for each of the SR-HC segments and inflowing tributaries for an average water year is shown in Tables 3.5.3 a and b.

Sediment loads from agricultural drains discharging to the SR-HC TMDL reach were determined using available concentration data and flow data where available. Flow data were not plentiful however, and most flows were estimated using general descriptions and the calculated return flow information by area supplied by the USBR (USBR, 2001). Concentrations were calculated averages where data were not available. These values should be viewed as best estimates. If drain specific data become available during the implementation of this TMDL it should be used

Table 3.5.3 a. Sediment (total suspended solids) loads calculated for point sources discharging directly to the Snake River - Hells Canyon TMDL reach (based on concentration data from 1995, 2000 and design flows).

Point Source	NPDES Permit Number	Location (RM)	Current Design-flow Load (kg/day)
City of Nyssa	101943 OR0022411	385	32 kg/day
Amalgamated Sugar	101174 OR2002526	385	Negligible
City of Fruitland	ID0020907	373	62 kg/day
Heinz Frozen Foods	63810 OR0002402	370	396 kg/day
City of Ontario	63631 OR0020621	369	209 kg/day
City of Weiser (WWTP)	ID0020290	352	213 kg/day
City of Weiser (WTP)	ID0001155	352	Negligible
Brownlee Dam (IPCo)	ID0020907	285	Negligible
Oxbow Dam (IPCo)	101275 OR0027286	272.5	Negligible
Hells Canyon Dam (IPCo)	101287 OR0027278	247	Negligible

in place of these estimates. Land area associated with the drains was calculated at 249,100 acres total (USBR, 2001).

Point source loads were calculated using total suspended solids values specified in NPDES permits specific to permitted facilities and the reported values supplied to the State of Oregon (permitted discharges in Oregon) and the US EPA (permitted discharges in Idaho). Constant concentrations from preceding months were assumed for months where discharge concentrations were not reported. For facilities discharging part time, only that time when discharge occurred was assessed. The total loading value for point sources in Tables 3.5.3 a and b reflects both part time discharges and seasonal discharge requirements for some facilities.

3.5.7 Total Suspended Solids - Relative Organic Content Determination

The relative distribution of inorganic and organic constituents within the total suspended solids measurement is helpful in determining source and treatment alternatives as well as in correlating this effort with that of total phosphorus reduction in Section 3.2. One method of identifying a good portion of the organic material in a sediment sample is to determine the volatile suspended solids (VSS) component. This analytical procedure uses high temperatures to “burn off” the organic content in a total suspended solids sample. The sample is weighed before and after the

Table 3.5.3 b. Sediment (total suspended solids) loads calculated for nonpoint sources discharging to the Snake River - Hells Canyon TMDL reach (based on concentration data from 1995 to 2000 and average flows).

Nonpoint Source	Location	Load (kg/day)
Snake River Inflow	RM 409: Upstream Snake River Segment	677,785
Owyhee River	RM 396.7: Upstream Snake River Segment	66,152
Boise River	RM 396.4: Upstream Snake River Segment	130,466
Malheur River	RM 368.5: Upstream Snake River Segment	92,870
Payette River	RM 365.6: Upstream Snake River Segment	137,887
Weiser River	RM 351.6: Upstream Snake River Segment	53,617
Drains	Upstream Snake River segment (RM 409 to 335)	143,430
Ungaged flows	Upstream Snake River segment (RM 409 to 335)	181,484
Agriculture, Stormwater and Forestry	Upstream Snake River segment (RM 409 to 335)	Included in the ungaged flow loading
Upstream Snake River Segment Total Loading	RM 409 to 335	1,483,691
Burnt River	RM 296: Brownlee Reservoir Segment	13,274
Powder River	RM 327.5: Brownlee Reservoir Segment	14,857
Agriculture, Stormwater and Forestry	Brownlee Reservoir segment (RM 335 to 285)	Cannot be calculated, assumed small
Agriculture, Stormwater and Forestry	Oxbow Reservoir segment (RM 285 to 272.5)	Cannot be calculated, assumed small

Data in this table are from US EPA STORET, 1998a; IPCo, 1999d, 2000a, 2000c, 2000d and USGS, 1999.

procedure and the volatile fraction is determined by difference. A limited data set was obtained from IPCo and Boise City Public Works (BCPW, 2001) monitoring efforts. This information included both the mainstem Snake River and some tributary sites. Total suspended solids and volatile suspended solids data collected from the Snake River are shown in Table 3.5.4 a. This data is plotted in Figure 3.5.2.

The plotted data show that the relative percent of total suspended solids that is volatile (organic) fluctuates over time from ~5 percent to ~ 35 percent. The extremes occur during the months of the year when algae growth would be expected to be at its lowest levels. During the spring and summer months (May through August), a gradual increase in the organic fraction is observed which correlates well with the algae growth observed within the SR-HC TMDL reach. The plot also shows that while there is a substantial change in overall concentration, there is much less fluctuation in the relative amount of organic material associated with the sediment measurements. Throughout the growing season, organic matter represents approximately 15 to 25 percent (~20% average) of the total sediment load within the mainstem Snake River in the vicinity of the SR-HC TMDL reach (RM 441.9 to 340).

Table 3.5.4 a. Monthly mean total suspended solids (TSS) and volatile suspended solids (VSS) data from the mainstem Snake River.

Month	Avg. TSS	Avg. VSS	% VSS
January	6.20	1.80	29.03
February	27.70	2.08	7.49
March	58.40	7.70	13.18
April	31.48	6.68	21.21
May	35.47	5.87	16.54
June	41.07	8.50	20.70
July	33.88	7.82	23.07
August	27.64	7.21	26.10
September	20.87	4.63	22.20
October	13.35	3.43	25.72
November	9.95	3.28	32.91
December	8.02	1.92	23.94

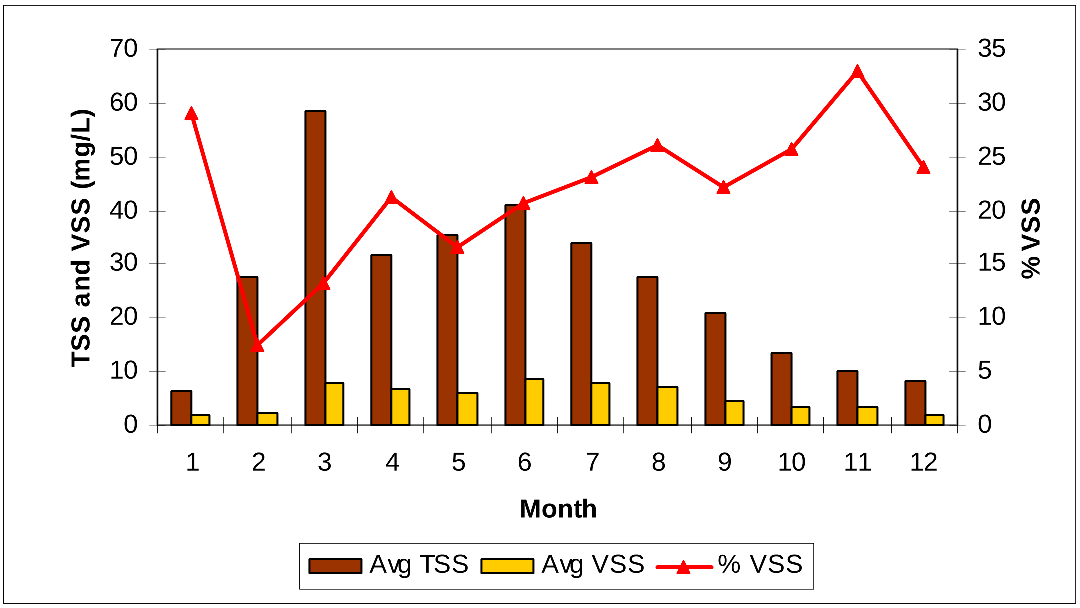


Figure 3.5.2. Total suspended solids (TSS) and volatile suspended solids (VSS) data plotted as monthly means for the mainstem Snake River.

A small data set was also available from IPCo and Boise City Public Works (BCPW, 2001) that allowed a comparison of relative percent organic content between the Snake River mainstem and some inflowing tributaries. This data is shown in Table 3.5.4 b; data is plotted in Figure 3.5.3. The plotted data show that the relative percent volatile suspended solids is reasonably stable within the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach and the inflowing tributaries (Boise and Payette Rivers). The relative percent volatile suspended solids is ~20 percent. This value increases steeply within the reservoir as larger, mostly inorganic sediments drop out and smaller, suspended matter dominates. Again, while the overall concentration of total suspended solids and volatile suspended solids fluctuate fairly widely, the

Table 3.5.4 b. Comparison data for mean total suspended solids (TSS) and volatile suspended solids (VSS) data from the mainstem Snake River, the Lower Boise River and the Lower Payette River.

Location	Mean TSS	Mean VSS	% VSS
Payette River	19.08	2.63	13.81
Boise River	26.65	3.99	14.97
284.4	3.31	1.07	32.40
340	25.29	4.60	18.19
351	42.93	8.87	20.67
403	22.16	4.78	21.59
441.9	16.10	4.89	30.35

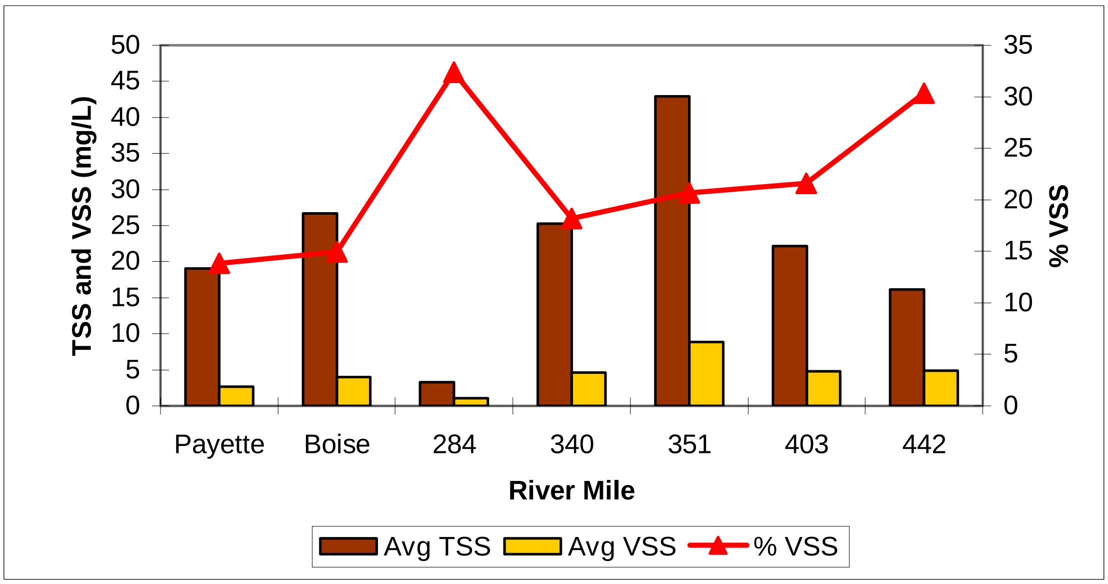


Figure 3.5.3. Total suspended solids (TSS) and volatile suspended solids (VSS) data plotted for the mainstem Snake River and some tributary inflows.

general correlation of total suspended solids and volatile suspended solids remains reasonably constant.

This reasonably stable ratio over the summer growing season indicates that reductions in algae growth within the Snake River will result in a consistent reduction of sediment concentrations in the SR-HC TMDL reach. It also indicates however, that the majority of sediment in the SR-HC TMDL reached, based on these data, is inorganic. Therefore, sediment reductions, while they will be assisted by the measures implemented to attain nutrient reductions, will still need to be addressed separately to attain the identified targets in some places and at some times.

3.5.8 TMDL Determination

Given the water quality concerns associated with sediment in the SR-HC TMDL reach, available information (both site-specific and literature values) was considered in the determination of an appropriate sediment target and TMDL for the SR-HC TMDL reach. Specific to direct negative effects on aquatic life, current targets recognized in other sediment TMDL efforts are reasonably correlated.

Recommendations of less than or equal to 80 mg/L total suspended solids concentration as a daily maximum, and less than or equal to 52 mg/L total suspended solids concentration as a monthly average have been proposed in the upstream Snake River (IDEQ 2000d). Concentrations of less than or equal to 80 mg/L suspended sediment concentration for acute events lasting less than 14 days, and less than or equal to 50 mg/L suspended sediment concentration for acute events lasting less than 60 days have been identified for the Lower Boise River (IDEQ, 1998a). Targets of less than or equal to 56 mg/L suspended sediment concentration have been identified in the Yakima TMDL for both sediment and DDT concerns (WDOE, 1997).

In addition to the protection of designated beneficial uses, the transport of adsorbed nutrients, mercury and organochlorine pesticides through sediment transport and delivery within the SR-HC TMDL reach is of concern. These compounds adsorb to entrained organic matter and fine particles with high surface areas. It is estimated that over 90 percent of adsorbed pollutant loading is carried by the silt/clay and fine to very fine particle fractions of sediment. The majority of the remaining adsorbed load is carried by entrained organic material (Baird, 1995; Clark and Maret, 1998; Rinella *et al.*, 1994).

Sediments in the bed of the Snake River in the Upstream Snake River segment (RM 409 to 335) average approximately 1 percent total organic carbon, 12 percent silt and clay, and 38 percent fine or very fine particles. Sediments in the Brownlee Reservoir segment (RM 335 to 285) average approximately 1.3 percent total organic carbon, 83 percent silt and clay, and 12 percent fine or very fine particles (IPCo, 2000d; Clark and Maret, 1998). As smaller particle sizes tend to travel farther before settling out, the majority of these sediment fractions in the reservoir most likely originated in the Upstream Snake River segment. A reduction in sediment in the SR-HC TMDL reach, and specifically these fractions, will result in a corresponding reduction in pollutant loading for nutrients, mercury and pesticides.

To specifically target that fraction of the entrained sediment that carries the largest pollutant load, total suspended solids-based targets were selected. To target that fraction of annual runoff most likely to contain the adsorbed pollutant load, the temporal distribution of sediment delivery to the SR-HC system was evaluated.

It was observed that the majority of total suspended solids loading to the SR-HC TMDL reach occurred over the summer growing season (April to October). Roughly 70 percent of the total sediment load is delivered during this time period (Table 3.5.5) even though the highest flows in the SR-HC TMDL reach generally occur during the spring season (February, March and April).

Figure 3.5.4, plots A through J (multiple pages) shows total suspended solids concentrations measured at points within the SR-HC TMDL reach and at the mouths of inflowing tributaries. The data sets displayed do not contain equal numbers of data points for the 1975 to 1980 and 1990 to 2000 time periods. In most cases, more data was available in the 1990 to 2000 time

Table 3.5.5. Mean and range of % total suspended solids (TSS) delivered seasonally to the Snake River - Hells Canyon TMDL reach. (Summer is defined as late April through October, spring is defined as February through early April, and winter is defined as November through January.)

	Summer Season	Spring Season	Winter Season
Average Water Year			
Mean % of TSS delivered	72%	19%	8%
Range of %TSS delivered	64% to 86%	27% to 22%	14% to 5%
High Water Year			
Mean % of TSS delivered	69%	29%	12%
Range of %TSS delivered	60% to 85%	20% to 30%	8% to 16%
Low Water Year			
Mean % of TSS delivered	73%	14%	16%
Range of %TSS delivered	55% to 87%	12% to 17%	11% to 28%

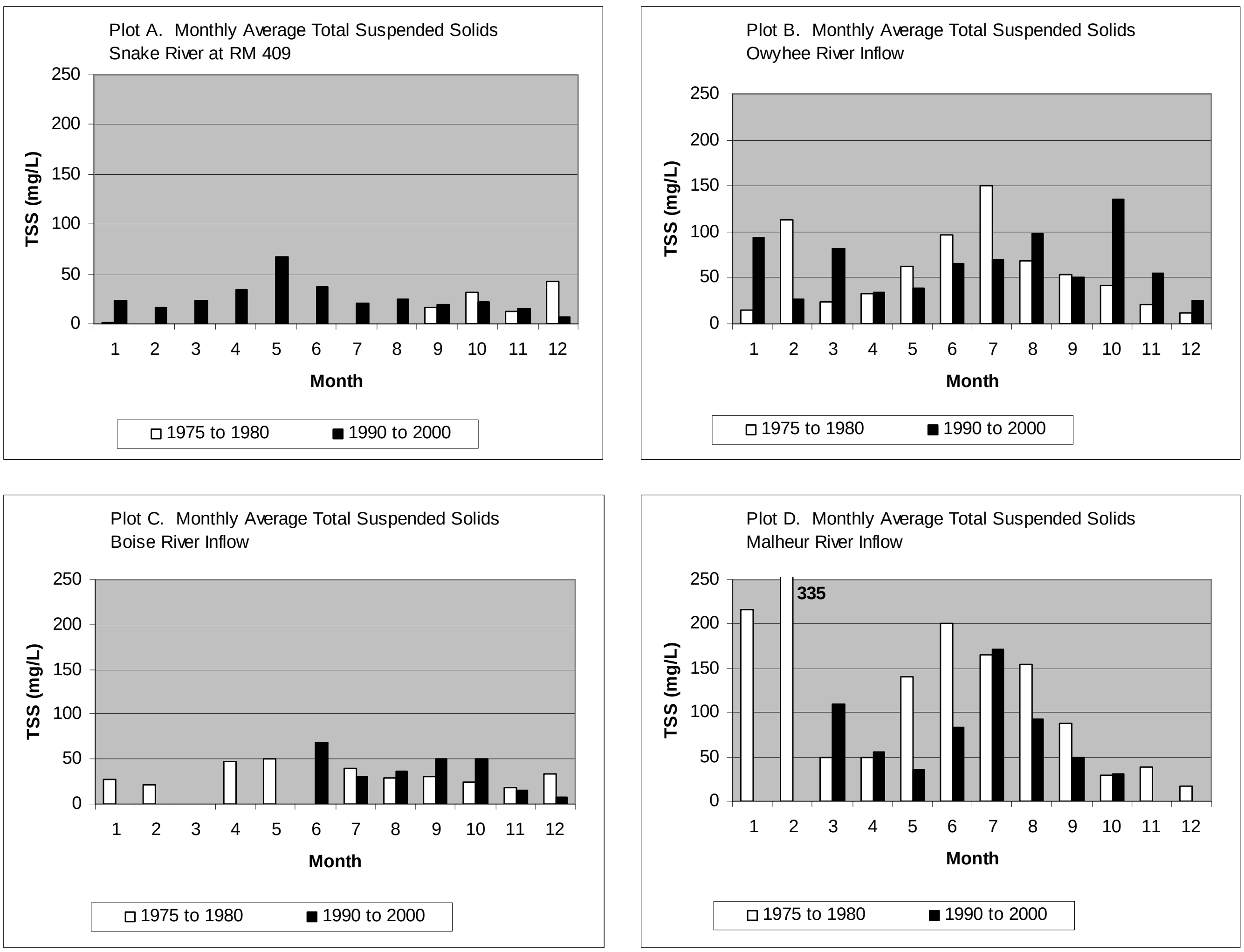


Figure 3.5.4. Mean monthly total suspended solids (TSS) concentrations for locations on the mainstem Snake River and at the mouths of the major tributary inflows within the Snake River - Hells Canyon TMDL reach. The data sets displayed do not necessarily contain equal numbers of data points.

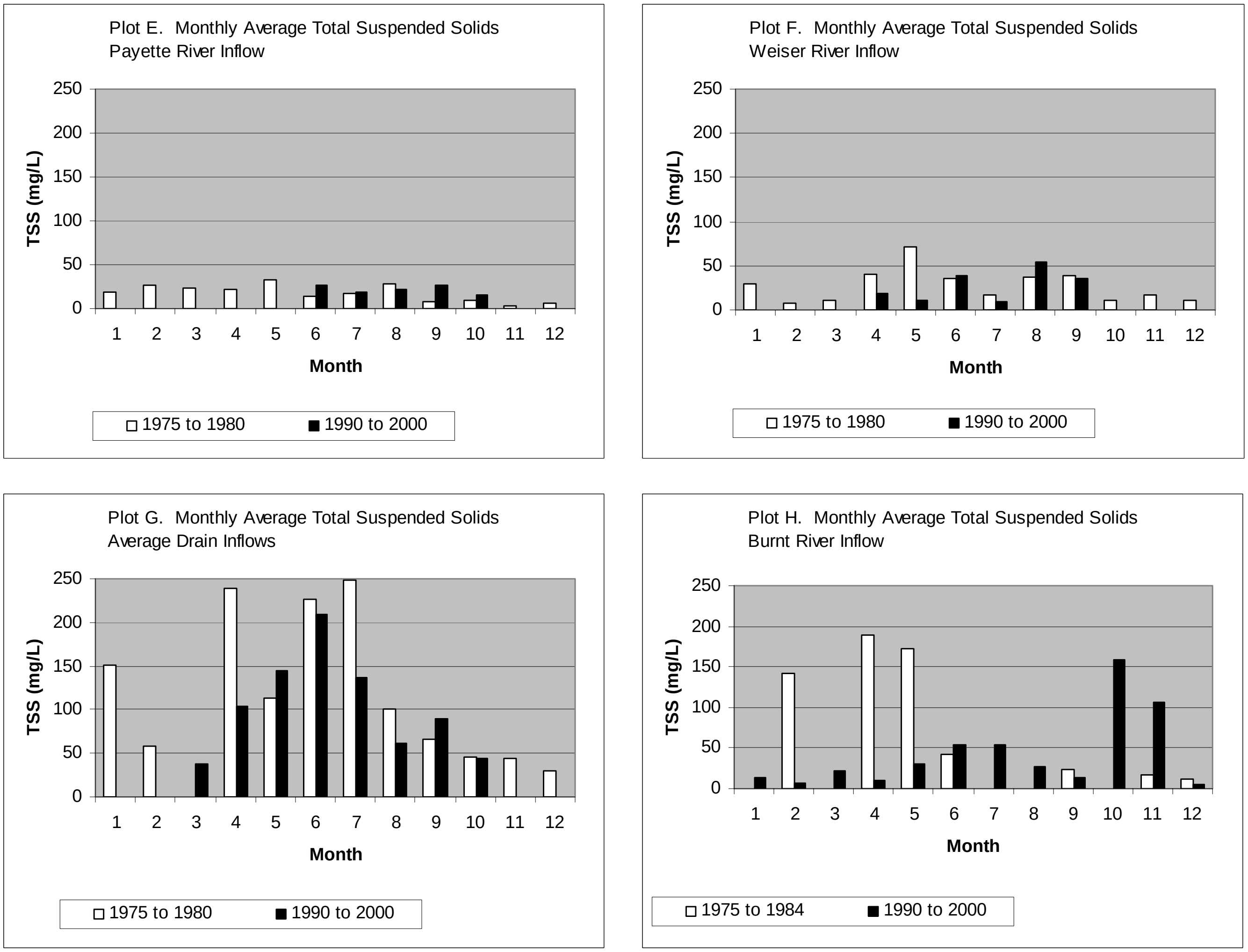
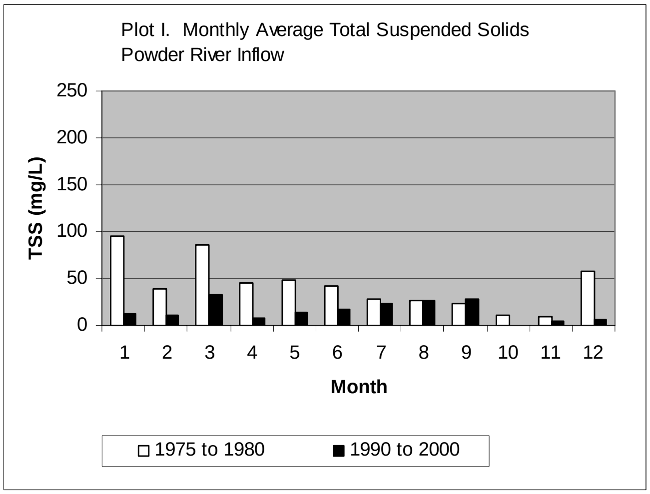


Figure 3.5.4. (cont.) Mean monthly total suspended solids (TSS) concentrations for locations on the mainstem Snake River and at the mouths of the major tributary inflows within the Snake River - Hells Canyon TMDL reach. The data sets displayed do not necessarily contain equal numbers of data points.

period than in the 1975 to 1980 time period. Data is presented as available. Lack of data or smaller than average data sets occurred in some years and locations. Therefore, these limited data may not be representative of average conditions. Scales on all plots were normalized to allow for an easier comparison of relative concentration differences.

The Malheur River (plot D), the Burnt River (plot H) and the Powder River (plot I) show reductions in total suspended solids concentrations from the 1975 to 1980 data as compared to the 1990 to 2000 data.

Total suspended solids concentrations at the mouth of inflowing tributaries do not exceed the average monthly target value of 50 mg/L until late April when they increase sharply. Concentrations continue to increase through July and then decline, dropping below the 50 mg/L monthly average in September. The months in which sediment reduction measures would be the most effective (based on this data) would therefore be from April through August. Winter total



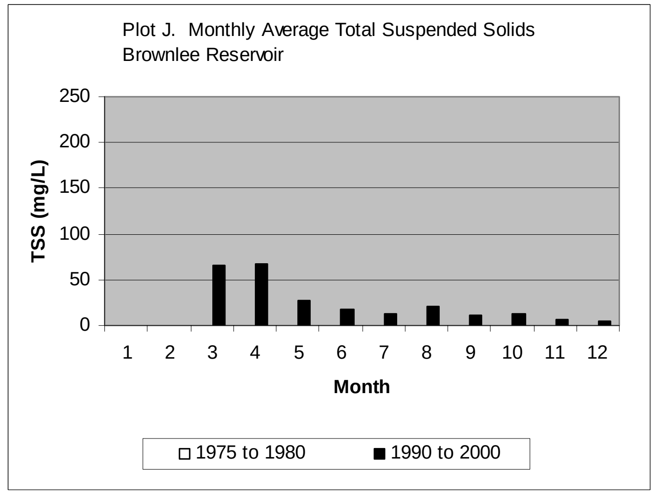


Figure 3.5.4. (cont.) Mean monthly total suspended solids (TSS) concentrations for locations on the mainstem Snake River and at the mouths of the major tributary inflows within the Snake River - Hells Canyon TMDL reach. The data sets displayed do not necessarily contain equal numbers of data points.

suspended solids concentrations in most inflows are rarely observed above 50 mg/L as a daily average and higher, snowmelt induced total suspended solids concentrations do not commonly last more than 14 consecutive days.

Therefore, setting targets that would address the loading occurring this critical time period would encompass the largest portion of the delivered load, while minimizing concerns associated with that time period where natural processes such as snow melt and precipitation result in high flows that are difficult to treat effectively. In the SR-HC TMDL, natural runoff patterns generally show the occurrence of high flow volumes during the months of March and April. Individual tributary systems may experience earlier or later snowmelt and runoff patterns. BMP-based treatment of snowmelt induced spring flows is not always effective. Both stormwater and agricultural BMPs, if properly installed and operated, will function to reduce this runoff-induced loading, but will function less efficiently in times of substantially increased flow volume, especially if it occurs during a time period when vegetation has not re-established after a winter die-off. Therefore, the highest treatment efficiencies will most likely occur during the summer and fall seasons when vegetation is well established and flows are less than spring runoff volumes.

Summer growing season flows are also the most likely sources of legacy pesticide and legacy seed-treatment based mercury transport, as this is when agricultural irrigation use and surface return flows are highest. Soil particles and organic material transported through erosive processes associated with irrigation and stormwater runoff are also likely to contain adsorbed phosphorus. Algae blooms observed in the Upstream Snake River in the late spring and early summer are well correlated with the irrigation season.

In investigating appropriate total suspended solids targets for the SR-HC TMDL reach, several factors were considered, including fish species present, land use distribution (for determining potential for adsorbed pollutant loads), flow and loading distribution, and data available.

At minimum, full support of designated beneficial uses can occur in an environment where sediment and other habitat conditions result in a “none-to-slightly reduced” fishery. An in-depth evaluation of sediment requirements was completed on the Lower Boise River to determine the fishery needs. This work resulted in the identification of a sediment target of less than or equal to 50 mg/L suspended sediment concentration for acute events lasting less than 60 days. This determination was specific to fishery support. In the Mid-Snake TMDL process, a similar evaluation was completed that resulted in the identification of a target of less than or equal to 52 mg/L suspended sediment concentration as a monthly average.

The range of 50 mg/L to 100 mg/L total suspended solids identified by Newcombe and Jensen (1996) was carefully evaluated for application to the SR-HC TMDL reach. The research is specific to rainbow trout, a species known to exist in the SR-HC TMDL reach and while all of the research is not specific to the SR-HC drainage, it represents the current understanding of sediment effects on aquatic life.

Also carefully reviewed was the caution that in order to protect against lethal or paralethal effects on fisheries, sediment concentrations at or above 80 mg/L total suspended solids cannot be sustained for more than 30 days.

The targets evaluated were established based on work that included a broad range of locations and fish species. The fish populations identified within the Mid-Snake and Boise River systems are very similar to those identified within the SR-HC TMDL reach. Therefore, these targets should also be protective of the fish species in the SR-HC TMDL reach.

In light of this information, a two part sediment target for the SR-HC TMDL reach was identified: a conservative target of less than or equal to 80 mg total suspended solids/L for acute events lasting no more than 14 days, and less than or equal to 50 mg total suspended solids/L monthly average. This target will be applied year round. The less than or equal to 50 mg/L total suspended solids monthly average will serve as the load capacity for the SR-HC TMDL. It is the professional opinion of IDEQ and ODEQ that attainment of these targets represent a valid interpretation of narrative standards and will result in support of the designated beneficial uses within the system. This two part target protects the fishery, results in reduction of that specific fraction of the sediment most likely to carry adsorbed pollutants into the SR-HC TMDL reach, and allows an off-ramp for naturally occurring events over which landowners and managers have little control. This target is applied to the SR-HC TMDL reach in the Upstream Snake River, Brownlee Reservoir and Oxbow Reservoir segments (RM 409 to 272.5) as they are listed for sediment in the SR-HC TMDL reach.

The type of sediments identified and the potential for pollutant transport are very similar between the Mid-Snake TMDL reach and the SR-HC TMDL reach. The target selected is conservative in nature (the lower end of the range identified as resulting in no-effect to slightly-reduced fisheries and should therefore ensure minimal negative impacts to the aquatic life in the SR-HC TMDL reach (EIFAC, 1964; NAS/NAE, 1973; IDEQ, 1991; Newcombe and Jensen, 1996, WDOE, 1997).

In absence of duration-specific data that would allow direct interpretation of how sediment transport occurs within the SR-HC TMDL reach; this target was selected as being protective of the system in general. Site-specific data will be collected during the first phase of implementation to refine this target if necessary.

The short term target of less than or equal to 80 mg/L total suspended solids for acute events of less than 14 day duration was derived from the recommendation that sediment concentrations of greater than 80 mg/L total suspended solids for more than 30 days could result in lethal or paralethal effects on fisheries. Given the concern that two, 30 day periods may occur in close proximity and result in a detrimental effect on the fishery, it was decided that a 14 day duration would provide appropriate salmonid rearing/cold water aquatic life support. If two 14-day events were to occur in close proximity (for example one day apart, worst case scenario) the collective effects would still be within the recommended duration for protection of fisheries. Most fish have adapted to survive short duration high intensity events, and most naturally occurring events, while they may result in sustained high flows, do not result in sustained high concentrations of sediment for long duration.

Due to the observed concentration and flow trends within the SR-HC TMDL reach and inflowing tributary systems, the critical period for this target will focus on the summer growing months as that is where the available data show the greatest number of total suspended solids concentrations above 50 mg/L (monthly average) occur. An example of this distribution is seen in the total suspended solids concentrations measured at points within the SR-HC TMDL reach and at the mouths of inflowing tributaries, as shown in Figure 3.5.4

The specific level of reduction realized by attainment of this target is dependent on the type of water year and the hydrology of the surface water system to which it is applied. Setting a concentration-based target means that in high flows, the loading delivered at the target value will be greater than the load delivered at the target value during medium or low flow years.

However, the concentration of total suspended sediment in the water column is a primary factor affecting aquatic life support, so a concentration-based target is reasonable. Additionally, the load delivered during high flow years will still be reduced from the load delivered without TMDL-based reductions. Low and average flow years may show a larger relative percentage reduction in sediment loading by meeting the monthly average 50 mg/L total suspended solids target as loading is based on instream flow (load = flow x concentration). High flow years will also see a reduced sediment load, but the overall relative magnitude of mass realized by the reduction will be smaller because of the higher flows.

Table 3.5.6 shows the calculated loading at current conditions. Calculated loading at the 50 mg/L target level is also shown that incorporates a 10 percent margin of safety. Under these conditions it can be observed that the inflow from the Snake River (at RM 409) and the Boise, Payette and Weiser Rivers does not exceed the target, while the inflow from the Owyhee and Malheur Rivers, and that of the drains exceeds the target and would need to reduce total suspended solids by between 27 percent and 60 percent in order to meet the target criteria at the mouth of the inflow to the Snake River.

3.5.9 Load Allocations

Specific information is presented in Section 4.0. Reductions identified in Table 3.5.6 are specific to the mouth of those tributaries where discharged total suspended solids concentrations are greater than 50 mg/L monthly average. These reductions are expected to minimize site-specific degradation of habitat and impairment of designated uses at the inflow point within the mainstem Snake River.

Table 3.5.6. Current sediment loads, projected loading based on 50 mg/L total suspended solids (TSS), and percent reduction realized (based on concentration data from 1995, 1996 and 2000, and average flow values).

Sample Site	Current Load (TSS) (kg/day)	Projected Loading at 50 mg/L (TSS) (kg/day)	% Reduction
Snake River at Marsing	677,785	1,054,463	
Tributary Mouths			
Owyhee	66,152	48,007	27
Boise	130,466	148,569	
Malheur	92,870	42,062	55
Payette	137,887	296,530	
Weiser	53,617	121,144	
Drains	143,430	57,628	60
Ungaged flows	181,484	118,178	35
Upstream Snake River Mainstem	1,483,691	1,886,581	
Burnt	13,274	9,713	27
Powder	14,857	26,348	
Brownlee Reservoir	193,093	1,888,952	
Oxbow Reservoir	275,470	1,904,434	

3.6 Temperature Loading Analysis

3.6.1 Water Quality Targets and Guidelines

The purpose of TMDL development is to meet applicable water quality standards. The SR-HC TMDL is a bi-state effort; therefore the most stringent of each state's water quality standards have been identified as targets for this TMDL. In this way the attainment of these targets will ensure that the water quality requirements of both states will be met.

The entire SR-HC TMDL reach (from RM 409 to RM 188) is listed for temperature on the state 303(d) lists. The water quality standards and guidance values identified for temperature in the SR-HC TMDL are numeric criteria specific to the designated beneficial uses of *cold water aquatic life* and *salmonid spawning and rearing* when and where these uses occur.

The entire SR-HC TMDL reach (from RM 409 to RM 188) has been designated for cold water aquatic life by the State of Idaho. This same segment has been designated for salmonid spawning and rearing by the State of Oregon. Within the beneficial use designation of salmonid spawning and rearing, the State of Oregon can differentiate separately between those areas where salmonid spawning occurs and those areas where salmonid rearing occurs within a watershed. The water quality targets applied to these areas are then determined by this localized designation of use with salmonid rearing targets applied to those areas designated for salmonid rearing and salmonid spawning targets applied to those areas designated for salmonid rearing.

Specific designation of the salmonid spawning and salmonid rearing beneficial uses in the SR-HC TMDL reach are as follows:

Salmonid Spawning. The states of Oregon and Idaho have designated the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach for salmonid spawning. Both the State of Idaho and the State of Oregon have designated tributaries to the SR-HC TMDL reach for salmonid spawning based on the available data and the current level of understanding of fish species present. Salmonid spawning within these drainage basins is most likely to occur within the tributaries to the SR-HC TMDL reach where flow and substrate conditions are favorable to support such uses. Salmonid spawning is not observed to occur in the Upstream Snake River (RM 409 to 335), Brownlee Reservoir (RM 335 to 285), Oxbow Reservoir (RM 285 to 272.5) or Hells Canyon Reservoir (RM 272.5 to 247) segments of the SR-HC TMDL. The salmonid spawning beneficial use designation and its accompanying water quality targets will apply to those tributaries to the SR-HC TMDL reach so designated, when and where that designated use occurs. As these tributaries are not interstate waters, and salmonid spawning use support is a localized habitat issue, state-specific targets for salmonid spawning will apply to those areas of the tributaries designated for salmonid spawning.

This localized designation of salmonid spawning areas is integral to the approach outlined in the initial sections of this document regarding the open acknowledgement by this TMDL effort that there are distinct spatial and temporal use patterns within the specific segments designated for specific beneficial uses within the SR-HC TMDL reach. Targets must be set to recognize those spatial/temporal use patterns that exist, as well as the needed connectivity within the mosaic of designated beneficial uses (including critical habitat for sensitive species) throughout the waterbody. This approach provides for full support of existing uses and the restoration of impaired designated uses within that mosaic. In setting specific salmonid rearing and salmonid spawning designations, the SR-HC TMDL also recognizes that this ecosystem is comprised of a variety of aquatic environments that include lentic (still water), lotic (flowing water) and transition areas, each with their own characteristic attributes, habitat types and beneficial uses. In this way the proposed approach can result in a TMDL that is achievable, that will meet criteria, and that will support designated beneficial uses without imposing inappropriate and unreachable water quality targets and implementation expectations.

Salmonid Rearing. The State of Oregon has designated the mainstem Snake River in the SR-HC TMDL reach for salmonid rearing (the State of Idaho designated beneficial use equivalent to *salmonid rearing* is *cold water aquatic life*). The State of Idaho has designated the entire reach for cold water aquatic life. The salmonid rearing/cold water aquatic life beneficial use designation, and the accompanying water quality targets apply to the mainstem Snake River within the SR-HC TMDL reach. As the mainstem SR-HC TMDL reach of the Snake River is an interstate waterway, the more stringent of the two states' standards applies and has been identified as the salmonid rearing/cold water aquatic life target for this TMDL. Temperature targets for the SR-HC TMDL were established based on a comparison between the temperature standards for Idaho and Oregon. A detailed description of the comparison methodology is contained in Appendix C.

The State of Idaho designation of salmonid spawning as a beneficial use for Brownlee Reservoir, Oxbow Reservoir and Hells Canyon Reservoir has been formally removed by state legislative action finalized on March 30, 2001. For the purposes of this TMDL, the current use designations identified by the states have been applied.

3.6.1.1 SALMONID REARING/ COLD WATER AQUATIC LIFE.

The temperature target identified for the protection of salmonid rearing/cold water aquatic life when aquatic species listed under the Federal Endangered Species Act are not present or, if present, a temperature increase would not impair the biological integrity of the Threatened and Endangered population, is: 17.8 ^{o}C (expressed in terms of a 7-day average of the maximum temperature) if and when the site potential is less than 17.8 ^{o}C. If and when the site potential is greater than 17.8 ^{o}C, the target is no more than a 0.14 ^{o}C increase from anthropogenic sources (0.14 ^{o}C is considered less than measurable by ODEQ).

When aquatic species listed under the Endangered Species Act are present and if a temperature increase would impair the biological integrity of the Threatened and Endangered population then the target is no greater than 0.14 ^{o}C increase from anthropogenic sources.

This target is based on Oregon temperature standards, which were found to be more stringent that Idaho cold water aquatic life temperature standards. It includes narrative criteria that acknowledges that "natural surface water temperatures at times exceed the numeric criteria due to naturally high ambient air temperatures, naturally heated discharges, naturally low stream flows or other natural conditions" (OAR 340-41-120 (11)(c)).

Language regarding standard exceedences from naturally occurring sources, similar to that outlined for Oregon State standards above is also contained in the Idaho State Water Quality Standards. At the start of this TMDL process, existing Idaho standards stated that "where natural background conditions from natural surface or ground water sources exceed any applicable water quality criteria...that background level shall become the applicable site-specific water quality criteria" (IDAPA 58.01.02.07.06). A clarification to this statement was added through legislative action during this TMDL process (effective March 15, 2002). Current Idaho State Water Quality Standards state "when natural background conditions exceed any applicable water quality criteria...the applicable water quality criteria shall not apply, instead, pollutant levels shall not exceed the natural background conditions, except that temperature levels may be increased above natural background conditions when allowed under Section 401" (IDAPA 58.01.02.200.09). While the current Idaho State language represents a clarification of the original statement, both recognize the existence of conditions where the presence of natural sources can result in conditions that exceed applicable water quality standards.

Therefore, this approach is supported by both the current Idaho State Water Quality Standards, the Idaho State Water Quality Standards existing at the start of the SR-HC TMDL process, and Oregon State Water Quality Standards.

Although the salmonid rearing/cold water aquatic life designation and the associated targets are applied year-round, the critical time period for salmonid rearing/cold water aquatic life in the SR-HC TMDL reach is from June through September, when elevated water temperatures are most likely to occur. Water temperatures throughout the remainder of the year generally meet the target criteria.

3.6.1.2 SALMONID SPAWNING.

The temperature target identified for the protection of salmonid spawning when aquatic species listed under the Endangered Species Act are not present or, if present, a temperature increase would not impair the biological integrity of the Threatened and Endangered population, is less than or equal to a maximum weekly maximum temperature of 13 ^{o}C (when and where salmonid spawning occurs) if and when the site potential is less than a maximum weekly maximum temperature of 13 ^{o}C (temporary rule, effective by action of the IDEQ board 11-14-03, pending approval by Idaho Legislature 2005, subject to US EPA action). If and when the site potential is greater than a maximum weekly maximum temperature of 13 ^{o}C, the target is no more than a 0.14 ^{o}C increase from anthropogenic sources. (The State of Oregon definition of no measurable increase (0.14 ^{o}C) was used as it is more stringent than the State of Idaho definition of 0.3 ^{o}C.)

When aquatic species listed under the Endangered Species Act are present and if a temperature increase would impair the biological integrity of the Threatened and Endangered population then the target is no greater than 0.14 ^{o}C increase from anthropogenic sources.

The temperature target for salmonid spawning is applicable only when and where salmonid spawning occurs within the SR-HC TMDL reach. This target applies to the Downstream Snake River segment (RM 247 to 188) only, and is specific to those salmonids identified to spawn in this area, namely fall chinook and mountain whitefish. This target is based on Idaho temperature

standards, which were found to be more stringent that Oregon salmonid spawning temperature standards.
Temperature targets for salmonid spawning in the SR-HC TMDL reach apply during critical time periods for salmonid spawning. These targets apply only to that portion of the SR-HC TMDL reach below Hells Canyon Dam (RM 247 to RM 188). Critical time periods for salmonid spawning in the Downstream Snake River segment of the SR-HC TMDL reach are from October 23rd to April 15th for fall chinook, and from November 1st to March 30th for mountain whitefish.

Critical time periods for fall chinook spawning were identified through site-specific data collected by IPCo and USFWS from 1991 through 2001. Fall chinook redds have been identified below Hells Canyon Dam as early as October 9th (IPCo, 2001c, 2001e). However, these early spawners represent less than 1.2 percent of the total number of fall chinook redds documented (Figure 3.6.0). The majority of fall chinook redds created were identified after October 23rd in all years. Of the total number of fall chinook redds counted, approximately 8 percent were present during the week of October 23rd, and approximately 30 percent were present during the week of October 30th. The remaining 70 percent were identified in the following weeks.

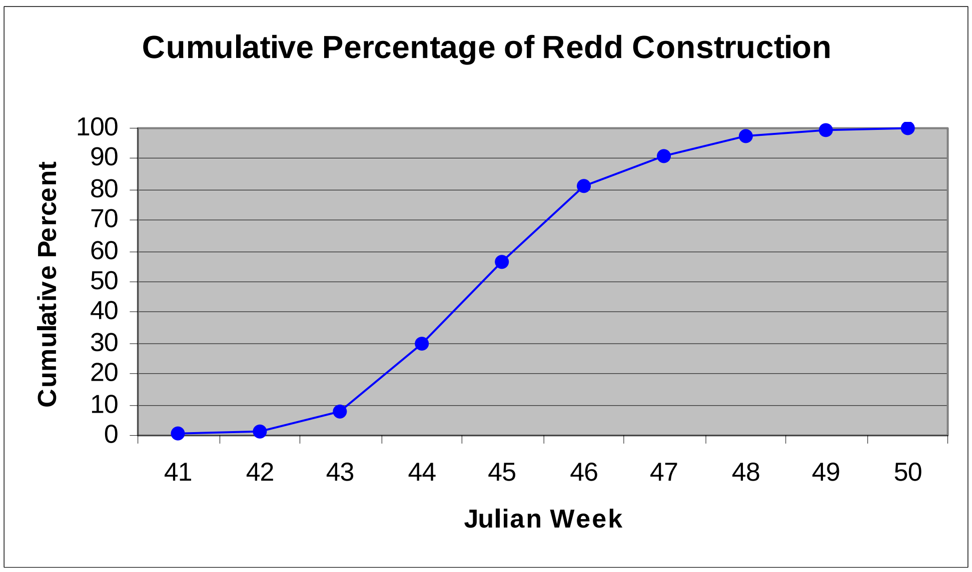


Figure 3.6.0. Cumulative percentage of redd construction for fall chinook observed in the Snake River below Hells Canyon Dam (RM 247) 1991 through 2001. Data collected by IPCo and USFWS (IPCo, 2002).

Given the fact that less than 1.2 percent of the identified fall chinook redds were in place prior to the week of October 23rd, it is the opinion of the DEQs that this week (October 23) represents a valid threshold for the initiation of fall chinook spawning below the Hells Canyon Dam. The fall chinook spawning period, based on this site-specific data, is therefore determined to extend from October 23rd to April 15th. This time period is also protective of the mountain whitefish spawning period (starting 01 November). Chinook spawning does not occur above Hells Canyon Dam, as the dam acts as a barrier to upstream migration.

The spawning and incubation times referenced in this document are based on existing site-specific data. If additional site-specific data on spawning and incubation times or a more complete understanding of critical water temperatures become available following the submission and approval of this TMDL, these data will be evaluated in the context of the iterative TMDL process. If it is determined that the additional data are appropriate to this TMDL, the time frames and/or temperatures identified for spawning and incubation will be updated as necessary to reflect the expanded data set and improved understanding of the SR-HC TMDL reach and related habitat and use-support needs; or a change in state standards for salmonid spawning.

3.6.1.3 SUMMARY OF SNAKE RIVER - HELLS CANYON TMDL WATER QUALITY TEMPERATURE TARGETS AND USE DESIGNATION.

The salmonid rearing/cold water aquatic life temperature target identified for the SR-HC TMDL reach applies to RM 409 to 188. This target is 17.8 ^{o}C (expressed in terms of a 7-day average of the maximum temperature) if and when the site potential is less than 17.8 ^{o}C. If and when the site potential is greater than 17.8 ^{o}C, the target is no more than a 0.14 ^{o}C increase from anthropogenic sources. The critical time period for this target is from June through September.

The salmonid spawning temperature target identified for the SR-HC TMDL reach applies to RM 247 to 188. The target is a maximum weekly maximum temperature of 13 ^{o}C (when and where salmonid spawning occurs) if and when the site potential is less than a maximum weekly maximum temperature of 13 ^{o}C. If and when the site potential is greater than a maximum weekly maximum temperature of 13 ^{o}C, the target is no more than a 0.14 ^{o}C increase from anthropogenic sources. This target applies only when and where salmonid spawning occurs and is specific to those salmonids identified to spawn in the designated segment (RM 247 to 188), namely fall chinook October 23rd through April 15th and mountain whitefish (November 1st through March 30th).

These targets apply when aquatic species listed under the Endangered Species Act are not present or, if present, a temperature increase would not impair the biological integrity of the Threatened and Endangered population. When aquatic species listed under the Endangered Species Act are present and if a temperature increase would impair the biological integrity of the Threatened and Endangered population then the target is no greater than 0.14 ^{o}C increase from anthropogenic sources.

Note: The temperature analysis set forth in this TMDL does not specifically address attainment of Oregon's criterion for protection of Threatened and Endangered Species. Oregon will address this in the Section 401 certification analysis for the Hells Canyon Complex.

3.6.1.4 CHANGES TO STATE OF IDAHO WATER QUALITY STANDARDS.

As stated above, language regarding standard exceedences from naturally occurring sources is contained in the Idaho State Standards. Previously, Idaho standards stated that "where natural background conditions from natural surface or ground water sources exceed any applicable water quality criteria...that background level shall become the applicable site-specific water quality criteria" (IDAPA 58.01.02.07.06 (2000)). This language has been interpreted to require a rule-making change to establish natural background as a site-specific standard. A change to this language has been completed by the State of Idaho to clarify that "when natural background conditions exceed any applicable water quality criteria...the applicable water quality criteria shall not apply, instead, pollutant levels shall not exceed the natural background conditions, except that temperature levels may be increased above natural background conditions when allowed under Section 401" (IDAPA 58.01.02.200.09 (2002)). This change was approved by the IDEQ Board and the Idaho State Legislature, effective 15 March 2002.

3.6.1.5 PACIFIC NORTHWEST TEMPERATURE CRITERIA GUIDANCE PROJECT.

In addition to the proposed change to the Idaho standards, a much broader effort is currently underway to formulate regional temperature guidance for the Pacific Northwest. This effort, with participation from US EPA, USFWS, NMFS, the states of Idaho, Oregon and Washington, and Tribes, had been initiated to recognize and incorporate some of the natural variations in water temperature occurring throughout the region in temperature standards for the Pacific Northwest.

The goal of this project is to develop regional temperature criteria guidance that meets the biological requirements of native salmonid species for survival and recovery pursuant to ESA, provides for the restoration and maintenance of surface water temperature to support and protect native salmonids pursuant to the CWA, and meets the salmon rebuilding needs of federal trust responsibilities with treaty tribes. It is also a goal of this project that the guidance produced will recognize the natural temperature potential and limitations of water bodies. This guidance is also expected to be fashioned in a manner that will allow it to be effectively incorporated by states and tribes in water quality standards programs (US EPA, 2002).

Once this guidance is finalized, it is expected that the States and Tribes in the Pacific Northwest will use the new criteria guidance to revise their temperature standards, if necessary, and that US EPA, USFWS and NMFS will use the new criteria guidance to evaluate state and tribal standard revisions (US EPA, 2002).

These ongoing processes to effect changes to water temperature standards in the SR-HC TMDL reach will be monitored throughout this TMDL effort. If these processes result in changes to state or federal water quality criteria, such changes may be incorporated as appropriate into the SR-HC TMDL through the long-term, iterative nature of the TMDL process.

3.6.2 Designated Beneficial Use Impairment

The designated beneficial uses within the SR-HC TMDL reach determined to be most at risk from elevated water temperature were those associated with aquatic life. Both direct and indirect impacts to aquatic life are possible due to elevated water temperatures.

Direct negative effects of elevated water temperature include lower body weight, poor oxygen exchange and reduced reproductive capacity in aquatic species. Extreme high water temperatures can result in death if they persist for an extended length of time. Juvenile fish are more sensitive to temperature variations and duration than adult fish, and can experience negative impacts at lower water temperatures than adult fish.

Indirect effects associated with elevated water temperature include low dissolved oxygen concentrations due to the growth of algae in the upper water column (diurnal), and increased decomposition rate for organic materials in the lower water column. Elevated water temperatures can also lead to improved growth and decomposition conditions for aquatic nuisance growth such as algae. Appendix C contains more detailed information specific to temperature tolerances of fish species found in the SR-HC TMDL reach.

No specific data is available showing direct effects to fish or other aquatic life due to elevated water temperature in the SR-HC TMDL reach. However, information is available that show differences in fish populations relative to the availability of cool water refugia within the SR-HC TMDL system. These data, collected by IPCo fish biologists (IPCo, 2001g) show a convincing trend in population support where cold water refugia are available during periods of elevated water temperature within the mainstem Snake River. A more detailed discussion of this information is included in the following sections of this document.

Given this understanding, impairment of the salmonid rearing/cold water aquatic life designated beneficial use occurs in the Upstream Snake River segment (RM 409 to 335) where population and species diversity are limited. The salmonid rearing/cold water aquatic life designated beneficial use is supported in the other segments due to the availability of cold water refugia.

Data collected by IPCo and USFWS indicate that fall chinook spawning is occurring under existing conditions throughout the 100-mile reach of the Snake River from below Hells Canyon Dam (RM 245) downstream to Asotin WA (RM 145). While the SR-HC TMDL extends only to the confluence of the Salmon River, the entire 100 miles of the Snake River from Hells Canyon Dam downstream to Asotin, WA currently supports (to some extent) salmonid spawning activity.

Data available for the Downstream Snake River segment (RM 247 to 188) show that the salmonid spawning temperature targets are exceeded in the late fall of some years. Fall chinook have been documented to spawn in the Snake River between Hells Canyon Dam and Asotin, WA as discussed above. The majority of spawning activity occurs from mid-October through the first week of December. Currently, the peak of spawning in the river downstream of Hells Canyon Dam occurs when daily mean and maximum water temperatures are between 12 ^{o}C and l6 ^{o}C.

Data currently available on fall chinook spawning (IPCo, 2002, attachment 13 and 14) does not show impairment due to elevated water temperatures occurring in the late fall. Additionally, studies undertaken by IPCo suggest that warmer fall and winter water temperatures can cause accelerated hatching and fry development. The accelerated hatching and fry development may provide a survival benefit to out-migrating juvenile fall chinook. However, these data, and their interpretation, are preliminary and further study will help to further clarify the support status of fall chinook in this section of the SR-HC TMDL reach. Water temperature data (IPCo, 2002) collected downstream of the SR-HC TMDL reach show that the Snake River downstream of river mile 188 meets the SR-HC TMDL salmonid spawning targets during this time period (October/November).

It is recognized that water temperature is only one component of salmonid spawning habitat requirements. The ability to maintain stable flows during the spawning period provides benefits to salmonid spawning. Stable flows provide redd protection and minimize de-watering during the incubation period.

3.6.3 Sources

Elevated water temperature increases in the SR-HC TMDL reach are the result of a combination of sources. Both natural and anthropogenic sources of temperature are present in the SR-HC TMDL drainage. Anthropogenic sources of temperature loading to this reach include both point and nonpoint sources in the form of point source discharges, agricultural and stormwater drains, and tributary inflows.

3.6.3.1 Natural Sources.

Natural heat exchange through elevated air temperatures and direct solar radiation on the water surface play a major role in summer water temperatures. Both the mainstem Snake River and the inflowing tributaries drain basins located in hot, dry climates (See Figure 2.3 for average daily air temperatures in the SR-HC TMDL reach). These river systems are characteristically wide and relatively slow moving in the lower portions of their respective watersheds as compared to the upper watersheds. Native vegetation in all but the headwaters of most drainages is relatively low growing and sparse and therefore provides little shading on the wider, downstream sections of these river systems. These environmental factors play a dominant role in water temperatures in the SR-HC TMDL reach.

Aerial photos taken of the mainstem Snake River in 1909 from a hot air balloon show relatively little vegetative cover on the banks of the Snake River or the tributaries (See Photo 3.6.0). One of these photos has been included on the following pages; others are available through the Oregon Historical Society (Portland, Oregon). All the photos show approximately the same low, rolling, sparsely vegetated terrain extending down to the Snake River. All show that what trees are present (mostly what appear to be juniper) are small and somewhat limited in distribution. A few, more leafy trees are visible along some of the river and tributary banks, but they are all very small in comparison to the size of the mainstem river channel. The photos clearly show the lack of ability of this vegetation to shade the mainstem Snake River, or the tributaries. They also serve to demonstrate the open nature of the river system to solar radiation and atmospheric temperature influences. These photos were obviously not taken prior to the advent of white settlers in the basin, and are not intended to represent the pre-anthropogenic condition of the Snake River, but they do help to establish an understanding of historic site vegetation in the early 1900’s, prior to extensive settlement of the area or substantial impoundment of the Snake River itself. It is recognized that migration west along the Oregon Trail, starting in the 1840's, and settlement, ranching and farming along the Snake River in the late 1800's had a substantial impact on the original vegetation bordering the Snake River and its tributaries. By 1909 the Snake River area had been grazed for a period of anywhere from decades to over half a century.

3.6.3.2 Anthropogenic Sources.

As discussed in detail in previous sections, the Snake River is a highly regulated river. Estimates indicate that nearly half the annual discharge is stored and diverted for irrigation upstream of the

Hells Canyon Complex of dams (usable storage capacity above Hells Canyon is ~10 million acre-feet, average annual runoff at Weiser, ID of 13.25 million acre-feet). With such a highly regulated system it is difficult to determine what are natural conditions for temperature, or precisely how altered current conditions are from natural conditions.

Photo 3.6.0 Aerial photograph (taken from a hot air balloon) of the Snake River near Vale, Oregon showing local vegetation in 1909. Photo courtesy of the Oregon Historical Society.

Because of its length, temperature changes in the headwaters of the Snake River cause little if any detectable change in temperature downstream, yet flow alteration due to extensive flow regulation within the Snake River system has resulted in spring flows at Weiser, Idaho that are from 20 to 30 percent lower, and late summer/early fall flows that are typically 40 percent greater than before flow regulation began (Table 2.1.0). This increase in summer flows potentially acts to decrease naturally induced heating due to meteorological effects.

Additionally, nearly all the water in the Snake River is diverted for irrigation above Milner Dam (RM 639) from July through September, often longer. Below Milner Dam the Snake River is replenished by springs fed by subsurface recharge and ground water, rapidly gaining 5,000 to 6,000 cfs in water averaging 11 ^{o}C to 13 °C, and from extensive surface water return flows with water temperatures that are potentially higher than those of the groundwater springs. During summer months the water warms rapidly as it traverses the desert canyon it has cut through Idaho's Snake River Plain. Water temperatures between 22°C and 25°C are commonly observed at RM 345, ten miles above the headwaters of Brownlee Reservoir. These water temperatures are not much different than those currently found in the Salmon River near its mouth, as shown in Figure 3.6.1.

Unlike the Snake River, discharge of the Salmon River is effectively unregulated. (While there are a few small dams in some headwater tributaries, total storage capacity is less than 0.1 percent of the Salmon's average annual runoff). Large portions of its watershed are in wilderness or roadless areas and the watershed is very sparsely populated. These factors combine to make the Salmon River, while not pristine, the most natural river of its size anywhere in the lower 48 states. It follows that its existing water temperatures are close to natural as well.

Figure 3.6.1 a shows water temperatures observed in the Salmon River just above its confluence with the Snake River for 1991 through 1999. Long-term average summer water-temperatures in the Snake River above the Salmon River, and in the Salmon River itself, show differences of less than one degree, as illustrated in Figure 3.6.1 b. The July average water temperature over a decade of monitoring was 20.0 °C in the Snake River above the Salmon River inflow (RM 188) and 19.5 °C in the Salmon River. The August average water temperature for this same time period was 21.7°C in the Snake River above the Salmon River inflow and 21.1°C in the Salmon River (personal communication, Ralph Myers, Idaho Power Company, August 2002). Snake River water temperatures below Hells Canyon Dam are closer to those measured in the Salmon River than those measured upstream of Brownlee Dam (at RM 345) from January through September.

Permitted point source discharges to the SR-HC TMDL reach include four municipal and two industrial discharges to the Upstream Snake River segment (RM 409 to 335). The combined flow from all six of these point sources averages 10.5 cfs annually (less than 1/1000 of the total mainstem flow). This flow is further reduced during the summer growing season, as the City of Ontario discharge is land applied during that time period. Three additional permitted point sources discharge to the remaining downstream segments below Brownlee Reservoir. They are all related to the operation of the Hells Canyon Complex dams and have relatively minor flow contributions (54 cfs maximum permitted flow combined, approximately 0.3 percent than of the total mainstem flow).

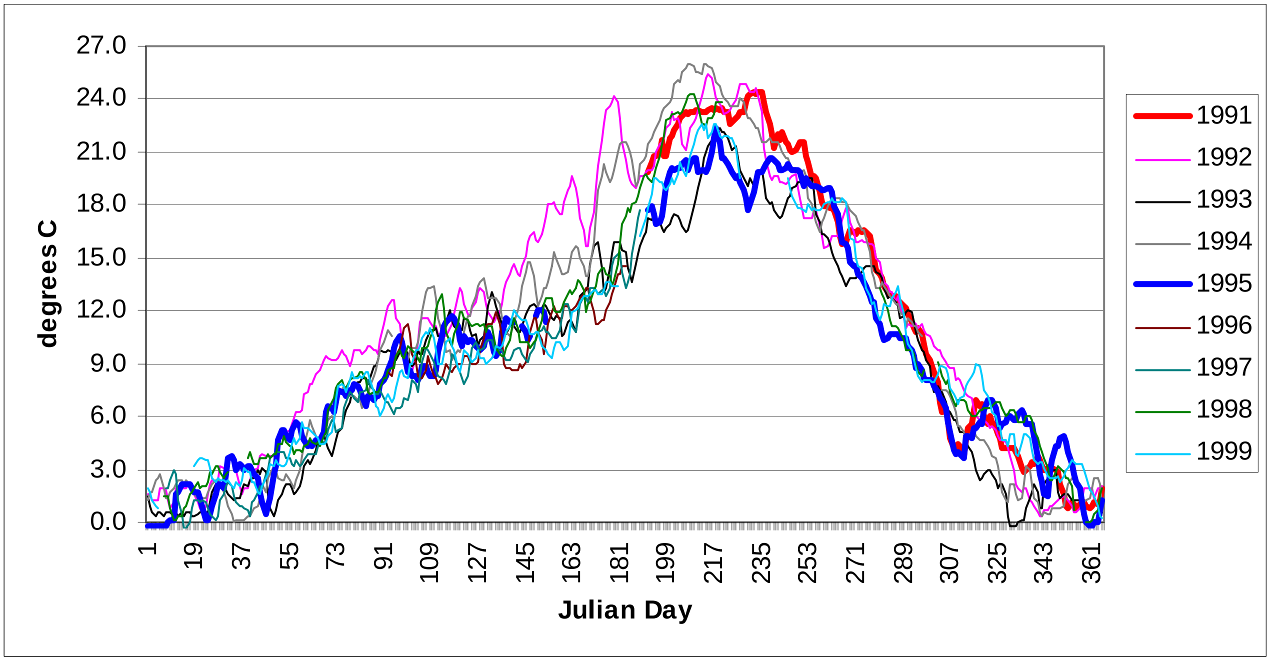


Figure 3.6.1 a. Water temperatures observed in the Salmon River near the confluence with the Snake River at Snake River mile 188. (1991 represents a low water year, 1995 represents a medium water year.)

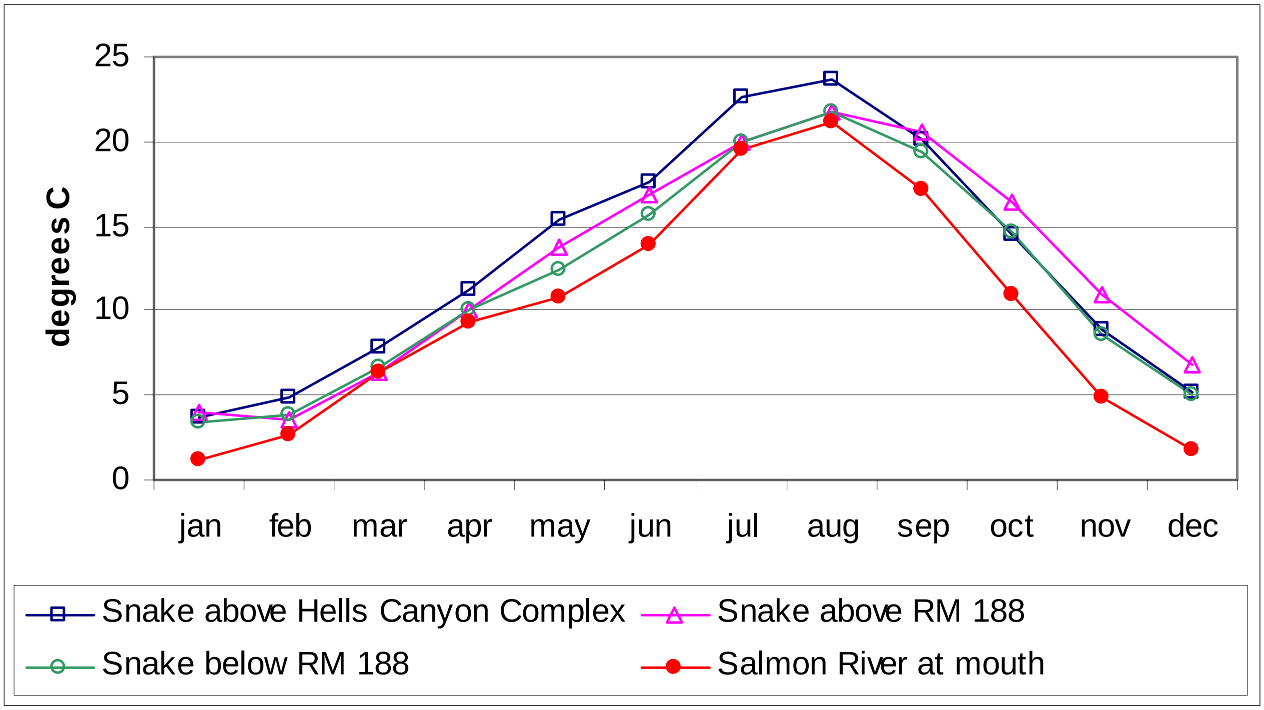


Figure 3.6.1 b. Long-term monthly mean water temperatures observed in the Snake and Salmon Rivers. (The Salmon River flows into the Snake at RM 188.)

Nonpoint sources of anthropogenic temperature increase include agricultural and stormwater drains, and tributary inflows. Agricultural, stormwater and other ungaged drains that discharge directly to the Snake River are estimated to contribute a combined flow of approximately 1,200 cfs annually (less than 8% of the total mainstem flow). Agricultural drain flows are highly seasonal in nature with the highest flow values occurring during the growing season (April to October) when irrigation is in use and very low flows, predominantly driven by precipitation or melt-off, occurring in the winter. The one exception to this trend is the conveyance of snowmelt flows in some drainages in the early spring when flows may exceed those observed during the irrigation season for short periods of time. Calculated agricultural return flows in the Upstream Snake River segment (RM 409 to 335) in the form of surface water range from 635 cfs to 764 cfs during June, July, August and September (USBR, 2001).

Tributary inflows to the SR-HC TMDL reach (including the mainstem Snake River above RM 409) total approximately 16,000 cfs annually, and approximately 14,000 cfs during the months of June, July, August and September (median water year). The tributaries to the SR-HC TMDL reach (including the mainstem Snake River above RM 409) represent the majority of the total mainstem flow. Tributary inflows are also seasonal in nature, as shown in Figure 2.8. The temperature of inflowing tributary waters is a combination of natural and anthropogenic temperature sources within the separate tributary drainages. Tributary water temperatures are seasonal in nature and generally do not deviate substantially from mainstem water temperatures during the critical months of June, July, August and September.

In addition to the above sources, ungaged flows, both ground and surface water, also represent temperature sources to the SR-HC TMDL. The annual water balance in median water years shows an average 6 percent difference (overall difference ranged from 1% to 12% depending on the specific water year) between the measured and estimated inflow and the measured instream flow. The water balance for June, July, August and September in median water years shows an average 9.7 percent difference (overall difference ranged from 5% to 14% depending on the specific month and water year) between the measured inflow and the measured instream flow. This ungaged gain/loss is due to a combination of ungaged inflows and diversions, ungaged overland runoff, ground water inflows, seepage losses, and gauge and estimation error.

3.6.3.3 ADDITIONAL CONSIDERATIONS

It is recognized by this TMDL that temperature is a highly variable pollutant and therefore needs to be addressed differently from other, conservative pollutants. These considerations and the approaches taken to identify and address these issues are discussed in the following sections.

3.6.4 Data Available for the Snake River - Hells Canyon TMDL Reach

A fairly robust data set for water temperature was available to the SR-HC TMDL effort. Temperature data has been collected over the time period from 1954 to current for both mainstem Snake River and tributary sites. Historic data gathered prior to the construction and completion of the Hells Canyon Complex have been utilized to identify pre-impoundment (Hells Canyon Complex) water temperatures. They do not represent an unregulated or un-impounded system as diversions and upstream and tributary impoundments were in place in many areas when these data were collected. They do, however, lend a better understanding of the conditions that existed in the SR-HC TMDL reach prior to the completion of the Hells Canyon Complex of dams. These data are displayed in Tables 2.3.22 and 2.3.30 and in Figures 2.3.19 and 2.3.24 in the preceding sections of this document.

Current data, collected from 1991 through 2000 is also available. Although the available data sets are not consistent in coverage, and do not always include co-monitored flow values, they are helpful in an evaluation of water temperature trends within the system. Distribution of the recent water temperature data available is shown in Table 3.6.1. A total data set is available in Appendix E.

Table 3.6.1. Distribution of recent water temperature data available for the Snake River - Hells Canyon TMDL (1990 through 2000).

Sample Site	Distribution and Duration of Temperature data available
Snake River near Murphy (RM 460 to 450)	Daily min, max, mean 03/1996 to 04/1997 06/1997 to 02/1998 04/1998 to 04/1999 10/1999 to 01/2000 04/2000 to 09/2000 11/2000 to 12/2000
Owyhee River Mouth (RM 396.7)	Daily min, max, mean 07/1996 to 08/1999 07/2000 to 08/2000 (From hourly temperature readings)
Boise River Mouth (RM 396.4)	Daily min, max, mean 11/1995 to 07/1996 05/1997 to 09/1997 11/1998 to 12/1998 01/1999 to 09/1999
Snake River at Nyssa (RM 385)	Daily mean – 04/1990 to 04/1991 Daily min, max, mean 03/1996 to 04/1999 01/2000 to 09/2000 12/2000
Malheur River Mouth (RM 368.5)	Daily min, max, mean 07/1996 to 08/1999 07/2000 to 08/2000 (From hourly temperature readings)
Payette River Mouth (RM 365.6)	Daily min, max, mean 08/1997 to 09/1997 07/1998 to 08/1998 05/1999 to 09/1999
Snake River near Weiser (RM 351 to 355)	Daily min, max, mean 03/1996 to 09/1999 01/2000 to 07/2000 10/2000 to 12/2000 RM 345, daily max, mean, min 01/1991 to 12/2001
Weiser River Mouth (RM 351.6)	Daily min, max, mean 08/1997 to 09/1997 06/1998 to 09/1998 05/2000 to 09/2000
Snake River at Porters Island (RM 340)	Daily mean – 04/1990 to 04/1991
Drains	Instantaneous measurements

Sample Site	Distribution and Duration of Temperature data available
	01/1975 to 12/1975 08/1977 05/1978 to 12/1978 01/1979 to 11/1979 01/1980 to 09/1980 (all dates not available for all drains, flow not available for all dates or drains)
Brownlee Reservoir (RM 335 to 285)	Mixed – depth and surface, not daily 03/1992 to 12/1992 03/1995 to 12/1995 03/1997 to 12/1997 03/1999 to 12/1999 Brownlee Dam outflow, daily max, mean, min 01/1991 to 12/2001
Oxbow Reservoir (RM 285 to 272.5)	Mixed – depth and surface, not daily 03/1995 to 11/1995 03/1997 to 11/1997 Oxbow Dam outflow, daily max, mean, min 01/1991 to 12/2001
Hells Canyon Reservoir (RM 272.5 to 247)	Mixed – depth and surface, not daily 01/1995 to 12/1975 01/1997 to 12/1979 Hells Canyon Dam outflow, daily max, mean, min 01/1991 to 12/2001
Downstream Snake River Segment (RM 247 to 188)	Mixed 01 to 12/1975 to 1989, not daily (all dates not available for all years) RM 239 to 192, daily max, mean, min 01/1991 to 12/2001

Data in this table are from US EPA STORET, 1998a; IPCo, 1999a, 2000a, 2000c and USGS, 1999.

3.6.5 Existing Conditions and Observed Water Temperatures

Figure 3.6.2 a shows the daily maximum water temperatures at several locations in the SR-HC TMDL reach. Data displayed is from 1999 and 2000 (relatively average water years). For the sake of comparison, similar data from 1990 and 1991 (relatively low water years) has been plotted for those locations for which it is available. As evidenced by the following plots, the absolute magnitude of change is specific to the data plotted, but the overall trends are consistent from year to year. The temperature of water inflowing from the upstream Snake River at RM 409, and the water temperature at all monitored locations within the SR-HC TMDL reach is often substantially warmer than the salmonid rearing/cold water aquatic life criterion during the summer months, especially July and August. By contrast, the water released from Brownlee, Oxbow and Hells Canyon dams is substantially cooler and does not show as great or extensive a level of exceedence.

3.6.5.1 Upstream Snake River Segment.

As water moves downstream within the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach, it gradually becomes warmer, and its temperature fluctuates more widely over time. Direct measurement of water temperature in the Snake River inflowing at RM 409 is not available. Measurements taken at Murphy, Idaho (RM 453.5) located upstream of the

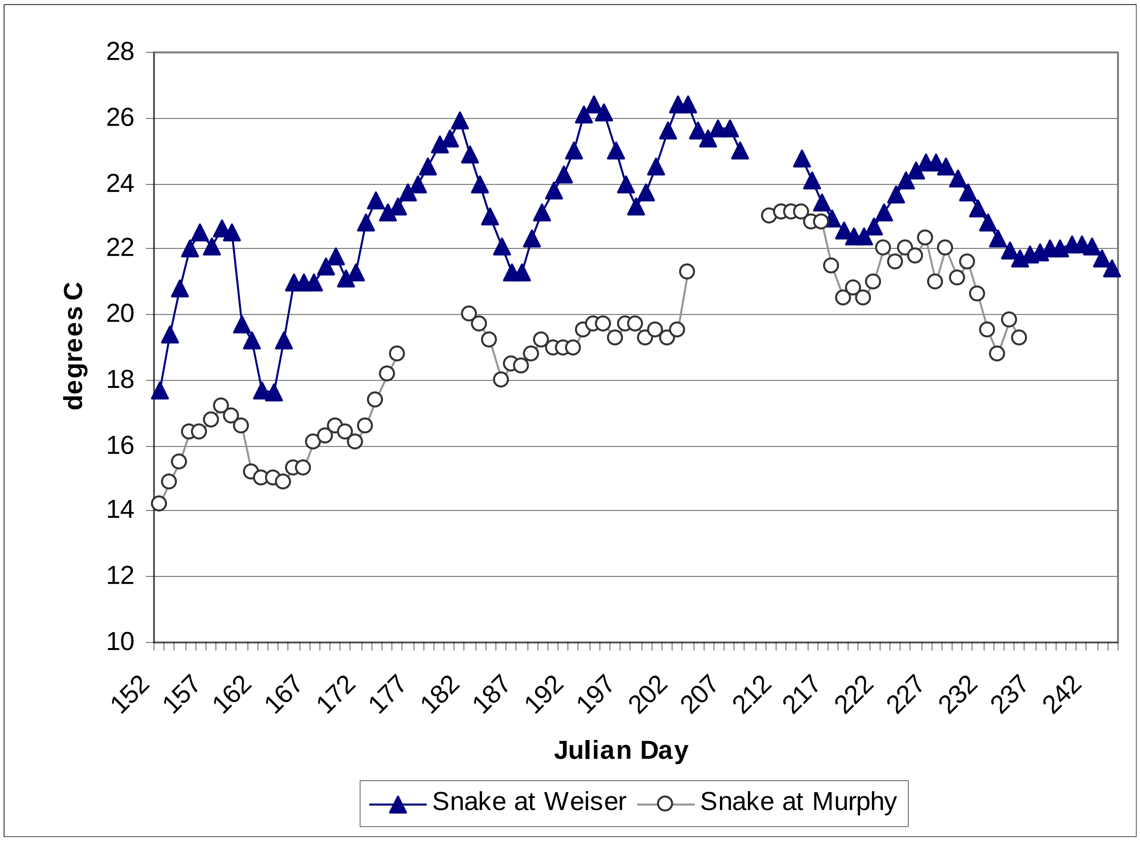


Figure 3.6.2 a – average water year. Daily maximum water temperatures observed in the Upstream Snake River segment (RM 409 to 335) of the Snake River - Hells Canyon TMDL reach, June 01 through August 30 1999-2000. (Precipitation in 1999 and 2000 was approximately 118% of the 30-year average.)

Idaho/Oregon border, show that the mainstem Snake River meets water quality criteria established for the support of salmonid rearing/cold water aquatic life from the first of September through the middle of June. Water temperatures at this site are above 17.8 ^{o}C from late June through late September (Julian days 177 to 265) in an average water year. In a dry water year this time period increases to include nearly the entire month of June.

Water temperatures rise gradually through the months of May and June, commonly peaking near 23 ^{o}C at the beginning of August and then decrease steadily through the month, reaching temperatures below the target by early September. Figure 3.6.2 a shows water temperatures throughout the summer for an average and a dry year in the Upstream Snake River segment (RM 409 to 335). Water temperatures above the 17.8 ^{o}C occur from early July through the end of August (Julian days 182 to 243). Given the above information, the critical time period for salmonid rearing/cold water aquatic life in the SR-HC TMDL reach includes the months of June, July, August and September. These values are tabulated in Table 3.6.2.

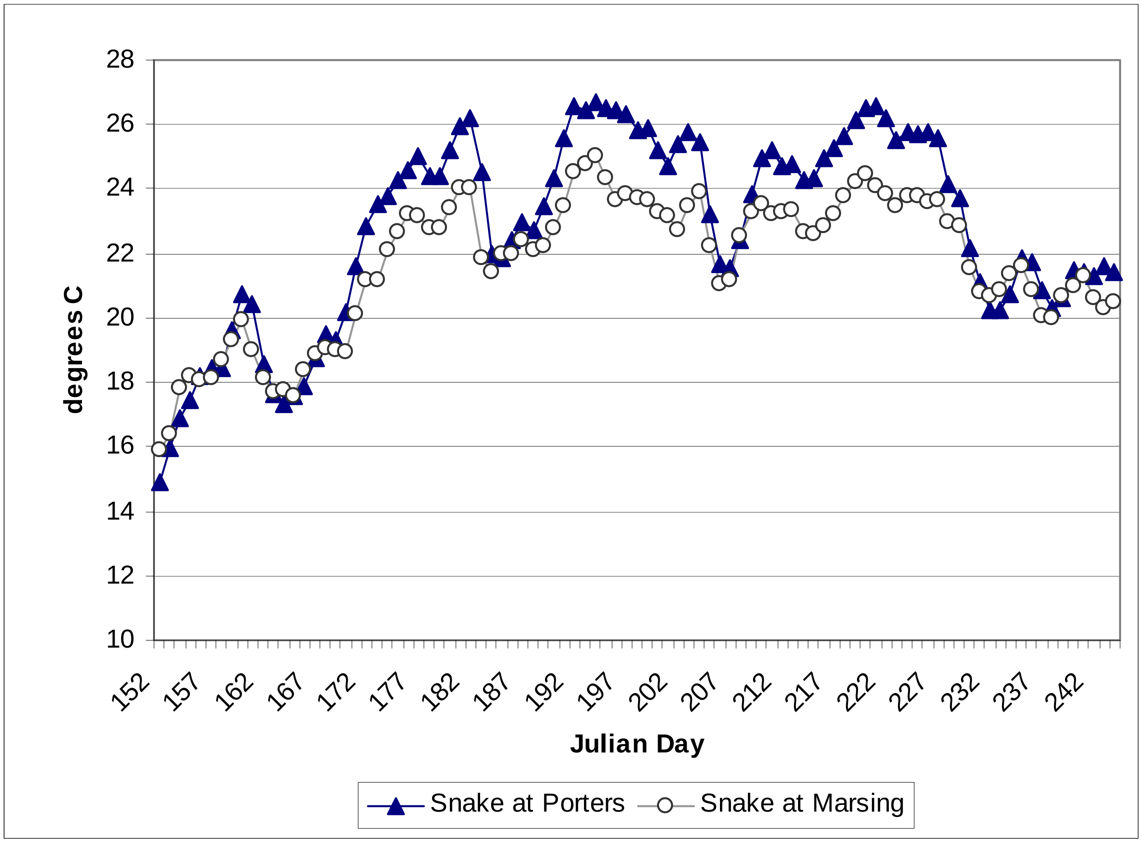


Figure 3.6.2 a – low water year. Daily maximum water temperatures observed in the Upstream Snake River segment (RM 409 to 335) of the Snake River - Hells Canyon TMDL reach, June 01 through August 30 1990 to 1991. (Precipitation in 1990 and 1991 was approximately 54% of the 30-year average.)

The trend observed in the mainstem Snake River near Murphy, Idaho (RM 453.5) is repeated in data collected downstream near Weiser, Idaho (RM 351). Temperatures observed in the mainstem Snake River near Weiser, Idaho (RM 351) show that the mainstem Snake River meets the water quality targets established for the support of salmonid rearing/cold water aquatic life from the first of October through the end of May. Routine, nearly continuous exceedences of the 17.8 °C target value are observed in the months of June, July, and August (Julian days 152 to 242) in both average and dry water years. Consistent daily maximum water temperature data is not available for September but the trend in water temperature evident at the end of August would project that exceedences would potentially occur through most of September (Julian days 243 to 274). Water temperatures in this section of the river rise gradually through the month of May, commonly peaking near 26 °C near the middle of July and then decrease through August and September, reaching temperatures below the 17.8 °C target in October.

In general, in an average water year, water temperatures measured in the mainstem Snake River near Weiser are approximately 5 °C higher than those observed near Murphy during early to mid-summer (4.8 °C in June, 4.9 °C in July). During the month of August, this difference narrows to approximately 2.2 °C as mainstem water temperatures begin to decrease within the Snake River system.

Table 3.6.2. Time periods of temperature target and standard exceedence for the Upstream Snake River segment (RM 409 to 335) of the Snake River - Hells Canyon TMDL reach.

	Target or standard value	Days at or below the target value	Days consistently greater than target value
Snake River at Murphy			
SR-HC TMDL salmonid rearing/cold water aquatic life target (State of Oregon salmonid rearing standard)	17.8 °C 7-day daily maximum average water temperature	01 Sept to 22 June (244 to 173)	23 June to 31 Aug (174 to 243)
State of Idaho cold water aquatic life temperature standard	22 °C instantaneous temperature	17 Aug to 29 July (229 to 210) 05 Aug to 09 Aug (217 to 221)	30 July to 04 Aug (211 to 216) 10 Aug to 16 Aug (222 to 228)
State of Idaho cold water aquatic life temperature standard	19 °C maximum daily average water temperature	01 Sept to 30 June (244 to 181)	01 July to 31 Aug (182 to 243)
Snake River at Weiser			
SR-HC TMDL salmonid rearing/cold water aquatic life target (State of Oregon salmonid rearing standard)	17.8 °C 7-day daily maximum average water temperature	02 Oct to 31 May est. (275 to 151)	01 June to 01 Oct est. (152 to 274)
State of Idaho cold water aquatic life temperature standard	22 °C instantaneous temperature	31 Aug to 03 June (243 to 154) 09 June to 20 June (160 to 171) 05 July to 06 July (186 to 187) 23 Aug to 25 Aug (235 to 237)	04 June to 08 June (155 to 159) 21 June to 04 July (172 to 185) 07 July to 22 Aug (188 to 234) 26 Aug to 30 Aug (238 to 242)
State of Idaho cold water aquatic life temperature standard	19 °C maximum daily average water temperature	11 June to 12 June (162 to 163) 16 Sept to 01 June (259 to 152)	02 June to 10 June (153 to 162) 13 June to 15 Sept est. (164 to 258)

Julian days are given in parentheses below the calendar dates

In general, in a dry water year, much smaller differences upstream to downstream are observed in water temperatures measured in the mainstem Snake River. Water temperatures measured near Porters Island (downstream of Weiser) are approximately 1 °C higher than those observed near Marsing (downstream of Murphy) during the early to mid-summer (0.8 °C in June, 1.5 °C in July). During the month of August, this difference narrows to approximately 1.1 °C as mainstem water temperatures begin to decrease within the Snake River system.

3.6.5.2 Brownlee Reservoir Segment.

Temperatures recorded historically (1957) at the Brownlee Dam-site prior to construction show that the average daily maximum water temperature in the river was 18.6 °C during June, 22.1 °C during July, 21.2 °C during August and 18.3 °C during September. Mean daily average water temperatures for this year showed that the water temperature exceeded 17.8 °C for the June through September time period and exceeded 19 °C during the months of July and August. During the month of July, daily maximum water temperatures averaged greater than 22 °C

(Table 2.3.21 and Figure 2.3.23). While these data do not represent pristine conditions (there were impoundments upstream at this time), they demonstrate quite conclusively that elevated water temperatures (above target values) do not occur solely as the result of the Hells Canyon Complex of impoundments within the SR-HC TMDL reach.

As identified in the previous discussion, water flowing into Brownlee Reservoir from the Upstream Snake River segment (RM 409 to 335) is often warmer than the salmonid rearing/cold water aquatic life maximum criterion during the summer months. Within the reservoir, the surface waters continue to warm as they move downstream, while deeper waters cool. A report on Brownlee Reservoir authored by IPCo in 1999 (IPCo, 1999d) states that Brownlee Reservoir consistently experiences thermal stratification during summer months, with the thermocline forming near the elevation of approximately 1948 ft (~37 m below the surface elevation at full pool) and extending approximately 25 miles upstream of the dam (Figure 3.6.2 b). The reservoir is typically stratified from March until November.

Surface waters in the reservoir are often warmer than the salmonid rearing/cold water aquatic life maximum criterion during the summer months. The temperature of hypolimnion waters is generally less than 10 °C, while surface water temperatures can reach above 26 °C. The strongest thermal stratification occurs during the months of July and August. Cooling starts to occur in surface waters in September, leading to a gradual breakdown of stratification in November.

Data collected by IPCo in 1992, 1995 and 1997 (Figure 3.6.2 b) show that maximum surface water temperatures generally range from 20 °C to 23 °C in early July to 23 °C to 26 °C in August. The Brownlee Reservoir Model Report (IPCo, 1999d) states that a maximum surface water temperature of 29 °C was recorded near Brownlee Dam. Minimum surface water temperatures observed in the report (surface to a depth of 50 feet) ranged from 18 °C to 20 °C in early July and 20 °C to 22 °C in August in 1992 and 1995. Surface waters exceeded 24 °C in August.

In 1995, a reasonably average year, instantaneous measurements of surface water temperature (<1 m below the surface) averaged 13.5 °C during May, 18.4 °C during June, 24.0 °C during July, 23.7 °C during August, 20.3 °C during September and 17.1 °C during October. Instantaneous water temperature data collected at a depth of 15 m (45 feet) averaged 12.2 °C during May, 17.3 °C during June, 20.5 °C during July, 21.7 °C during August, 20.6 °C during September and 16.3 °C during October. Similar data, collected by the Boise City Public Works in 1999 (BCPW, 2001), show surface water temperatures that ranged from 19 °C to 25 °C in July, and 22 °C to 26 °C in August. Temperatures near the metalimnion ranged from 19 °C to 23 °C in July and from 22 °C to 23 °C in August. Deep (hypolimnetic) water temperatures ranged from 12 °C to 15 °C in July and from 12 °C to 14 °C in August over the same time period.

The stratification of the reservoir and the resulting water temperature ranges are dependent on the operation of the reservoir as a mechanism for flood control. The Brownlee Reservoir Model Report (IPCo, 1999d) compares 1992 data to 1997 data to illustrate this difference (Figure 3.6.2, 1992 and 1997). In 1992, relatively low precipitation levels necessitated little drawdown for flood control purposes, while above average precipitation levels in 1997 necessitated substantial drawdowns. During the summer of 1997, the report states that the volume of water in the reservoir below 10 °C was nearly nonexistent due to heating from shallow depths and delayed

Figure 3.6.2 b – 1992 Temperature isopleths for Brownlee Reservoir for June, July and August of 1992 (a dry water year). (Data collected and plotted by Idaho Power Company.)

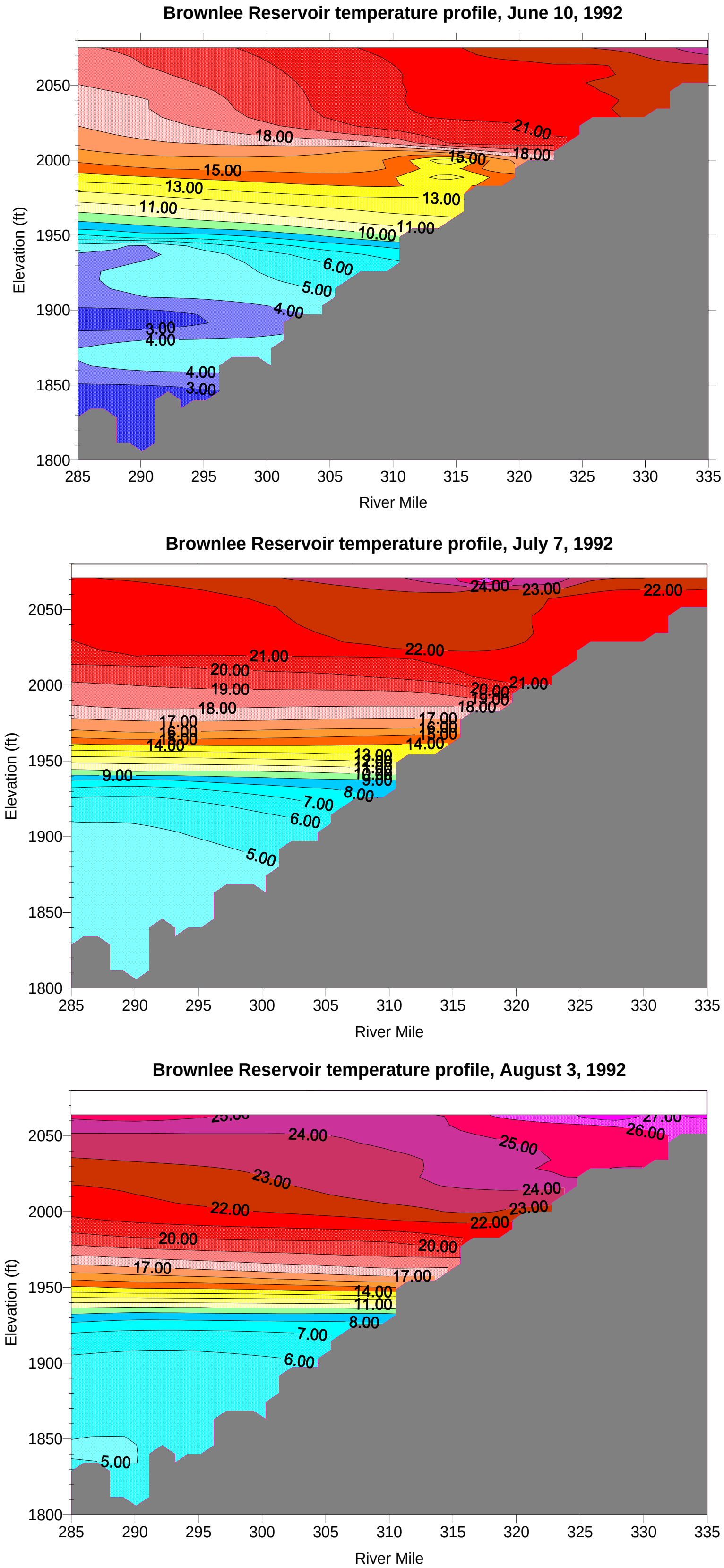
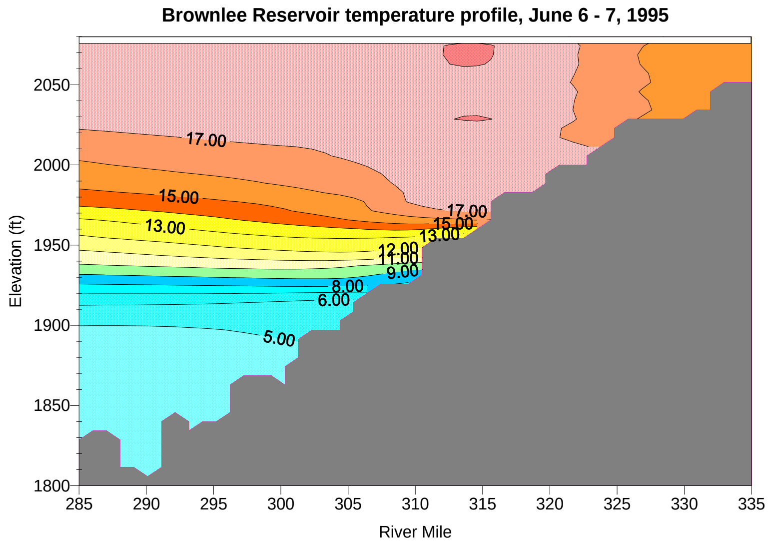
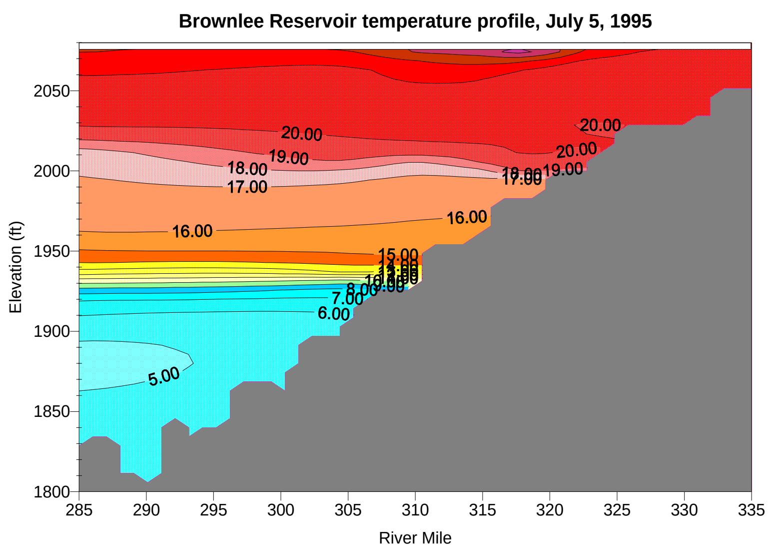


Figure 3.6.2 b – 1995 Temperature isopleths for Brownlee Reservoir for June, July and August of 1992 (an average water year). (Data collected and plotted by Idaho Power Company.)





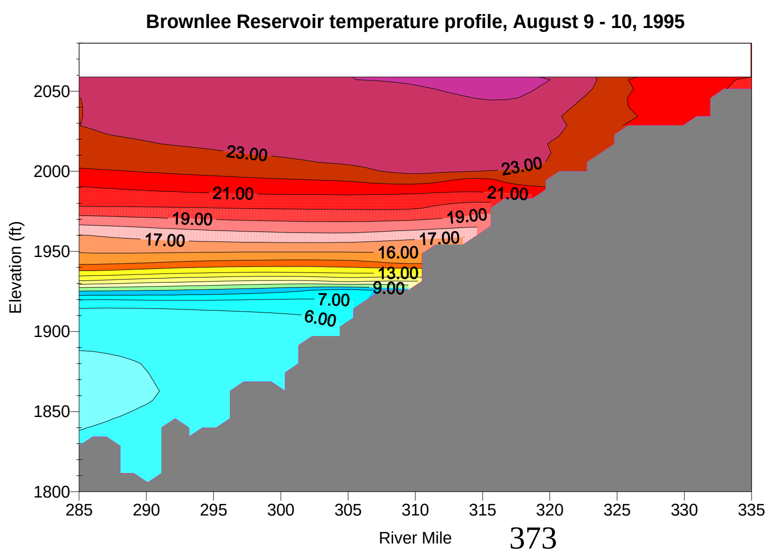
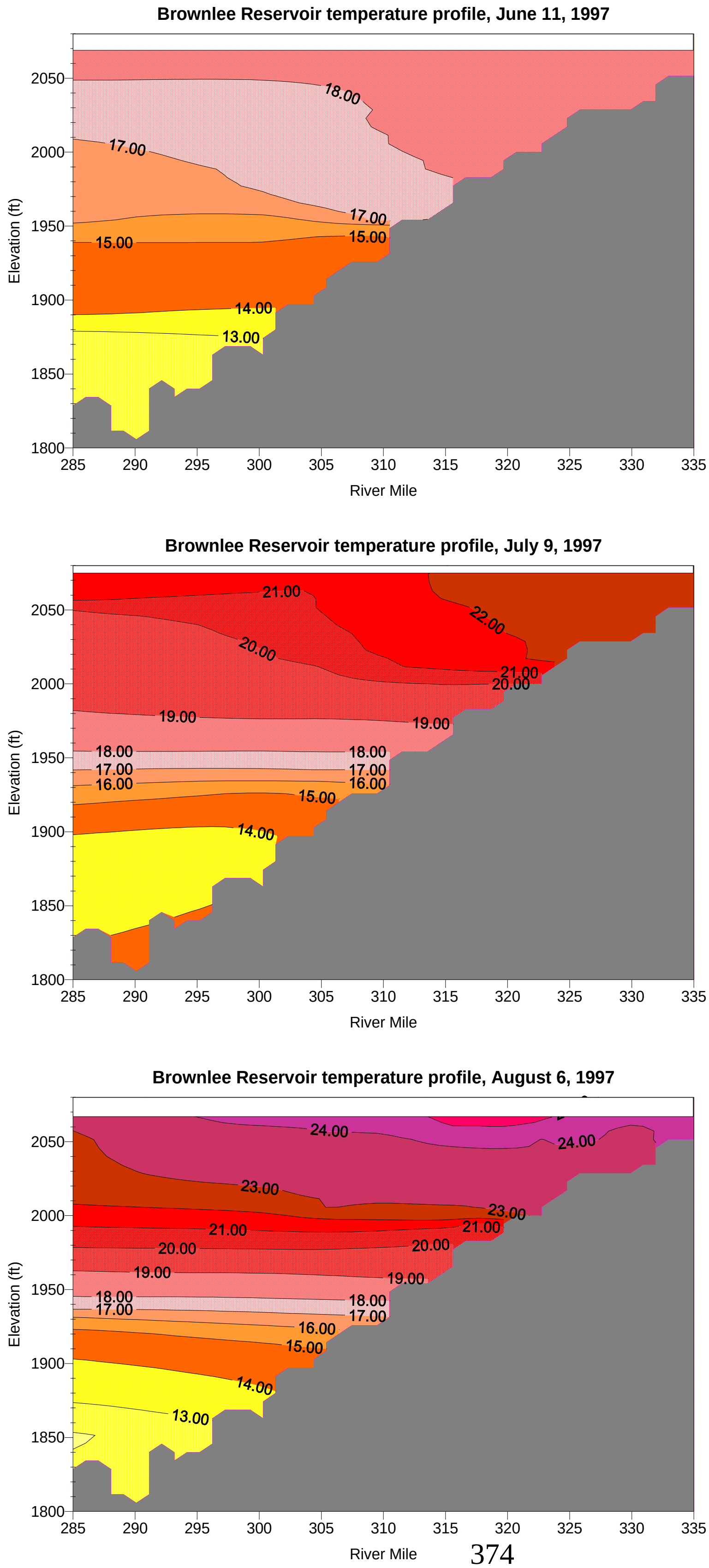


Figure 3.6.2 b – 1997 Temperature isopleths for Brownlee Reservoir for June, July and August of 1992 (a high water year). (Data collected and plotted by Idaho Power Company.)



storage. Water temperatures at the thermocline in July of 1992 were approximately 11 ^{o}C, in July of 1997 the temperature was approximately 17 ^{o}C. Similarly, hypolimnion temperatures for the two years were 5 ^{o}C and 13 ^{o}C, respectively. Substantial drawdown within the reservoir system results in higher overall water temperatures due to more effective heating within the shallower reservoir depths, and less storage of cold, snow-melt runoff water. Figure 3.6.2 b, from the Brownlee Reservoir Water Quality and Model Development Report (IPCo, 1999d) illustrates the temperature variability within the reservoir and the influence of drawdown timing and magnitude on water temperatures during the summer months.

The greater surface area of Brownlee Reservoir allows more solar and atmospheric influence on temperature within the surface water layers. However, increasing depth and channel width act to cool the majority of the water volume below the inflow temperature. While water at the surface in Brownlee Reservoir is observed to exceed the salmonid rearing/cold water aquatic life maximum criterion during the summer months, water in deeper layers of the reservoir is substantially cooler and does not show as great or extensive a level of exceedence.

3.6.5.3 Oxbow Reservoir Segment.

Temperatures recorded historically (1954 to 1957) at the Oxbow Dam-site prior to construction (Table 2.3.30) show that the average daily maximum water temperature in the river was greater than 17.8 ^{o}C from June through September for all four years. The trend observed here shows a pattern very similar to that observed at the Brownlee Reservoir Dam-site prior to construction. While these data do not represent pristine conditions (there were impoundments upstream at this time), they demonstrate quite conclusively that the elevated water temperatures (above target values) currently observed do not occur solely as the result of the Hells Canyon Complex of impoundments within the SR-HC TMDL reach.

Oxbow Reservoir is a moderately sized, run-of-river reservoir, and water passes through very quickly (approximately 1.4 days). As shown by the temperatures in the metalimnetic waters of Brownlee Reservoir, water flowing into Oxbow Reservoir is often cooler than the river inflow to Brownlee Reservoir. The majority of the water flowing into Oxbow Reservoir is released from the outlet of Brownlee Dam. Water released from the outlet of the dam is from the lower water column of Brownlee Reservoir and therefore remains cooler during summer months than surface water layers. Water temperature data available to this TMDL effort for the downstream portion of Oxbow Reservoir are very limited, and most were collected in the mid to late 1970's.

In the absence of a complete, reservoir-wide data set, this TMDL effort recognizes that most of the water entering Oxbow Reservoir is from the outlet of Brownlee Dam (Figure 3.6.2 c). The temperature of water introduced into Oxbow is generally cooler than that of the surface waters upstream of Brownlee Dam. Temperature ranges and depth related trends are expected to mimic those observed in Brownlee Reservoir. As Oxbow is a small, run-of-river reservoir, water passes through very quickly, and an increase in water temperature is more likely to be observed at the downstream end of the reservoir as a result of atmospheric conditions than at the immediate outlet of the dam.

The small data set available for downstream portions of Oxbow Reservoir contains only instantaneous measurements of surface water temperature, not daily maximum temperatures and

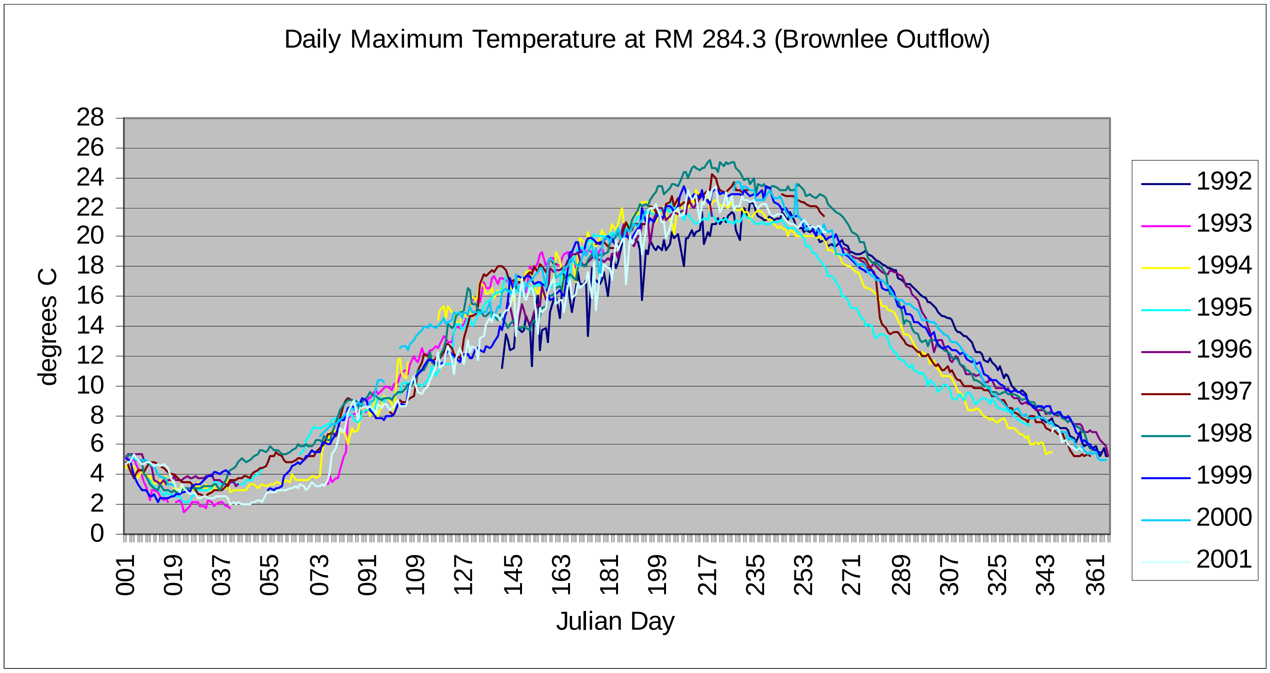


Figure 3.6.2 c Water temperatures observed at the outflow of Brownlee Reservoir in the Oxbow Reservoir segment (RM 285 to 272.5) of the Snake River - Hells Canyon TMDL reach.

therefore cannot be used to determine whether or not an exceedence of water quality standards or target values has occurred. However, the limited data available show that surface water near the dam (at RM 272.3) in Oxbow Reservoir is at slightly warmer temperatures than those measured at the outlet of Brownlee Dam in the early summer (approximately 2 ^{o}C during the month of June). This difference decreases later in the summer when the water entering Oxbow from Brownlee Reservoir upstream is warmer (0.5 ^{o}C increase). Water temperature overall increases during summer months. Instantaneous surface water temperature data collected at RM 284.3 are routinely above 17.8 ^{o}C from July through September (Julian days 182 through 273). The fact that the majority of water discharging into Oxbow Reservoir exhibited water temperatures above 17.8 ^{o}C indicate that surface water temperatures in downstream portions of Oxbow Reservoir were, most likely, also above 17.8 ^{o}C during this same time frame.

Similar to the trends observed in Brownlee Reservoir, increasing depth and channel width in Oxbow Reservoir act to minimize the effect of natural sources of warming in the majority of the water volume.

3.6.5.4 Hells Canyon Reservoir Segment.

Surface water temperature data is not available for downstream portions of Hells Canyon Reservoir. The majority of the water entering Hells Canyon Reservoir is from the outlet of Oxbow Dam (Figure 3.6.2 d), and is somewhat cooler than that of surface waters upstream of Oxbow Dam.

Hells Canyon Reservoir is a moderately sized, run-of-river reservoir, and water passes through very quickly (approximately 4 days). An increase in surface water temperature is more likely to

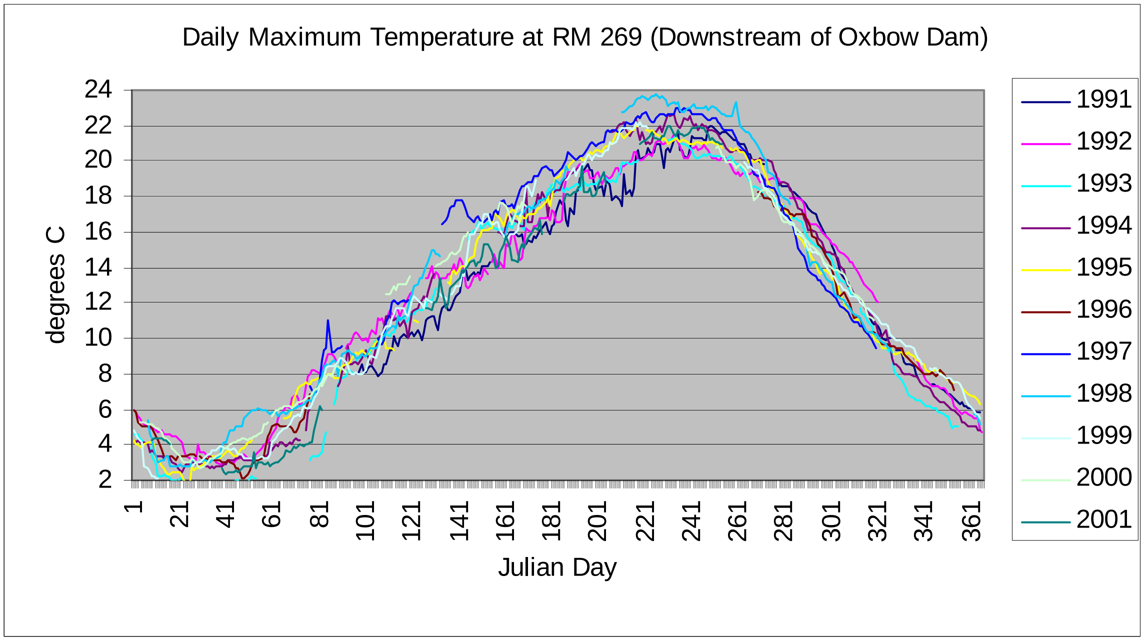


Figure 3.6.2 d. Water temperatures observed downstream of the outflow of Oxbow Reservoir (RM 269) in the Hells Canyon Reservoir segment (RM 272.5 to 247) of the Snake River - Hells Canyon TMDL reach.

be observed at the downstream end of the reservoir as a result of atmospheric conditions than at the immediate outlet of the dam. Data collected from downstream of the outlet of Oxbow Dam (RM 269) between 1991 and 2001 show water temperatures above 17.8 °C during the months of July, August and September (Julian days 182 through 273). The fact that the majority of water discharging into Hells Canyon Reservoir exhibited water temperatures above 17.8 °C indicate that surface water temperatures in downstream portions of Hells Canyon Reservoir were, most likely, also above 17.8 °C during this same time frame.

Similar to the trends observed in the upstream reservoirs (Brownlee and Oxbow), increasing depth and channel width in Hells Canyon Reservoir act to minimize the effect of natural sources of warming in the majority of the water volume.

3.6.5.5 Downstream Snake River Segment.

Water moving through the outlet of Hells Canyon Dam represents the dominant source of flow to the Downstream Snake River segment (RM 247 to 188). Water temperature data available for the Downstream Snake River segment includes three years of monthly average temperatures from June 1955 through June 1958 at RM 203 below the Hells Canyon dam, and 10 years (1991 through 2001) of daily minimum, mean and maximum water temperature data provided by IPCo for various sites within the Downstream Snake River segment (RM 247 to 188). Water temperatures measured immediately downstream from the outlet to Hells Canyon Dam (Figure 3.6.2 e) show exceedences of the 17.8 °C target in July, August, and September (Julian days 182 through 273). Water temperatures further downstream of the outlet of Hells Canyon Dam (Figure 3.6.2 f), show summer high temperatures above 17.8 °C for most of June, July, August and September (Julian days 152 through 273).

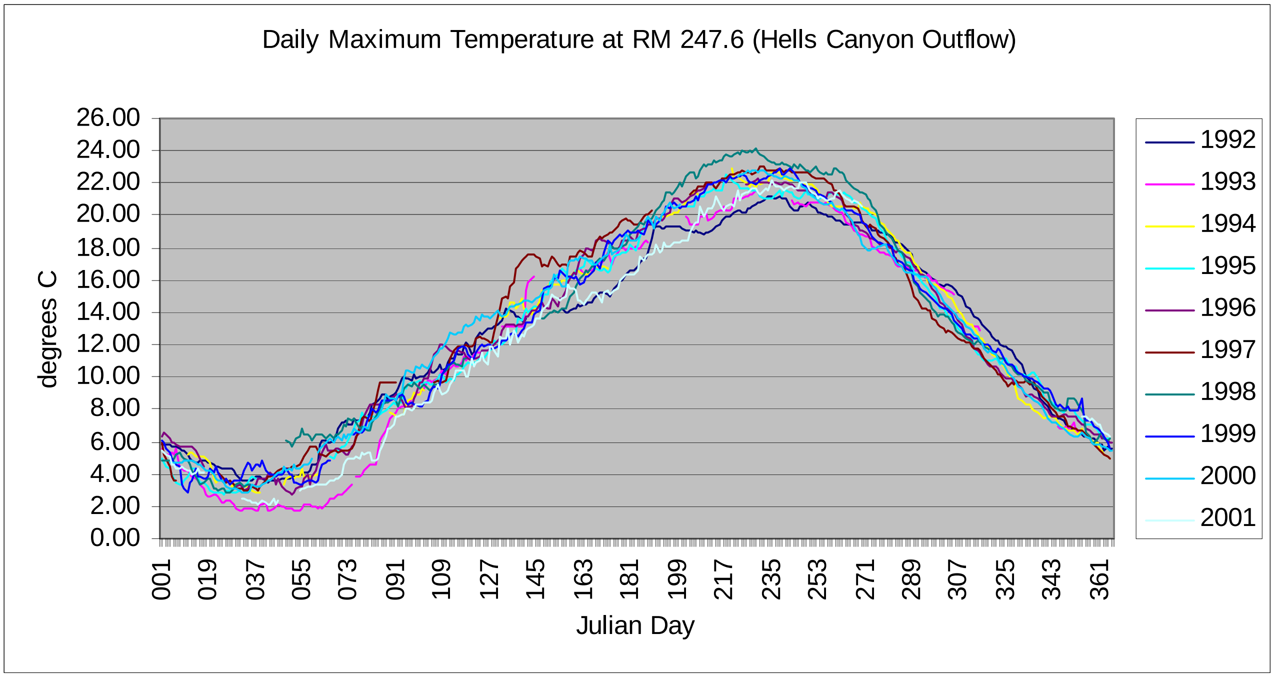


Figure 3.6.2 e. Water temperatures for the Downstream Snake River segment (RM 247 to 188) of the Snake River - Hells Canyon TMDL reach near Hells Canyon Dam.

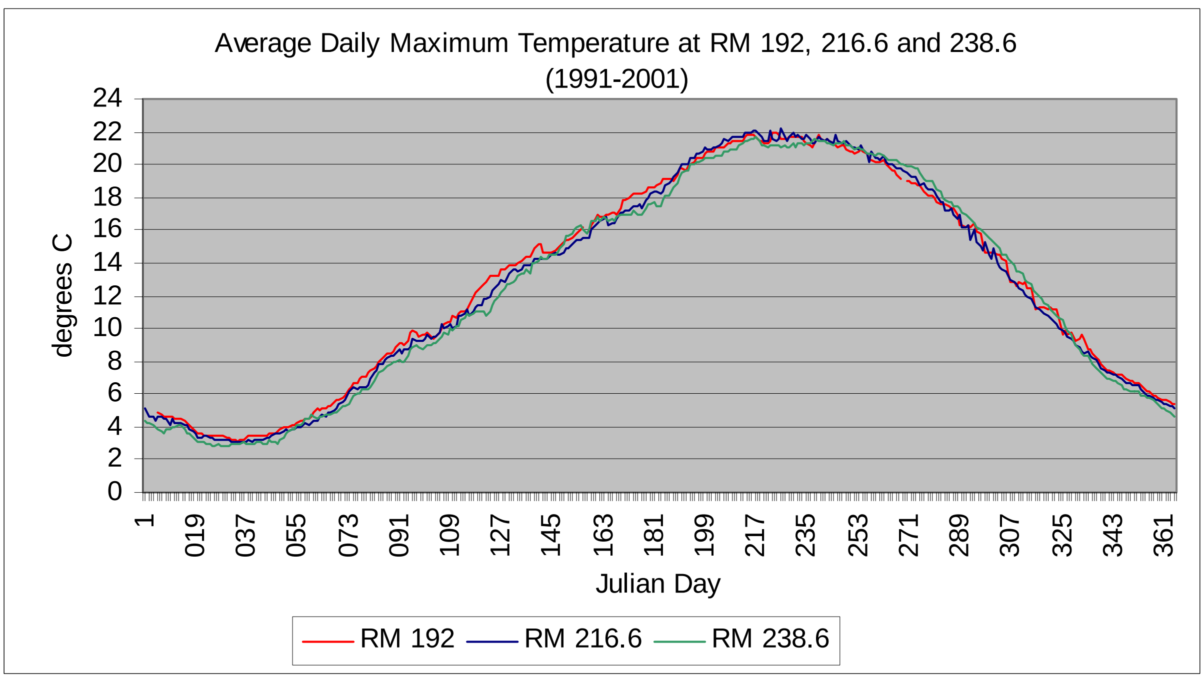


Figure 3.6.2 f. Water temperatures for the Downstream Snake River segment (RM 247 to 188) of the Snake River - Hells Canyon TMDL reach.

Average conditions over the 10 year time period available, as plotted in Figure 3.6.2 f, show only minor temperature change occurring between the outlet of Hells Canyon Dam (RM 247) and the inflow of the Salmon River (RM 188). A more discernable, general trend in water temperature can be observed over the course of a single year as in Figure 3.6.2 g, where fall water temperatures leaving Hells Canyon Dam are slightly warmer than those downstream.

During the early summer months (20 June to 03 August, Julian day 170 to 215), as water moves downstream, temperatures at RM 192 are observed to be slightly warmer (by approximately 0.4 ^{o}C maximum in 1995) or very similar to water temperatures near the outlet of Hells Canyon Dam (RM 239). The opposite trend is observed in the later summer months (08 August to 01 October, Julian day 220 to 274) when temperatures at RM 192 are slightly cooler than water temperatures near the outlet of Hells Canyon Dam (RM 239) (by approximately 0.7 ^{o}C maximum in 1995). Water temperatures observed at RM 192 are essentially the same as those observed at RM 239 during the mid-summer months (Julian days 194 to 220). However, the magnitude of the observed changes is very small and may represent less of an overall temperature change than the diurnal variations observed for this reach of the river.

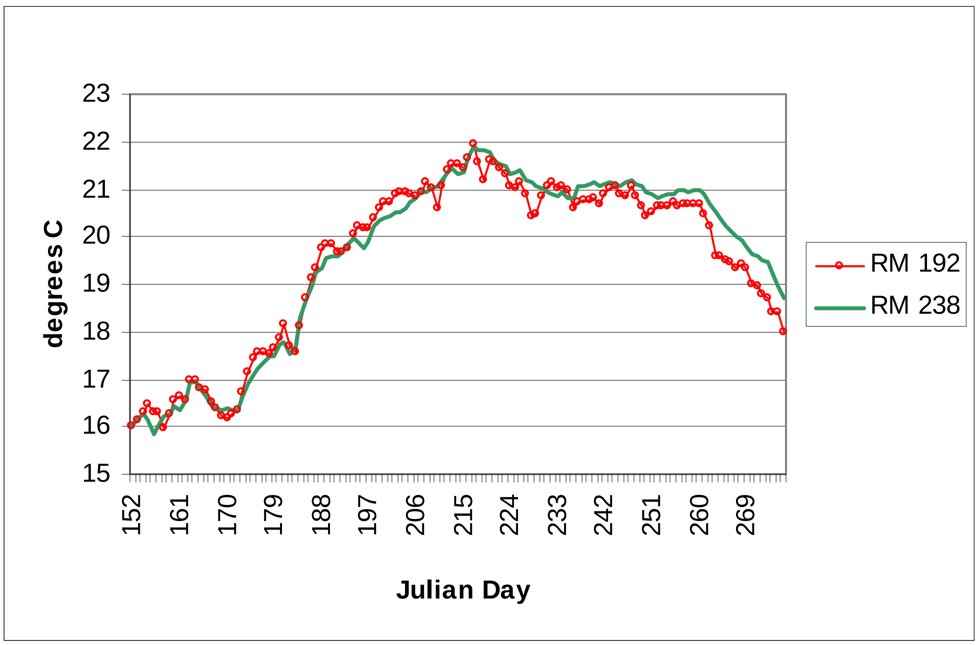


Figure 3.6.2 g. Water temperatures near the outflow of Hells Canyon Dam (RM 238) and above the inflow of the Salmon River (RM 192) measured June through September of 1995.

Water temperatures in the Downstream Snake River segment (RM 247 to 188) are shown in Figure 3.6.2 h for the 1950s, pre-construction of the Hells Canyon Complex and the 1990s, post-construction. Pre-construction water temperature data is available for RM 203, (approximately 44 miles downstream of the Hells Canyon Dam-site) for water years 1955 through 1958 as monthly averages. Water years 1955 and 1959 are slightly below average (75% and 73% of the 50-year average respectively), 1958 is close to an average water year (102% of the 50-year average), and 1956 and 1957 are slightly above average water years (116% and 113% of the 50-year average respectively). These data are not intended to represent natural temperature

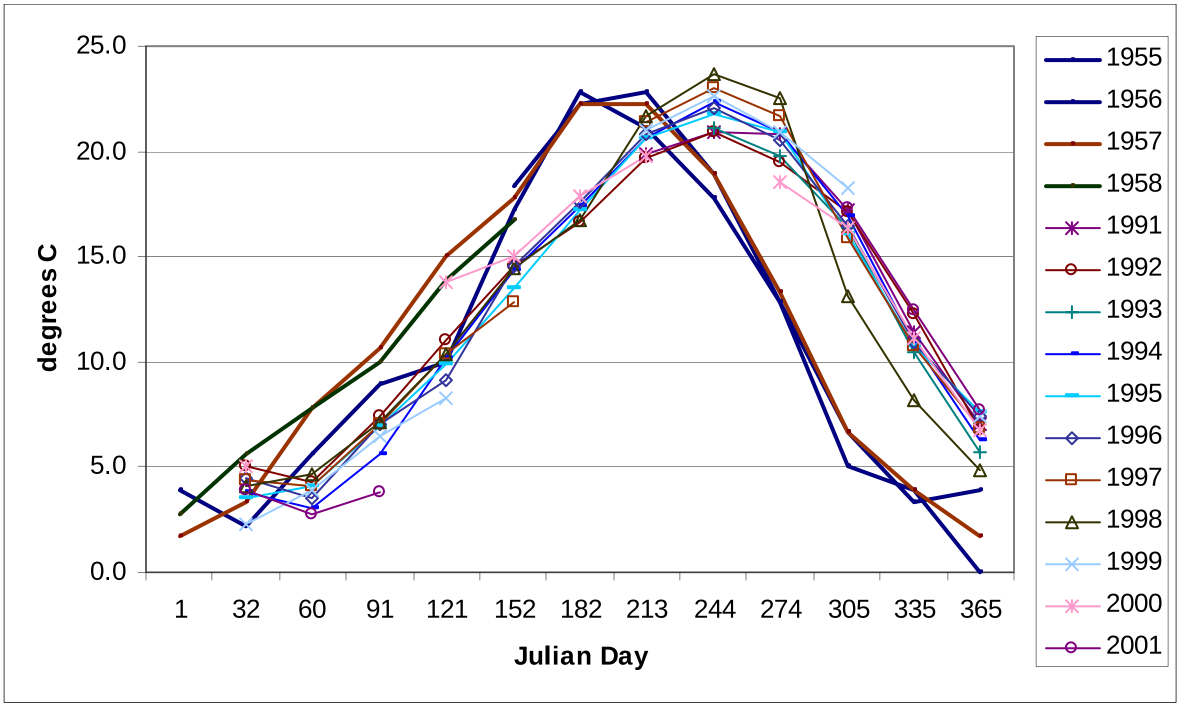


Figure 3.6.2 h. Comparison of the monthly average of daily maximum water temperatures below Hells Canyon Dam pre-construction (RM 203) and post-construction (RM 202).

conditions as a substantial level of diversion and impoundment was occurring upstream when the data were collected.

Post-construction water temperature data is available for RM 202 (1991 through 2001) that covers a range of water years including 1995, a close to average water year (94% of the 50-year average), 1996, a high water year (131% of the 50-year average), and 1991, a low water year (55% of the 50-year average). Data was provided as daily maxima, minima and mean water temperatures (IPCo, 2002). Daily mean water temperatures were averaged to monthly means to provide consistency in this comparison (Figure 3.6.2 h). The water temperature data available for this segment show that monthly average water temperatures are in excess of the 17.8 ^{o}C salmonid rearing/cold water aquatic life target from mid-June through mid-September, Julian days 170 through 265 for pre-construction data (approximately 90 days total). Post-construction data show exceedences occur between the first week of July and mid-October, Julian day 182 through 295 (approximately 113 days total). However, the overall shape of the curve observed on the downsloping side of the post-construction plots does not appear different from the pre-construction plots, only the timing is changed. Additionally, while these periods of exceedence are temporally shifted by approximately two weeks, they are of very similar duration.

The 1950s data pre-dates completion of the three Hells Canyon Complex dams. Data from 1991 through 2001 are representative of post-construction conditions. In both cases, exceedences of the 17.8 ^{o}C salmonid rearing/cold water aquatic life target occurred. This comparison demonstrates quite clearly that changes in water temperature specific to the impoundments in the SR-HC TMDL reach are related to how the water is processed through the Hells Canyon

Photo 3.6.1. Snake River at approximately RM 250, near the Hells Canyon Dam site, circa 1939 to 1940. This photo was proposed to be used for a state stamp. Photo from the collection of Dr. Lyle M. Stanford.

Complex. The impoundments themselves do not act as heat sources, but rather act to delay temperature changes within the mainstem Snake River downstream. The water temperature curve described by the post-construction data shows a shifted temporal distribution where water temperatures following construction of the Hells Canyon Complex reservoirs are slightly warmer for longer in the fall and cooler for longer in the spring. Upstream sources of elevated water temperature, many potentially in place prior to the completion of the Hells Canyon Complex, are the primary source of increased water temperature within the SR-HC TMDL reach.

Overall, the data available for the Downstream Snake River segment (RM 247 to 188) show that average monthly summer water temperatures in this segment were higher prior to the construction of the Hells Canyon Complex reservoirs. The Hells Canyon Complex reservoirs act to cool the overall summer water temperature below those observed in the Snake River upstream of Brownlee Reservoir (Figure 3.6.2 i). Data collected 1991 through 2001, above Brownlee Reservoir at RM 345 and below Hells Canyon Dam at RM 247 show that cooling occurs throughout the spring and summer months relative to inflow water temperatures. The average magnitude of cooling observed during July and August (Julian days 182 through 250) is approximately 4 °C. This trend is not as dominant during the later fall months of September or October (Julian days 253 through 304) due to the temporal lag in water temperatures discussed earlier. The data plotted in Figure 3.6.2 i represent a wide range of water years; 1995 was a relatively average water year (94% of the 50-year average annual flow), 1996 and 1997 were high water years (131% and 170% of the 50-year average annual flow respectively), and 1991 was a relatively low water year (55% of the 50-year average annual flow).

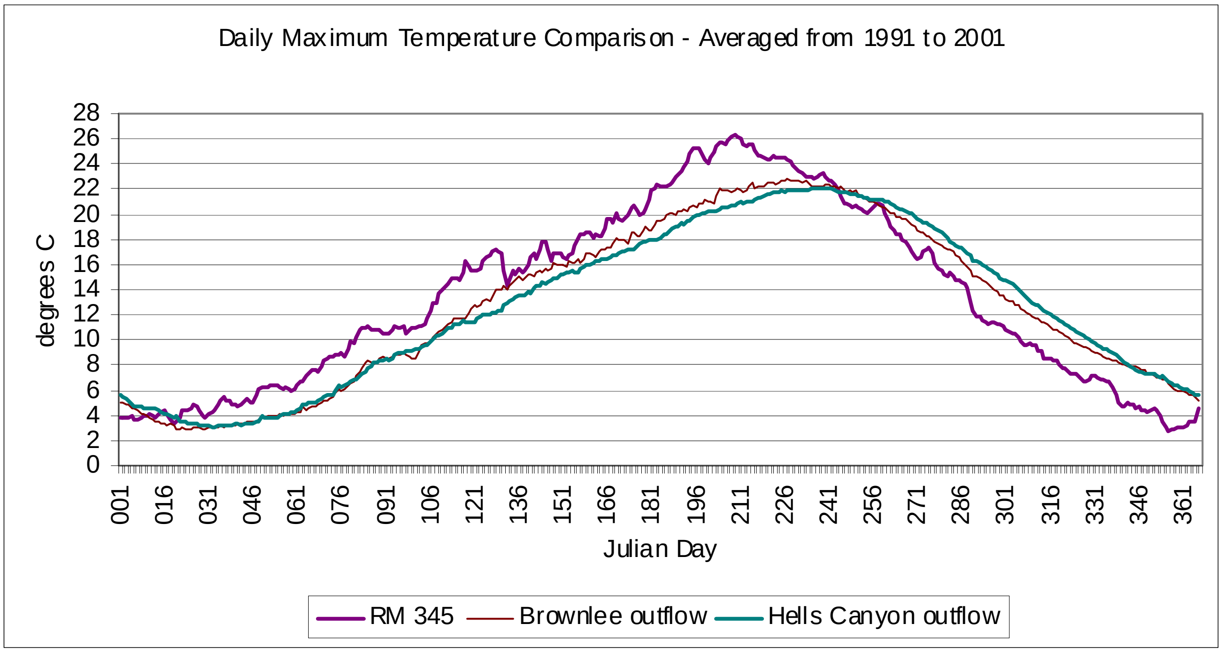


Figure 3.6.2 i. Differences in daily maximum surface water temperatures observed between the Upstream Snake River segment (measured downstream of Weiser, Idaho (RM 345)) and the Downstream Snake River segment (measured below the Hells Canyon Dam site (RM 247)).

It should be recognized that the Snake River above RM 345, and the tributary inflows to the SR-HC TMDL reach reflect the effects of substantial diversion and impoundment upstream and therefore are not representative of natural temperature or flow conditions for this system.

The Imnaha River flows into the Snake River at RM 191. Temperature data available from 1995 and 1996 for the Imnaha show daily maximum water temperatures that average 18.8 °C during July, 20.7 °C during August and 17.1 °C during September, Julian days 182 through 273 (Figure 3.6.3). Exceedences of the 17.8 °C salmonid rearing/cold water aquatic life target occur during July, August and part of September (Julian days 196 through 256).

3.6.5.6 THREATENED AND ENDANGERED SPECIES AND SALMONID SPAWNING.

A number of species listed as threatened or endangered under the Federal Endangered Species Act (ESA), are known to inhabit the SR-HC TMDL reach. The SR-HC TMDL reach provides habitat for the Idaho spring snail (*Pyrgulopsis idahoensis,* formerly *Fontelicella idahoensis*), identified in the region between RM 422 and 393 and between RM 372 and 366; and the Bliss

Photo 3.6.2. The mouth of the Imnaha River (RM 191), circa 1939 to 1940. Photo shows boatmen collecting mail from a receptacle anchored on the shoreline. Photo from the collection of Dr. Lyle M. Stanford.

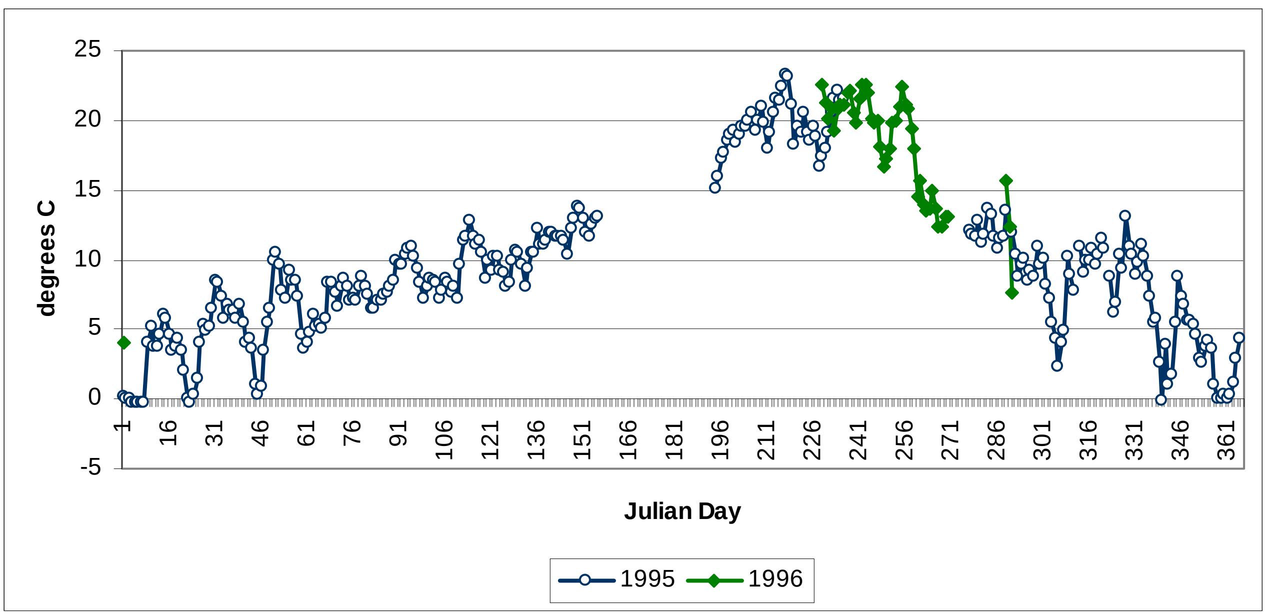


Figure 3.6.3. Water temperatures measured in the Imnaha River during 1995 and 1996.

Rapids snail (*Taylorconcha serpenticola*), identified in the region between RM 228 and 225 and in several areas of the Snake River upstream of the SR-HC TMDL reach. Both of these snail species are listed as threatened under the ESA, both are listed as requiring cold, clear, well oxygenated water for full support. Adult bull trout (*Salvelinus confluentus*), known to utilize the reservoir segments, are listed as threatened under the ESA. The SR-HC TMDL reach and some inflowing tributaries below Hells Canyon Dam also provide habitat for the Snake River fall (*Oncorhynchus tshawytscha*) and spring/summer chinook (*Oncorhynchus tshawytscha*), as well as steelhead (*Oncorhynchus mykiss*), all of which are listed as threatened under the ESA. A more complete description of these species, their status and their habitat needs is outlined in the Subbasin Assessment (Section 2.2.2.3).

All of the species listed above as threatened or endangered rely on good water quality for survival. Some species are sensitive to elevated water temperatures.

3.6.5.7 Salmonid Spawning and Rearing

Waters are designated for salmonid spawning and rearing in the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach. Waters so designated are required to exhibit appropriate levels of water column dissolved oxygen, intergravel dissolved oxygen, temperature, pH, ammonia, toxics, and turbidity for full support of fish during the spawning, incubation and rearing periods for those salmonid species inhabiting the designated waters. General time periods for spawning and incubation of the salmonid species identified to use the Downstream Snake River segment (RM 247 to 188) are:

- Chinook salmon (fall) October 23 through April 15 (Julian day 296 to 105)*
- Mountain Whitefish Nov 01 through March 30 (Julian day 305 to 89)*

* represents spawning and incubation times identified as specific to the SR-HC TMDL reach.

A complete table of fish species in the SR-HC TMDL reach is available in section 3.6.9.2 of this document.

3.6.5.8 Influence of Impoundments on Downstream Water Temperatures Relative to Salmonid Rearing/Clod Water Aquatic Life and Salmonid Spawning

Water temperatures in the Downstream Snake River segment (RM 247 to 188) are shown in Figure 3.6.2 h for the 1950s, pre-construction of the Hells Canyon Complex and the 1990s, post-construction. Pre-construction water temperature data is available for RM 203, (approximately 44 miles downstream of the Hells Canyon Dam-site) for water years 1955 through 1958 as monthly averages representing a variety of low, average and high water years. Post-construction water temperature data is available for RM 202 (1991 through 2001) and also covers a range of water years. Daily mean water temperatures from 1991 through 2001 were averaged to monthly means to provide consistency.

Data available for the pre-impoundment time period (1955 through 1958) are monthly mean water temperature values and therefore cannot be used to determine if the 13 ^{o}C maximum weekly maximum target value was exceeded. A general evaluation of pre-impoundment data shows that monthly averages above 13 ^{o}C occurred at the beginning of the salmonid spawning period identified by this TMDL and extended for approximately 2 weeks.

A general evaluation of this data shows that monthly averages above 13 °C did not occur within this data set during the fall chinook spawning period (Julian day 296 to 105). Please note, Figure 3.6.4 a shows daily mean water temperature data, and Figure 3.6.2 h shows monthly average daily maximum water temperature data for post-construction (current) conditions.

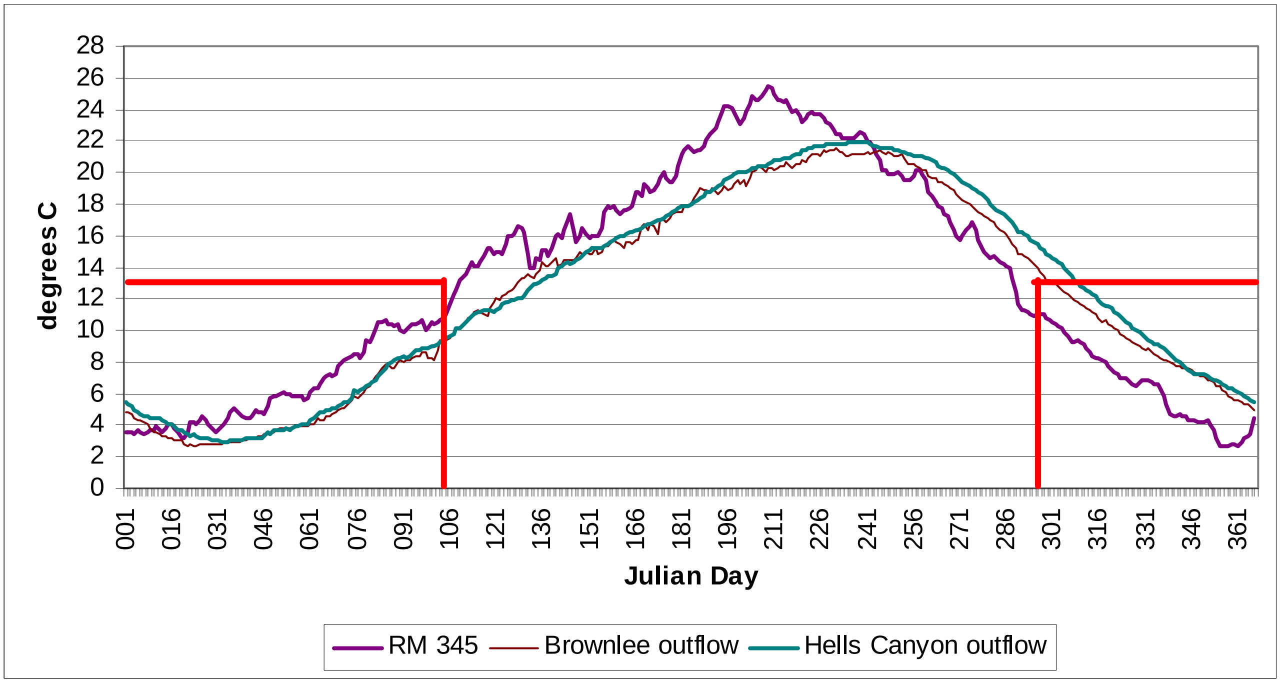


Figure 3.6.4 a. Post-construction daily mean water temperature data for the Snake River above and below the Hells Canyon Complex dams. (Salmonid spawning periods (boxes) for the Snake River below Hells Canyon Dam are displayed specific to fall chinook in this reach.)

The data displayed in Figure 3.6.2 h and Figure 3.6.4 a indicate several points. First, the effect of the Hells Canyon Complex of dams on water temperatures is one of cooling during much of the year, particularly through the time of peak summer temperatures. Secondly, an effect of the Hells Canyon Complex reservoirs has been to delay cooling of stored water in the fall relative to upstream water temperatures. Warm summer temperatures in water inflowing to Brownlee Reservoir, coupled with the storage capacity of the impoundment are factors in the timing and magnitude of this delayed cooling effect downstream of Hells Canyon Dam.

Finally, both the summer cooling and the delayed fall cooling effect appears largely attributable to Brownlee Reservoir as indicated by the narrow difference between the average outflow water temperature from Brownlee Dam as compared to the average outflow water temperature of Hells Canyon Dam (Figure 3.6.4 a). Brownlee Dam (RM 285) is the farthest upstream of the Hells Canyon Complex dams. It backs up the only significant storage reservoir of the three. By comparing water temperatures measured at RM 345 to those below Hells Canyon Dam at RM 247, the effect of the Hells Canyon Complex, primarily Brownlee Reservoir, on downstream Snake River water temperatures can be observed.

3.6.5.9 Site Potential Assessment

To more accurately assess the influence of the Hells Canyon Complex on water temperatures in the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach, an approach using thermal "site potential" has been employed. For the purposes of this TMDL, site potential is defined as the temperature that is predicted to have occurred without the influence of the Hells Canyon Complex dams and other direct sources of heat to the mainstem itself, but with the current altered hydrological regime, climate, and tributary inputs. Use of site potential relates to provisions in the water quality standards of the states of Idaho and Oregon, which allow for natural conditions when such conditions result in water temperatures, which exceed numeric criteria. These water quality standards further prescribe a small allowable increase in water temperatures when natural conditions, ergo "site potential", are above numeric criteria or target thresholds.

For the purpose of modeling mainstem Snake River site potential, tributary inflows were modeled at their current (recent) condition irrespective of their specific temperatures in relation to water quality criteria. The assumptions made in relation to modeled temperature influences for the mainstem Snake River should be applied only as appropriate within this assessment. Caution must be used when interpreting and applying the results of this temperature model analysis more broadly to other systems, particularly the tributaries. While the major heat contributions to large rivers may be predominantly due to natural atmospheric inputs, this is not likely to be the case for smaller streams and rivers, including most of the tributaries to this TMDL reach. As such, it is expected that a more comprehensive evaluation of temperature loading to tributary systems will be conducted when TMDLs for the tributaries are prepared. The assumptions made in this TMDL should not be applied to the tributary-specific TMDLs. It is likely that a more detailed analysis of the tributaries will indicate that temperature reductions are needed in the tributaries and upstream of this TMDL segment in order to fully attain water quality standards.

Since modeling to date has determined that water temperatures in the mainstem would still exceed criteria under site potential, the goal of the TMDL is to not exceed the small incremental increase in water temperature allowed by applicable water quality rules in such circumstances. Mathematical notation for this change in water temperature is delta T (ΔT). This TMDL seeks to limit the incremental effect of heat loads to that which does not cause violation of the temperature target (Oregon's 0.14 °C allowable increase, the most limiting criterion). Water temperatures measured at RM 345 were used as site potential for the downstream temperature assessment. It should be noted that while water temperatures at RM 345 should not be interpreted as "natural conditions", this approach acts to remove the effect of the Hells Canyon Complex on estimation of site potential further downstream.

Data available (1996 to 2001) show that mainstem water temperatures at RM 345 (Figure 3.6.4 b) exceed criteria at times under the site potential scenario, though for a shorter period of time than observed at the outflow of Hells Canyon Dam (Figure 3.6.4 a).

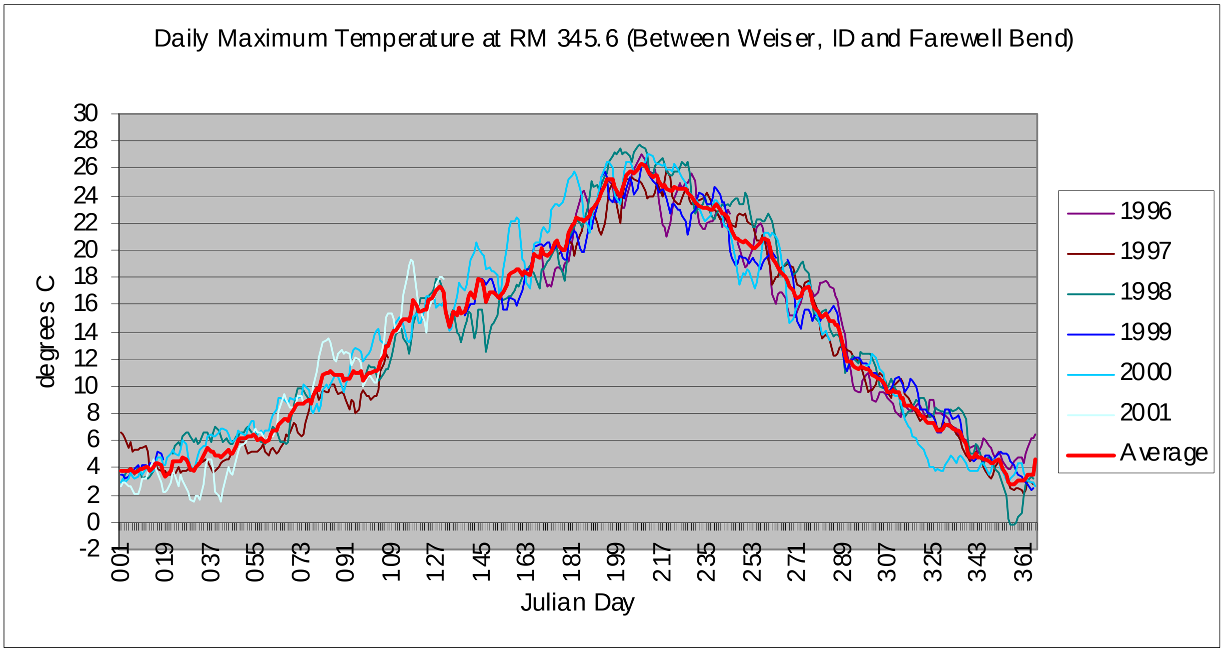


Figure 3.6.4 b. Daily maximum water temperature data for the Snake River at RM 345, 10 miles upstream from the headwaters of Brownlee Reservoir.

If existing water temperatures at RM 345 are in fact a high estimate of natural conditions this would cause a slightly higher estimate of site potential downstream, and would in turn result in a conservative estimate of load reductions needed below Hells Canyon Dam to limit the change in temperature.

3.6.6 Determination of Temperature Loading

As discussed previously, there are a variety of sources that influence water temperature in the SR-HC TMDL reach. These sources may act to increase or decrease water temperature within the mainstem Snake River. They include inflowing tributaries and drains, ground water and industrial discharges. In addition to these sources, it is well recognized that in hot arid climates such as that in which the SR-HC TMDL reach is located, natural atmospheric heat sources will also have a noticeable influence on water temperatures.

Tributaries, drains and industrial discharges can act as heating, neutral or cooling influences on the mainstem depending on their temperature relative to that of the Snake River. The influence of these inflowing waters can be measured in-river if the resulting difference is of sufficient magnitude, or can be calculated using known temperature and flow volume/dilution relationships.

Ground water inflows can also be heating, neutral or cooling influences on the mainstem depending on their temperature relative to the Snake River. Geothermal waters would generally be heating influences. Ground water from aquifer or irrigation sources is generally a cooling or a neutral source during the summer months.

3.6.6.1 Temperature Input Calculation Mechanisms.

An assessment of temperature sources to the SR-HC TMDL reach has been incorporated as part of this TMDL process. Industrial discharge influences were evaluated through direct discharge volume measurements, available discharge temperature data and estimation based on best professional judgement where data were not available.

Temperature influences from tributary, drain, ground water and natural atmospheric sources were also evaluated. Due to the variability and interconnected nature of surface and ground water systems, a calculational model was used to evaluate the influences of these inflows on water temperature in the mainstem Snake River. A spreadsheet water temperature model reported by Sharpe (1980) was used to calculate the change in water temperature in the mainstem Snake River due to tributary, drain and ground water inflows. The magnitude of the temperature influence exerted on the mainstem by tributary, drain and ground water inflows was calculated directly using the model. Model output was then compared to the measured temperature change within the system. The magnitude of natural atmospheric temperature influences and non-quantifiable influences was determined by difference. The difference between the instream temperatures produced by modeled inflow values and the measured water temperature was assumed to be the combination of the net natural atmospheric heat input and these non-quantifiable influences (these influences are discussed in more detail in Section 3.6.8.3).

Consecutive, daily water temperature and flow data were critical to this modeling effort. Consecutive daily maximum average water temperature and flow data were available for the major tributaries in the Upstream Snake River segment (RM 409 to 335) for summer months in 1999 or summer months in 2000. Few tributaries had data for both years (See Table 3.6.1). The data set included water temperature and flow measurements for all tributary and mainstem sites. Where data was available, data was compiled for the same day and year. In cases where data was unavailable, correlations between overlapping data sets were derived using direct linear interpolation and applied to the appropriate day and year for the compiled data set. Because they represent the most complete data set available, and the most current conditions, 1999 and 2000 data were selected for use in this exercise.

Within these two years of collected data, the most complete set for the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach contained data from June, July and August. June data, while relatively complete, required some estimation of temperature values based on linear interpolation from 1996 and therefore was not as robust as data available for July and August, which did not require as much estimation. However, July and August represent the months in which the greatest and most consistent elevation of water temperature is observed to occur. These two months therefore represent the basis of this analysis. June generally shows temperature exceedences occurring consistently at the latter end of the month, and September data generally shows the majority of temperature exceedences occurring at the beginning of the month. In those instances where flow data was unavailable (the Malheur and Owyhee Rivers and drains) calculated data from USBR was utilized (USBR, 2001) and from previous monitoring efforts (IPCo, 2000c; US EPA 1974 to 1995).

Consecutive, daily water temperature and flow information was not available for the Burnt or Powder rivers. The understanding of temperature influences to the Upstream Snake River segment (RM 409 to 335) was therefore applied with accommodation for increases in total surface area to the extent possible.

Precipitation levels from 1999 and 2000 are reasonably close to average conditions. The 1999 and 2000 data therefore represent median conditions for the SR-HC TMDL system, thus characterization of these conditions for relative temperature influences would be expected to apply the majority of the time. In-river, low flow years would be expected to exhibit higher levels of natural atmospheric-induced heating due to lower flow volume and decreased water depth in the mainstem, while high water years would be expected to show less natural atmospheric-induced heating due to greater flow volume and water depth.

Temperature loads from agricultural drains discharging to the SR-HC TMDL reach were determined using available temperature data. Neither water temperature nor flow data were plentiful; however, data were collected between 1975 and 1980, most as part of US EPA studies (US EPA STORET data, 1998). Temperature data for monitored drains were available for June, July and August of 1975 and August of 1977. Collected data show water temperatures that average 19.5 ^{o}C in June, 21.4 ^{o}C in July, 22.8 ^{o}C in August, and 17.6 ^{o}C in September. The data were not collected on a consistent time schedule, and do not necessarily represent maximum daily averages. These data are instantaneous measurements only; therefore, average water temperatures were used as the best estimate of overall drain temperatures. The available temperature data set did not include consistent flow data.

For the purposes of this exercise, available flow information was utilized. In some cases, flows were estimated using general flow descriptions supplied by the US EPA study (1974 and 1975), in other cases, return flow information by drainage area supplied by the USBR (USBR, 2001) was utilized. Care was taken to preserve the highest possible level of accuracy in these calculations, however, due to the level of uncertainty associated with water temperature and flow determinations for the agricultural drains, these values should be viewed as best estimates only. If drain-specific data become available during the implementation of this TMDL they should be used in place of these estimates.

Only limited data are available on ground water inflows to the Snake River. However, a substantial amount of information is available on the temperature of ground water in the Snake River Basin. These data were utilized to estimate average ground water temperatures in the SR-HC TMDL reach (USGS, 1999; IDEQ, 2000c; IDWR, 2000). Data available from ground water (well) records in the SR-HC TMDL watershed were evaluated. Wells less than 75 feet deep were selected as being most representative of ground water inflows to the Snake River in the SR-HC TMDL reach. Of the well records available in this area, 780 were 75 feet deep or less. The majority of the wells identified for this evaluation were located on the Idaho side of the river. Many well records were available for the Oregon side of the river but the majority of these was over 75 feet in depth and thus did not meet the depth requirement for this assessment. Temperature values obtained for the selected wells ranged from 8 ^{o}C to 21.5 ^{o}C but most (85%) were well correlated with a fairly narrow temperature range (13 ^{o}C to 16 ^{o}C). The mean ground water temperature was calculated to be 14.7 ^{o}C (median = 14.5 ^{o}C). In order to estimate ground water temperatures conservatively, a 95th percentile temperature value of 17.5 ^{o}C was used in place of the mean ground water temperature value of 14.7 ^{o}C. A complete set of all well data utilized is available in Appendix E.

The temperature model was applied using the available daily water temperature and flow volumes from all measured tributaries and drains. Ground water influences were calculated using the 17.5 ^{o}C temperature identified and the flow multiplied by the linear distance between gauges for the purposes of this calculational model.

Flow within the SR-HC TMDL reach was quantified using gauged measurements where possible and calculated flows where gauged measurements were not available. This was most critical for the Owyhee and Malheur rivers where gauged flows near the mouth were not always available. Flows for these systems were calculated using gauge data from upstream locations and calculating downstream increases based on estimated diversion and return flows within the system.

Ungauged gain/loss measurements within the reach were calculated from flow data evaluated over the time periods to which the modeling effort was applied. The overall reach "gain/loss" measurements identified using the water balance calculated for the loading analysis process were compared to those calculated by the USBR (USBR, 2001). The USBR quantified 1991 and 1992 (relatively low water years) and 1997 and 1998 (relatively high water years).

Daily water temperature and flow data used were collected from 1999 and 2000 (reasonably average water years). While there is no direct overlap between these data sets, the reach gain/loss values calculated for 1999 and 2000 are an approximate average of the low and high water year values, which is logical. For the purposes of this modeling effort, the ungaged flow difference was assumed to be related to a mixture of ungaged ground and surface water input, and was assumed to enter the river evenly on a per mile basis between the two gauges.

The maximum ungaged gains in flow from 1999 and 2000 were selected as conservative overall estimates of ungaged flows. These values were then evaluated as if the entire volume were from ground water inflows (representing a maximum cooling influence) and as if the entire volume were from surface water inflows (a maximum heating influence). To allow the determination of a relative range of temperature variation from ground and surface water inflows, ungaged flows were applied evenly over the stretches for which they were measured by dividing the total gained flow by the length of the segment in miles.

Using this modeled approach, the overall influence of surface and ground water inflows was evaluated. A comparison was then made to calculate the difference between the modeled and measured water temperatures. This difference was assumed to be the combination of the net natural atmospheric heat input and these non-quantifiable influences on water temperatures within the SR-HC TMDL reach.

An example calculation of the average mainstem water temperature after mixing is outlined below.

Tm = [(Q*T) + (Qi*Ti)] / (Q + Qi)

Where:

Q	= mainstem river flow, cfs
T	= mainstem river temperature, °C
Qi	= tributary flow, cfs
Ti	= tributary temperature, °C
Tm	= average mainstem temperature after mixing, °C

Example day: 30 July, from RM 453.5 to RM 396.7, based on daily maximum average water temperatures. (NOTE: for the sake of simplification, only major inflows were used in this example)

A	Per mile ungaged flow	=	6 cfs
B	Ground water temperature	=	17.5 °C
C	Snake River flow at RM 409	=	6,880 cfs
D	River temperature at RM 409	=	23.0 °C
E	Owyhee River flow	=	123 cfs
F	Owyhee River temperature	=	20.9 cfs
G	Boise River flow	=	1100 cfs
H	Boise River temperature	=	23.6 °C

Temperature after the Boise River is mixed into the Snake River:

$$(((C*D)+(E*F)+(G*H))+((A*12.3)*B)) / (C+E+G) +(A*12.3))$$

(Note that the per-mile ground water flow, 6 cfs, is multiplied by 12.3 miles, the total flow is then multiplied by 17.5 °C.)

- If only tributary and drain inflows are assessed, the mixed (modeled) water temperature in the mainstem = 23.05 °C
- If tributary and drain inflows are assessed, in combination with ungaged flows assumed to be 100 percent ground water, the mixed (modeled) water temperature in the mainstem = 23.0 °C
- If tributary and drain inflows are assessed, in combination with ungaged flows assumed to be 100 percent surface water inflows, the mixed (modeled) water temperature in the mainstem = 23.12 °C

The measured mainstem water temperature at the downstream end of this reach = 25.5 °C

In this example, if all of the ungaged flow is assigned to ground water inflows, the model shows that the mainstem water temperature is essentially unchanged over this section of the SR-HC TMDL reach. (Inflow temp was measured at 23 °C, and outflow temperature is calculated to equal 23 °C.) If all of the ungaged flow is assigned to surface water inflows (using an averaged temperature of 21.5 °C from measured drain data), the model shows that the mainstem water temperature increases by 0.12 °C over this section of the SR-HC TMDL reach.

The measured water temperature changed by 2.5 ^{o}C over the same section, increasing from 23 ^{o}C to 25.5 ^{o}C. The calculated temperature influence from tributary and drain inflows accounted for 0.05 ^{o}C of this change. Ungaged ground and/or surface water inflows in this same section accounted for between -0.05 ^{o}C (where all ungaged flow was assumed to be ground water inflow) and 0.07 ^{o}C (where all ungaged flow was assumed to be surface inflow). Assuming an even mixture of ground and ungaged surface water inflows, this temperature change is calculated to be 0.01 ^{o}C. The total modeled temperature change resulting from tributary, drain and ungaged inflows (assuming a 50/50 mixture of ground and surface water) is 0.06 ^{o}C (0.05 ^{o}C + 0.01 ^{o}C = 0.06 ^{o}C). Natural atmospheric and non-quantifiable temperature influences based on an equal mixture of ungaged inflows and the measured tributary and drain inflows are responsible for the remaining warming, equal to 2.44 ^{o}C (2.5 ^{o}C – 0.06 ^{o}C = 2.44 ^{o}C). Tributary, drain and ground water influences accounted for 2.4 percent of the heating that occurred, the combination of natural atmospheric and non-quantifiable influences accounted for 97.6 percent of the warming.

The mechanism for determining the relative contribution of temperature sources outlined in this example was applied to the SR-HC TMDL reach. The following discussion details the assumptions made and results obtained from this analysis.

3.6.6.2 ASSUMPTIONS.

Several assumptions were made in order to allow the calculation of temperature changes in mainstem Snake River water temperatures as a result of inflowing surface and ground water, and natural atmospheric temperature influences. The assumptions made are discussed below.

Temperature Variation.

The calculational model used only daily maximum water temperatures. There is no accommodation for cooling from lower nighttime air temperatures, or for cooling due to weather or heat loss throughout the system as water moves downstream. These factors result in an overestimation of the downstream influence of both mainstem water temperature increases and inflowing sources.

Mixing.

The temperature modeling analysis assumed uniform mixing of both surface and ground water inflows to the mainstem river. This analysis does not attempt to quantify variability of water temperatures laterally or through the depth of the river in the Upstream Snake River and Downstream Snake River segments. Temperature differences at varying depths within the reservoir segments were identified in a semi-quantitative fashion as discussed below. Temperatures within the reservoirs were assumed to be laterally uniform.

Water Temperatures in Tributaries.

Natural atmospheric temperatures are expected to influence water temperatures in tributaries to the Snake River. This influence may occur to a greater or lesser degree than that calculated for the mainstem Snake River depending on water depth, flow volume, and other factors. However, the magnitude of this influence was not directly assessed for the tributaries in this evaluation. All inflow temperatures were assessed as occurring at the point of discharge to the Snake River.

Water Temperatures in Tributaries without Monitoring.

Minor tributary and drain influences were calculated where flow and water temperature data were available. Where flow and water temperature data were not available, these inputs were assumed to be included in the "ungaged" inflow/outflow calculation.

Natural Temperature Loading.

Natural atmospheric temperature sources can be divided into two general categories: (1) Direct solar radiance, where sunlight striking the water results in a transfer of energy from the light waves to heat in the water, and (2) Direct heat conduction from the air itself. This calculational model does not differentiate between these two mechanisms, but rather seeks to identify the total atmospheric input that occurs from both processes simultaneously.

3.6.6.3 POINT SOURCE TEMPERATURES.

Six NPDES permitted discharges are identified in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL (Table 3.6.3). Two of these point sources are industrial discharges, four are municipal discharges. Only two of the NPDES permits for this segment have identified temperature discharge limits. There are three additional NPDES permitted point sources in the SR-HC TMDL reach; all are related to the operation of the Hells Canyon Complex dams (Brownlee, Oxbow and Hells Canyon). These discharges are composed of cooling water from the turbines in Brownlee, Oxbow and Hells Canyon dams. Discharge mixes directly with the outflow of the dams.

Table 3.6.3. Point source discharge volume and water temperature information for the Snake River - Hells Canyon TMDL reach.

Point Source	Discharge Volume (average)	Permitted Discharge Temperature
City of Nyssa	0.33 MGD	none
Amalgamated Sugar	Seepage ponds	< 32 ^{o}C
City of Fruitland	0.23 MGD	none
Heinz Frozen Foods	2.5 MGD	none
City of Ontario	1.9 MGD*	none
City of Weiser	1.8 MGD	none
Brownlee Dam	10 MGD	Not to exceed 79 ^{o}F
Oxbow Dam	11 MGD (max)	Not to exceed background + 10 ^{o}F
Hells Canyon Dam	9 MGD (max)	Not to exceed background + 10 ^{o}F

* land application during the critical season

Discharge volumes are available for all point source discharges. Temperature data however, is very limited. Where both discharge temperature and volume data were available, this information was used directly in the calculations. Where water temperature data was not available, as in the case of the Upstream Snake River segment (RM 409 to 335) wastewater treatment plant discharges, the maximum water temperature observed in smaller tributaries was applied.

Wastewater treatment plant discharge data available from other drainage basins show that discharge temperatures are commonly lower than those observed in the tributaries. The estimate applied in this modeling effort is therefore most probably and over estimate of the total increase in temperature contributed by the permitted point sources. This value was retained in the calculation effort as it represents a conservative (worst case scenario) overall.

The point source discharges represent no-measurable-increase in the water temperature of the mainstem Snake River within the SR-HC TMDL reach. (No-measurable-increase is defined by the State of Oregon as 0.25 ^{o}F (0.14 ^{o}C), and by the State of Idaho as 0.3 ^{o}C.) The point source discharges are calculated to contribute less than 0.012 ^{o}F (0.0066 ^{o}C) increase in mainstem water temperature in the Upstream Snake River segment (RM 409 to 335).

3.6.6.4 GROUND WATER.

Ground water influences were addressed in two ways to provide a relative range of effect:

1. In the first scenario, all of the flow unaccounted for in the water balance on a segment-specific basis was assumed to be ground water inflow. This volume was distributed evenly by distance along the length of the segment. This scenario represents the greatest possible ground water influence on a segment, given the data available. Because ground water is generally cooler than the surface water during the months for which natural atmospheric temperature influences were evaluated, this scenario represents the "coolest" conditions as calculated by the temperature model.
2. In the second scenario, none of the flow unaccounted for in the water balance on a segment-specific basis was assumed to be ground water. All ungaged inflow was assumed to be surface water. The temperature assigned to this ungaged flow was calculated as the average temperature of the measured drains in the segment. This scenario represents the least effect ground water may have on the mainstem Snake River water temperature. Because surface water is generally similar in temperature to the mainstem flow, or warmer, this scenario represents the "warmest" conditions as calculated by the temperature model.

This two part scenario provides a relative range for interpretation of the potential variability in calculated values. The actual conditions probably fall somewhere between the extremes represented by these two scenarios. This evaluation also provided information on the relative influence of ground water inflows on water temperatures in the mainstem Snake River. During the summer months of July and August, the greatest ground water influence calculated here is shown to average 0.33 ^{o}C of cooling.

3.6.7 Temperature Loading Analysis

Water temperature data from 1999 to 2000 was selected for use in this calculational modeling effort because it represented the best coverage for the SR-HC TMDL reach overall. The fact that this data also represents a reasonably average water year was very fortunate. Had the best coverage been available on a water year representing extreme conditions, a greater level of estimation and associated level of error would have been necessary to define generally occurring conditions.

The critical months of June, July and August were the focus of this evaluation. June shows the initial increase from spring to summer temperatures, and July and August represent those months where the greatest temperature exceedences occur. September could not be evaluated, as a complete data set was not available for most of the major tributaries. However, a similar, opposite trend in water temperature as observed in June is assumed to apply (i.e. Water temperature was observed to increase gradually over the first two weeks of June, with the majority of exceedences occurring the last two weeks of the month. A reverse of this trend is assumed to occur in September with the majority of water temperature exceedences occurring the first two weeks of the month, observed to decrease gradually over the last two weeks of the month.)

As in the example above, the level of increase in water temperature was evaluated based on tributary and drain inflows. Ungaged flow was assessed in two ways: assuming that all of the flow was the result of ground water inflows, and (2) assuming that all of the flow was the result of surface water inflows. Both of these scenarios were assessed separately and a separate equal mixture was also evaluated. The calculated output from the water temperature model is shown in Table 3.6.4.

Table 3.6.4. Calculated model output for temperature influences in the Upstream Snake River segment (RM 409 to 335) of the Snake River - Hells Canyon TMDL reach. (GW = ground water, SW = surface water)

JUNE	100% GW Temp change	100% GW Percent change	100% SW Temp change	100% SW Percent change	50/50 mix Temp change	50/50 mix Percent change	Range (+/-)
Modeled Tributary Influence	0.297 ^oC	7.1%	0.297 ^oC	7.1%	0.297 ^oC	7.1%	
Modeled Drain Influence	0.022 ^oC	0.5%	0.022 ^oC	0.5%	0.022 ^oC	0.5%	
Modeled Ungaged Flow Influence	-0.143 ^oC	-3.4%	0.034 ^oC	0.8%	-0.055 ^oC	-1.3%	0.177 ^oC
Modeled Point Source Influence	0.007 ^oC	0.2%	0.007 ^oC	0.2%	0.007 ^oC	0.2%	
Total Modeled Temperature Change	0.183 ^oC	4.4%	0.360 ^oC	8.6%	0.271 ^oC	6.5%	0.177 ^oC
Total Measured Temperature Change	4.2 ^oC		4.2 ^oC		4.2 ^oC		
Natural Atmospheric and Non-Quantifiable Influence	4.02 ^oC	95.7%	3.84 ^oC	91.4%	3.93 ^oC	93.6%	0.177 ^oC

JULY	100% GW Temp change	100% GW percent change	100% SW Temp change	100% SW percent change	50/50 mix Temp change	50/50 mix percent change	Range (+/-)
Modeled Tributary Influence	0.785 °C	15.1%	0.785 °C	15.1%	0.785 °C	15.1%	
Modeled Drain Influence	-0.030 °C	-0.6%	-0.030 °C	-0.6%	-0.030 °C	-0.6%	
Modeled Ungaged Flow Influence	-0.500 °C	-9.6%	-0.031 °C	-0.6%	-0.266 °C	-5.1%	0.469 °C
Modeled Point Source Influence	0.006 °C	0.1%	0.006 °C	0.1%	0.006 °C	0.1%	
Total Modeled Temperature Change	0.261 °C	5.0%	0.730 °C	14.0%	0.495 °C	9.5%	0.469 °C
Total Measured Temperature Change	5.2 °C		5.2 °C		5.2 °C		
Natural Atmospheric and Non-Quantifiable Influence	4.9 °C	95.0%	4.47 °C	86.0%	4.71 °C	90.5%	0.469 °C

AUGUST	100% GW Temp change	100% GW percent change	100% SW Temp change	100% SW percent change	50/50 mix Temp change	50/50 mix percent change	Range (+/-)
Modeled Tributary Influence	0.449 °C	12.8%	0.449 °C	12.8%	0.449 °C	12.8%	
Modeled Drain Influence	0.004 °C	0.1%	0.004 °C	0.1%	0.004 °C	0.1%	
Modeled Ungaged Flow Influence	-0.350 °C	-10%	0.004 °C	0.1%	-0.173 °C	-4.9%	0.354 °C
Modeled Point Source Influence	0.007 °C	0.2%	0.007 °C	0.2%	0.007 °C	0.2%	
Total Modeled Temperature Change	0.110 °C	3.1%	0.464 °C	13.3%	0.287 °C	8.2%	0.354 °C
Total Measured Temperature Change	3.5 °C		3.5 °C		3.5 °C		

AUGUST	100% GW Temp change	100% GW percent change	100% SW Temp change	100% SW percent change	50/50 mix Temp change	50/50 mix percent change	Range (+/-)
Natural Atmospheric and Non-Quantifiable Influence	3.39 ^oC	96.9%	3.04 ^oC	86.9%	3.21 ^oC	91.7%	0.354 ^oC

3.6.8 Loading Analysis Results

The relative change in mainstem water temperature in the Upstream Snake River segment (RM 409 to 335) from modeled tributary, drain and point source influence is shown for June, July and August (Table 3.6.4).

Modeled total tributary temperature influences range from 0.297 ^oC to 0.785 ^oC. The calculated temperature influences are higher in July, when the highest air and water temperatures are observed, and lowest in June when water and air temperatures start out relatively cool and then increase sharply as summer progresses. Calculated temperature influences in August are midway between those for June and July, and represent the slower cooling trend observed in the fall. Total tributary temperature influences account for an average of 12 percent of the temperature change in the mainstem river. July shows the highest relative percent contribution with 15.1 percent (monthly average).

Modeled temperature influences from the drains are also greatest in the month of July, where they represent 0.6 percent of the total temperature change modeled. During both June and August, the drains show a small positive temperature influence on mainstem temperatures (0.022 ^oC and 0.004 ^oC respectively), while in July they exert a cooling influence (-0.030 ^oC). This may be an outcome of shading from maturing plant growth in irrigated areas or an artifact of using averaged drain data in the calculation, as daily maximum water temperature data is unavailable. Averaged data do not allow differences in water temperature due to variations in sampling time and weather to be accounted for. Therefore, drain data taken in early morning hours may show cooler water temperatures due to the fact that most drains are fairly small and shallow and would respond to atmospheric temperature changes more rapidly than the mainstem Snake or major tributaries. However, both heating and cooling influences calculated for the drains are small compared to the overall temperature changes measured and should not be a dominant factor in determining the relative heat source balance.

Modeled point source temperature influences on the mainstem are very small, and relatively constant, ranging from 0.006 ^oC to 0.007 ^oC. The overall relative temperature change calculated for point sources averaged 0.17 percent. As stated previously, this is an overestimation of the total point source temperature influence, and is applied as a conservative value.

The relative change in mainstem water temperature calculated for the ungaged flows is shown for the two scenarios outlined, influence assuming that the total ungaged flow is ground water (maximum cooling effect) and the influence assuming that the total ungaged flow is surface water (maximum warming effect). In the first scenario, where all ungaged flow is assumed to be ground water, the ungaged inflows consistently represented a cooling influence during the critical time period. These flows resulted in the greatest cooling influence occurring in July (-0.500 ^{o}C overall) when the relative difference between ground and surface water temperatures is the greatest and would have the most effect. The smallest calculated cooling influence occurred in June (-0.143 ^{o}C) when the relative difference between ground and surface water temperatures is the least and the temperature change from ground water would be minimized by cooler instream water temperatures before mixing. August showed a value midway between those for June and July (-0.350 ^{o}C), and again represents the slower cooling trend of surface waters observed in the fall. The relative temperature change calculated for this scenario ranged from 3.4 percent to 10 percent and was consistently a cooling influence on mainstem water temperatures.

The second scenario showed a somewhat different outcome, as would be expected. In this scenario the total ungaged flow is assumed to be surface water. The temperature of the ungaged flow was assigned to be that of the measured drains. Little precipitation falls in the SR-HC TMDL reach during June, July and August. It was assumed that if the ungaged flow were associated with surface runoff, the majority of this flow would be from unmeasured agricultural and storm drains. Therefore, a similar temperature range should apply. In this evaluation, the ungaged inflows mimicked the temperature influence from the drains, exerting a relatively modest warming influence on the mainstem water temperature during June and August (0.034 ^{o}C and 0.004 ^{o}C respectively), and a relatively modest cooling influence in July (-0.031 ^{o}C). The relative temperature change calculated for this scenario ranged from 0.1 percent (warming) to 0.6 percent (cooling).

The overall range in the two scenarios was calculated to be 0.177 ^{o}C in June, 0.469 ^{o}C in July and 0.354 ^{o}C in August. While this exercise is helpful in determining a relative operating range for further interpretation, neither of the two scenarios modeled have a high probability of occurring within the SR-HC TMDL reach. A more realistic estimate of actual temperature influences from ungaged flows is a combination of ground and surface water inflows. As the range for possible conditions is well defined by the above discussion, an equal distribution of ground and surface water inflows was used to characterize the ungaged flow.

An equal (50:50) distribution was selected for further modeling based on the return flow calculations of the USBR and best current understanding of the SR-HC TMDL reach during summer months. This modeled scenario resulted in calculated values halfway between the two scenarios modeled previously. Cooling influences were consistently projected for this scenario, but were smaller in magnitude than those projected for the total ground water modeling. The temperature influence from the ungaged flow exerted a relatively modest cooling influence on the mainstem water temperature during June and August (-0.055 ^{o}C and -0.173 ^{o}C respectively), and a moderately higher cooling influence in July (-0.266 ^{o}C). The relative temperature change calculated for this scenario ranged from 1.3 percent to 5.1 percent (cooling).

Using the equal distribution scenario, the sum of all modeled temperature influences in the Upstream Snake River segment (RM 409 to 335) equaled 0.271 ^{o}C in June, 0.495 ^{o}C in July and 0.287 ^{o}C in August. The vast majority of the modeled differences are from the tributary influences. The measured difference in water temperature equaled 4.2 ^{o}C in June, 5.2 ^{o}C in July and 3.5 °C in August. The modeled values represent less than 10 percent of the measured change in water temperature within the Upstream Snake River segment (6.5%, 9.5% and 8.2% respectively). July showed the highest relative temperature influence from modeled inflows.

The calculated combination of the net natural atmospheric heat input and these non-quantifiable influences on the Upstream Snake River segment equals 93.6 percent of the total increase in June, 90.5 percent of the total temperature increase in July, and 91.8 percent of the total temperature increase in August. These calculations indicate that the dominant source of temperature increase in the mainstem Snake River is attributable to natural atmospheric inputs and non-quantifiable influences (discussed in detail in Section 3.6.8.3).

3.6.8.1 Determination of Tributary-Based Anthropogenic Temperature Loading

As stated previously, tributary inflows were modeled using water temperatures measured at the inflow to the Snake River. No tributary-specific modeling was undertaken to distinguish the relative influence of natural atmospheric inputs and non-quantifiable influences to these systems. However, tributary systems flowing into the mainstem Snake River in the SR-HC TMDL reach encounter the same hot, arid climate as they leave higher elevations and make their way across the valley floor to their inflow to the Snake River.

Flow volume and channel depth are smaller for all tributaries flowing into the Snake River, than those existing within the mainstem Snake River, therefore, natural atmospheric conditions have the probability to exert a larger influence on these systems than on the mainstem Snake River. Given these circumstances, and the modeled information on natural atmospheric influences and non-quantifiable influences on the mainstem Snake River, a general differentiation of these sources and quantifiable anthropogenic temperature sources for tributary inflows was undertaken.

In estimating the magnitude of natural atmospheric and non-quantifiable temperature influences to the inflowing tributary systems, the overall relative temperature influence determined for the mainstem Snake River was applied. As outlined previously, given the lower flow volumes and shallower depths of the inflowing tributaries as compared to the mainstem Snake River, the relative natural atmospheric influence on the tributaries would generally be greater than that determined for the mainstem river. For the purposes of this calculation, the relative influence of drains and point sources was assumed to be entirely (100%) anthropogenic. The calculated influence of ungaged flows was acknowledged to be a cooling influence on the system, but was not included in the calculations due to the level uncertainty involved. The relative percent natural atmospheric and non-quantifiable influence from the Snake River mainstem was only applied to the tributary inflows. Therefore, this application of Snake River values represents a conservative estimate of the natural atmospheric and non-quantifiable influences within the SR-HC TMDL reach. Table 3.6.5 shows the calculated changes in tributary temperature influences relative to anthropogenic loading.

The total anthropogenic temperature load to the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach as calculated by this method equals 0.048 °C in June (1.1% of the total measured load), 0.026 °C in July (0.5% of the total measured load) and 0.048 °C in August

Table 3.6.5 Estimated Relative Temperature Influence of Anthropogenic Sources to the Snake River – Hells Canyon TMDL Reach

	June (model total)	June (calculated anthropogenic influence)	July (model total)	July (calculated anthropogenic influence)	August (model total)	August (calculated anthropogenic influence)	Average Calculated Anthropogenic Influence
Anthropogenic influences on water temperature in the Upstream Snake River Segment of the Snake River – Hells Canyon TMDL listed in this table were calculated using the relative percent anthropogenic influence calculated for the mainstem Snake River							
Modeled Tributary Influence	0.297 °C	0.019 °C	0.785 °C	0.050 °C	0.449 °C	0.037 °C	0.035 °C
Modeled Drain Influence	0.022 °C	0.022 °C	-0.030 °C	-0.030 °C	0.004 °C	0.004 °C	0.001 °C
Modeled Ungaged Flow Influence*	cooling	cooling	cooling	cooling	cooling	cooling	cooling
Modeled Point Source Influence	0.007 °C	0.007 °C	0.006 °C	0.006 °C	0.007 °C	0.007 °C	0.007 °C
Total Calculated Anthropogenic Influence		0.048 °C		0.026 °C		0.048 °C	0.043 °C
Measured Temperature Change		4.2 °C		5.2 °C		3.5 °C	4.3 °C
Percent of Total Measured Temperature Change from Calculated Anthropogenic Influences		1.1%		0.5%		1.5%	1.0%
Percent of Temperature Increase Calculated as Atmospheric (Background) Influences		98.9%		99.5%		98.5%	99.0%

* These values assume a 50/50 mixture of ground and surface water for ungaged flows.

(1.5% of the total measured load). The average calculated anthropogenic loading is 0.043 ^{o}C (1.0% of the total measured load).

The State of Oregon has defined "no-measurable-increase" as less than 0.25 ^{o}F (0.14 ^{o}C). The State of Idaho has recently approved a definition of "no-measurable-increase" as 0.3 ^{o}C. The US EPA has defined "no-measurable-increase" as 0.3 ^{o}C in association with joint efforts to identify water quality standards for the Colville Tribe. These definitions are not arbitrary units assigned for measurement purposes only, but rather carry an inferred interpretation that changes in water temperature must be at levels greater than this amount to be biologically significant to aquatic life. For the purposes of this TMDL, the State of Oregon definition of 0.14 ^{o}C has been applied as the most conservative definition of no-measurable-increase. This value is less than one half of the amount identified by the US EPA, and that defined by the State of Idaho.

Using the methodology outlined previously, the calculated change in water temperature in the Snake River in the SR-HC TMDL reach due to measurable anthropogenic influences during the critical time period is well below the defined no-measurable-increase value of 0.14 ^{o}C. Even if a 100 percent margin of error was assumed, and the calculated anthropogenic loadings were doubled, they would still fall well below the defined no-measurable-increase limit of 0.14 ^{o}C.

Therefore, the findings of this TMDL effort indicate that natural atmospheric sources and non-quantifiable influences on temperature are the dominant source of elevated water temperatures in the mainstem Snake River. This indicates that, in the case of salmonid rearing/cold water aquatic life targets, site potential is above the 17.8 ^{o}C therefore, the target is no more than 0.14 ^{o}C increase from anthropogenic sources. (Salmonid spawning is discussed in the following sections.)

Stream temperature change is an expression of heat exchange between a stream and its environment. This dynamic exchange process can only be evaluated when the individual components of the heat exchange process are either known or estimated. This information is required to accurately predict the temperature of the river, and its response to the surrounding environment. The accuracy of the prediction correspondingly depends on the accuracy of the data or estimates used in the analysis.

The analysis provided in this TMDL did not include any evaluation of the heat exchange processes within the river system. Instead, it was assumed for the purpose of the analysis, that all heat exchange processes or heat inputs outside of the discretely measured sources are natural or non-quantifiable and the result of "natural atmospheric and non-quantifiable influences." Using this assumption, the TMDL utilized a mixing zone evaluation (model) to predict the relative impacts of pollutant loads from external sources (i.e., tributaries, point source discharge, groundwater and other ungaged flows).

It should be recognized however, because of the underlying assumptions used, that the level of analysis to evaluate the magnitude of natural atmospheric or non-quantifiable influences within this TMDL is rough. Moreover, while the assumption that all other sources of heat inputs are "natural or non-quantifiable" may be correct, there is only limited information in this TMDL to support this conclusion. It will be necessary to collect more data and conduct additional analyses to determine the accuracy of this assumption.

Accordingly, caution must be applied when interpreting and applying the results of this temperature model analysis more broadly to other systems, particularly the tributaries. While the major heat contributions to large rivers may be due to natural atmospheric inputs, this is not likely to be the case for smaller streams and rivers, including most of the tributaries to this TMDL reach. As such, it is expected that a more comprehensive evaluation of the temperature loading to tributary systems will be conducted when TMDLs for the tributaries are prepared. The assumptions made in this TMDL should not be applied to those TMDLs. Furthermore, it should be clearly understood that the assessment in this TMDL only evaluates the impact of current tributary temperatures on the Snake River and makes no attempt to analyze compliance with water quality standards in the tributaries themselves.

Site potential as used in this analysis is based upon a cursory or general review of the watershed. A more intense review might determine that, in some areas, riparian conditions are at less than site potential due to anthropogenic causes. It is likely that a more detailed analysis of the tributaries will indicate that temperature reductions are needed in the tributaries and upstream of this TMDL segment in order to fully attain water quality standards. The information developed and the conclusions reached in the tributary and upstream processes will be reviewed and incorporated, as appropriate, into future revisions to this mainstem TMDL.

Thus, for the purposes of clarity, the temperature loading assessment in this TMDL only analyzed the impact of current tributary temperatures on the Snake River and made no direct attempt to collect data and assess quantitatively whether or not the tributaries are currently complying with State water quality standards.

In interpreting and applying the outcome of this temperature assessment, it is critical to bear in mind the assumptions utilized in developing this TMDL. For instance, the TMDL does not attempt to address temperature modifications due to upstream mainstem and tributary sources, impoundments, water withdrawals, channel straightening and diking and removal of streamside vegetation. While these limitations are qualitatively outlined in Section 3.6.8.3, they are not reflected in the quantification to establish the loading capacity and loading allocations in the TMDL. It is important to remember that these alterations can lead to increases in water temperature (at least locally) and thus the TMDL addresses existing site potential conditions as opposed to natural conditions. As such, in addressing water quality management in the Snake River basin, these other factors should be considered.

3.6.8.2 Hells Canyon Complex and Downstream Temperature Loading.

There are few anthropogenic temperature sources in the Hells Canyon Complex. As stated previously, the impoundments do not function as heat sources. Rather, the temperature issue related to the dams is the result of the impoundment and how the water is stored and processed. In addition to the small permitted point source discharges associated with the operation of the dams, the Burnt and Powder rivers represent the source of the majority of anthropogenic inputs to the system as a whole.

Within Brownlee Reservoir, there are no permitted point sources discharges. Agricultural land use around the reservoir is very limited and no major drain flows have been identified. Therefore, the Burnt and Powder rivers represent the most likely source of non-atmospheric temperature influences to the reservoir segment. Data are not available to evaluate the water temperature influences from the Burnt and Powder Rivers, however, an evaluation of the Upstream Snake River segment (RM 409 to 335), where the majority of the instream flow was from tributaries, showed that water temperature influences from anthropogenic sources were below the defined no-measurable-increase level of 0.14 ^{o}C. It is unlikely therefore, that the Burnt and Powder rivers, which collectively equal less than 4 percent of the total inflow to Brownlee Reservoir, would exert sufficient warming to create a measurable water temperature increase. Other tributaries to Brownlee Reservoir, such as Brownlee Creek, contain minimal anthropogenic sources and are therefore not estimated to increase water temperatures measurably. They are, in fact, known to be a source of cooling inflows to the reservoir.

While surface water temperatures exceed the 17.8 ^{o}C target in Brownlee Reservoir during the critical time period, the lower layers of the reservoir are cooled well below the surface temperatures (See Figures 3.6.2 b and 3.6.4 a). The overall effect for Brownlee Reservoir is that of cooling to the downstream segments. As they are acting in a similar manner and flowing directly from one into another, the reservoir segments as a whole can be assumed to act as cooling influences on the water column. Figure 3.6.4 a shows discharge temperatures from Hells Canyon Dam. When compared to mainstem water temperatures at RM 345, a marked cooling effect can be observed over the critical time period. Given the available data, water exiting Hells Canyon Dam is cooler than that entering the SR-HC TMDL reach near Murphy during the critical time period (June through September).

One permitted point source (cooling water for the turbines at Brownlee Dam) discharges to Oxbow Reservoir. This discharge has been evaluated using the maximum discharge temperature and the maximum flow value recorded in the discharge monitoring reports for this facility. It is likely that this is an overestimate of the actual temperature influence of this facility. Using the calculational model discussed previously with averaged maximum daily water temperatures (data were not available for all days of the month), and calculated average monthly discharge values for Brownlee Dam, the total influence on water temperature within Oxbow Reservoir was calculated to be 0.0175 ^{o}C in June, 0.0102 ^{o}C in July and 0.0105 ^{o}C in August. These calculated values represent the maximum allowable temperature of permitted discharge to the reservoir, but do not necessarily represent the maximum temperature influence due to lack of consistent outflow temperature data. However, they act to give a relative magnitude of temperature influence that is obviously well below the defined measurable increase level of 0.25 ^{o}F (0.14 ^{o}C).

One permitted point source (cooling water for the turbines at Oxbow Dam) discharges to Hells Canyon Reservoir. This discharge has been calculated in the same manner as outlined for Oxbow Reservoir above and is also likely to be an overestimate of the actual temperature influence of this facility. Using the calculational model discussed previously with averaged maximum daily water temperatures (data were not available for all days of the month), and calculated average monthly discharge values for Oxbow Dam, the total influence on water temperature within Hells Canyon Reservoir was calculated to be 0.0066 ^{o}C in June, 0.0058 ^{o}C in July and 0.0096 ^{o}C in August. As in Oxbow Reservoir, these calculated values represent the maximum allowable temperature of permitted discharge to the reservoir, but do not necessarily represent the maximum temperature influence. However, they provide a relative magnitude of temperature influence that is obviously well below the defined measurable increase level of 0.25 ^{o}F (0.14 ^{o}C).

The Hells Canyon Complex reservoirs act to cool water within the SR-HC TMDL reach. Direct temperature loading and designated beneficial support needs for the reservoir system are discussed in the following sections.

There is one permitted point source that discharges to the Downstream Snake River segment (RM 247 to 188). It is the cooling water for the turbines at Hells Canyon Dam. This discharge has been calculated as outlined previously and the total influence on water temperature within the Downstream Snake River segment was calculated to be 0.0044 ^{o}C in June, 0.0040 ^{o}C in July and 0.0066 ^{o}C in August. As in Oxbow Reservoir, these calculated values represent the maximum allowable temperature of permitted discharge to the reservoir, but do not necessarily represent the maximum temperature influence. However, they provide a relative magnitude of temperature influence that is obviously well below the defined measurable increase level of 0.25 ^{o}F (0.14 ^{o}C).

Given an average flow contribution and average daily maximum water temperatures from 1995, the inflow from the Imnaha River was calculated to influence the water temperature in the mainstem Snake River by a maximum of -0.12 ^{o}C during July, -0.05 ^{o}C during August and -0.06 ^{o}C during September. All calculations showed a cooling effect on the mainstem Snake River.

In the absence of water column data to generate a quantitative assessment of relative temperature loading to the reservoir segments, the data available show that the reservoirs act to cool the overall water volume released to temperatures below those measured in the mainstem Snake River near Weiser, and that the permitted point source influences are below the defined measurable increase level of 0.25 ^{o}F (0.14 ^{o}C).

Water temperature data collected from 1991 through 2001 show that the presence of the Hells Canyon Complex causes a shift in temperatures from those that would occur were the Hells Canyon Complex not in place. While peak summer temperatures are several degrees cooler due to withdrawals from below the reservoir surface, the decline in temperatures in the fall is delayed from that observed immediately upstream of the Hells Canyon Complex. This temperature delay is commonly observed to begin in early September. While the temporal distribution of this temperature shift is due to the delay in flow caused by water moving through the Hells Canyon Complex, the actual heat load (warmer water) is not. The impoundments are not a heat source. Sources of elevated water temperature include natural, unquantifiable and anthropogenic sources upstream of the Hells Canyon Complex and similar sources on inflowing tributaries.

Modeling work completed by IPCo (IPCo, 2002b) has shown that if the water inflowing to Brownlee Reservoir at RM 335 were at or below 17.8 ^{o}C, water leaving the Hells Canyon Complex at Hells Canyon Dam would also be at or below 17.8 ^{o}C, regardless of the temperature shift specific to the Hells Canyon Complex. While the DEQs do not agree that the 17.8 ^{o}C water temperature used in this modeling is an appropriate or attainable condition (as outlined in the discussion of the calculational model earlier in this document), the modeling does show that the Hells Canyon Complex is not the source of the heat load in the reservoirs and that if upstream conditions were cooler, the water exiting the Hells Canyon Complex would also be cooler. Therefore, it is concluded that the Hells Canyon Complex is not contributing to temperature exceedences specific to the cold water aquatic life/salmonid rearing designated use

However, the IPCo water temperature modeling also shows that even if the inflowing water temperature were less than or equal to 17.8 ^{o}C, the water exiting the Hells Canyon Complex would not meet the salmonid spawning criteria (although by only a small margin) because of the temporal shift created by the Hells Canyon Complex. Data assessment and calculational modeling by the DEQs (as discussed earlier) have identified a similar trend. It is, therefore, concluded that the responsibility for exceeding the salmonid spawning criteria is specific to the presence and operation of the Hells Canyon Complex.

3.6.8.3 Anthropogenic Influences on Temperature not Accounted for in this Analysis

The Pacific Northwest Water Quality Temperature Criteria Guidance Project (US EPA, 2002) identified the four largest sources of increased temperature in the Pacific Northwest to be (1) removal of streamside vegetation, (2) channel straightening or diking, (3) water withdrawals, and (4) dams and impoundments. The fourth item listed, dams and impoundments, has been discussed in the preceding sections. Water temperature data collected from sites within, above and below the Hells Canyon Complex show that the impoundments result in cooler overall maximum water temperatures during the summer months and a slight delay in heating (spring) and cooling (fall) below the Hells Canyon Complex (as discussed in Section 3.6.5.5 and Section 3.6.8.2).

While this analysis makes full use of the data and methodologies appropriate to evaluate temperature influences on the SR-HC TMDL reach, changes in water temperature due to items one through three above are non-quantifiable on a watershed scale. While these influences undoubtedly result in increased water temperatures within the SR-HC TMDL reach, the magnitude of this increase is unknown.

Removal of Streamside Vegetation.

Streamside vegetation on the mainstem and inflowing tributaries acts to reduce heating from solar radiation through shading. This effect is minimal on a site-specific basis, especially in the mainstem Snake River where the channel is very wide compared to the width of the riparian area, however, cumulative effects on smaller tributary systems can result in improved cool water refugia for aquatic species. The removal of this vegetation reduces the potential for shading within the system. While available water temperature data for the SR-HC TMDL are not sufficient to quantify the magnitude of this change, it is projected to result in increased water temperatures on, at minimum, a site-specific scale. Additional, consistent water temperature data would allow the use of more advanced modeling techniques that will aid in the identification of water temperature changes through restoration of streamside vegetation. If identified as an appropriate mechanism for reducing water temperatures, ground surveys to identify areas where streamside vegetation is degraded or non-existent can be undertaken as part of the implementation process. Areas identified as needing treatment could then be re-vegetated and water temperature monitored on a site-specific basis.

Channel Straightening or Diking.

The effects of channel straightening or diking on water temperatures in the SR-HC TMDL reach have not been quantified in this assessment. As with streamside vegetation removal, the influence of this action on water temperatures in both the mainstem and the tributaries can have both site-specific and cumulative effects. The magnitude of this effect is unknown at this time.

Water Withdrawal.

The analysis of relative temperature influences detailed previously does not account for anthropogenic influences due to changes in stream flow from water withdrawal for either the mainstem Snake River or the tributary systems. This analysis does not attempt to quantify the increase in water temperature due to diversion of mainstem Snake River or tributary flow. It is recognized that such diversions lead (during some portions of the growing season) to elevated water temperatures due to removal of instream flow. Water is diverted from the mainstem Snake River and inflowing tributaries as per existing water rights. The resulting reductions in instream flow result in shallower water, more susceptible to atmospheric heating. It is also recognized that such diversions (especially during the summer irrigation season) often act to increase naturally occurring instream flows through late season irrigation recharge and drain flow.

Diversion flows and total river flow (April through October) were calculated for the mainstem Snake River between Murphy and Weiser by the USBR (2001). This information was used to make a comparison of diverted flows and instream flows. Data was available for low (1991) and high (1997) water years. The comparison showed that the total flow (April through October) in the Snake River in 1991 (a low water year) was approximately 2,920,000 acre-feet at Murphy (RM 453.5) and 4,220,000 acre-feet at Weiser (RM 351). The total flow diverted during 1991 was approximately 1,980,000 acre-feet. The diverted flow is equal to 68 percent of the total instream volume at Murphy and 47 percent of the total instream volume at Weiser. The total flow (April through October) in the Snake River in 1997 (a high water year) was approximately 7,150,000 acre-feet at Murphy and 12,060,000 acre-feet at Weiser. The total flow diverted during 1997 was approximately 2,100,000 acre-feet. The diverted flow is equal to 29 percent of the total instream volume at Murphy and 17 percent of the total instream volume at Weiser.

While it is estimated that nearly half of the water diverted from the Snake River in the SR-HC TMDL reach returns to the system, that return is spread out between surface and ground water inflows and the return period is estimated to be close to a year (USBR, 2001). The management and diversion of water within the SR-HC TMDL reach, and upstream of this TMDL reach have a substantial influence on water flow and volume within the SR-HC TMDL reach. In the case of the SR-HC TMDL reach, the volume of water diverted in the dry year (1991) was over one and a half times more than the difference in water volume between 1991 and 1997. (The diverted flow is 1.5 times the difference between a high and a low water year.) This indicates that diverted flows, especially in average or low water years, represent a very substantial portion of the water volume in the river, and thus potentially have a large influence on the water temperature. This effect is not quantified by the temperature evaluation detailed here.

Return flows, in the form of subsurface recharge, are observed to have a cooling effect on surface water temperatures as shown in the previous analysis. A portion of the return flows in the SR-HC TMDL reach is in the form of subsurface recharge and no doubt exerts a cooling influence on the river. A general evaluation of the potential magnitude of this cooling influence was undertaken as part of the temperature source assessment; however, it provides only a general estimate. These same flows often act to increase late season stream flows over that which would occur naturally without management.

Other Considerations.

Changes in the water table resulting from water management practices have resulted in reduction of riparian or marshy areas along the mainstem Snake River in the SR-HC TMDL reach. Photos showing the Snake River in 1909 (too dark for reproduction) in the archives of the Oregon Historical Society show large marshy areas in the Snake River near the present day site of Ontario, Oregon. The existence of these areas historically in the SR-HC TMDL reach has been discussed repeatedly during the public meetings held as part of the SR-HC TMDL process.

Work currently in progress in the John Day River system has shown that recharge through such marshy areas can result in a substantial cooling influence on water temperatures. Temperature effects resulting from the loss of these types of marshy/riparian areas on the mainstem Snake River and the inflowing tributaries have not been quantified. Data collected from other systems may be generalized to project what the influences on the SR-HC TMDL reach may be, but it is doubtful that SR-HC specific data can be generated to quantify this influence directly.

Additionally, the fact that the Snake River is heavily impounded, together with the return flows from diversions along the SR-HC TMDL reach have resulted in a more stable, static flow pattern within the mainstem. Summer flow volumes in low water years are, without question, greater than those observed before the current level of management was in place.

3.6.8.4 AIR TEMPERATURE.

As stated previously, natural atmospheric temperature sources can be divided into two general categories: (1) Direct solar radiance, where sunlight striking the water results in a transfer of energy from the light waves to heat in the water, and (2) Direct heat conduction from the air itself. As the SR-HC TMDL reach and the mouths of many of the inflowing tributaries are contained in wide, relatively shallow channels where vegetation (current and historic) is sparse, direct solar radiance will result in efficient heat transfer to the system. Additionally, daily high air temperatures over the SR-HC TMDL reach regularly exceed 32 ^{o}C (90 ^{o}F) and often are over 37 ^{o}C (100 ^{o}F). During the majority of the summer months, maximum daily air temperatures routinely exceeded the maximum average daily water temperature in the mainstem river. This condition results in a situation where energy flows from the atmosphere into the river throughout the major portion of the sunlight hours, leading to substantial levels of naturally induced heating.

As natural atmospheric and non-quantifiable influences were shown to be a dominant factor in mainstem and potentially tributary water temperatures, air temperatures were assessed in correlation with water temperature target exceedences. Air temperature data was available for three sites in close proximity to the SR-HC TMDL reach. Data collected at Boise, Idaho, Weiser, Idaho and Brownlee Dam (RM 285) by the Western Regional Climate Center (WRCC) include daily minimum, average, and maximum air conditions. These data were available for 1999 to 2000. Figures 3.6.5 a and b show the average and maximum air temperatures in these locations throughout the summer season.

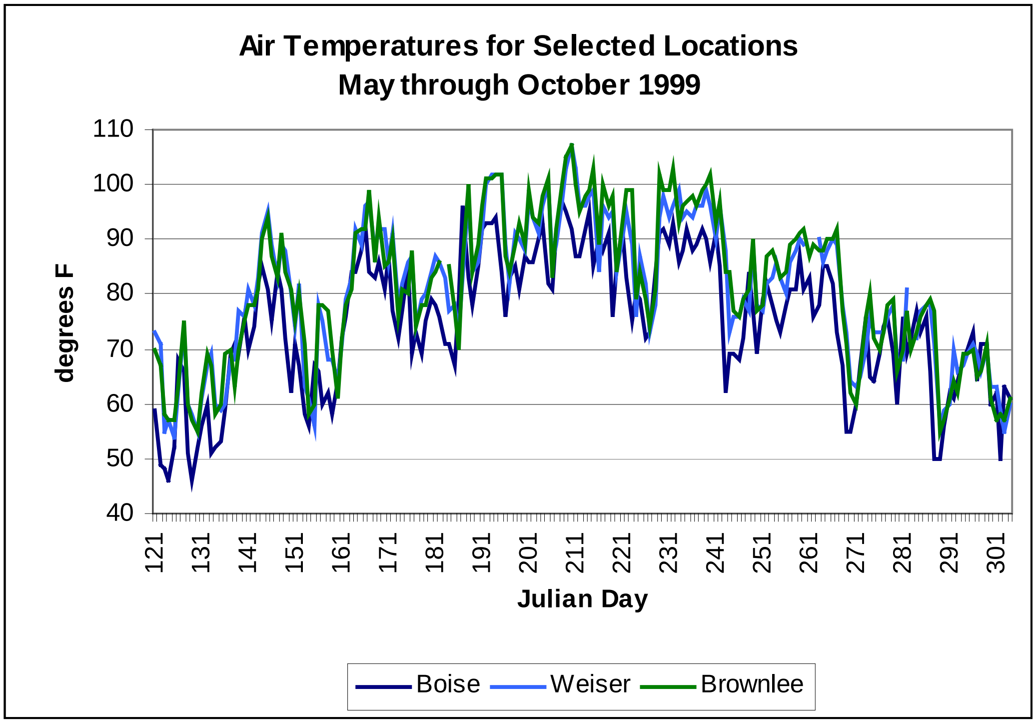


Figure 3.6.5 a. Air temperatures recorded at Boise, Weiser and Brownlee Dam from May through October of 1999.

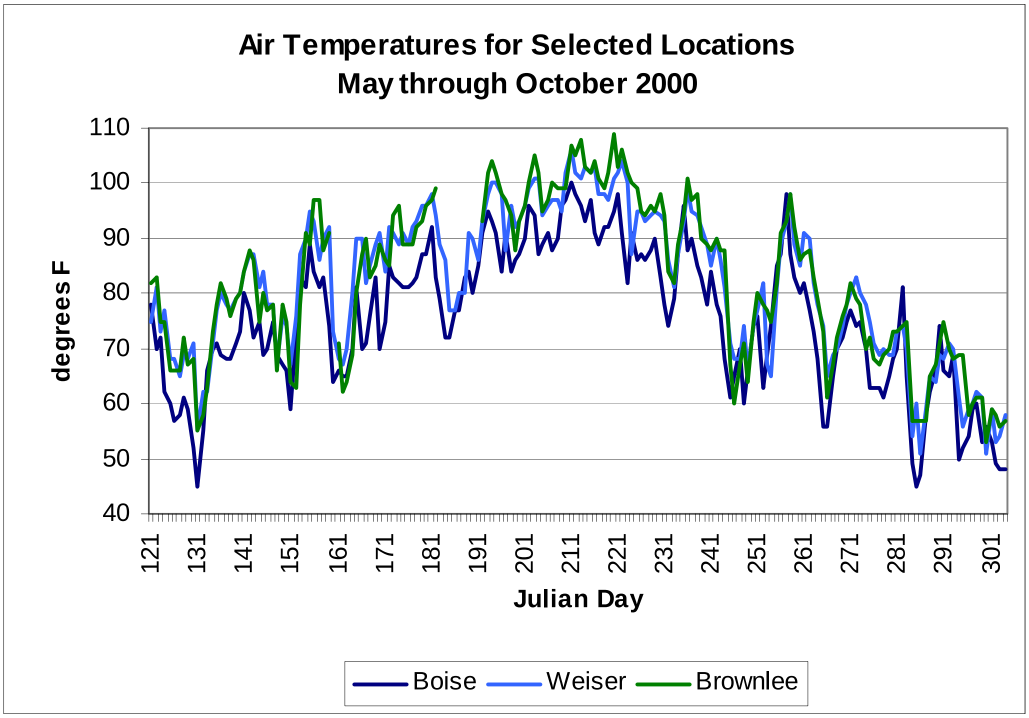


Figure 3.6.5 b. Air temperatures recorded at Boise, Weiser and Brownlee Dam from May through October of 2000.

The pattern of highs and lows in air temperature closely follows that observed in the water temperatures recorded for the same time period.

Air temperatures associated with maximum water temperatures exceeding the salmonid rearing/cold water aquatic life criterion of 17.8 ^oC are substantially warmer than the air temperatures associated with days on which the maximum water temperatures are less than 17.8 ^oC. Table 3.6.6 shows the typical daily maximum air temperatures associated with exceedence and non-exceedence water temperatures in the SR-HC TMDL reach.

Air temperature data from the Boise area, when compared with water temperatures in the mainstem Snake River near Murphy, Idaho, RM 453.5 (air temperatures from Murphy were not available), averaged approximately 6.2 ^oC (11.1 ^oF) higher on days when maximum water temperatures were greater than 17.8 ^oC. For air temperatures in the Weiser area this difference was even more pronounced, averaging 12 ^oC (21.6 ^oF) higher when water temperatures were greater than 17.8 ^oC.

Table 3.6.6. Mean daily maximum air temperatures at Boise, Weiser and Brownlee Dam, 1999 to 2000.

Month	Air temperatures when max. water temperatures do not exceed 17.8 ^oC	Air temperatures when max. water temperatures exceed 17.8 ^oC
Boise		
June	75.2 ^oF	84.3 ^oF
July	None	87.4 ^oF
August	None	87.2 ^oF
Mean	**75.2 ^oF**	**86.3 ^oF**
Difference	**11.1 ^oF**	
Weiser		
June	71.0 ^oF	89.9 ^oF
July	None	93.4 ^oF
August	None	94.6 ^oF
Mean	**71.0 ^oF**	**92.6 ^oF**
Difference	**21.6 ^oF**	
Brownlee Dam		
June	55 ^oF	64 ^oF
July	None	92.7 ^oF
August	None	95 ^oF
September	None	88 ^oF
October	65 ^oF	None
Mean	**60 ^oF**	**85 ^oF**
Difference	**25 ^oF**	

Daily maximum average water temperatures were not available for Brownlee Reservoir. Instantaneous data was used for the purposes of this comparison and showed a similar trend. On days when the available surface water temperature were greater than 17.8 °C, the corresponding air temperatures were more than 13.9 °C (25 °F) higher than those measured on days when water temperatures did not exceed the 17.8 °C target.

This substantial difference in temperature supports the relatively high level of natural atmospheric and non-quantifiable temperature influence calculated above.

3.6.8.5 Tributary Cooling Evaluation.

After analyzing the existing conditions in the SR-HC TMDL reach, the effects of cooling the tributaries to the mainstem Snake River in the SR-HC TMDL reach were examined using the same calculational model described earlier. For this analysis, the water temperatures for all major tributaries to the mainstem Snake River in the SR-HC TMDL reach were gradually reduced to simulate cooling of the inputs to the river. Point sources, agricultural drains and ungaged inflows were kept at the initial values described earlier. The scenario modeling an equal (50:50) distribution of surface and ground water within the ungaged flow was employed in these calculations. This analysis used daily maximum water temperatures for an average water year as they represented the most complete data set available. However, the resulting outputs most likely represent a slight overestimation of the actual cooling necessary, as daily maximum water temperatures do not account for diurnal cooling influences.

The results of this analysis showed that the tributaries would all have to be cooled substantially to ensure that exceedences of the 17.8 °C seven-day average of daily maximum water temperatures instream in the mainstem Snake River at the Weiser gauge (RM 351) occurred less than 10 percent of the time.

The calculated reductions in daily maximum tributary water temperatures are as follows:

- an average of 7 °C during the month of June
- an average of 10 °C during the month of July
- an average of 10 °C during the month of August

Even when acknowledged to be a slight overestimate of the actual cooling necessary, these results show that the reductions needed in tributary water temperatures are very large, and unlikely to be achievable. The result is not unexpected given that in the initial evaluation performed, natural atmospheric and non-quantifiable temperature influences were identified as the primary factor driving temperature conditions in the mainstem river.

3.6.8.6 Conclusions.

From the temperature loading assessment discussed above, several conclusions can be drawn:

1. Ground water inflows exert a cooling effect on water temperatures observed within the mainstem Snake River. However, given the assumptions used in this calculation, the magnitude of cooling projected appears to be well within the general error and assumptions associated with this modeling exercise.

2. The overall magnitude of the influence of point sources on mainstem water temperatures within the SR-HC TMDL reach is calculated conservatively at 0.007 ^{o}C. This accounts for less than 0.2 percent of the total temperature load during the critical months of June, July, August and September. (Due to lack of consistent data, September temperature influences were not calculated, but were estimated to occur at a level similar to that observed in June.)

3. The average magnitude of the influence of tributary and drain inflows on mainstem water temperatures within the SR-HC TMDL reach is calculated conservatively at 0.5 ^{o}C. This accounts for approximately 12 percent of the total temperature during the critical months of June, July, August and September. (Due to lack of consistent data, September temperature influences were not calculated, but were estimated to occur at a level similar to that observed in June.). This does not account for natural atmospheric and non-quantifiable temperature influences within tributary systems. If the relative proportion of natural atmospheric and non-quantifiable temperature loading calculated for the mainstem Snake River within the SR-HC TMDL reach is applied to the tributary water temperature influences, the calculated average measurable anthropogenic temperature load to the Upstream Snake River segment (RM 409 to 335) would equal approximately 0.043 ^{o}C.

4. Calculated measurable anthropogenic temperature influences to the mainstem Snake River within the SR-HC TMDL reach are well below the "no-measurable-increase" value defined by the State of Oregon as 0.14 ^{o}C (0.25 ^{o}F).

5. Calculated natural and non-quantifiable temperature influences to the mainstem Snake River within the SR-HC TMDL reach equal over 90 percent of the increase in water temperature for the critical months of June, July, August and September. Natural atmospheric and non-quantifiable inputs are clearly the dominant influence on the water temperature of the river. Air temperature plays an important role in water temperature in the SR-HC TMDL reach.

3.6.9 Temperature and Designated Use Support Status

In correlation with the evaluation of the relative magnitude of temperature sources to the SR-HC TMDL reach discussed above, the existing language in the Oregon and Idaho state standards addressing temperature violations occurring from natural causes, and the ongoing process for improved temperature standards and policy in the Pacific Northwest, this TMDL recognizes the fact that water temperatures above those identified in the appropriate state standards can and do occur within the SR-HC TMDL reach due to natural atmospheric sources. Because of the situation occurring in the SR-HC TMDL reach, careful consideration has been given to the needs of designated aquatic life uses within the reach.

Although there are data that show water temperatures that exceed the temperature target in the reach, there is considerable information (data as well as anecdotal) available that indicates there were water temperatures over this target historically (prior to dam construction), even when aquatic species were present in healthy populations (USFWS, 1957 and 1958). One explanation for this is the occurrence of colder water refugia during periods of high stream temperatures in the bulk of the waterway. Such refugia are known to be present in the form of cold water tributaries in the SR-HC TMDL reach, and may also include springs or other ground water inflows where localized water temperatures are cooler than those observed for the system as a whole.

A second explanation is that water temperatures have always been elevated in much of the SR-HC TMDL reach and the lower portions of its tributaries due to high summer air temperatures, high solar radiation, and low summer flows. Climatologically, this area is classified as xeric, indicating little precipitation and high summer air temperatures. Native fish species may have adapted to these conditions. Fish species present (both native species and those introduced due to stocking or other management practices) may be capable of surviving and thriving in water temperatures in excess of those defined by the targets identified in this TMDL either with physiological or migration adaptations. Cold water refugia may have been more extensive historically than it is today due to anthropogenic effects in tributaries and the upstream Snake River. It is assumed that a combination of more extensive cold water refugia and an evolutionary temperature tolerance may both have been factors in supporting healthy population levels historically.

Both explanations have validity in this segment of the Snake River. Cold water refugia may have been more extensive historically than it is today due to anthropogenic effects in tributaries, the upstream Snake River and dam construction. It is assumed that a combination of more extensive cold water refugia and an evolutionary temperature tolerance may both have been factors in supporting healthy population levels historically. Both factors are explored further in the application of the creative approach outlined in the general loading analysis portion of this document.

The basic premise for developing the SR-HC TMDL is that the targets for the water body (Snake River mainstem from RM 409 to RM 188) must be set so that the water body will meet water quality standards. The reason water quality standards are established is the protection of designated beneficial uses. The criteria within water quality standards are developed as surrogate measures of beneficial use health/support, and it is assumed that attainment of those criteria will provide for full support of the designated beneficial uses. Therefore, water quality targets within the Snake River-Hells Canyon TMDL must be set so that water quality standards are met in such a manner that the designated beneficial uses are protected.

A second premise of this approach is the acknowledgement that there are distinct spatial and temporal (including seasonal) use patterns of the specific segments by the designated beneficial uses within the Snake River-Hells Canyon aquatic ecosystem. These spatial/temporal use patterns are not always captured in designation of beneficial uses by reach or watershed. Therefore, the Snake River-Hells Canyon TMDL targets and resulting implementation strategies need to recognize those spatial/temporal use patterns that exist, as well as the needed connectivity within the mosaic of designated beneficial uses (including critical habitat for sensitive species) throughout the waterbody. This would provide for full support of existing uses and the restoration of impaired designated uses within that mosaic. The Snake River-Hells Canyon TMDL also recognizes that this ecosystem is comprised of a variety of aquatic environments that include lentic, lotic and transition areas, each with their own characteristic attributes and beneficial uses.

3.6.9.1 COLD WATER REFUGIA.

It has been observed that there is often a natural component to any water body that may represent a source of pollutant loading. Surface water temperatures are observed to exceed water quality criteria within the SR-HC TMDL reach. The dominant cause of these exceedences is natural temperature loading. However, even with these exceedences, the Hells Canyon Complex manages to support viable populations of cold water species such as rainbow and redband trout.

Population Distribution.

Studies completed by IPCo have documented the distribution of salmonid species within the Snake River (Figure 3.6.6). Viable populations of rainbow trout have been documented to occur within the river system from American Falls to Swan Falls. While there is some variation in species composition throughout the studied sections of the mainstem Snake River, noticeably

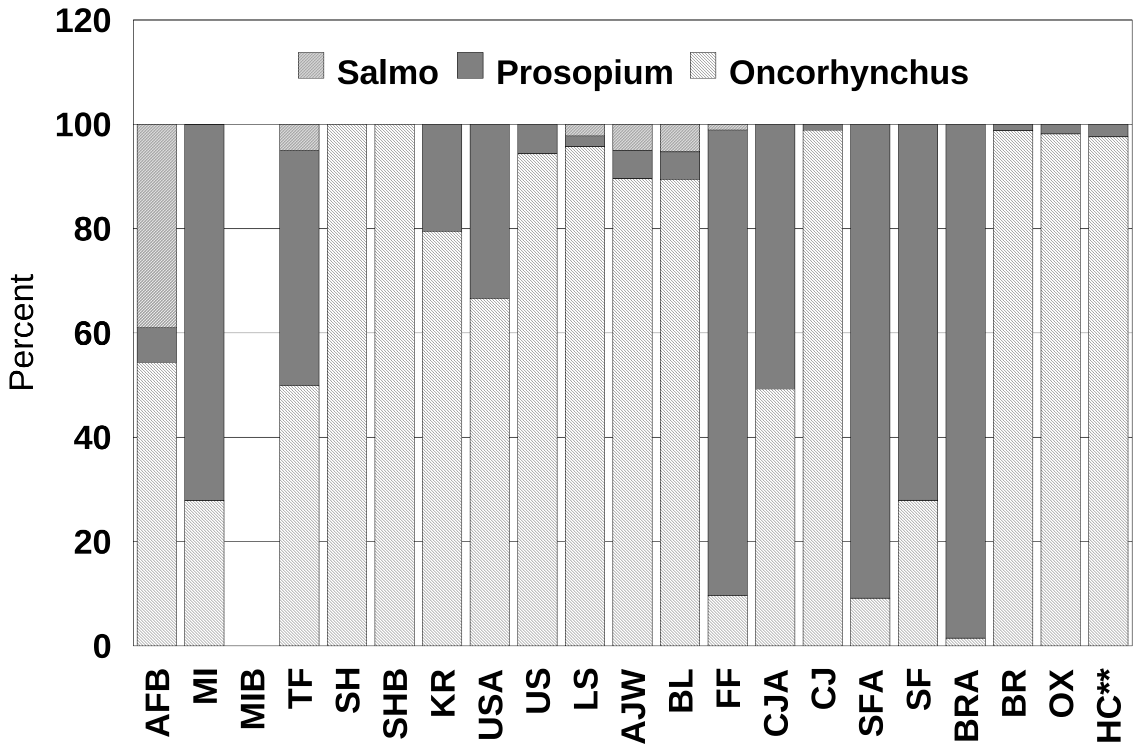


Figure 3.6.6. Percent composition of the family Salmonidae in the Snake River from the tailrace of American Falls Dam to Hells Canyon Dam. The genus *Salvelinus* is also present in small numbers in Hells Canyon Reservoir. Sampling is based on electrofishing spring and fall months periodically from 1991 to 2000. (Data was collected and plots were generated by Idaho Power Company).

The reach codes are as follows: AFB – American Falls Dam Tailrace, MI – Milner Reservoir, MIB – Milner Bypass Reach, TF – Twin Falls Reservoir, SH – Shoshone Falls Reservoir, SHB – Below Shoshone Falls to Pillar Falls, KR – Snake River from Buhl Bridge to Kanaka Rapids, USA – Snake River from Box Canyon to Thousand Springs, US – Upper Salmon Falls Reservoir, LS – Lower Salmon Falls Reservoir, AJW – Snake River from Lower Salmon Falls Dam to the upper end of Bliss Reservoir, BL – Bliss Reservoir, FF – Snake River from Bliss Dam to the upper end of CJ Strike Reservoir, CJ – CJ Strike Reservoir, SFA – CJ Strike Dam to the upper end of Swan Falls Reservoir, SF – Swan Falls Reservoir, BRA – Swan Falls Dam to the upper end of Brownlee Reservoir, BR – Brownlee Reservoir, OX – Oxbow Reservoir, HC – Hells Canyon Reservoir.

smaller relative populations of rainbow trout were observed in the sections of the Snake River from Bliss Dam to the upper end of CJ Strike Reservoir, in Swan Falls Reservoir and in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach where whitefish dominate. The Upstream Snake River segment of the SR-HC TMDL reach showed the lowest relative rainbow trout populations in the study.

Downstream of the Upstream Snake River segment (RM 409 to 335), populations of rainbow trout rebound as the dominant salmonid species within the Hells Canyon Complex reservoirs. Both stocked and wild trout populations have been tracked in this study. Figure 3.6.7 shows the relative abundance of wild and hatchery rainbow trout in the mainstem Snake River. Although hatchery fish are more abundant, Brownlee, Oxbow and Hells Canyon reservoirs support viable populations of wild fish. Similar wild populations have not been observed in the Upstream Snake River segment (RM 409 to 335) of the SR-HC TMDL reach.

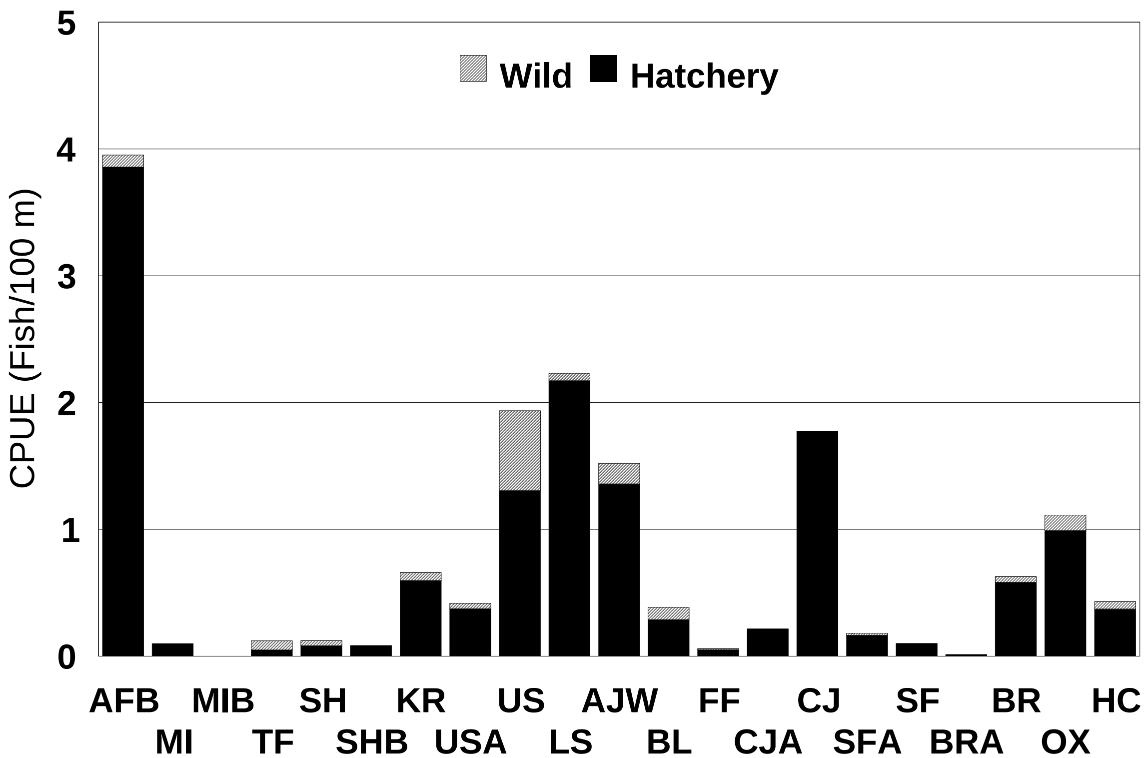


Figure 3.6.7. Relative abundance of wild and hatchery rainbow trout based on catch per unit of effort (CPUE fish/100 m of shoreline) in the Snake River from electrofishing effort in the Snake River from American Falls Dam tailrace to Hells Canyon Dam. Sampling is based on electrofishing spring and fall months periodically from 1991 to 2000. (Data was collected and plots were generated by Idaho Power Company). (The reach codes are defined in Figure 3.6.6)

A breakdown of spatial distribution within most of the SR-HC TMDL reach is displayed in greater detail in Figure 3.6.8. The data illustrated in this figure show hatchery rainbows present in the Snake River near Swan Falls Dam. Wild rainbows have not been documented in this section of the river. No rainbow populations (wild or hatchery) are observed between the area

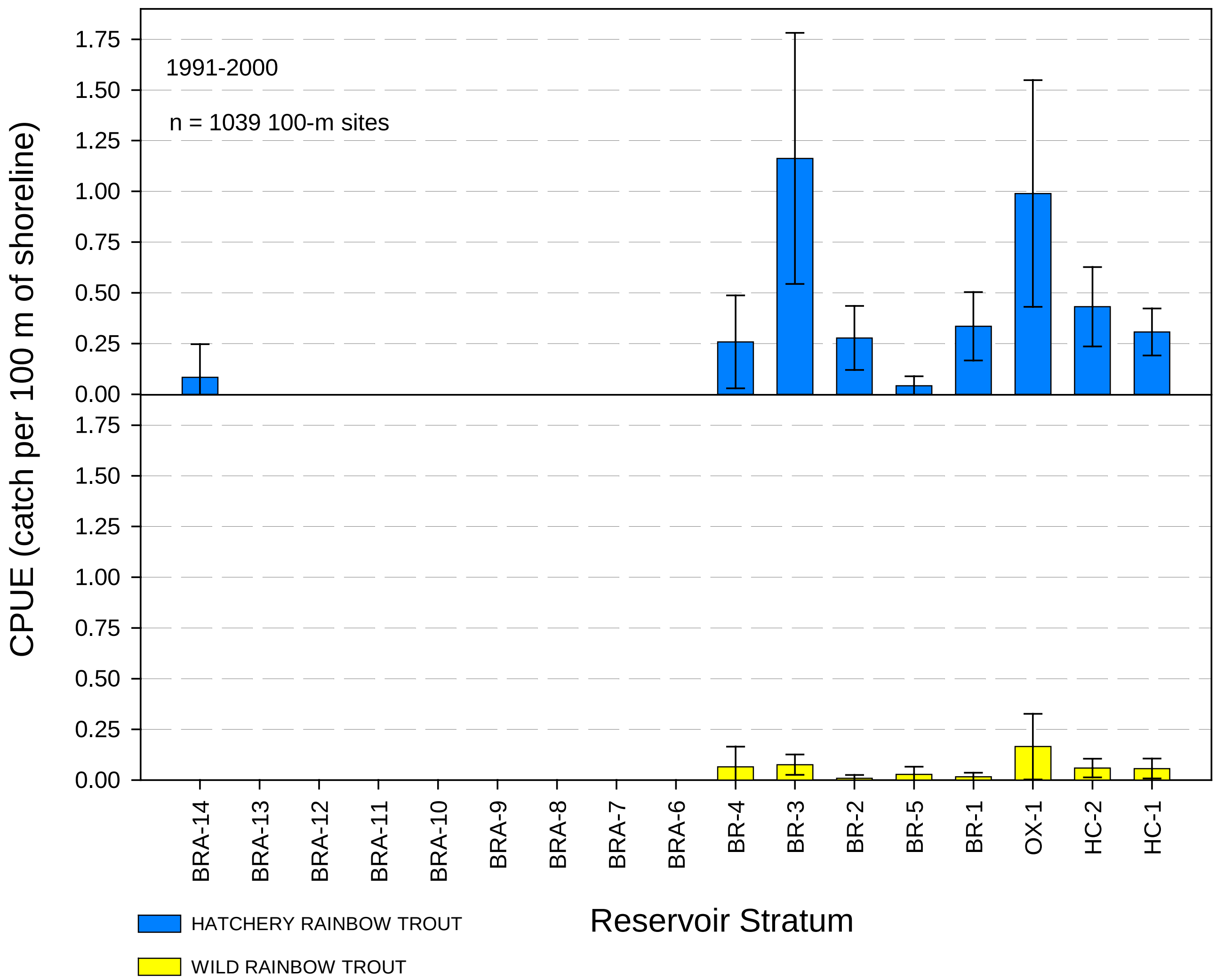


Figure 3.6.8. Relative abundance based on catch per unit of effort (CPUE per 100 m of shoreline electrofishing) of hatchery and wild rainbow trout in the Snake River from Swan Falls Dam to Hells Canyon Dam by sampling stratum. Sampling occurred annually during spring and fall, 1991 to 2000. Sampling strata BRA-14 to BRA-6 include the free-flowing reach from Swan Falls Dam to Brownlee Reservoir, sampling strata BR4-BR1 include Brownlee Reservoir, and sampling stratum BR-5 includes the Powder River Arm of the Brownlee Reservoir, OX1 includes Oxbow Reservoir, and HC1-HC2 include Hells Canyon Reservoir. (Data collected and plots generated by Idaho Power Company). (The reach codes are defined in Figure 3.6.6)

downstream of Swan Falls Dam and the inflow of Brownlee Reservoir. Within the reservoir segments however, both hatchery and wild rainbows are observed. The largest relative abundance based on catch per unit of effort values for both hatchery and wild rainbow trout were observed in Brownlee Reservoir (at BR3) and in Oxbow Reservoir.

The rainbow trout observed in Brownlee, Oxbow and Hells Canyon reservoirs and the Downstream Snake River segment (RM 247 to 188) showed a fairly wide range of size classes. As total body length in most fish species is substantially dependent on habitat, genetic and climatological factors, a straight length to age correlation cannot be accurately applied. Site-specific data is recommended for any such correlation. A study conducted by ODFW in McGraw Creek (a tributary to Hells Canyon Reservoir) provides a general estimation of these site-specific correlations.

This study developed length to age relationships for rainbow trout by using scale characteristics to age fish for which length measurements had been recorded. As fish age, thicker bands or growth "rings" known as annulus are formed, usually during cooler winter months when growth is slower. By counting the number of these rings present on scales a general idea of the number of winters a fish had lived could be determined. This study found that rainbow trout with scales containing 2+ annulus averaged 160 mm (6.3 inches) in length; these fish were estimated to be approximately 2 years old. Rainbow trout with 6+ annulus averaged 288 mm (11.3 inches) in length, these fish were estimated to be approximately 6 years old. Fish with 1+ annulus (considered fingerling fish) averaged 51 mm (2.0 inches) in length; these fish were estimated to be approximately 1 year old or less. If these same relationships are applied to the fish length data collected by IPCo shown in Figure 3.6.9, it can be seen that the reservoirs and the Downstream Snake River segment (RM 247 to 188) are home to a broad age range of fish.

Within Brownlee Reservoir, wild rainbows range from fingerling fish one year of age or less to over six years of age. In Brownlee Reservoir wild rainbows aged from fingerlings to approximately two years of age were most abundant. Wild rainbow trout in Oxbow range from approximately one year to over six years of age. In Oxbow Reservoir wild rainbows aged from two years to over six years were the most abundant. In Hells Canyon Reservoir wild rainbow trout range from fingerlings to over six years in age. In Hells Canyon Reservoir wild rainbows approximately two years of age and those over six years of age were the most abundant. Below Hells Canyon Dam, in the Downstream Snake River segment (RM 247 to 188), wild rainbow trout ranged from approximately six years in age.

Current beneficial use reconnaissance protocol defines full support criteria for fishes as supporting three age classes. If the assumptions above are correct, all three reservoirs support the designated salmonid rearing/cold water aquatic life use.

Spatial and Temporal Use Patterns.

As stated previously, a primary premise of the approach applied by this TMDL is the acknowledgement of distinct spatial and temporal (including seasonal) use patterns of the specific segments by the designated beneficial uses within the Snake River-Hells Canyon aquatic ecosystem. Within the complex system of mainstem and tributary waters within the SR-HC TMDL reach, these spatial and temporal use patterns are not always completely captured in designation of beneficial uses by reach or watershed. In the reservoir and Downstream Snake River segments of the SR-HC TMDL, joint use of reservoir and tributary systems provides support of salmonid rearing/cold water aquatic life designated uses.

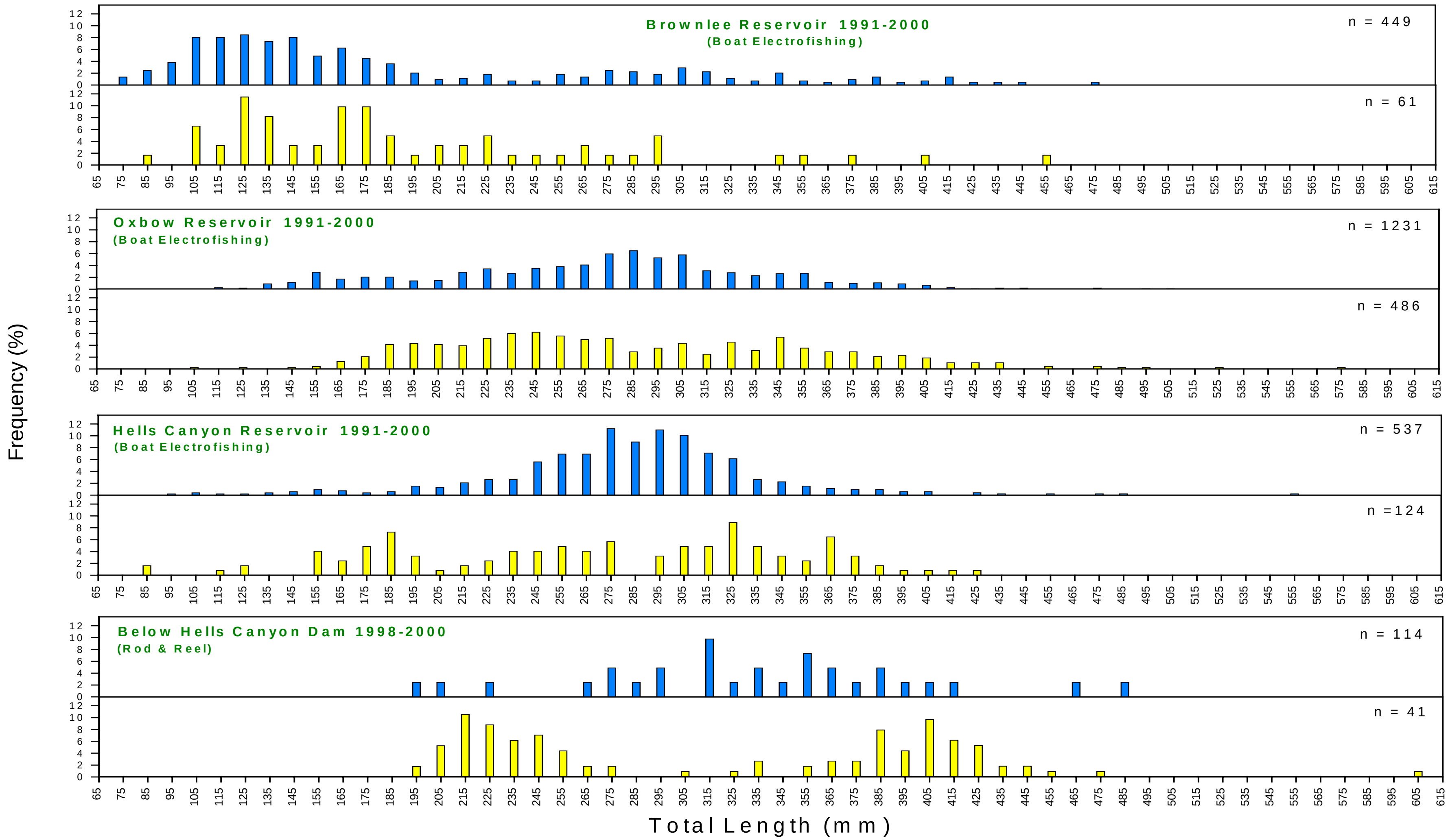


Figure 3.6.9. Percent length frequencies of wild and hatchery rainbow trout in Brownlee, Oxbow and Hells Canyon reservoirs from annual shoreline electrofishing sampling during spring and fall months from 1991 to 2000 (top three graphs). Percent length frequencies of wild and hatchery trout below Hells Canyon Dam from rod and reel sampling from 1998 to 2000 (bottom graph). (Data were collected and plots generated by Idaho Power Company.)

This temporal and spatial use mosaic is documented through a tracking study authored by IPCo for the reservoir and Downstream Snake River segments. Data was collected to identify relative population distributions on a monthly basis in the mainstem Snake River in the Hells Canyon Complex. The collected data for the 1998 through 2000 time period are shown in Figure 3.6.10.

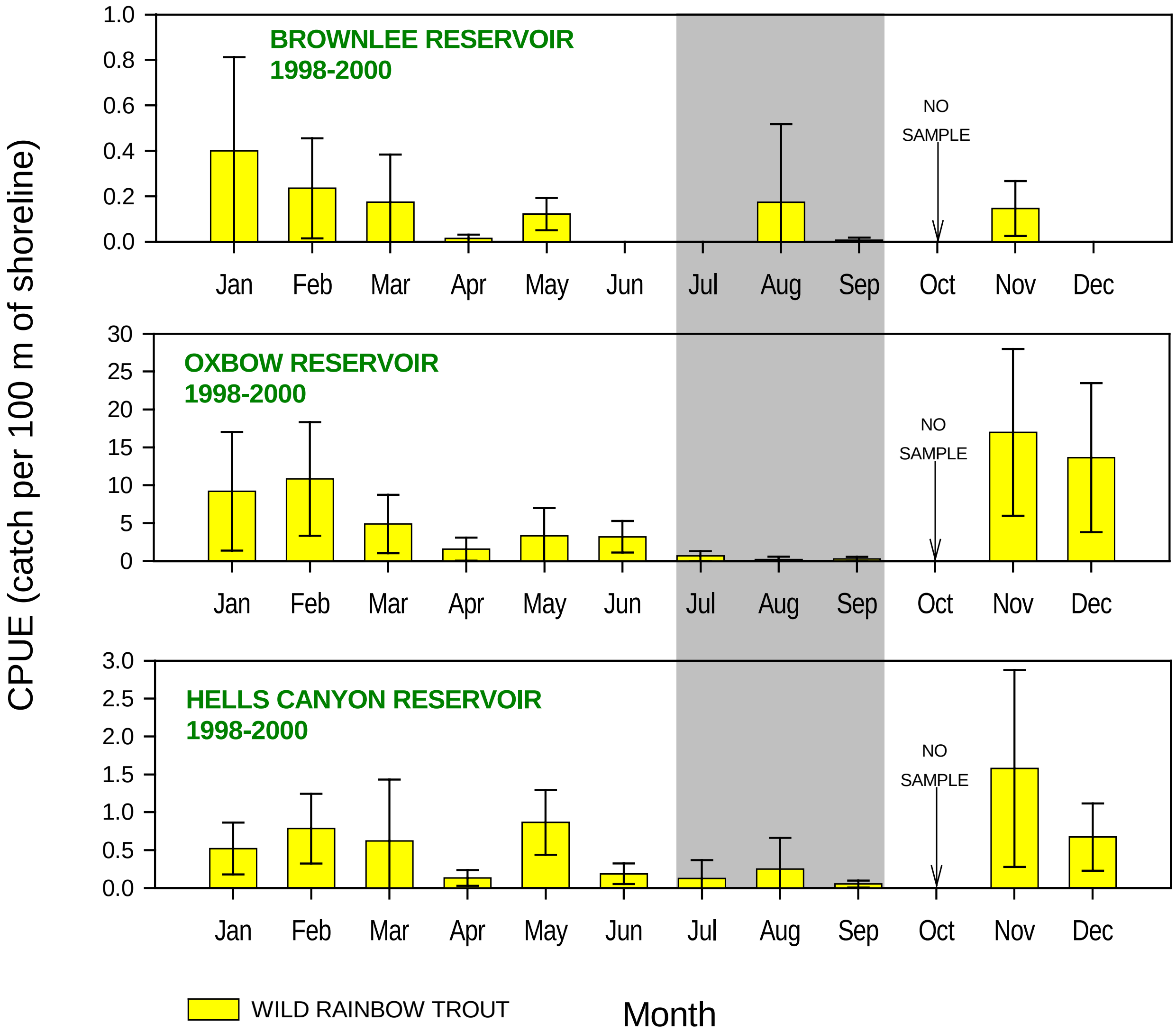


Figure 3.6.10. Monthly relative abundance of wild rainbow trout in Brownlee, Oxbow and Hells Canyon Reservoirs based on catch per unit of effort (CPUE per 100 m of shoreline electrofishing) during 1998 to 2000. Gray shaded area represents the period of warm summer water temperatures. (Data were collected and plots generated by Idaho Power Company.)

For all three reservoir systems, relative abundance of wild rainbow trout increases during the fall and winter months, then decreases during late spring and summer months. Data collected for hatchery raised rainbow trout show a similar relative abundance pattern.

When compared to the available water temperature data for the Hells Canyon Complex discussed in the preceding sections, a temperature triggered pattern is evident. Wild populations are present in Brownlee, Oxbow and Hells Canyon reservoirs throughout the winter and spring months (November through May). During the month of June, when water temperatures become elevated, relative abundance of rainbow trout in the reservoirs start to decrease. The lower relative abundance levels in-reservoir continue through the summer months (July through September) and then increases again in November.

Tributary monitoring through migrant weir placement shows an opposite pattern. In-migration to the reservoir occurs in October and November. Out-migration from the tributaries was observed during this same time period. Figures 3.6.11 a – c illustrate this pattern for tributaries to Brownlee Reservoir (Brownlee Creek), Oxbow Reservoir (Wildhorse Creek), Hells Canyon Reservoir (Indian Creek) and the Downstream Snake River segment (Sheep Creek). Relatively few fish were detained behind the migrant weirs in early to mid-September; frequency of daily captures increases throughout late September into October, and then decreases through November.

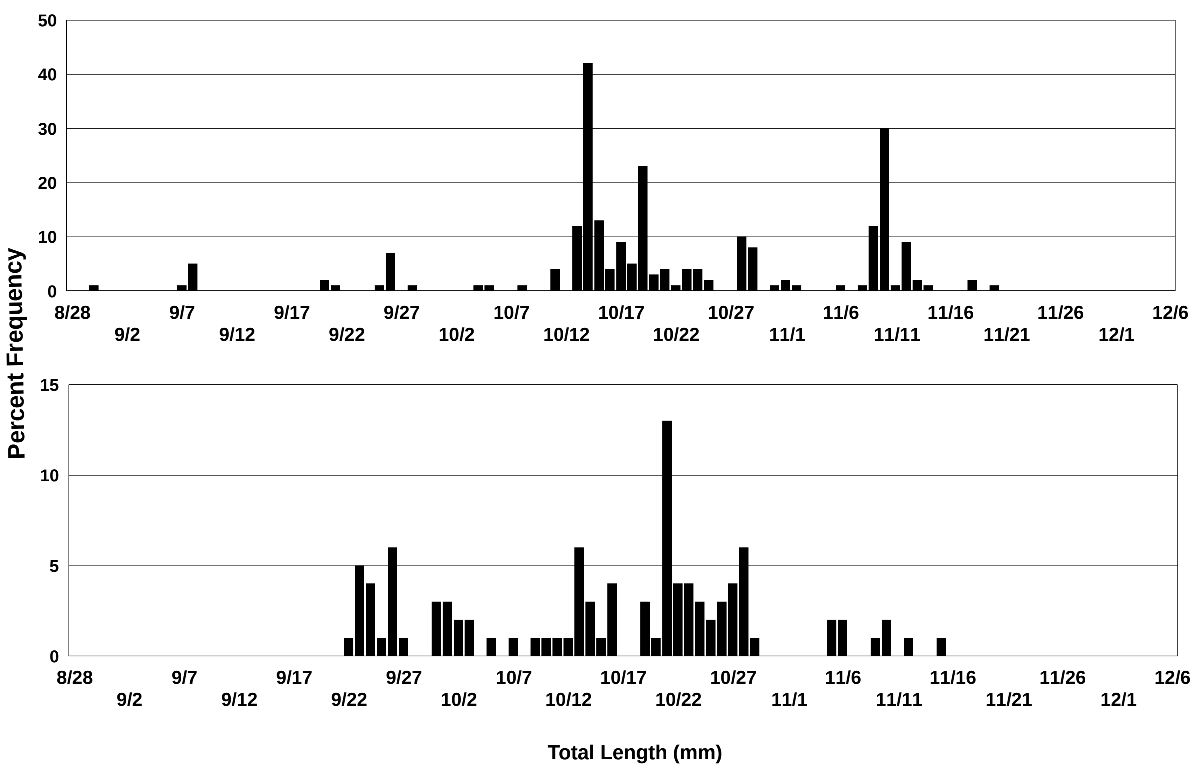


Figure 3.6.11 a. Frequency of daily captures of wild rainbow trout in a downstream migrant weir in Wildhorse River during 1998, and Brownlee Creek during 2000. (Data collected and plots generated by Idaho Power Company.)

This observed migratory pattern correlates well with water temperature increases in the mainstem Snake River in early summer (i.e. water temperatures above 18 ^{o}C become common near the surface in Brownlee Reservoir) and with water temperature decreases in the reservoir systems and tributaries in the late fall. The water temperature data shown in Figure 3.6.12 suggests that tributary temperatures below 10 ^{o}C may act as a trigger for migration into the reservoir systems. Observed relative abundance of both wild and hatchery rainbow trout in Brownlee, Oxbow and Hells Canyon reservoir rebound in close correlation with the occurrence of these temperature levels in the inflowing tributaries. It is theorized that the somewhat higher water temperatures in the reservoir segments may represent a less stressful overwinter environment for some fish species than the inflowing tributaries that experience substantial ice cover during the winter months.

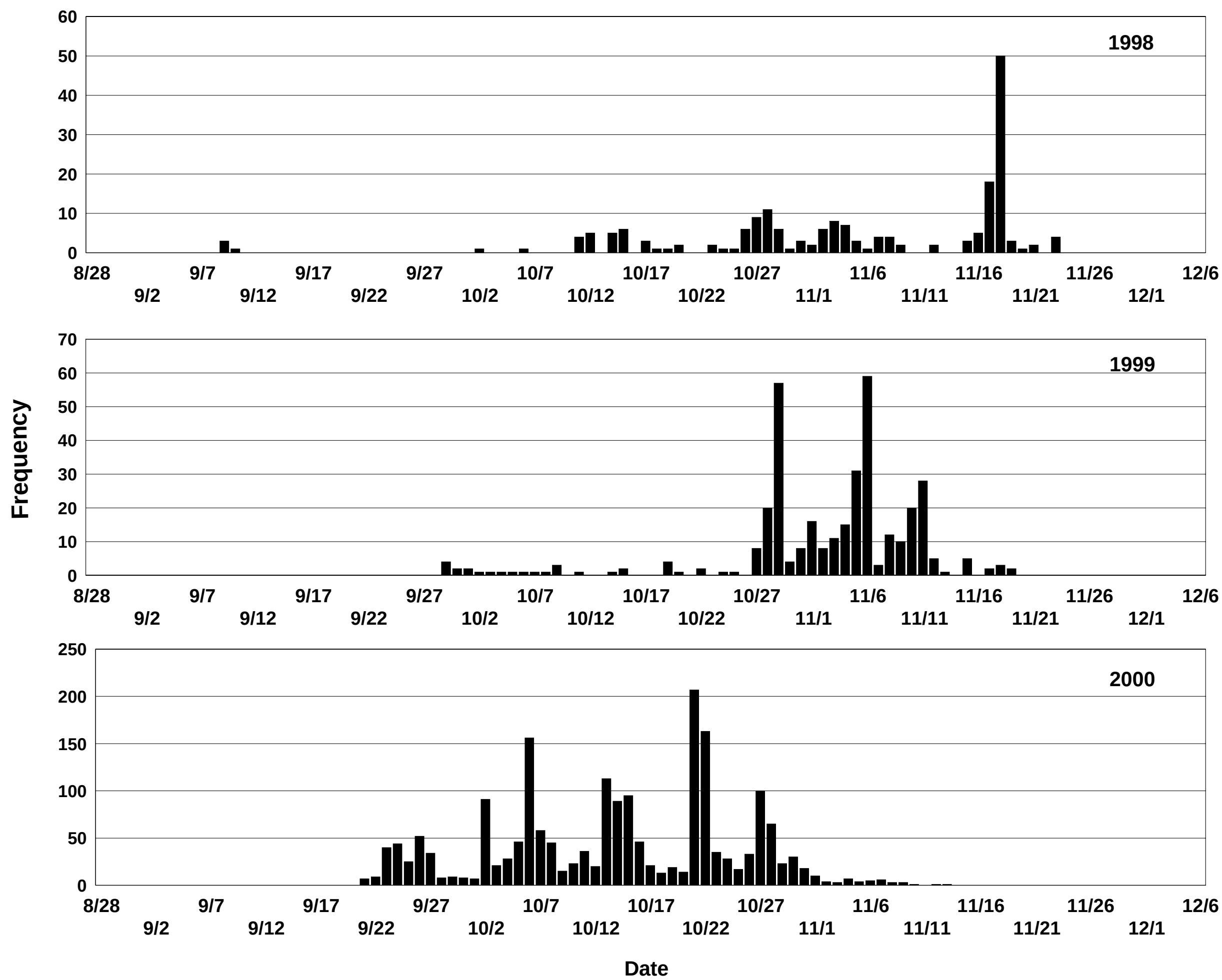


Figure 3.6.11 b. Frequency of daily captures of wild rainbow trout in a downstream migrant weir in Indian Creek during 1998, 1999 and 2000. (Data collected and plots generated by Idaho Power Company.)

As shown in Figure 3.6.13 a – c, the age distribution of migrating tributary populations observed in the above study correlate well with those identified for Brownlee, Oxbow and Hells Canyon reservoirs and the Downstream Snake River segment (RM 247 to 188). In Brownlee Creek (discharging to Brownlee Reservoir at RM 285.5), wild rainbows range from fingerling fish one year of age or less to over six years of age. In Brownlee Creek wild rainbows approximately two years of age were most abundant. Wild rainbow trout in Wildhorse Creek (discharging to Oxbow at RM 284.4) range from approximately one year to over six years of age.

In Oxbow Reservoir wild rainbow fingerlings and those from two years to three years of age were the most abundant. In Indian Creek (discharging to Hells Canyon Reservoir at RM 270) wild rainbow trout range from fingerlings to over six years in age. Indian Creek wild rainbows approximately two years of age and under were the most abundant. In Sheep Creek (discharging to the Downstream Snake River segment at RM 229), wild rainbow trout ranged from

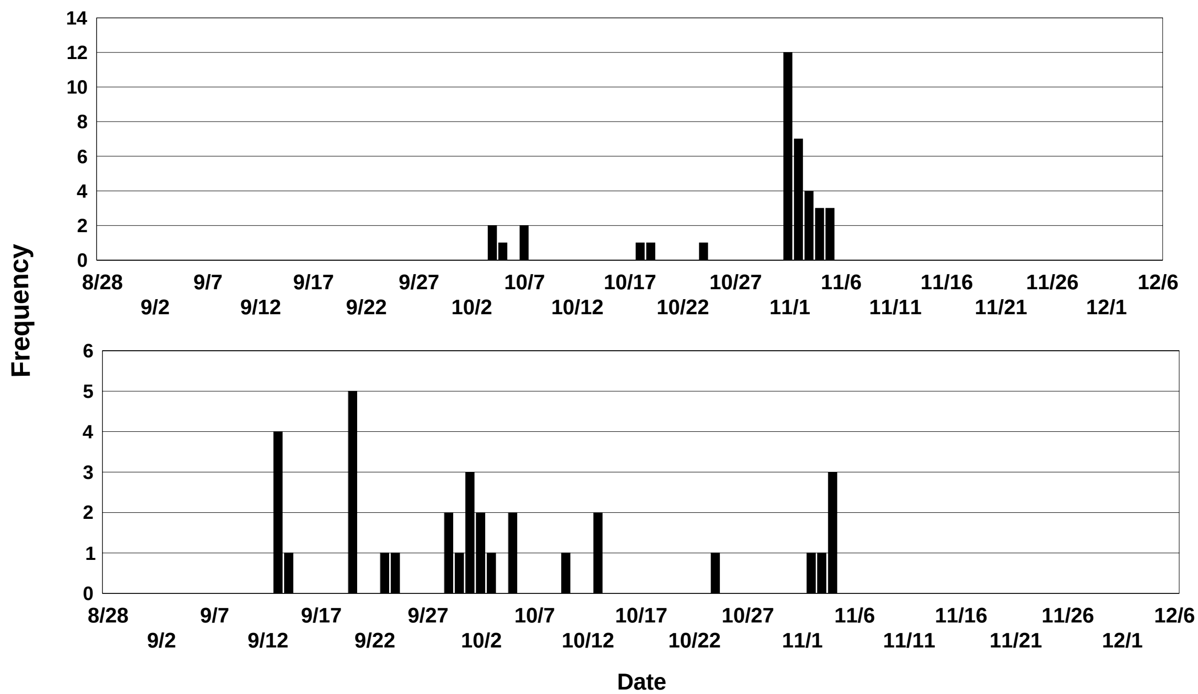


Figure 3.6.11 c. Frequency of daily captures of wild rainbow trout in a downstream migrant weir in Sheep Creek during 1999 and 2000. (Data collected and plots generated by Idaho Power Company.)

approximately six years in age, with wild rainbows approximately two years of age and under being the most abundant.

The tributaries to Brownlee, Oxbow and Hells Canyon reservoirs and the Downstream Snake River Segment are cooler during the critical summer months than the reservoir waters. Thus these tributaries provide cold water refugia that allows cold water species to avoid the higher water temperatures in the reservoirs during the summer months. The collected data show that designated beneficial use support is occurring given joint use of both reservoir and tributary systems. Within the Hells Canyon Complex of reservoirs and the Downstream Snake River segment, these distinct spatial and temporal (seasonal) use patterns occur to support salmonid rearing/cold water aquatic life designated beneficial uses.

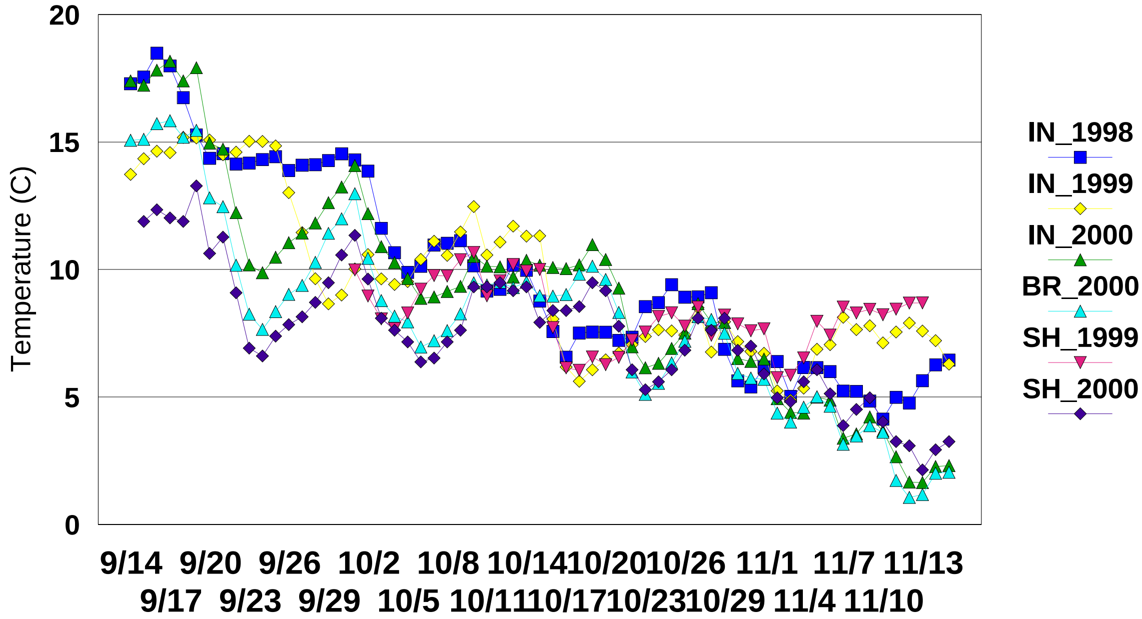


Figure 3.6.12. Water temperature (°C) from Indian Creek (IN), Brownlee Creek (BR), and Sheep Creek (SH) during fall months of 1998 to 2000. (Data collected and plots generated by Idaho Power Company.)

In contrast, rainbow trout populations in the Upstream Snake River segment (RM 409 to 335) are nearly nonexistent. For the most part, the tributaries discharging to the Snake River in this segment are not cold, fast moving streams like those inflowing to the Hells Canyon Complex reservoirs and do not provide the necessary level of cold water refugia for rainbows and other cold water fish in the system. Therefore, a viable population of rainbows is not observed in the Upstream Snake River segment (RM 409 to 335).

Creation of this type of refugia in the Upstream Snake River segment may represent a possible mechanism to deal with natural temperature loading concerns and lower rainbow trout populations in this section. Where slopes are more gradual in this section, it is unclear how possible or successful the creation of such refugia would be. A separate option is a full evaluation of the appropriateness of the designated beneficial uses of salmonid rearing and cold water aquatic life in this segment of the SR-HC TMDL reach. An effort toward this end is currently underway by stakeholders of the SR-HC TMDL process. Data generated by this effort will be evaluated within the iterative nature of the SR-HC TMDL process. If designated use refinement is judged to be necessary, the appropriate legislative processes will be followed and the TMDL will be adjusted accordingly.

Within the Hells Canyon Complex and the Downstream Snake River segment (RM 247 to 188), designated beneficial uses are being supported through availability of cold water refugia. Without question, existing refugia in the SR-HC TMDL reach must be protected and improved as necessary to continue support of the designated beneficial uses.

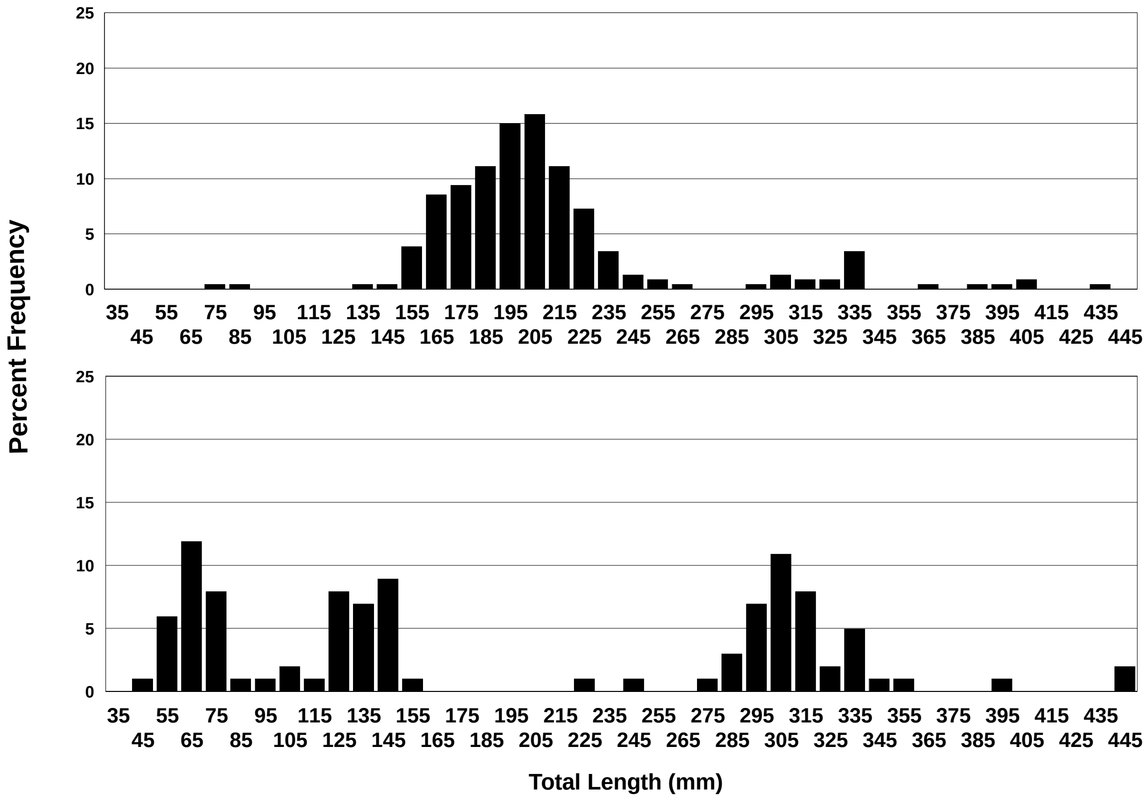


Figure 3.6.13 a. Length frequencies (percent) of wild rainbow trout captured in the downstream migrant weir near the mouth of Wildhorse River during fall of 1998 (top graph) and near the mouth of Brownlee Creek during fall of 2000 (bottom graph). (Data collected and plots generated by Idaho Power Company.)

In correlation with the proposed approach therefore, tributaries currently providing cold water refugia must be managed so that they continue to represent alternative habitat for salmonid rearing/cold water aquatic life during the critical months of June, July, August and September. Additionally, those tributaries that could provide such refugia but are not currently doing so due to anthropogenic influences should be managed so that such refugia is provided as appropriate.

In this way those portions of the SR-HC TMDL system that are being utilized as habitat for support of the designated beneficial uses of salmonid rearing/cold water aquatic life, namely those tributaries that currently are or could be providing cold water refugia during the critical time period, will meet criteria, and will support designated beneficial uses without imposing inappropriate and unreachable water quality targets and implementation expectations on the system as a whole.

3.6.9.2 ADAPTATION OF FISH SPECIES PRESENT.

The alternative explanation proposed above, that water temperatures have always been elevated in much of the SR-HC TMDL reach due to climatological influences and that native fish species may have adapted to these conditions with either physiological or migration adaptations also has some application. The discussion of cold water refugia above cited work by IPCo showing

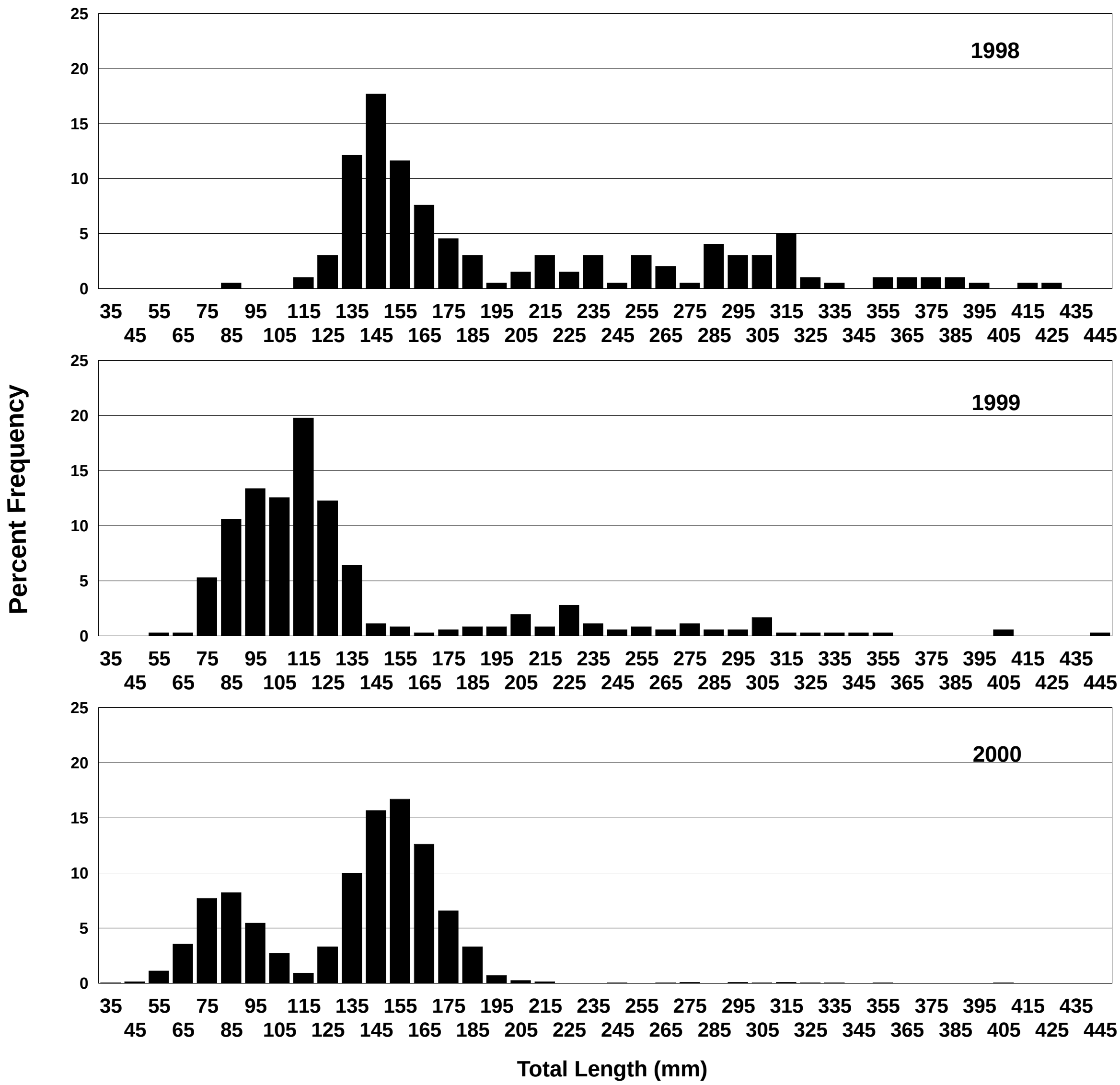


Figure 3.6.13 b. Length frequencies (percent) of wild rainbow trout captured in the downstream migrant weir near the mouth of Indian Creek during fall months of 1998, 1999 and 2000. (Data collected and plots generated by Idaho Power Company.)

migration patterns of rainbow trout within the Hells Canyon Complex (IPCo, 2001g). This migration is an adaptive behavior apparently triggered by temperature changes within the water column. Warm water temperatures trigger the out-migration to cooler tributary waters during the critical time period of June through September. Return-migration also appears to be temperature driven in that the majority of movement from the tributaries to the reservoir occurs when the tributary water temperatures first drop below 10 ^{o}C.

This adaptive behavior serves two purposes for the migrating fish. It removes them from tributaries that may not have enough flow to support a larger population over the winter period

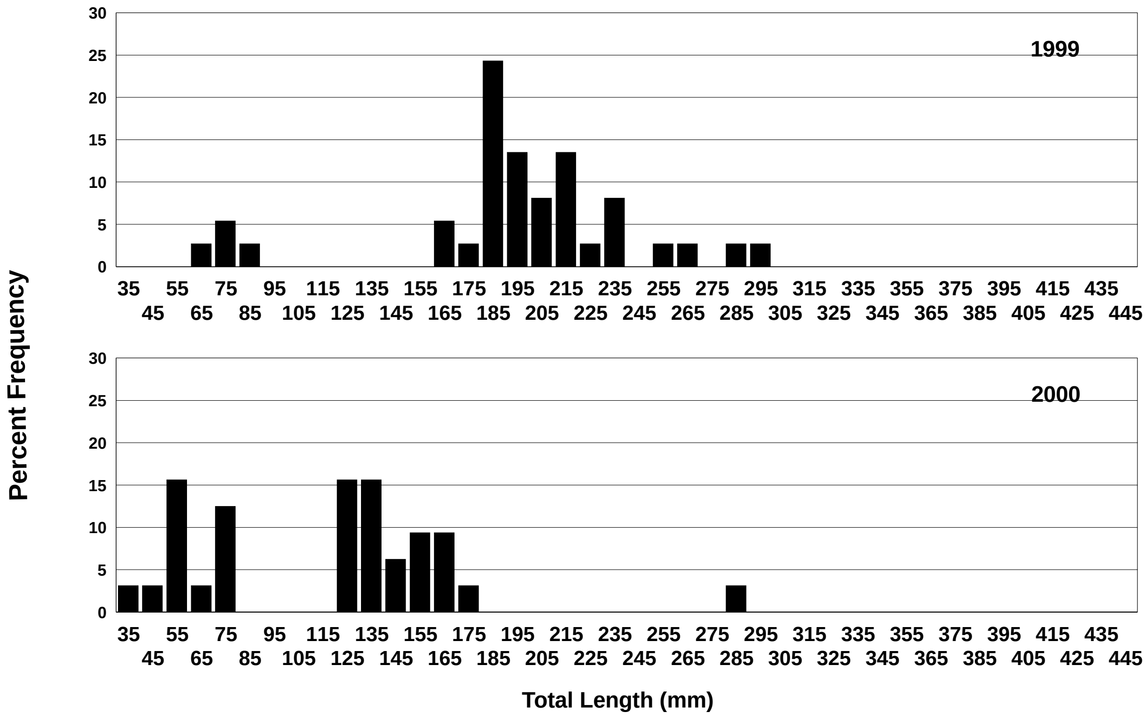


Figure 3.6.13 c. Length frequencies (percent) of wild rainbow trout captured in the downstream migrant weir near the mouth of Sheep Creek during fall months of 1999 and 2000. (Data collected and plots generated by Idaho Power Company.)

(ice-in and over winter concerns increase with smaller pool size and depth) and provides, through migration back into the reservoir, and more plentiful food source than would be available in the tributaries over the winter months. Studies have shown that moderate water temperatures result in better growth characteristics than waters that are substantially colder over extended periods of time (Appendix C and associated references). Therefore, this temperature triggered migration potentially provides a source of cool water during the critical summer months and an improved food supply during the colder winter months.

Additionally, an assessment of total population distribution for the SR-HC TMDL reach shows that warm water fishes dominate the system. Data on species distribution is available from before the CWA was finalized in 1975 (IDFG, 1973a and b) that indicates that warm water species were the dominant population. More recent studies (IPCo, 2000a; IDFG, 2000; ODFW, 2001) show that a similar distribution remains today within the SR-HC TMDL reach.

Rainbow trout, redband trout and mountain whitefish are listed as present in the Upstream Snake River segment (RM 409 to 335); although population counts like the one described earlier (Figure 3.6.6) show that the dominant cold water species in this segment is mountain whitefish. In the Brownlee and Oxbow reservoir segments rainbow trout, redband trout and mountain whitefish are listed as the cold water species present. While the population of mountain whitefish does not dominate in the reservoirs, the warmwater and coolwater species still substantially outnumber the cold water species (Table 3.6.7).

Table 3.6.7. Fish species present in the Snake River - Hells Canyon TMDL reach as identified by IDFG, ODFW, IDEQ, USFWS/IPCo and ACOE.

Segment	Warm Water Species	Cool Water Species	Cold Water Species
Upstream Snake River	largemouth bass channel catfish flathead catfish bluegill white crappie black crappie bullhead	smallmouth bass yellow perch pumpkinseed bridgelip sucker largescale sucker white sturgeon	rainbow trout* redband trout* mountain whitefish white sturgeon
Brownlee Reservoir	largemouth bass channel catfish bluegill white crappie black crappie bullhead common carp tadpole madtom flathead catfish warmouth	smallmouth bass pumpkinseed chiselmouth northern pike minnow bridgelip sucker largescale sucker peamouth sculpin[1] yellow perch white sturgeon	rainbow trout* redband trout* mountain whitefish* sculpin[1] white sturgeon
Oxbow Reservoir	largemouth bass bluegill white crappie black crappie bullhead common carp bridgelip sucker largescale sucker bridgelip sucker warmouth	smallmouth bass yellow perch pumpkinseed chiselmouth northern pike minnow white sturgeon	rainbow trout* redband trout* mountain whitefish* sculpin white sturgeon
Hells Canyon Reservoir	largemouth bass channel catfish bluegill white crappie black crappie bullhead common carp warmouth	smallmouth bass yellow perch pumpkinseed chiselmouth northern pike minnow bridgelip sucker largescale sucker sculpin[1] white sturgeon	rainbow trout* redband trout* mountain whitefish* bull trout** sculpin[1] white sturgeon
Downstream Snake River	largemouth bass channel catfish flathead catfish bluegill white crappie black crappie bullhead goldfish common carp tadpole madtom	stoneroller[2] smallmouth bass pumpkinseed chiselmouth northern pike minnow longnose dace bridgelip sucker largescale sucker yellow perch white sturgeon	chinook salmon (spring)* chinook salmon (summer)* chinook salmon (fall) sockeye salmon** rainbow trout/steelhead* redband trout* mountain whitefish kokanee salmon bull trout** white sturgeon

* Indicates species that spawn in the tributaries only – not in the mainstem.

[1] Depending on Species

[2] Not previously described in Idaho

** Indicates species that spawn in the upper tributaries only – not in the mainstem

The Hells Canyon Reservoir shows the addition of adult Bull Trout to the cold water species list but the warm water species still substantially outnumber the cold water species. Tributaries to the SR-HC TMDL reach are often nearly exclusively cold water species, especially in the upper reaches; however, the mainstem segments are consistently dominated by warm water species.

In the Downstream Snake River segment (RM 247 to 188), cold water species represent a greater portion of the overall fish population but warm water species are still present in a nearly equal role. The shift from cold to warm water species with distance downstream from the headwaters is certainly driven to some extent by water temperatures. Cold water fish are observed to be more plentiful in those areas where water temperatures are lower and warmer water species are more plentiful in areas with elevated water temperatures.

In addition to the overall population distribution however, some selectivity has been noted within the cold water species. Redband trout are plentiful in the Hells Canyon Complex. These fish are somewhat more elastic than the rainbow trout in adapting to elevated water temperatures, and show viable populations in the reservoir complex (IPCo, 2001g).

Fish requiring colder water temperatures or more stringent substrate conditions are not known to spawn within the SR-HC TMDL reach. Rather, these fish have been observed to spawn higher up in the tributaries to the system, using the available resources in a spatial and temporal fashion to meet habitat requirements for all life stages within the SR-HC watershed.

3.6.10 Conclusions

Temperature increases naturally within the SR-HC TMDL reach, the relative levels calculated for natural atmospheric and non-quantifiable (background) temperature influence in the Upstream Snake River segment (RM 409 to 335) during June equal 98.9 percent of the total, during July equal 99.5 percent of the total, during August equal 98.5 percent of the total and during September are assumed to be comparable to the values calculated for June (> 98%).

Temperature increases calculated for the permitted point sources within the Hells Canyon Complex of reservoirs and the Downstream Snake River segment (RM 247 to 188) are less than 10 percent of the level defined as no-measurable-increase by the State of Oregon, and less than 5 percent of the level defined as no-measurable-increase by the US EPA (Colville tribe) and the State of Idaho. All calculations were made in a conservative fashion and are based on available data.

The calculations indicate that natural atmospheric and non-quantifiable sources are clearly the dominant influence on the water temperature of the river, and that air temperature plays an important role in the elevated water temperatures observed in the SR-HC TMDL reach.

An evaluation of cold water aquatic life focusing on rainbow trout and redband trout show that they are present in viable populations in Brownlee, Oxbow and Hells Canyon Reservoirs. Evidence indicates that these populations have adapted to the naturally elevated water temperatures in the SR-HC TMDL reach by migrating into cold water tributaries during the summer season when reservoir temperatures exceed the conditions appropriate for salmonids. Alternatively, the reservoirs provide an appropriate habitat for over-winter growth when the tributary temperatures drop below approximately 10 ^{o}C. Support of these species is being provided by the availability of cold water refugia during the critical time period of June through September.

The same level of support is not available in the Upstream Snake River segment (RM 409 to 335), as is evidenced by the lack of diversity in local populations and the dominance of mountain whitefish as opposed to rainbow trout and other salmonid species. This section of the SR-HC TMDL reach experiences elevated water temperatures due predominantly to natural atmospheric and non-quantifiable influences. As the climate and landforms are very similar throughout the lower end of the Snake River Basin, it is expected that exceedence of water quality targets in inflowing tributary systems is also driven predominantly by natural atmospheric and non-quantifiable influences.

The Hells Canyon Complex causes a shift in temperatures from those that would occur were the Hells Canyon Complex not in place. Peak summer temperatures are several degrees cooler due to withdrawals from below the reservoir surface, and the decline in temperatures in the fall is delayed from that observed immediately upstream of the Hells Canyon Complex. While the temporal distribution of this temperature shift is due to the delay in flow caused by water moving through the Hells Canyon Complex, the actual heat load (warmer water) is not. The impoundments are not a heat source.

Data available to this TMDL effort and modeling work completed by IPCo shows that the Hells Canyon Complex is not the source of the heat load in the reservoirs and that if upstream conditions were cooler, the water exiting the Hells Canyon Complex would also be cooler. Therefore, it is concluded that IPC is not contributing to temperature exceedences specific to the cold water aquatic life/salmonid rearing designated use

However, data assessment and calculational modeling by the DEQs, and IPCo water temperature modeling also shows that water exiting the Hells Canyon Complex would not meet the salmonid spawning criteria (although by only a small margin) because of the temporal shift created by the Hells Canyon Complex. It is, therefore, concluded that the responsibility for exceeding the salmonid spawning criteria is specific to the presence and operation of the Hells Canyon Complex.

3.7 Total Dissolved Gas Loading Analysis

3.7.1 Water Quality Targets and Guidelines

The purpose of TMDL development is to meet applicable water quality standards. The SR-HC TMDL is a bi-state effort; both Oregon and Idaho share the same numeric water quality standard for total dissolved gas (TDG). The target concentration for the SR-HC TMDL reach is therefore, the common water quality standard; that the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection shall not exceed 110 percent of saturation, except when stream flow exceeds the ten-year, seven-day average flood flow (See Section 2.2.4.7). Attainment of this target will ensure that the water quality requirements of both states will be met. Currently, exceedences of this target are known to have occurred downstream of Brownlee Dam.

The State of Oregon has an additional requirement that in hatchery receiving waters and waters of less than two feet in depth, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection shall not exceed 105 percent of saturation. The total dissolved gas target for the SR-HC TMDL will include this additional requirement where applicable.

While total dissolved gas exceedences have been documented to occur within the SR-HC TMDL reach, no segment of the reach is listed for total dissolved gas by either the State of Oregon or the State of Idaho. However, as part of the public process outlined in Idaho by House Bill 1284, if a local watershed advisory group (WAG) requests that an unlisted pollutant be addressed in a TMDL, IDEQ should make every reasonable effort to accommodate the request. Two members of the SR-HC Public Advisory Team (which acts as the WAG for the SR-HC TMDL process) requested that the SR-HC TMDL address total dissolved gas. In an effort to accommodate this request, total dissolved gas has been incorporated into this loading assessment.

The Hells Canyon Complex is licensed by FERC, and requires 401 Certification from both the State of Oregon and the State of Idaho. Re-licensing of the Hells Canyon Complex is running somewhat concurrently with the TMDL process, and 401 Certification will run concurrently with the FERC re-licensing process. A very broad and capable effort involving many at the private, state and federal level is currently working to identify the full extent of total dissolved gas concerns, designated use support needs, and viable treatment options associated with total dissolved gas violations in the Hells Canyon Complex. As the re-licensing process proceeds, these efforts will be used to augment the general discussion included here, through 401 Certification of the Hells Canyon Complex. In addition, these processes will act in an enforcement capacity to provide reasonable insurance that total dissolved gas improvements in the Hells Canyon Complex will be realized and designated beneficial uses fully supported.

3.7.2 Designated Beneficial Use Impairment

Elevated total dissolved gas concentrations (above 110% of saturation) are known to have a detrimental effect on aquatic biota. High concentrations of gas dissolved in the water can result in *gas bubble trauma*. This condition occurs when air bubbles form in the circulatory systems of salmon and resident fish (USA COE, 1999) "Gas bubble trauma results when the sum of the dissolved gas pressures exceeds the compensating pressures of hydrostatic head, blood, tissue, and water surface tension" (IPCo, 1998c, 1999b, 1999f).

The severity of the effects of this condition varies among the different aquatic species and among life stages within a species. Signs of gas bubble trauma have been observed in trapped adult fish below Hells Canyon Dam. Spring chinook salmon and steelhead trout are exposed to elevated total dissolved gas concentrations during spills, in both the adult and smolt stages of life. Fall chinook juveniles are exposed to elevated total dissolved gas. Little is known about the life stages and populations of resident and fluvial bull trout within the Snake River (IPCo, 1998c).

Elevated total dissolved gas levels from spills through the Hells Canyon Complex reservoirs may be a significant factor in resident and anadromous fish survival both in the reservoirs and downstream in the Snake River. A study by IPCo determined that in general, spills in excess of 2,000 to 3,000 cfs result in total dissolved gas levels that exceed the state standard of less than 110 percent of saturation both within the reservoirs and downstream in the Snake River (IPCo, 1998c, 1999b, 1999f).

3.7.2.1 SALMONID SPAWNING.

This designated beneficial use applies to the Downstream Snake River segment (RM 247 to 188) only, and is specific to those salmonids identified to spawn in this area, namely fall chinook and mountain whitefish. When runoff volume forecasts consistently indicate that an upcoming season will be an above average runoff year, reservoir volumes are evacuated to make a sort of buffer for the snowmelt/runoff. As a result, spill occurs and total dissolved gas concentrations downstream have the potential to exceed the state standards for saturation. This can often occur for much of the juvenile and adult spring migration period (April through June).

3.7.2.2 THREATENED AND ENDANGERED SPECIES.

A number of species listed as threatened or endangered under the Federal ESA, are known to inhabit the SR-HC TMDL reach. Adult bull trout, known to utilize the reservoir segments, are listed as threatened under the ESA. The SR-HC TMDL reach and some inflowing tributaries below Hells Canyon Dam also provide habitat for the Snake River fall and spring/summer chinook as well as steelhead, all of which are listed as threatened under the ESA.

A more complete description of these species, their status and their habitat needs is outlines in the Subbasin Assessment (Section 2.2.2.3). A general listing is included below.

Bliss Rapids snail (*Taylorconcha serpenticola*)
Distribution: mainstem Snake River below Hells Canyon Dam from RM 229 to 225 (IPCo, 2001a).

Bull Trout (*Salvelinus confluentus*)
Distribution: mainstem Snake River from RM 272.5 to RM 188

Fall Chinook (*Oncorhynchus tshawytscha*)
Distribution: Mainstem Snake River from RM 247 to RM 188.

Spring and Summer Chinook (*Oncorhynchus tshawytscha*)
Distribution: Mainstem Snake River from RM 247 to RM 188.

Steelhead (*Oncorhynchus mykiss*)
Distribution: Mainstem Snake River from RM 247 to RM 188.
All of the species listed above as threatened or endangered rely on good water quality for survival. Waters are designated for salmonid spawning and rearing in the downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach. Waters so designated are required to exhibit appropriate concentrations of water column dissolved oxygen, intergravel dissolved oxygen, temperature, pH, ammonia, toxics, and turbidity for full support of fish during the spawning, incubation and rearing periods for those salmonid species inhabiting the designated waters. General time periods for spawning and incubation of the salmonid species identified to use the Downstream Snake River segment are shown below. A complete table of fish species in the SR-HC TMDL reach is available in section 3.6.9.2 of this document.

- Chinook salmon (fall) Oct 23 to April 30*
- Mountain Whitefish Nov 01 to March 15*

*represents spawning times identified by IDFG and ODFW as specific to the SR-HC reach.

Elevated total dissolved gas concentrations from spills through the Hells Canyon Complex reservoirs may be a significant factor in resident and anadromous fish survival both in the reservoirs and downstream in the Snake River. A study by IPCo determined that in general, spills in excess of 2,000 to 3,000 cfs result in total dissolved gas concentrations that exceed the state standard of less than 110 percent of saturation both within the reservoirs and downstream in the Snake River (IPCo, 1998c, 1999b, 1999f).

3.7.3 Sources

Elevated total dissolved gas from hydropower operations is a wide spread problem throughout the Pacific Northwest. Gas supersaturation is caused when air becomes dissolved in water while spilling over a dam into the depth of a plunge pool. High hydrostatic pressure causes the air to be driven into solution, resulting in supersaturation. The detrimental effects of supersaturation on aquatic biota are well documented. Elevated total dissolved gas concentrations pose a potential threat to threatened and endangered species of fish along with other aquatic biota within the Snake River (IPCo, 1998c, 1999b, 1999f). Elevated total dissolved gas concentrations are the result of spilling water over spillways of dams. Spill at Brownlee and Hells Canyon Dams is the only source of elevated total dissolved gas in the SR-HC reach.

3.7.3.1 Natural Sources.

There are no known natural sources of total dissolved gas that result in substantial loading or standards violations in the SR-HC TMDL reach.

3.7.3.2 Anthropogenic Sources.

Elevated total dissolved gas concentrations are the result of spilling water over spillways of dams. Spill at Brownlee and Hells Canyon Dams is the only source of elevated total dissolved gas in the SR-HC reach.

Voluntary Spill. At this time, voluntary spill does not occur within the Hells Canyon Complex. Spill at dams occurs only involuntarily, usually as a result of flood control constraints.

Involuntary Spill. The US Army Corps of Engineers (USA COE) is responsible for defining flood control requirements for the Hells Canyon Complex. At times of rapid runoff within the Snake River system, upstream facilities may not be able to retain the quantity of water passing through. In these cases, Brownlee Reservoir may be required to evacuate some reservoir volume to retain this excess flow and prevent flood events downstream. In this event, water may be spilled with attendant high total dissolved gas concentrations. Brownlee Reservoir is the only reservoir in the Hells Canyon Complex to be operated for flood control. The decision to release water from Brownlee Dam for flood control purposes is made on a system wide basis, and may be in response to conditions upstream rather than in response to hydraulic capacity concerns specific to Brownlee Reservoir or the Hells Canyon Complex.

3.7.4 Transport and Delivery

A study conducted by IPCo in 1999 showed a declining trend in total dissolved gas concentrations with distance downstream from the Hells Canyon Dam. Spill episodes at Hells Canyon Dam over 19,000 cfs caused exceedences of the less than 110 percent of saturation standard throughout the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL. Total dissolved gas concentrations did not drop below 110 percent of saturation upstream of RM 188 at this level of discharge. Standard exceedences from spill volumes between 9,000 cfs and 13,400 cfs were not observed below RM 200, and spill volumes of 2,400 cfs showed standard exceedences that extended downstream to RM 230 only. The total distance downstream of the dam where water was observed to exceed the less than 110 percent of saturation standard was directly related to the volume of the spill. When spill occurred at 16,500 cfs at Brownlee Dam, but with no spill at Hells Canyon Dam, the less than 110 percent of saturation standard was not observed to be exceeded downstream of Hells Canyon Dam. In this case, elevated total dissolved gas concentrations were not "transported" through the reservoir complex to downstream segments.

3.7.5 Data Available for the Snake River - Hells Canyon TMDL Reach

Only summary data was available for this assessment. Plant capacities for the Hells Canyon Complex Reservoirs are 35,00 cfs (Brownlee Dam), 28,000 cfs (Oxbow Dam), and 30,500 cfs (Hells Canyon Dam) (IPCo, 1998c, 1999b, 1999f). Because of the limited capacity for flood storage within the Hells Canyon Complex reservoirs, high flows are spilled through the three dams on a regular basis. Whenever the reservoirs are full, river flows that exceed the hydropower plant capacity of the dams are passed over the spillway (IPCo, 1998c, 1999b, 1999f).

Spill within the SR-HC TMDL reach generally occurs during the time period from December through June/July for the Hells Canyon Complex reservoirs. The highest frequency of spill is during the time period from April through June.

It should be noted that while upstream impoundments are known to have no effect on total dissolved gas concentrations in Brownlee Reservoir, water entering the reservoir is often at or near saturation (100%).

3.7.5.1 Observed Effects of Spills from Brownlee Dam.

Spill tests were conducted at Brownlee Dam on June 4, 1998 at a spill level of 39,000 cfs. The tests were conducted to determine if spilling through the upper or lower gates resulted in a measurable difference in total dissolved gas in the downstream waters. The total dissolved gas concentrations observed from spilling through the upper gates averaged 114 percent of saturation while spill through the lower gates averaged 127.7 percent of saturation. This difference, probably due to degassing from wave effects and surface turbulence after the plunge from the spillway, was considered to represent a potential benefit to aquatic species in the Oxbow and Hells Canyon reservoirs as spill from Brownlee Dam is the largest influence on total dissolved gas concentrations within these reservoirs (IPCo, 1998c, 1999b, 1999f).

When spill occurred at 16,500 cfs at Brownlee Dam, with no spill at Hells Canyon Dam, the less than 110 percent of saturation standard was not observed to be exceeded downstream of Hells Canyon Dam. Therefore, while elevated total dissolved gas concentrations from spill at Brownlee Dam have been observed to have an effect on the total dissolved gas in Oxbow and Hells Canyon reservoirs, the effect is not observed to extend to the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach.

3.7.5.2 Observed Effects of Spills from Hells Canyon Dam.

Spill tests were conducted at Hells Canyon Dam on June 3, 1998 at a spill level of 28,000 cfs. The tests were conducted to determine if spilling through the upper or lower gates resulted in a measurable difference in total dissolved gas in the downstream waters. The total dissolved gas concentrations observed from spilling through the upper gates averaged 139 percent of saturation while spill through the lower gates averaged 135 percent of saturation. This difference was much smaller than that observed with Brownlee Dam, but was considered to represent sufficient benefit to aquatic species in the Downstream Snake River segment (RM 247 to 188) that the lower gates were recommended to be used for spill when ever possible.

Spill episodes at Hells Canyon Dam over 19,000 cfs caused exceedences of the less than 110 percent standard throughout the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL. Total dissolved gas concentrations did not drop below 110 percent of saturation upstream of RM 188 at this level of discharge. Standard exceedences from spill volumes between 9,000 cfs and 13,400 cfs were not observed below RM 200, and spill volumes of 2,400 cfs showed standard exceedences to RM 230 only. The total distance downstream of the dam where water was observed to exceed the less than 110 percent standard was directly related to the volume of the spill.

During the period of no spill, the state standard of less than 110 percent of saturation within the Snake River below Hells Canyon Dam was never exceeded.

Hourly monitoring of total dissolved gas concentrations below Hells Canyon Dam in 1999 (IPCo, 1999f) showed a defined relationship between spill and total dissolved gas below the dam. Total dissolved gas in the tailwater area of Hells Canyon Dam ranged from 108 percent of saturation to 136 percent of saturation while spill was occurring from Hells Canyon Dam. Nearly all levels of spill monitored resulted in total dissolved gas concentrations above the less than 110 percent of saturation target. The data collected indicate that total dissolved gas concentrations in the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL are largely dependent on the occurrence of spill at Hells Canyon Dam and that upstream spill has little effect (IPCo, 1999f). Turbine operations seem to have little affect on total dissolved gas concentrations relative to the effects of spill (IPCo, 1999f, 2000e).

3.7.6 Determination of Total Dissolved Gas Loading

An accurate determination of total dissolved gas loading is not possible with the limited amount of data available to the SR-HC TMDL process. This assessment is being accomplished as part of the FERC re-licensing process, and will be evaluated as part of the State 401 Certification processes. It is not critical to this effort therefore, to generate an estimate of total loading at this time. Rather, it is sufficient to observe that the Hells Canyon Complex reservoirs along with dam operations have resulted in periodic exceedences of the less than 110 percent of saturation total dissolved gas target within the SR-HC TMDL reach.

Exceedences of the total dissolved gas target of less than 110 percent of saturation occur in both Oxbow and Hells Canyon reservoirs (as related to spill from Brownlee Dam in excess of 2,000 to 3,000 cfs).

Similarly, spills from Hells Canyon Dam in excess of 2,000 to 3,000 cfs result in total dissolved gas concentrations exceeding the total dissolved gas target of less than 110 percent of saturation in the Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach (IPCo, 1998c, 1999b, 1999f).

As they represent both a direct violation of state standards and an exceedence of the SR-HC TMDL target, and therefore pose a potential threat to threatened and endangered species of fish along with other aquatic biota within the Snake River, a TMDL for total dissolved gas in the SR-HC TMDL reach has been established that will ensure support of designated beneficial uses and attainment of the SR-HC total dissolved gas target. This will result in attainment of State total dissolved gas standards.

3.7.7 TMDL Determination

The TMDL for total dissolved gas in the SR-HC TMDL reach is set at the target value of less than 110 percent of saturation.

The total allowable mass of total dissolved gas (as nitrogen) equates to: Allowable Saturation ($\leq$110%) multiplied by the solubility constant of N_2 (as determined for the appropriate temperature and pressure), multiplied by the appropriate flow value for the designated mixing zone. This applies to all discharge flows not exceeding the ten-year, seven-day average flood flow volume for Brownlee and Hells Canyon Dams, identified by Idaho Power Company as 72,500 cfs.

It is recognized that the FERC re-licensing and State 401 Certification processes may utilize site specific data and designated beneficial use needs to identify a more site specific target for total dissolved gas in the SR-HC TMDL reach. If this occurs, and if the alternative target proposed by these processes is shown to fully support the designated beneficial uses within the system, the load allocation from this TMDL will be revised to reflect the new target.

3.7.8 Load Allocations

Section 4.0 contains detail on load allocations for total dissolved gas.

3.7.9 Appropriate Actions

Controlling elevated total dissolved gas can be achieved through controlling spill. If possible, spilling from projects with the least propensity for developing high total dissolved gas level, changing the spill patterns, and using spillway bays with deflectors are all potential options for reducing total dissolved gas exceedences. Additional options in a managed system may include storing more water in the upstream reservoirs within the system, putting more water through the turbines, or transferring spills outside the system.

Unfortunately, given the nature of the SR-HC TMDL system and the conditions during which spill occurs (high runoff volumes), there is not always enough time or system capacity to utilize the full suite of options.

A number of options for the management of total dissolved gas within the Hells Canyon Complex have been discussed as part of the FERC re-licensing process. The options selected will be the decision of the Complex operators (IPCo) and the overall requirements of the re-licensing process. Obviously, key decisions needed to manage high total dissolved gas will be driven by aquatic life support considerations, based on projected spill and total dissolved gas conditions.

The implementation of the final TMDL load allocation requirements for total dissolved gas will be incorporated into the state specific 401 Certification process, thus lending a substantial amount of assurance that a mechanism for implementation will be available to the process.

4.0 Load Allocations

Pollutant sources, load capacities, and pollutant loading have been discussed in detail in the preceding pollutant-specific sections. This section contains a summary of all load allocation information on a pollutant-specific basis. The pollutant load allocations assessed include a margin of safety to take into account seasonal variability and uncertainty. It is acknowledged that uncertainty may be attributed to incomplete knowledge or understanding of the system, incomplete data, or variability in data.

Allocable loads were identified using a combination of information including pollutant loading, margin of safety, natural loads, and reserve capacities as appropriate. As discussed previously, appropriate margins of safety were used in determining load capacity for all pollutants for which a TMDL was completed. Natural pollutant loading was recognized and quantified to the extent possible in all cases. Reserve capacities were recognized for point sources for those pollutants where such capacities were appropriate. Load allocations were then determined using the remaining load capacity for each SR-HC TMDL segment.

For the purposes of the SR-HC TMDL, "point sources" refer only to those permitted facilities that discharge directly to the mainstem Snake River within the SR-HC TMDL reach (Section 3.0). These sources as listed in Table 2.5.0. Point sources that discharge to the tributaries will be accounted for in the tributary TMDL processes. Point sources that discharge to the mainstem above or below the SR-HC TMDL reach will be accounted for in the separate TMDL processes for the Snake River segments into which they discharge.

Tributary inflows to the SR-HC TMDL reach have been treated as discrete, nonpoint sources for the purposes of loading analysis and allocation within this TMDL. Gross allocations have been assigned to each inflowing tributary. Existing or future tributary TMDL processes will distribute load allocations in the form of load allocations and/or waste load allocations within their specific watersheds. It should be kept in mind that while inflowing loads to the SR-HC TMDL reach represent nonpoint sources within the SR-HC TMDL framework, actual tributary loading is composed of both point and nonpoint discharges within the respective tributaries. In some tributary watersheds, point source discharges from municipalities or industries combine with nonpoint discharges from agricultural and rural stormwater in the river channel as flow moves downstream. All of these will be represented as nonpoint source loading to the Snake River for purposes of the SR-HC TMDL.

In some cases, tributaries to the Snake River – Hells Canyon TMDL have been assigned load allocations for pollutants for which the tributaries do not have 303(d) listings.

In the case where a TMDL for other pollutants is already in place (Payette and Boise Rivers), IDEQ will prepare a tributary-specific TMDL through the existing tributary TMDL process as part of the Implementation Plan for the approved TMDL. This TMDL will be written as an extension of the SR-HC TMDL process, but will utilize the WAG and other technical and stakeholder groups that participated in the preparation of the tributary TMDL.

In the case where a TMDL is not already in place (Weiser, Owyhee and Malheur Rivers), IDEQ will prepare a tributary-specific TMDL through the existing tributary TMDL process as part of the scheduled tributary TMDL. This TMDL will be written as an extension of the SR-HC TMDL process, but will utilize the WAG and other technical and stakeholder groups that participate in the preparation of the tributary TMDL.

The Oregon Department of Environmental Quality does not intend to list the tributaries to the Snake River/Hells Canyon TMDL for these pollutants. ODEQ, however, does intend to analyze pollutant levels and sources within the tributary subbasins and set allocations as appropriate as part of the development of TMDLs for the subbasins. The water quality management plan (WQMP) for the subbasins will also address implementation of pollutant load allocations as appropriate. If the analyses indicate that the target criteria for the inflow of the tributary to the Snake River cannot be achieved as a result of non-anthropogenic sources, the Department will, as resources allow, reopen the Snake TMDL and adjust the allocations accordingly, as appropriate.

It should be clarified that the allocations discussed in the following sections are based only upon an assessment of what is required to attain water quality standards in the mainstem Snake River within the SR-HC TMDL reach. This TMDL attempts no assessment of whether these conditions will attain tributary water quality criteria. Thus, it is possible that future tributary work could require reductions greater than those assigned in the SR-HC TMDL and could find conditions different from those assumed herein. In particular, the assumptions made herein regarding natural and anthropogenic contributions of heat in the tributaries are not to be assumed to be accurate for purposes of developing tributary TMDLs.

4.0.1 Mercury

Due to the fact that essentially no water column data are available to this effort, a TMDL cannot be established for mercury for the SR-HC TMDL reach. Therefore, IDEQ and ODEQ have determined it is in the public interest to reschedule the mercury TMDL for the SR-HC TMDL reach. IDEQ will reschedule the mercury TMDL to 2006 in order to gather additional data to better determine the sources and extent of mercury contamination. ODEQ's schedule for the mercury TMDL coincides with this date.

The state of Oregon is developing capability to model site-specific bioaccumulation factors. This schedule change will allow a better use of these capabilities and the opportunity to collect additional data.

Both Idaho and Oregon have interim measures in place to deal with mercury contamination such as sediment controls and fish consumption advisories as described in Section 3.1. It is the opinion of the DEQs that this schedule change will not present an adverse impact to the SR-HC TMDL reach.

4.0.2 Nutrients/Dissolved Oxygen

A detailed discussion of sources, available data, associated water quality-related concerns and loading is available in Sections 2.2.4.1, 2.2.4.3, 2.3.1.2, 2.3.2.2, 2.3.3.2, and 3.2.

4.0.2.1 LOADING

Nutrient concentrations are closely linked with dissolved oxygen and organic matter concentrations. Elevated concentrations of nutrients can lead to increased growth of algae and associated organic matter when other conditions such as water flow, depth, clarity, sunlight penetration, and temperature are conducive to enhanced growth. Algae and aquatic plants in turn consume oxygen from the water column during periods when respiration is the dominant process and in the aerobic decomposition of the dead algae and other detritus (non-living organic material). Total phosphorus has been identified as the nutrient of concern in the SR-HC TMDL reach. Improvements in dissolved oxygen can be achieved through attainment of growth-limiting concentrations of phosphorus (Section 3.2). Tables 4.0.5 and 4.0.6 contain calculated total phosphorus loading for point and nonpoint sources within the SR-HC TMDL reach.

Table 4.0.5. Total phosphorus waste loads from point sources in the Snake River - Hells Canyon TMDL reach for the critical time period based on 1995, 2000 data (May through September).

Point Source	NPDES Permit Number	Location (RM)	Current Design-Flow Load (kg/day)
City of Nyssa	101943 OR0022411	385	11
Amalgamated Sugar	101174 OR2002526	385	50
City of Fruitland	ID0020907	373	5.5
Heinz Frozen Foods	63810 OR0002402	370	412
City of Ontario	63631 OR0020621	369	0 [1]
City of Weiser (WWTP)	ID0020290	352	32
City of Weiser (WTP)	ID0001155	352	5.5 (max)
Brownlee Dam (IPCo)	ID0020907	285	Unmeasured assumed minimal[2]
Oxbow Dam (IPCo)	101275 OR0027286	272.5	Unmeasured assumed minimal[2]
Hells Canyon Dam (IPCo)	101287 OR0027278	247	Unmeasured assumed minimal[2]

1 City of Ontario uses land application in the summer months and does not currently contribute a phosphorus load to the SR-HC TMDL reach during the critical season.

2 Facilities sump discharge and turbine cooling water, not a phosphorus or waste treatment source.

Table 4.0.6. Calculated total phosphorus loading from tributary and nonpoint sources to the Snake River - Hells Canyon TMDL reach for the critical time period based on 1995, 1996 and 2000 data and average flow values (May through September).

Load Type	Location	Load (kg/day)	Estimation Method
Snake River Inflow	RM 409: Upstream Snake River Segment	1,912	See Section 3.2
Owyhee River	RM 396.7: Upstream Snake River Segment	265	See Section 3.2
Boise River	RM 396.4: Upstream Snake River Segment	1,114	See Section 3.2
Malheur River	RM 368.5: Upstream Snake River Segment	461	See Section 3.2
Payette River	RM 365.6: Upstream Snake River Segment	710	See Section 3.2
Weiser River	RM 351.6: Upstream Snake River Segment	392	See Section 3.2
Drains	Upstream Snake River segment (RM 409 to 335)	660	See Section 3.2
Ungaged flows	Upstream Snake River segment (RM 409 to 335)	385	See Section 3.2
Agriculture, Stormwater and Forestry	Upstream Snake River segment (RM 409 to 335)	Included in the ungaged flow loading	See Section 3.2
Burnt River	RM 327.5: Brownlee Reservoir Segment	52	See Section 3.2
Powder River	RM 296: Brownlee Reservoir Segment	126	See Section 3.2
Agriculture, Stormwater and Forestry	Brownlee Reservoir segment (RM 335 to 285)	Cannot be calculated due to reservoir "sink" effect, assumed small	See Section 3.2
Agriculture, Stormwater and Forestry	Oxbow Reservoir segment (RM 285 to 272.5)	Cannot be calculated due to reservoir "sink" effect, assumed small	See Section 3.2

The available data show that total phosphorus loading to the SR-HC reach originates almost entirely from the Upstream Snake River segment (RM 409 to 335). Measured total phosphorus loading to this segment accounts for the majority of the phosphorus load to the SR-HC reach, tributary loading equals 76 percent, point source loading represents approximately 8 percent, ungaged (estimated) drain flows accounting for 10 percent of the total system load and unmeasured sources accounting for approximately 6 percent of the total. Sources of unmeasured load may include nonpoint source runoff from anthropogenic sources and precipitation events, unidentified small tributaries and drains, error in gauged flow measurements and ground water sources.

Nutrient processing within the Hells Canyon Complex results in dramatic changes in measured total phosphorus concentrations downstream of Hells Canyon Dam as compared to those measured in the Upstream Snake River segment (RM 409 to 335). The change in phosphorus form and phosphorus sink characteristics of the reservoirs makes it impossible to determine loading from nonpoint sources within the immediate drainage area to the Hells Canyon Complex. The potential loading from these sources has been evaluated and assumed to be small as the incidence of recreational housing, agricultural practices (cropping and ranching) and municipal stormwater runoff is minimal, as is the intensity of use.

4.0.2.2 LOAD CAPACITY

Load capacity is calculated as the sum of the natural background load, point source loads and nonpoint source loads. In the tributary systems, the allocable load is equal to the load capacity, as outlined in the following equation.

Load Capacity = Allocated Tributary Load = Natural Background Load + Point Source Contribution + Nonpoint Source Contribution

The SR-HC TMDL reach load capacity for nutrients (Table 4.0.7) was determined by calculation using the target of 0.07 mg/L total phosphorus identified for the SR-HC TMDL, and average flow values (Table 2.1.1). These values represent total phosphorus loading capacity as identified for average flows. While these values are helpful in giving a relative understanding of the reductions required, and will apply reasonably over most water years, it should be noted that the absolute level of reduction required will depend on flow and concentration values specific to a given water year. The target shown to result in attainment of water quality standards and support of designated uses in the SR-HC TMDL reach is an instream concentration of less than or equal to 0.07 mg/L total phosphorus.

Table 4.0.7. Total phosphorus allocable load for segments in the Snake River - Hells Canyon TMDL reach based on the water column target concentration of 0.07 mg/L and calculated average flows (May through September).

Segment	Location	Load (kg/day)
Total Upstream Snake River segment	RM 409 to 335	2,735
Total Brownlee Reservoir segment *	RM 335 to 285	2,829
Total Oxbow Reservoir segment **	RM 285 to 272.5	2,839

*equal to the measured inputs of the upstream Snake River plus the Powder and Burnt Rivers, plus the estimated inputs of unmeasured tributaries (such as Brownlee Creek). Loads from unmeasured tributaries were estimated at 80 kg/day (approximately 2x the loading assessed for the Weiser Flat tributaries that discharge into the Snake immediately upstream of Brownlee Reservoir, most is projected to be delivered in the spring and summer seasons).
** equal to the measured inputs of Brownlee Reservoir, plus the estimated inputs of unmeasured tributaries (such as Wild Horse River). Loads from unmeasured tributaries were estimated at 20 kg/day (approximately 50% the loading assessed for the Weiser Flat tributaries that discharge into the Snake immediately upstream of Brownlee Reservoir, most is projected to be delivered in the spring and summer seasons). Load allocations to unmeasured tributaries were calculated at 50% reduction from estimated loads due to high probability for high natural loading.

Transport and deposition of phosphorus, and the resulting algal growth within the SR-HC TMDL reach is seasonal in nature. Transport and delivery of natural loading occurs primarily as a result of erosive forces during spring flows. Other natural sources of nutrient loading are discussed in Section 2.2.4.3. Transport and delivery of anthropogenic loading and the resulting algal growth occurs primarily during early summer to early fall. Therefore, the 0.07 mg/L total phosphorus target is seasonal in nature, extending from the beginning of May through the end of September. For the determination of allocable load for the five tributary streams to the Snake River, tributary specific data will be collected and reviewed as part of the implementation plan process. These data will allow for accurate, tributary-specific estimates of naturally occurring total phosphorus concentrations so that anthropogenic loads can be identified and allocated to point and nonpoint sources within the tributary systems. The sum of total phosphorus load and waste load allocations in each tributary will equal the load capacities listed in Table 4.0.7. These allocations will be identified on a tributary by tributary basis using tributary TMDL processes with the goal of establishing accurate site-specific targets for each anthropogenic source.

4.0.2.3 Margin of Safety

A 13 percent margin of safety has been applied to total phosphorus load allocations and capacity for this TMDL as determined by the accuracy and representativeness of sampling techniques and analytical methods. This margin of safety has been incorporated into the identification of the 0.07 mg/L total phosphorus target for the SR-HC TMDL. Other areas of uncertainty such as system uptake, assimilative capacity, and relative impairment to different use categories were addressed to the extent possible through the use of conservative assumptions in the identification of the nutrient target, sensitive designated uses and critical period.

4.0.2.4 Background/Natural Loading

For the mainstem Snake River portion of the SR-HC TMDL reach, the natural total phosphorus loading was calculated using the natural background concentration of 0.02 mg/L total phosphorus identified within the SR-HC TMDL, along with average flow values for the Snake River (Table 2.1.1). A necessary set of data for the tributary streams is not currently available. Therefore, natural background concentrations for all tributaries will be determined as part of upcoming TMDL development on the Weiser, Owyhee, and Malheur Rivers, and tributary implementation plans for the Payette and Boise Rivers.

4.0.2.5 Reserve

Waste load allocations to point sources were determined based on design capacity. The reserve capacity allocation is therefore the difference between the current discharge and design flow discharge. This allows for expansion of existing sources or addition of new point source discharges through trading or demonstration of an offset within the SR-HC system.

4.0.2.6 Total Phosphorus Load Allocations

Total Phosphorus load and waste load allocations have been identified for point and nonpoint sources in the SR-HC TMDL reach based on the less than 0.07 mg/L total phosphorus target and the seasonal application period (May through September).

Point Sources.

Biological nutrient removal (BNR) was identified as an appropriate mechanism for phosphorus removal for point sources currently employing activated sludge as a treatment process and discharging directly to the Snake River within the SR-HC TMDL reach. Application of this treatment reduction mechanism commonly results in an 80 percent reduction of total phosphorus concentration in the discharged effluent. As BNR represents a reasonable mechanism for the reduction of total phosphorus concentrations in point source discharges, and as the reductions commonly realized from BNR approximate the average reductions required from nonpoint sources (direct and tributary discharges to the Snake River) within the SR-HC TMDL reach, this mechanism was used as an initial basis for assigning total phosphorus waste load allocations for point sources discharging directly to the Snake River within the SR-HC TMDL reach (as outlined in Appendix I).

Table 4.0.8 contains waste load allocations for those permitted point sources that discharge directly to the Snake River within the SR-HC TMDL reach. Waste load allocations have been assigned to permitted point source discharges based on an evaluation of phosphorus reduction mechanisms available, the relative loading from each point source and type of treatment currently in place.

Waste load allocations to point sources discharging directly to the Snake River within the SR-HC TMDL reach have been assigned as follows:

- The critical time period over which total phosphorus reductions apply is from May through September.
- Point sources currently employing facultative lagoons (Table 4.0.8) represent a miniscule proportion of the total point source phosphorus loading (1.2%) within the SR-HC TMDL reach and will therefore not receive specific total phosphorus reduction requirements at this time. These facilities will prepare facilities plans to determine the costs and time frames associated with upgrading treatment mechanisms which will be used as the basis for future evaluation of potential phosphorus reductions.
- Point sources (activated sludge or other treatment method) (Table 4.0.8) represent a greater proportion of the total point source phosphorus loading (98.8%) within the SR-HC TMDL reach. These facilities will reduce total phosphorus loading by 80 percent (applied daily on a monthly average basis and based on design flows). While BNR was utilized as a basis for assigning appropriate point source load reductions, it is not required as a method of reduction under this TMDL. Any approved mechanism or treatment alternative (or combination of such) that results in the required daily 80 percent reduction (calculated on a monthly average basis) required will be acceptable under this TMDL (for example, land application during the target season would potentially be an acceptable method of achieving the total phosphorus reduction required if it were implemented in an approved and responsible fashion).
- The waste load allocations identified here for permitted point sources apply ONLY to those point sources discharging directly to the Snake River within the SR-HC TMDL reach. Waste load allocations to point sources discharging to tributaries that flow into the SR-HC TMDL reach will be the result of tributary TMDLs crafted through the state-specific tributary TMDL processes and will be completed on a state-specific basis and schedule.
- The current level of effort for total phosphorus reduction on the part of Amalgamated Sugar Company, and the identified goal of load minimization through stockpile removal are recognized in the waste load allocation identified in Table 4.0.8. Progress toward the identified goal will be documented through the iterative TMDL process and appropriate adjustments to the waste load allocation will be made if necessary.
- The current loading and thus the waste load allocations are based on limited effluent data. Waste load allocations for permitted point sources may be modified through the facility planning process if new information indicates that actual design loads were higher than originally determined.

Table 4.0.8. Total phosphorus waste load allocations (WLAs) for permitted point sources in the Snake River - Hells Canyon TMDL reach. (Waste load allocations are based on design flows and discharge concentrations from Table 2.5.0 for the critical period: May through September)**.**

Point Source	NPDES Permit Number	River Mile	Treatment Type	Total phosphorus Concentration (mg/L)	Current Design-Flow Load (kg/day)	Waste Load Allocation (kg/day)	% Reduction
City of Nyssa	101943 OR0022411	385	Activated sludge	3.5 mg/L[1]	11 kg/day	2.2 kg/day	80%
Amalgamated Sugar	101174 OR2002526	385	Seepage ponds	50 kg/day[2] (estimated)	50 kg/day	50 kg/day (initial) and continue with current reduction measures	
City of Fruitland	ID0020907	373	Facultative lagoon	2.9 mg/L	5.5 kg/day[3]	5.5 kg/day	0%
Heinz Frozen Foods	63810 OR0002402	370	Activated sludge	32 mg/L	412 kg/day	83 kg/day	80%
City of Ontario	63631 OR0020621	369	Facultative lagoon	3.5 mg/L[1]	0 kg/day [4]	0 kg/day	0%
City of Weiser (WWTP)	ID0020290	352	Activated sludge	3.5 mg/L[1]	32 kg/day	6.4 kg/day	80%
City of Weiser (WTP)	ID0001155	352	Settling pond	3.5 mg/L[1]	5.5 kg/day[3] (max)	5.5 kg/day	0%
Brownlee Dam (IPCo)	ID0020907	285		Assumed Negligible[5]	Unmeasured assumed minimal	Appropriate BMPs and source control	
Oxbow Dam (IPCo)	101275 OR0027286	272.5		Assumed Negligible[5]	Unmeasured assumed minimal	Appropriate BMPs and source control	
Hells Canyon Dam (IPCo)	101287 OR0027278	247		Assumed Negligible[5]	Unmeasured assumed minimal	Appropriate BMPs and source control	

1. Estimated value provided by Boise City Public Works for use in absence of monitored data.
2. Estimated value provided by Amalgamated Sugar for use in absence of monitored data.
3. Wastewater treatment systems utilizing lagoons will be required to prepare facilities plans showing potential treatment mechanisms to reduce phosphorus loading as part of any proposed upgrade or expansion of the facility.
4. City of Ontario uses land application in the summer months and does not currently contribute a phosphorus load to the SR-HC TMDL reach during the critical season.
5. Facilities sump discharge and turbine cooling water, not a phosphorus or waste treatment source.

Nonpoint Sources.

Table 4.0.9 lists the total phosphorus load allocations to nonpoint sources in the SR-HC TMDL reach.

Tributary inflows to the SR-HC TMDL reach have been treated as discrete, nonpoint sources for the purposes of loading analysis and allocation within this TMDL. Gross allocations have been

Table 4.0.9. Calculated total phosphorus load allocations for tributary, point and nonpoint sources to the Snake River - Hells Canyon TMDL reach based on calculated average flows (May through September).

Segment	Load Allocation[a,b] (kg/day)	Percent Reduction
Snake River Inflow	1,379	28
Owyhee River	71	73
Boise River	242	78
Malheur River	58	88
Payette River	469	34
Weiser River	136	65
Drains	91	86
Ungaged flows	137	64
Total Upstream Snake River Load Allocations	2582	54
Total Upstream Snake River Waste Load Allocations	153	
Total Upstream Snake River Segment Load and Waste Load Allocations	2,735[c]	
Burnt River	21	60
Powder River	33	74
Unmeasured Tributaries to Brownlee	40	50
Total Brownlee Reservoir Segment	2,829[d]	
Unmeasured Tributaries to Oxbow	10	50
Total Oxbow Reservoir Segment	2,839	

[a] The SR-HC TMDL target for total phosphorus for each tributary is a concentration of less than or equal to 0.07 mg/L total phosphorus as measured at the mouth of the tributary and applies from May through September. Because the total phosphorus target is concentration-based, actual allowable tributary load allocations under the TMDL are dependant on actual tributary flow and will fluctuate year to year. The total phosphorus load allocations listed in this table are based on averaged tributary flows measured in 1979, 1995 and 2000, which were average Snake River flow years, not necessarily average tributary flow years. Therefore they do not necessarily represent the calculated load allocations for any specific year or different series of years.

[b] Future data collection and analyses may determine that, due to natural conditions or other factors, the target concentrations for the mouths of the tributaries cannot be practicably achieved. This, in most cases, will occur when TMDLs are conducted on the tributaries. If subsequent tributary TMDLs indicate that the target concentration is not achievable, the Snake River/Hells Canyon TMDLs for total phosphorus will be reopened and appropriately revised.

[c] Total allocable load for this segment is 2,735 kg/day (2,582 kg/day from nonpoint sources and 153 kg/day from point sources)

[d] Total allocable load includes point source wasteload allocation from upstream sources. A dissolved oxygen load allocation has also been established for this segment.

assigned to each inflowing tributary equal to the load capacities listed in Table 4.0.7. Existing or future tributary TMDL processes will distribute load allocations in the form of load allocations and/or waste load allocations within their respective watersheds. Tributary loads are allocated to the mouth of the tributary and do not attempt to identify point and nonpoint source contributions within the tributary watersheds. Load allocations for tributaries are based on the less than or equal to 0.07 mg/L total phosphorus target and average flows (Table 2.1.1), and applies at the mouth of the tributary system. It is anticipated that tributary-specific data will be collected and will allow for accurate estimates of the naturally occurring total phosphorus loading so that anthropogenic loads can be identified and distributed to point and nonpoint sources within each tributary.

4.0.2.7 IMPLEMENTATION

The geographic scope of the SR-HC TMDL is extensive. The SR-HC watershed encompasses a 221 mile stretch of the Snake River with a 73,000 square mile drainage area. It is expected that attaining the SR-HC TMDL targets will require implementation of control strategies throughout this massive watershed, from facilities and return flows that discharge directly to the Snake River, to more remote activities affecting tributaries many miles upstream of their confluences with the Snake River.

Water users, administrative agencies, and research organizations in Idaho and Oregon have many years of experience developing and implementing strategies to improve water quality. Efforts in several tributary (e.g. Rock Creek) and upstream Snake River (e.g. the Middle Snake River) watersheds have become more focused during recent years as instream water quality objectives have been defined through TMDLs and other programs. These ongoing efforts provide incremental improvements to water quality as new treatments are applied to additional agricultural lands, storm drains, and point source discharges.

SR-HC PAT members and other PAT participants and consultants representing water users, administrative and research groups, together with the DEQs, utilized their collective experience to determine the time frame required to implement necessary control strategies throughout the SR-HC watershed to attain SR-HC TMDL targets. Due to the extraordinary size and complexity of the SR-HC watershed, its hydrology, and the various factors that affect the implementation of control strategies (discussed in Appendix I), it was determined that a time frame of approximately 50 to 70 years will be required to implement all necessary control strategies and fully attain SR-HC TMDL targets. This does not mean, however, that Snake River water quality will not improve until the TMDL targets are fully attained. For example, the DEQs have determined that there is a direct relationship between instream phosphorus concentrations and algal growth so that algal biomass will decrease incrementally as the instream concentration of phosphorus decreases. Water quality will consistently improve as treatments are applied to point and nonpoint discharges. To ensure measurable, consistent progress, interim, 10-year objectives (corresponding to 0.01 mg/l reductions in instream phosphorus concentrations) will be established. Progress in implementing control strategies will be reviewed periodically, and the time frame for full implementation can be evaluated in light of data and experience.

In identifying an appropriate time frame for implementation, the schedules of the tributary TMDLs and their Implementation Plans have to be considered. While there are some tributary TMDLs currently in place, others will not all be completed until the end of 2006. The tributary TMDLs must then be approved by EPA. The approval process can take several months. Implementation plans are completed approximately 18 months following EPA approval of TMDLs. For tributary TMDLs already in place this 18-month time frame starts with the approval of the SR-HC TMDL. For tributary TMDL processes that are not yet complete, the implementation plan will be prepared within 18 months of the approval of the tributary TMDL.

After completing an implementation plan, site-specific analyses must be performed to determine the most appropriate and effective control strategies for particular locations and land use activities. The time required for ground-level planning and project approval process varies widely depending upon the nature of the land and related hydrology, the land use, the parties involved, the type of treatment selected, and other factors.

Construction and implementation of management practices follows project approval. As with the planning and approval process, the time required to complete a project and realize water quality improvements varies from more the more immediate, as with introduction of rotational grazing as a management practice, to longer term, as with streambank re-vegetation and created wetlands (6 to 7 years may be necessary to establish vegetation that will produce adequate results).

In addition to the time required to achieve effective reductions, the time required for the river and reservoirs to fully respond to the improvement in inflowing water quality and process the existing pollutant loads already in place within the system must also be recognized. The occurrence of low water years or drought cycles can extend the instream response time by affecting the processing and transport of preexisting loads, just as high flows, which increase transport, and streambank erosion can affect instream response time.

In identifying what effect such an extended time frame for implementation would have on aquatic species that are currently at risk due to water quality concerns, it should be noted that generally the initial phases of implementation result in the most substantial reductions. Starting implementation as soon as possible, in a manner that will address the areas of greatest concern first and then work toward the areas of lower priority will allow substantial improvements in the water quality to occur in a shorter period of time than that described by the total implementation timeframe. While these initial improvements will most likely not result in meeting water quality targets all the time, everywhere, all at once, they will undoubtedly result in substantial, consistent improvement in water quality conditions throughout the reach.

As time and implementation progresses, the level of improvement will also increase until water quality targets are met. If dissolved oxygen concentrations in the areas of sturgeon habitat can be increased from near lethal levels to concentrations that are much closer to the target, then the support status will improve as well. This offers the potential for a positive outlook in the case of at-risk aquatic life such as the white sturgeon in the Upstream Snake River segment (RM 409 to 335). They will benefit from these initial improvements in habitat in many places, and from the improvement in water quality conditions overall.

4.0.2.8 DISSOLVED OXYGEN LOAD ALLOCATION

In addition to the total phosphorus load allocations for the Upstream Snake River segment (RM 409 to 335) and the tributaries, a dissolved oxygen load allocation has been established for Brownlee Reservoir (RM 335 to 285) (IPCo) to offset the calculated reduction in assimilative capacity due to the Hells Canyon Complex reservoirs.

The dissolved oxygen allocation requires the addition of 1,125 tons of oxygen (1.02 x10^6 kg) into the metalimnion and transition zone of Brownlee Reservoir (approximately 17.3 tons/day (15,727 kg/day)). The total dissolved oxygen mass required to address the loss of assimilative capacity in the metalimnion over this time frame is 1,053 tons (957,272 kg). This is equivalent to an even distribution of 16.2 tons/day (14,727 kg/day) over 65 days. The total dissolved oxygen mass required to address the loss of assimilative capacity in the transition zone over this time frame is 72 tons (65,454 kg). This is equivalent to an even distribution of 3.0 tons/day (2,727 kg/day) over 24 days.

The calculated time period when exceedences occurred in the metalimnion of Brownlee Reservoir is between Julian days 182 and 247 (the first of July through the first week of September) when dissolved oxygen sags are observed to occur to a greater degree than those identified as the result of poor water quality inflowing from the upstream sources. However, this time frame should not be interpreted as an absolute requirement. This approach recognizes that the actual mass of dissolved oxygen necessary per day is not static. It is variable depending on system dynamics and may vary from a few tons to as many as 30 tons per day. Timing of oxygen addition or other equivalent implementation measures should be such that it coincides with those periods where dissolved oxygen sags occur and where it will be the most effective in improving aquatic life habitat and support of designated beneficial uses. Water column dissolved oxygen monitoring is expected to be undertaken as part of this scheduling effort.

This load allocation does not require direct oxygenation of the metalimnetic and transition zone waters. It can be accomplished through equivalent reductions in total phosphorus or organic matter upstream, or other appropriate mechanism that can be shown to result in the required improvement of dissolved oxygen in the metalimnion and transition zones to the extent required. A reduction of 1.7 million kg of organic matter/algal biomass would equate to the identified dissolved oxygen mass. This translates to approximately 11,000 kg/day over the critical period (May through September) or 26,000 kg/day over the 65-day load period identified in the calculations for reduced assimilative capacity. Direct oxygenation can be used, but should not be interpreted as the only mechanism available. Cost effectiveness of both reservoir and upstream BMP implementation should be considered in all implementation projects.

Because there are both total phosphorus and dissolved oxygen load allocations assigned within different segments of the SR-HC TMDL reach, it must be clearly understood that Upstream Snake River segment (RM 409 to 335) pollutant sources are responsible for those water quality problems occurring in the Upstream Snake River segment. They are not responsible for those water quality problems that would occur if the waters flowing into Brownlee Reservoir met water quality standards and are exclusive to the reservoir. Similarly, IPCo (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.

Load allocations for the Upstream Snake River (RM 409 to 335) pollutant sources were identified to meet water quality standards in the Upstream Snake River segment and load allocations for Brownlee Reservoir (RM 335 to 285) were identified to address those water quality violations that would occur if the waters flowing into the Hells Canyon Complex met water quality standards.

It should not be interpreted from this load allocation scenario that the load allocations to Brownlee Reservoir (RM 335 to 285) do not have to be implemented until after all implementation has been completed upstream. All implementation (both that in the Upstream Snake River segment and that required from the Brownlee Reservoir segment) will be expected to proceed concurrently in a timely fashion following the approval of the SR-HC TMDL.

This TMDL will proceed toward completing site-specific implementation plans within 18 months of approval of the TMDL. Data collection will continue throughout the implementation process to determine progress and improve understanding of the SR-HC TMDL system. As this TMDL is a phased process, it is projected that the goals and objectives of this TMDL will be revisited periodically to evaluate new information and assure that the goals and milestones are consistent with the overall goal of meeting water quality standards in the SR-HC TMDL reach.

Monitoring of both point source discharge loads and instream water column concentrations will be undertaken as part of the implementation process. Instream monitoring will be identified in more detail in the site-specific implementation plans that will be completed 18 months following the approval of the SR-HC TMDL. It is expected that at minimum such monitoring will include the measurement of water column total phosphorus, chlorophyll *a*, and dissolved oxygen within each segment during time frames that represent high, low and average flow conditions. Measurement of sediment/water interface dissolved oxygen will also be accomplished in the Upstream Snake River segment (RM 409 to 335) during the first phase of implementation (5 year from approval of the SR-HC TMDL), or sooner.

4.0.2.9 TOTAL PHOSPHORUS LOAD AND WASTE LOAD ALLOCATION MECHANISMS.

As stated in Section 1.0, the overall goal of the SR-HC TMDL is to improve water quality in the SR-HC TMDL reach by reducing pollution loadings from all appropriate sources to restore full support of designated beneficial uses within the SR-HC TMDL reach. Two elements critical to achieving this goal are:

- To establish load allocation mechanisms that will allow attainment of the water quality targets through (to the extent possible) fair and equitable distribution of the identified pollutant loads, and result in productive implementation without causing undue hardship on any single pollutant source.
- To outline necessary implementation steps to attain the SR-HC TMDL pollutant targets. (This is accomplished in a general fashion in the water quality management plan (Oregon) and implementation plan (Idaho) submitted with this document, and in detail in the implementation plans to be completed within 18 months of US EPA TMDL approval).

Establishing long-term, scientifically supported water quality objectives, interim targets and load allocations based on feasible and attainable control strategies is consistent with the goal of the Clean Water Act and associated administrative rules for Oregon and Idaho that water quality standards shall be met or that all feasible steps will be taken towards achieving the highest quality water attainable. It is also consistent with the agencies' responsibility to provide reasonable assurance that TMDL objectives can be met.

With these principles in mind, members of the SR-HC PAT have worked together to develop a load allocation strategy for total phosphorus for point and nonpoint sources within the SR-HC TMDL reach. A complete copy of the strategy for point and nonpoint source dischargers is included in Appendix I.

This strategy seeks to establish interim targets and load allocations designed to reflect feasible control strategies and time frames within which those strategies can be implemented. These interim targets and load allocations were developed to recognize the various factors affecting the nature and extent of feasible and attainable BMP implementation.

As with the long-term targets and load allocations, periodic review will enable the DEQs and the stakeholders to adjust these interim targets and load allocations in accordance with information, analysis, and experience developed during the implementation of the SR-HC TMDL objectives.

The DEQs fully support and encourage stakeholder participation in this process and acknowledge the substantial progress that has been made on a multi-stakeholder front to develop an allocation mechanism for total phosphorus that will meet the requirements of the CWA and the TMDL process, while addressing the needs of the implementation participants.
The TMDL processes for both Oregon and Idaho require that water quality targets and the accompanying load allocation mechanisms will collectively result in attainment of water quality standards. Therefore, the goal of this total phosphorus TMDL for the SR-HC TMDL reach is to meet and sustain instream mainstem concentrations of 0.07 mg/L or less total phosphorus during the critical period of May through September. The framework of this approach is to meet TMDL targets and represents a valid process for implementation of the total phosphorus TMDL. As with any implementation process, progress on the ground and monitored water quality trends will be critical indicators as to whether this approach is successful in attaining the implementation goals identified.

Periodic review of additional data, level of implementation, system response and other pertinent factors will be carried out and necessary changes made. These changes may, among others, occur on the part of the TMDL, with better understanding of the system; on the part of the implementation process and the associated goals and interim milestones, and the part of the allocation mechanism discussed here.

Feasible pollution control strategies as those that can reasonably be taken by stakeholders to improve water quality within the physical, operational, economic and other constraints which affect their individual enterprises and their communities. Control strategies that will injure existing or future social and economic activity and growth are neither reasonable nor feasible. Attainable water quality goals are those that reflect control strategies that are feasible on a broad, watershed basis and recommended that highest cost management practices should not be the basis for water quality planning.

The SR-HC PAT members further identified several factors affecting BMP implementation for irrigated agriculture. As with irrigated agriculture, available funding is the primary constraint on BMP implementation for municipalities and other point sources. Most of the municipalities whose discharges affect the SR-HC reach are small communities with modest economies and tax bases. The principal factors affecting the implementation and effectiveness of BMPs for point sources are available funding, BMP costs, and the limits of currently available technology in reducing phosphorus in point source discharges. These factors are particularly important for small communities.

It is neither reasonable nor feasible to expect BMP implementation throughout the SR-HC TMDL watershed to achieve zero discharge, or widespread conversion to sprinkler irrigation, due to the extremely high costs and potential hydrologic impacts. Similarly, it is not reasonable to expect point sources to implement highest cost BMPs.

Nonpoint Source Load Allocation Mechanism

Attainable interim water quality goals for irrigated agriculture can be defined by identifying or estimating: (1) historically available private and public funding for water quality projects; (2) BMP costs; (3) pollutant reductions resulting from the installation of BMPs; (4) the status of BMP implementation within a watershed, community, or at a farm; and (5) the number of acres to be treated. Each of these factors was applied to an analysis of the Malheur, Boise, and Payette watersheds to project BMP implementation and resulting overall pollutant reductions over time from irrigation agriculture.

Assuming that historic annual funding for BMP implementation continues, and that funding doubles at least every 20 years to pay for replacement of equipment, so that all the identified priority acres are treated with $500.00 per acre treatment (representing feasible treatment strategies) to yield 68 percent overall reduction in the discharge of loads, the above analysis projects annual BMP implementation and corresponding reductions in total phosphorus loading from irrigated lands of 0.47 percent from the Payette watershed, 0.54 percent from the Boise watershed, and 0.97 percent from the Malheur watershed. The projected average annual total phosphorus reduction from irrigated lands in these watersheds is 0.66 percent. Since these three watersheds represent nearly 600,000 irrigated acres, and there are active, long-standing programs to implement BMPs in these watersheds, this rate of reduction can be used to project a rate of reduction throughout the SR-HC TMDL watersheds. At this rate of reduction, it would take 103 years to reach the maximum feasible 68 percent reduction of total phosphorus from irrigated lands in the SR-HC TMDL watersheds.

In order to compress the time frame for attainment of 68 percent total phosphorus reduction from irrigated lands, it will be assumed that federal and state funding levels increase to those currently available for BMP implementation in the Malheur River and Owyhee River watersheds. This will require doubling funding for the other watersheds, from $4.04 per acre annually in the Payette watershed and $4.66 per acre annually in the Boise watershed for all priority acres to the $8.43 per acre level that has been expended in the Malheur & Owyhee watersheds for all priority acres. This means that, for the Payette River and Boise River watersheds alone, federal and state programs and/or pollution trading must increase the annual non-farm investment in BMP implementation from $371,706 to $1,827,500. This increase is significant when annual state BMP funding, for the entire State of Idaho, has been approximately $1,500,000, and has recently been reduced to $1,400,000. It will also be assumed that funding doubles every 20 years to pay for replacement of equipment so that treatment of additional acres at the assumed rate of treatment may continue.

If this additional funding is made available, it is possible to project an annual total phosphorus reduction of 1 percent from irrigated lands in SR-HC TMDL watersheds, assuming the other factors affecting BMP implementation, cost, and performance do not impose their own constraints on BMP implementation. Applying an annual 1 percent total phosphorus reduction rate results in the following interim, ten-year load reduction objectives for the aggregate of irrigated lands in the Owyhee, Boise, Malheur, Payette, Weiser and Snake Rivers below RM 409.

Increased funding can affect the **rate** at which BMP implementation occurs (annually .66% vs. 1.0%) and the overall time it takes to attain 68 percent reductions from irrigated lands (103 years vs. 68 years). Currently, based on known techniques, technologies, BMP costs, hydrology, crop requirements, and the other factors that affect BMP implementation, it is not possible to project total phosphorus reductions from irrigated lands in the aggregate greater than 68 percent. Watershed-wide nonpoint source reductions greater than 68 percent will require currently unforeseeable changes in the factors affecting BMP implementation. This reduction rate together with projected reductions in point source loads and private industry participation in total phosphorus reduction through pollution trading is used to determine interim, ten-year targets and load allocations.

	Annual 1% nonpoint source total phosphorus reductions						
Current	10 (2014)	20 (2024)	30 (2034)	40 (2044)	50 (2054)	60 (2064)	68 (2064)
6,452 lbs/day	5,806(10%)	5,162(20%)	4,516(30%)	3,871(40%)	3,226 (50%)	2,581(60%)	2,065(68%)

Figure 4.0.1 Example interim load reduction goals based on 10-year objectives for irrigated agriculture. NOTE: The dates identified above are for illustration purposes only and are based on the assumption that the SR-HC TMDL will be approved in 2002, and that site-specific implementation plans will be completed by 2004. If the SR-HC TMDL is approved on a different time frame, the dates for the implementation process will follow the actual completion date of the site-specific implementation plans at 10-year increments.

Point Source Waste Load Allocation Mechanism

In correlation with the load allocation strategy for nonpoint sources above, a similar assessment was completed by members of the SR-HC PAT for point source discharges. The findings of this assessment are summarized below:

1. Based on recent Idaho experience, anticipated nonpoint source reductions could be 65 to 70 percent, however post treatment concentrations likely will be >100 ug/l where furrow irrigation is the primary irrigation practice.
2. Point Source controls occur in three technology steps. Cost increase rapidly after the first increment. Total phosphorus reduction costs range from $<5 to $2,600 lb/day and removal rates vary from 80 to 94 percent depending on technology used.
3. An allocation alternative evaluation is useful and provides critical information to the allocation process and decision makers. Allocation method has significant influence on basinwide TMDL implementation costs.

4. The members of the SR-HC PAT determined that, based on known techniques, point source controls beyond biological nutrient removal are neither feasible nor equitable.
5. Nutrient criteria or target determination methods have not been adopted be either Idaho or Oregon. Technical and regulatory approach to determine nutrient targets are rapidly evolving and likely will result in changes to the target during the implementation period anticipated for this TMDL, making adaptive management an important aspect of this TMDL.
6. Trading is a necessary tool in achieving cost effective implementation and should be an acceptable tool incorporated in the TMDL as an option in meeting allocations.

Preliminary, interim goals for total phosphorus reduction (cumulative point and nonpoint source activities) have been identified as part of this load allocation process. They include a reduction goal for total phosphorus concentration of 0.01 mg/L every 10 years. It is expected that this preliminary schedule will encourage the identification of implementation priorities that will result in consistent reduction activities. It is also expected that these preliminary goals will be refined as site-specific implementation plans are finalized and information on reduction efficiency is collected.

4.0.3 Pesticides

A detailed discussion of sources, available data, associated water quality-related concerns and loading is available in Sections 2.3.3.2, and 3.3.

4.0.3.1 LOADING

As the pesticides of concern (DDT and dieldrin) are no longer in use (both are banned pesticides), the existing loading is assumed to occur solely from legacy application or contamination. Anthropogenic sources are confined to runoff from areas that have been treated historically and areas where storage or spillage occurred historically. Current practices make municipal or stormwater sources from urban areas very unlikely to be significant loading sources. Point source loading is considered negligible. Pesticide concentrations in treated effluent occur as the result of concentrations in incoming source water rather than as an artifact of the treatment process.

No pesticide data are available for the Oxbow Reservoir segment (RM 285 to 272.5). The data set available for the Upstream Snake River and Brownlee Reservoir segments (RM 409 to 285) were used to provide a rough approximation of pesticide loading to the SR-HC TMDL reach. Loading at the USGS gage at Weiser (mainstem Snake River) was calculated to be approximately 42 kg/year t-DDT and 28 kg/year dieldrin for an average water year. Assuming that the data collected were representative of the average annual concentrations in the water column, this shows that the current pesticide loading is between 30 and 100 times greater in the Upstream Snake River segment (RM 409 to 335) of the SR-HC reach than the targets would allow.

4.0.3.2 LOAD CAPACITY

The SR-HC TMDL reach load capacity for t-DDT and dieldrin (Table 4.0.10) was determined by calculation using the target of 0.024 ng/L DDT water column concentration and the 0.07 ng/L dieldrin water column concentration identified for the SR-HC TMDL, and average flow values (calculated from 1979, 1995 and 2000 flow data). Water column data was available for the Upstream Snake River segment (RM 409 to 335) only.

Table 4.0.10. t-DDT and dieldrin (pesticide) load capacity for segments in the Snake River - Hells Canyon TMDL reach based on the water column target concentrations of 0.024 ng/L (DDT) and 0.07 ng/L (dieldrin) and calculated average flows.

Segment	Annual Load Capacity t-DDT (kg/year)	Annual Load Capacity Dieldrin (kg/year)
Upstream Snake River Segment (RM 409 to 335)	0.34	0.98
Brownlee Reservoir Segment (RM 335 to 285)	0.37	1.1
Oxbow Reservoir Segment (RM 285 to 272.5)	0.37	1.1

4.0.3.3 Margin of Safety

An explicit margin of safety of 10 percent has been used in calculation of the load allocation. An implicit margin of safety is also present, based on conservative values identified for the assimilative capacity. Other areas of uncertainty such as bioconcentration capacity and relative threat to different use categories are accounted for to the extent possible in the identification of the target concentrations as a conservative value.

4.0.3.4 Background/Natural Loading

There is no natural DDT or dieldrin loading.

4.0.3.5 Reserve

Due to the fact that these are banned pesticides, no reserve capacity was established for DDT or dieldrin.

4.0.3.6 Load Allocations

Table 4.0.11 lists the load allocations for DDT and dieldrin on a general basis for the Upstream Snake River segment (RM 409 to 335). Insufficient data are available to further differentiate pollutant sources within the segment. These load allocations represent the sum of point and nonpoint source-related loading to the SR-HC TMDL reach, and therefore to the Oxbow Reservoir segment (RM 285 to 272.5), the only segment in the SR-HC TMDL reach that is listed for pesticides.

Due to the lack of data necessary to accurately characterize pesticide loading to the Oxbow Reservoir segment (RM 285 to 272.5), and the diffuse and widespread legacy nature of pesticide loading to the Snake River; a watershed-based approach will be employed wherein reductions in pesticide loading will be accomplished through best management practices for sediment control. This reduction strategy will be implemented in direct correlation with other reduction efforts identified by this TMDL and concurrent efforts already underway in the SR-HC drainage. In the SR-HC TMDL, sediment (total suspended solids, TSS) targets and monitored trends will function as an indicator of changes in transport and delivery for these attached pollutants.

Table 4.0.11. Identified load allocations for the reduction of pesticides in the Snake River - Hells Canyon TMDL reach.

Segment	Load Allocation for t-DDT (kg/year)	Load Allocation for Dieldrin (kg/year)
Load allocation specific to legacy applications		
Upstream Snake River Segment (RM 409 to 335)	0.31	0.88
Brownlee Reservoir Segment (RM 335 to 285)	0.33	1.0
Oxbow Reservoir Segment (RM 285 to 272.5)	0.33	1.0
Load allocation specific to current application		
Upstream Snake River Segment (RM 409 to 335)	0	0
Brownlee Reservoir Segment (RM 335 to 285)	0	0
Oxbow Reservoir Segment (RM 285 to 272.5)	0	0

In this manner, diffuse legacy sources will be effectively addressed by best management practices that will improve water quality for a number of listed constituents simultaneously (i.e. mercury, pesticides, sediment and nutrients). Load allocations for pesticides do not vary seasonally and will be applied year-round. Critical conditions, when the majority of transport is projected to occur, are April through October, encompassing the spring runoff and summer irrigation seasons.

NOTE: The load allocations identified do not require monitoring of pesticide loading or load reductions. Such monitoring is not considered feasible and will therefore not be required as part of this TMDL process. Rather, appropriate management techniques specific to responsible stewardship will be employed as part of the TMDL implementation process. These management techniques are projected to result in reduction of overall DDT and dieldrin loading related to nonpoint source discharge to the mainstem Snake River.

Available data do not yield a clear answer on the support status of designated beneficial uses but indicate that sufficient concern exists to justify the collection of additional water column data in both the Oxbow Reservoir segment (RM 285 to 272.5) and the segments upstream.

4.0.4 pH and Bacteria

A detailed discussion of sources, available data, associated water quality-related concerns and loading is available in Sections 2.2.4.4, 2.3.1.2, and 3.4.

4.0.4.1 LOADING

Based on the available data, the SR-HC TMDL process recommends that the mainstem Snake River (RM 409 to RM 347, OR/ID border to Scott Creek inflow) be delisted for bacteria by the State of Idaho as part of the first 303(d) list submitted by the State of Idaho subsequent to the approval of the SR-HC TMDL. The SR-HC TMDL process further recommends that monitoring of bacteria levels (*E. coli*), especially in those areas of the SR-HC TMDL reach where recreational use consistently occurs, continue to be an integral part of the water quality monitoring of the Upstream Snake River segment (RM 409 to 335).

Based on the available data, the SR-HC TMDL process recommends that the mainstem Snake River from RM 409 to RM 347 (OR/ID border to Scott Creek inflow) and from RM 335 to RM 285 (Brownlee Reservoir) be delisted for pH by the State of Idaho as part of the first 303(d) list submitted by the State of Idaho subsequent approval of the SR-HC TMDL. The SR-HC TMDL process further recommends that monitoring of pH continue to be an integral part of the water quality monitoring of the Upstream Snake River segment (RM 409 to 335).

4.0.4.2 Load Allocations

The data showed no exceedences of water quality targets for the SR-HC TMDL reach. Delisting of these two pollutants is recommended; therefore no load allocations have been identified.

4.0.5 Sediment

A detailed discussion of sources, available data, associated water quality-related concerns and loading is available in Sections 2.2.4.5, 2.3.1.2, 2.3.2.2, 2.3.3.2, and 3.5.

4.0.5.1 Loading

The Upstream Snake River (RM 409 to 335), Brownlee Reservoir (RM 335 to 285) and Oxbow Reservoir segment (RM 285 to 272.5) of the SR-HC TMDL are listed for impairment due to sediment. No duration data is available to assess the extent of impairment or support in these reaches. During the first phase of implementation (the five years following the approval of the SR-HC TMDL) duration data will be collected to determine if designated aquatic life uses are being impaired. Targets have been set in a conservative fashion so that aquatic life uses will be protected in the listed segments.

Sediment loading within the SR-HC TMDL reach is also of concern because of the attached pollutant loads (mercury, pesticides and nutrients) that the sediment carries. In the SR-HC TMDL, sediment (total suspended solids (TSS)) targets and monitored trends will function as indicators of changes in the transport and delivery of these attached pollutants.

The available data show that sediment loading into the SR-HC reach originates almost exclusively from the Upstream Snake River segment (over 95%). Sources of unmeasured load may include nonpoint source runoff from anthropogenic sources and precipitation events, unidentified small tributaries and drains, error in gauged flow measurements and ground-water sources.

Tables 4.0.12 and 4.0.13 contain calculated total suspended solids loads for point and nonpoint sources in the SR-HC TMDL reach.

Sediment deposition and processing within the Hells Canyon Complex reservoirs results in dramatic changes to the measured total suspended solids concentration as compared to upstream concentrations. This change makes it impossible to determine loading from nonpoint sources within the immediate drainage area to the Hells Canyon Complex. The potential loading from these sources has been evaluated and assumed to be small as the incidence of agricultural

Table 4.0.12. Sediment (TSS) loads from point sources in the Snake River - Hells Canyon TMDL reach based on 1995, 2000 data.

Point Source	NPDES Permit Number	Location (RM)	Current Design-Flow Load (kg/day)
City of Nyssa	101943 OR0022411	385	32 kg/day
Amalgamated Sugar	101174 OR2002526	385	Negligible
City of Fruitland	ID0020907	373	62 kg/day
Heinz Frozen Foods	63810 OR0002402	370	396 kg/day
City of Ontario	63631 OR0020621	369	209 kg/day
City of Weiser (WWTP)	ID0020290	352	213 kg/day
City of Weiser (WTP)	ID0001155	352	Negligible
Brownlee Dam (IPCo)	ID0020907	285	Negligible
Oxbow Dam (IPCo)	101275 OR0027286	272.5	Negligible
Hells Canyon Dam (IPCo)	101287 OR0027278	247	Negligible

practices (cropping and ranching) and municipal stormwater runoff is minimal, as is the intensity of use.

4.0.5.2 Load Capacity

The SR-HC TMDL reach load capacity for total suspended solids was determined by calculation using the target of 50 mg/L monthly average water column concentration identified for the SR-HC TMDL, and average flow values (Table 2.1.1), as shown in Table 4.0.14.

Transport and deposition of sediments into and within the SR-HC TMDL reach is seasonal in nature. Erosion of natural sources and transport of anthropogenic sources occurs primarily during spring and summer flows.

4.0.5.3 Margin of Safety

An implicit margin of safety is incorporated into the SR-HC TMDL sediment targets, as all parameters used to identify these targets were conservative in nature. An additional explicit margin of safety of 10 percent has been used in calculation of the load allocations.

4.0.5.4 Background/Natural Loading

As there are no undeveloped watersheds in the SR-HC TMDL reach to use as a reference system for determining natural loading, an estimate was derived using the data available for spring runoff in the SR-HC TMDL reach as described in Section 3.5.3.1. The average relative natural sediment loading delivered was calculated at 24 percent of the total suspended solids loading for the mainstem Snake River and represents a conservative estimate.

A necessary set of data for the tributary streams is not currently available. Therefore, natural background concentrations for all tributaries will be determined as part of upcoming TMDL development on the Weiser, Owyhee, and Malheur Rivers, and tributary implementation plans for the Payette and Boise Rivers.

Table 4.0.13. Sediment (TSS) loads from nonpoint sources in the Snake River - Hells Canyon TMDL reach for 1995, 1996 and 2000 data and average flow values.

Load Type	Location	Load (kg/day)	Estimation Method
Snake River Inflow	RM 409: Upstream Snake River Segment	677,785	See Section 3.5
Owyhee River	RM 396.7: Upstream Snake River Segment	66,152	See Section 3.5
Boise River	RM 396.4: Upstream Snake River Segment	130,466	See Section 3.5
Malheur River	RM 368.5: Upstream Snake River Segment	92,870	See Section 3.5
Payette River	RM 365.6: Upstream Snake River Segment	137,887	See Section 3.5
Weiser River	RM 351.6: Upstream Snake River Segment	53,617	See Section 3.5
Drains	Upstream Snake River segment (RM 409 to 335)	143,430	See Section 3.5
Ungaged flows	Upstream Snake River segment (RM 409 to 335)	181,484	See Section 3.5
Agriculture, Stormwater and Forestry	Upstream Snake River segment (RM 409 to 335)	Included in the ungaged flow loading	See Section 3.5
Upstream Snake River Segment Total Loading	RM 409 to 335	1,483,691	See Section 3.5
Burnt River	RM 296: Brownlee Reservoir Segment	13,274	See Section 3.5
Powder River	RM 327.5: Brownlee Reservoir Segment	14,857	See Section 3.5
Agriculture, Stormwater and Forestry	Brownlee Reservoir segment (RM 335 to 285)	Cannot be calculated, assumed small	See Section 3.5
Agriculture, Stormwater and Forestry	Oxbow Reservoir segment (RM 285 to 272.5)	Cannot be calculated, assumed small	See Section 3.5

4.0.5.5 Reserve

Waste load allocations to point sources were determined based on design capacity. The reserve capacity allocation is therefore the difference between the current discharge and design flow discharge. This allows for expansion of existing sources or addition of new point sources discharge through trading or demonstration of an offset within the SR-HC system.

4.0.5.6 Load Allocations

Table 4.0.15 a and b identify the load and waste load allocations for point and nonpoint sources in the SR-HC TMDL reach. Point source discharges represent less than 0.04 percent of the total load capacity for the SR-HC TMDL reach. Many point sources employ treatment measures that dramatically reduce the sediment concentrations in their effluent as compared to the source water. Due to the fact that point source loading represents such a miniscule proportion of the total load, waste load allocations have been established at existing NPDES permit levels for all point sources discharging directly to the mainstem Snake River. In cases where existing NPDES permits do not identify limits for total suspended solids (or an appropriate equivalent measure), limits will be established at no greater than 50 mg/L applied on a monthly average. Quantitative load allocations in kg per unit of time can be calculated from Table 4.0.15 a by multiplying the existing permit limits by the design flows identified in Table 2.0.5.

Table 4.0.14. Sediment (TSS) load capacity for segments in the Snake River - Hells Canyon TMDL reach based on the water column target concentration of 50 mg/L (monthly average), current discharge concentrations and calculated average flows.

Segment	Location	Load (kg/day)
Snake River Inflow	RM 409: Upstream Snake River Segment	1,171,626
Owyhee River	RM 396.7: Upstream Snake River Segment	53,341
Boise River	RM 396.4: Upstream Snake River Segment	165,077
Malheur River	RM 368.5: Upstream Snake River Segment	46,735
Payette River	RM 365.6: Upstream Snake River Segment	329,478
Weiser River	RM 351.6: Upstream Snake River Segment	134,604
Drains	Upstream Snake River segment (RM 409 to 335)	64,031
Ungaged flows	Upstream Snake River segment (RM 409 to 335)	131,309
Total Upstream Snake River Segment	RM 409 to 335	2,096,201
Burnt River	RM 296: Brownlee Reservoir Segment	10,792
Powder River	RM 327.5: Brownlee Reservoir Segment	29,276
Total Brownlee Reservoir Segment	RM 335 to 285	2,098,835
Total Oxbow Reservoir Segment	RM 285 to 272.5	2,116,038

If monitored trends indicate that sediment concentrations are increasing, despite implementation efforts, new, more conservative targets will be considered and load allocations will be revised. If monitored trends indicate that sediment concentrations are decreasing in correlation with implementation efforts, an associated decrease in attached pollutants will be assumed to occur and load allocations will not be reduced.

In the meantime, while duration data is being collected, the targets will function as a loading “cap” in the listed segments, representing a reasonable assurance that aquatic life uses are being protected until a more accurate of designated use support can be made.

This allocation mechanism does not place additional restrictions on those sources already at or below target concentrations. Due to the nature of most nutrient reduction BMPs, total suspended solids loading is expected to decrease with implementation for total phosphorus load allocations. These two processes are highly correlated and implementation is projected to occur in a complimentary fashion

This TMDL will proceed toward completing site-specific implementation plans within 18 months of approval of the TMDL. Data collection for duration information is projected to be accomplished within the first five years following the approval of the TMDL. Additional data gathering will throughout the implementation process to determine progress and improve

Table 4.0.15 a. Total suspended solids (TSS) waste load allocations for point sources discharging directly to the Snake River - Hells Canyon TMDL reach (RM 409 to 188).

Point Source	NPDES Permit Number	Location (RM)	Load Allocation (no greater than)
City of Nyssa	101943 OR0022411	385	30 mg/L (monthly average)
Amalgamated Sugar	101174 OR2002526	385	4,924 lbs/day (monthly average)
City of Fruitland	ID0020907	373	70 mg/L (monthly average)
Heinz Frozen Foods	63810 OR0002402	370	4,200 lbs/day (monthly average)
City of Ontario	63631 OR0020621	369	85 mg/L (monthly average)
City of Weiser (WWTP)	ID0020290	352	400 mg/L (daily average)
City of Weiser (WTP)	ID0001155	352	50 mg/L (monthly average)
Brownlee Dam (IPCo)	ID0020907	285	50 mg/L (monthly average)
Oxbow Dam (IPCo)	101275 OR0027286	272.5	50 mg/L (monthly average)
Hells Canyon Dam (IPCo)	101287 OR0027278	247	0.25 lbs/day (monthly average)

understanding of the SR-HC TMDL system. As this TMDL is a phased process, it is projected that the goals and objectives of this TMDL will be revisited periodically to evaluate new information and assure that the goals and milestones are consistent with the overall goal of meeting water quality standards in the SR-HC TMDL reach.

Monitoring of both point source discharge loads and instream water column concentrations will be undertaken as part of the implementation process. Instream monitoring will be identified in more detail in the site-specific implementation plans that will be completed 18 months following the approval of the SR-HC TMDL. However, it is expected that at minimum such monitoring

Table 4.0.15 b. Total suspended solids (TSS) load allocations (shown in bold type), sediment thresholds and percent reductions required for nonpoint sources within the Snake River - Hells Canyon TMDL reach (RM 409 to 188).

Source	Location (RM)	Calculated Load (kg/day)	Load Allocations [a] (kg/day)	Loading Capacity (kg/day)	% Reduction Required
Snake River Inflow	RM 409: Upstream Snake River Segment	677,785	677,785		0%
Owyhee River	RM 396.7: Upstream Snake River Segment	66,152	**48,007**		27%
Boise River	RM 396.4: Upstream Snake River Segment	130,466	130,466		0%
Malheur River	RM 368.5: Upstream Snake River Segment	92,870	**42,062**		55%
Payette River	RM 365.6: Upstream Snake River Segment	137,887	137,887		0%
Weiser River	RM 351.6: Upstream Snake River Segment	53,617	53,617		0%
Drains	Upstream Snake River segment (RM 409 to 335)	143,430	**57,628**		60%
Ungaged flows	Upstream Snake River segment (RM 409 to 335)	181,484	**118,178**		35%
Total Upstream Snake River Segment	RM 409 to 335	1,483,691		1,265,630	15% [c]
Burnt River	RM 296: Brownlee Reservoir Segment	13,274	**9,713**		27%
Powder River	RM 327.5: Brownlee Reservoir Segment	14,857	14,857		0%
Total Brownlee Reservoir Segment	RM 335 to 285	n/a [b]		1,290,200	
Total Oxbow Reservoir Segment	RM 285 to 272.5	n/a [b]		1,305,682	

[a] Load allocations (shown in bold type) are based on calculated load capacities, less a 10% margin of safety. In those cases where measured sediment concentrations were not observed to exceed the target values, no reductions are required. However, in an effort to prevent further degradation within the SR-HC TMDL reach, threshold values have been established at the current sediment loads. These thresholds will be recognized in considering future management options, and will act to direct future decisions to those options that will not result in an increase in sediment loading from these tributaries to the SR-HC TMDL reach.

[b] The sediment loading to these reaches cannot be accurately calculated due to the sink effect of the reservoirs. Thresholds have been determined using load capacity determinations and upstream loading calculations.

[c] The % reduction listed is representative of the reduction in total loading to the identified segment as a result of required reductions in loading realized upstream.

will include the measurement of duration-based water column total suspended solids within each segment during time frames that represent high, low and average flow conditions.

Load allocations and reductions identified in Tables 4.0.15 a and b, and Table 3.5.6 are specific to those tributaries discharging at total suspended solids concentrations greater than 50 mg/L monthly average. These reductions are expected to minimize the potential for site specific degradation of habitat and impairment of designated uses at the inflow point within the mainstem Snake River.

The majority of treatment mechanisms to reduce total phosphorus also offer sediment reduction benefits. Therefore, it is anticipated that implementation measures for sediment and total phosphorus reduction will be mutually beneficial. Full implementation for attainment of total phosphorus targets (Section 3.2) is expected to result in attainment of sediment targets in many cases.

4.0.6 Temperature

A detailed discussion of sources, available data, associated water quality-related concerns and loading is available in Sections 2.2.4.6, 2.3.1.2, 2.3.2.2, 2.3.3.2, 2.3.4.2, 2.3.5.2 and 3.6.

4.0.6.1 LOADING

The assumptions utilized in the loading assessment for this TMDL were applied for the purpose of calculating the potential impact of tributary loading on main stem temperatures. These assumptions have not been verified and thus, may not reflect the actual conditions present in the tributaries. In addition, this TMDL does not address temperature reductions that may be required in the tributaries themselves to meet water quality standards in the tributaries. Those will be assessed through the tributary TMDL process.

Load and waste load allocations identified are based on the attainment of water quality targets for salmonid rearing/cold water aquatic life and salmonid spawning as outlined below.

4.0.6.2 SALMONID REARING/COLD WATER AQUATIC LIFE BENEFICIAL USES

The temperature target identified for the protection of salmonid rearing/cold water aquatic life when aquatic species listed under the Endangered Species Act are not present or, if present, a temperature increase would not impair the biological integrity of the Threatened and Endangered population, is: 17.8 ^{o}C (expressed in terms of a 7-day average of the maximum temperature) if and when the site potential is less than 17.8 ^{o}C. If and when the site potential is greater than 17.8 ^{o}C, the target is no more than a 0.14 ^{o}C increase from anthropogenic sources.

When aquatic species listed under the Endangered Species Act are present and if a temperature increase would impair the biological integrity of the Threatened and Endangered population then the target is no greater than 0.14 ^{o}C increase from anthropogenic sources.

The salmonid rearing/cold water aquatic life temperature target identified for the SR-HC TMDL reach applies to RM 409 to 188. This target applies year-round; the critical time period (as defined by elevated water temperatures) is from June through September.

Although it is observed that water temperatures throughout the SR-HC TMDL reach exceed the water quality targets for salmonid rearing/cold water aquatic life during the critical time period (June through September) the analysis of temperature sources undertaken as part of this TMDL has demonstrated that natural atmospheric and non-quantifiable influences preclude the attainment of these targets rather than quantifiable anthropogenic influences. Available data on fish species and temporal/spatial distribution within the Hells Canyon Complex of reservoirs indicates that the designated salmonid rearing/cold water aquatic life use is supported through the availability of cold water refugia. Such refugia does not appear to exist in the Upstream Snake River segment (RM 409 to 335) of this TMDL at the same level as in the reservoir systems.

Modeling work completed by IPCo (IPCo, 2002b) has shown that if the water inflowing to Brownlee Reservoir at RM 335 were at or below numeric temperature targets for salmonid rearing/cold water aquatic life, water leaving the Hells Canyon Complex at Hells Canyon Dam would also be at or below numeric temperature targets for salmonid rearing/cold water aquatic life, regardless of the temperature shift specific to the Hells Canyon Complex. This modeling shows that the Hells Canyon Complex is not the source of the heat load in the reservoirs during the summer season. Therefore, it is concluded that the Hells Canyon Complex is not contributing to temperature exceedences specific to the to salmonid rearing/cold water aquatic life designated use and no requirement for temperature adjustment, specific to salmonid rearing/cold water aquatic life use has been identified for the Hells Canyon Complex dams.

Point Sources.

Waste load allocations specific to temperature for this TMDL will limit point sources to existing loads based on design flow. Currently, cumulative, calculated anthropogenic increases in temperature do not occur above the defined "no-measurable-increase" value of 0.14 ^{o}C. Therefore, the focus of this TMDL is to ensure that additional, anthropogenic temperature influences do not occur over the defined no-measurable-increase value, to protect the cold water refugia currently in place within the SR-HC TMDL reach, and to improve water temperatures in a site-specific fashion in the Upstream Snake River segment (RM 409 to 335) where cold water refugia may be restored. Table 4.0.16 outlines general waste load allocations.

These allocations are calculated on estimated average daily discharge temperatures and design flows. Point source waste load allocations were calculated using the following equation:

WLA = (Discharge Quantity (design flow), # water/day) x (Pt. Source Average Daily Temperature, ^{o}F)

A waste load allocation for future point sources of no measurable increase has been identified as part of this TMDL.

Specific actions identified to accomplish these goals are as follows:

- Point source allocations will be set at current discharge levels.
- Specific temperature effluent limitations in NPDES permits for permitted point sources as listed in Table 3.6.8 will be determined using additional data collection and analysis provided through the facilities plan required of each point source.

- In addition to meeting specified waste load allocations, point source permits will also be expected to address any potential, near field (or mixing zone) water quality issues.

Table 4.0.16. Permitted point source discharge temperature waste load allocations specific to cold water aquatic life/salmonid rearing for the Snake River - Hells Canyon TMDL reach (RM 409 to 188).

Point Source	Point Source Average Daily Temperature (^oF)	Discharge Volume (design flow)	Allocated Heat Load in Million BTU/day
City of Nyssa	72*	0.8 MGD	480
Amalgamated Sugar		Seepage ponds	NA
City of Fruitland	72*	0.5 MGD	300
Heinz Frozen Foods	32 ^oC (90 ^oF)*	3.4 MGD	2,557
City of Ontario	72*	Land Application	NA
City of Weiser	72*	2.4 MGD	1,440
Brownlee Dam	76**	15 MGD	9,500
Oxbow Dam	76**	11 MGD	6,880
Hells Canyon Dam	76**	9 MGD	4,750

* Estimated values.
** Existing permit effluent limits.

These allocations are specific to the salmonid rearing/coldwater aquatic life target, which applies year-round. The critical period for this target in the SR-HC TMDL reach (that time period in which target exceedences are most likely to occur) is from May through September. During the non-critical period, NPDES permits shall ensure that discharges are limited to ensure that each source does not violate water quality standards.

These findings and requirements will be periodically reviewed as additional data and information become available to ensure that the assumptions made and the goals identified remain consistent with full support of designated beneficial uses.

More precise data will be collected and analyzed as part of the facility planning process discussed in the Water Quality Management Plan included with the TMDL. Actual effluent limitations will be derived from the facility plan data.

Also, it must be recognized that the temperature TMDL and associated load allocations are intended to address far field or accumulative impacts from point sources. Permits must also address near field impacts to ensure that appropriate standards are not violated either outside or inside the regulatory mixing zone.

Nonpoint Sources.

Table 4.0.17 lists load allocations specific to cold water aquatic life/salmonid rearing designated beneficial uses.

A gross nonpoint source temperature load allocation has been established as a total anthropogenic loading of less than 0.14 ^oC. (This load allocation applies primarily to agricultural and stormwater drains and similar inflows.) This allocation applies at discharge to the Snake

River in the SR-HC TMDL reach, during those periods of time that the site potential temperature in the mainstem Snake River is greater than 17.8 °C. It is projected that implementation associated with total phosphorus and suspended solids reduction will result in reduced inflow temperatures in the smaller drains and tributaries to the mainstem Snake River as many of the approved methods for the reduction of total phosphorus and suspended solids are based on streambank re-vegetation and similar methodologies that will increase shading.

Table 4.0.17. Nonpoint source temperature load allocations specific to cold water aquatic life/salmonid rearing for the Snake River - Hells Canyon TMDL reach (RM 409 to 188). Applicable when water temperatures are in excess of 17.8 °C.

Segment	Nonpoint Source Load Allocation
Nonpoint sources discharging directly to the Snake River in the SR-HC TMDL reach	
SR-HC TMDL Reach	total anthropogenic loading less than 0.14 °C at RM 409 during that period of time that the site potential of the mainstem Snake River is above 17.8 °C due to natural or non-quantifiable temperature sources.
Associated actions: assessment of impacts to anthropogenic loading as part of management changes	
Tributary sources discharging directly to the Snake River in the SR-HC TMDL reach	
Upstream Snake River (RM 409 to 335)	total anthropogenic loading less than 0.14 °C at RM 409 during that period of time that the site potential of the mainstem Snake River is above 17.8 °C due to natural or non-quantifiable temperature sources.
Brownlee Reservoir (RM 335 to 285)	total anthropogenic loading less than 0.14 °C at RM 409 during that period of time that the site potential of the mainstem Snake River is above 17.8 °C due to natural or non-quantifiable temperature sources.
Oxbow Reservoir (RM 285 to 272.5)	total anthropogenic loading less than 0.14 °C at RM 409 during that period of time that the site potential of the mainstem Snake River is above 17.8 °C due to natural or non-quantifiable temperature sources.
Hells Canyon Reservoir (RM 272.5 to 247)	total anthropogenic loading less than 0.14 °C at RM 409 during that period of time that the site potential of the mainstem Snake River is above 17.8 °C due to natural or non-quantifiable temperature sources.
Downstream Snake River (RM 247 to 188)	total anthropogenic loading less than 0.14 °C at RM 409 during that period of time that the site potential of the mainstem Snake River is above 17.8 °C due to natural or non-quantifiable temperature sources.
Associated actions: assessment of anthropogenic loading at the mouth as part of the tributary TMDL process	

* Direct monitoring of anthropogenic temperature increases is not feasible for these sources and therefore will not be required as part of this TMDL process. Rather, appropriate management techniques specific to proper stewardship will be employed as part of the overall TMDL implementation process. These management techniques are projected to result in reduction of overall anthropogenic temperature increases related to nonpoint source discharge to the mainstem Snake River.

A gross nonpoint source temperature load allocation has been established at no greater than 0.14 °C for tributaries discharging to the SR-HC TMDL reach. This is equal to the sum of the waste load allocation and the load allocation for anthropogenic tributary sources. This allocation applies at the inflow to the Snake River in the SR-HC TMDL reach, during those periods of time that the site potential temperature in the mainstem Snake River is greater than 17.8 °C. For this TMDL, there was neither time nor resources to specifically analyze anthropogenic loads in the individual tributaries. Both IDEQ and ODEQ, however, will evaluate these loads when tributary-specific temperature TMDLs are completed. If the calculations of tributary heat loads are significantly different from those determined in this TMDL, the load allocations will be adjusted accordingly.

It should be noted that no explicit load allocation is provided to natural background due to the form of the load capacity.

4.0.6.3 Salmonid Spawning Designated Beneficial Uses

The temperature target identified for the protection of salmonid spawning when aquatic species listed under the Endangered Species Act are not present or, if present, a temperature increase would not impair the biological integrity of the Threatened and Endangered population, is less than or equal to a maximum weekly maximum temperature of 13 ^{o}C (when and where salmonid spawning occurs) if and when the site potential is less than a maximum weekly maximum temperature of 13 ^{o}C (temporary rule, effective by action of the IDEQ board 11-14-03, pending approval by Idaho Legislature 2005, subject to US EPA action). If and when the site potential is greater than a maximum weekly maximum temperature of 13 ^{o}C, the target is no more than a 0.14 ^{o}C increase from anthropogenic sources. (The State of Oregon definition of no measurable increase (0.14 ^{o}C) was used, as it is more stringent than the State of Idaho definition of 0.3 ^{o}C.)

When aquatic species listed under the Endangered Species Act are present and if a temperature increase would impair the biological integrity of the Threatened and Endangered population then the target is no greater than 0.14 ^{o}C increase from anthropogenic sources.

This target applies only when and where salmonid spawning occurs and is specific to those salmonids identified to spawn in this area, namely fall chinook (October 23rd through April 15th) and mountain whitefish (November 1st through March 30th). The salmonid spawning target applies from RM 247 to 188. The critical period for salmonid spawning in the Downstream Snake River segment (RM 247 to 188) is from October 23 to April 15. This period is protective of both fall chinook and mountain whitefish.

The start of fall chinook spawning was identified using data collected by IPCo and USFWS from 1991 through 2001. The information and methodologies used to identify the spawning period is discussed in detail in Section 3.6.1.2. Chinook spawning does not occur above Hells Canyon Complex as the Complex represents a barrier to upstream migration.

Point Sources.

There is one permitted, point source discharge to the Downstream Snake River segment (RM 247 to 188). This discharge is for turbine cooling water from Hells Canyon Dam. Current discharge limits are 7.5 MGD, temperature not to exceed background + 10 ^{o}F. Due to the very small temperature loading associated with this discharge as compared to the total outflow of Hells Canyon Dam, no additional permit limits will imposed on this discharge at this time. The waste load allocation for this source will be set at the existing NPDES permit limits. If further information or understanding of the SR-HC TMDL system identifies a need for temperature reductions specific to this discharge, the permit requirements will be revisited as part of the iterative TMDL process.

Nonpoint Sources.

Water temperature modeling by IPCo shows that even if the inflowing water temperature were less than or equal to numeric criteria for salmonid rearing/cold water aquatic life uses, the water exiting the Hells Canyon Complex would not meet the salmonid spawning criteria (although by only a small margin) because of the temporal shift created by the Hells Canyon Complex. Data assessment and calculational modeling by the DEQs (as discussed earlier) have identified a similar trend. It is, therefore, concluded that the responsibility for exceeding the salmonid spawning criteria is specific to the presence and operation of the Hells Canyon Complex dams.

Available water temperature data show that numeric salmonid spawning targets are exceeded during the first few weeks of the spawning period for fall chinook for some years. Limited data collected in the 1950's suggest that criteria were also exceeded before the completion of the Hells Canyon Complex dams in the 1950's, but for a shorter period of time (Figure 3.6.4 a). At those times when exceedences occur, a reduction in thermal loading is needed to bring water temperature during spawning down to the 13 °C daily maximum temperature or to site potential temperatures as defined at RM 345. The critical period for this portion of the temperature TMDL begins on October 23 of each year and extends through the spawning period as long as water temperatures at the outflow from Hells Canyon Dam are 13 °C (daily maximum) or greater.

The 13 °C daily maximum temperature target is utilized as an instantaneous measurement that can be applied in "real time" to determine compliance. Calculation of a daily average temperature would create a time lag in the measurement of ΔT and the management of operations to achieve the target value. This situation could result in short-term exceedences within the outflow.

The site potential comparison approach (water temperatures at RM 345 above Brownlee Reservoir compared to water temperatures at RM 247 below Hells Canyon Dam (1992 to 2001)) is at present the best available estimate of the effect of the Hells Canyon Complex dams on water temperature in the Snake River below Hells Canyon Dam.

The temperature change required by the thermal load allocation consists of a change in water temperature such that the temperature of water released from Hells Canyon Dam is less than or equal to the water temperature at RM 345, or the 13 °C daily maximum temperature target for salmonid spawning. Specific compliance parameters for meeting this load allocation will be defined as part of the 401 Certification process. Figure 4.0.2 outlines this temperature load allocation as calculated from daily maximum temperatures averaged from 1991 through 2001.

The actual excess thermal load (allowable load) is flow dependent. It may be nominally calculated by: flow x ΔT x K, where flow is the discharge rate at any time of concern; ΔT is the difference between the observed temperature at the outflow of Hells Canyon Dam (RM 247) and the target temperature; and K is a conversion factor taking into account the time period of interest, units of energy, and heat capacity and density of water, such as to express a thermal load in terms of energy/time.

Load (kcal/day) = [ΔT x Q_R x (86400 sec/day) x (62.4#water/ft^3)]/ (1.1 x (3.968 BTU/kcal)

where: ΔT = allowable change in temperature
(When river temperatures below Hells Canyon Dam are greater than 13 °C (daily maximum), ΔT is no more than 0.14 °C increase over site potential temperature at RM 345)
Q_R = flow in the river in cfs
1.1 = safety factor of 10 percent

The entire thermal load allocation consists of the required change in temperature (such that the temperature of water released from Hells Canyon Dam is less than or equal to the flow-weighted average temperature at RM 345, or the 13 °C daily maximum temperature target for salmonid spawning) and the allowable temperature change described by the preceding equation. The entire load for the Downstream Snake River segment (RM 247 to 188) is allocated to the Hells Canyon Complex of dams owned and operated by IPCo.

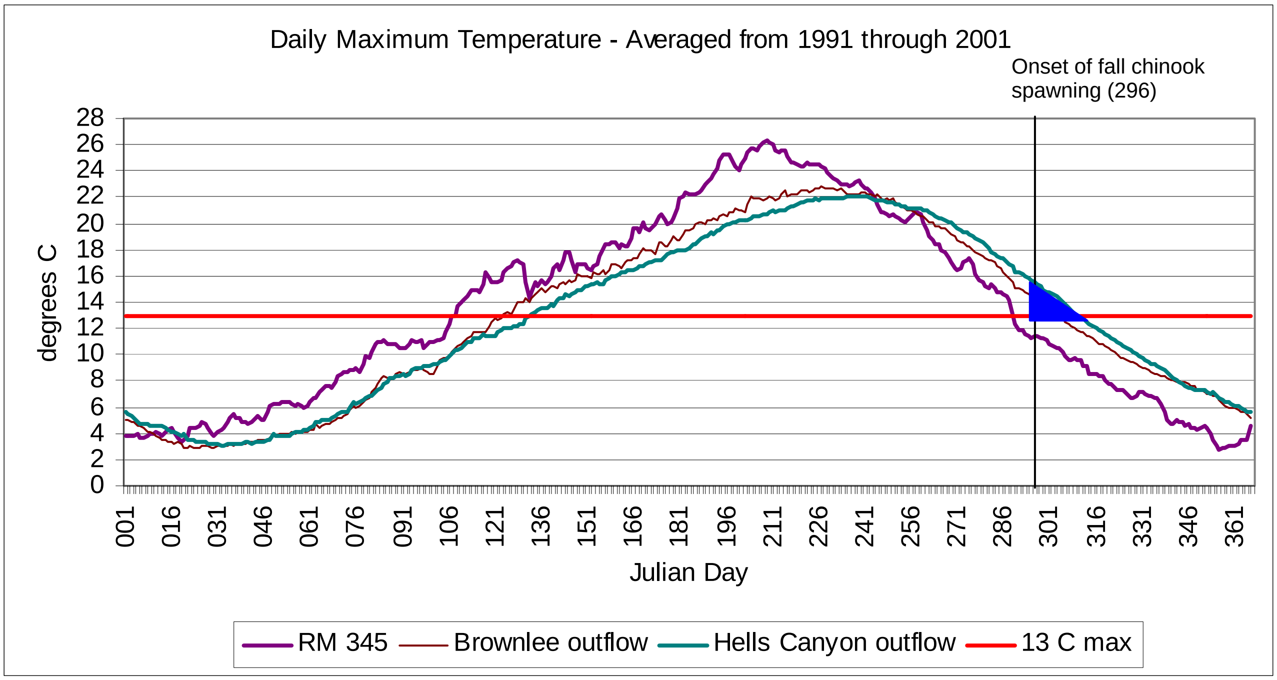


Figure 4.0.2 Load allocation for temperature change below Hells Canyon Dam using a comparison of daily maximum water temperatures for the Snake River at RM 345 (10 miles upstream of the headwaters of Brownlee Reservoir) which acts as the "thermal site potential" surrogate for the Hells Canyon Complex, and water temperatures at the outflow of Hells Canyon Dam (RM 247). (The horizontal line describes the 13 °C maximum allowable temperature that applies from October 23 (Julian day 296) through April 15 (Julian day 105) for Hells Canyon fall chinook. The vertical line identifies the start of salmonid spawning period (October 23, Julian day 296). The triangle describes the mean temperature change necessary to meet the temperature load allocation below Hells Canyon Dam, RM 247).

In the plot in Figure 4.0.2, the 13 °C salmonid spawning temperature target for the SR-HC TMDL is identified, as is the change in temperature required at the outflow of Hells Canyon Dam to meet the target (no greater than 13 °C maximum weekly maximum water temperature) or less than 0.14 °C increase due to anthropogenic influences from the water temperature at RM 345 (the thermal potential surrogate for the Hells Canyon Complex). The data plotted are the mean values derived from water temperature data collected from 1991 through 2001. The maximum temperature change illustrated by this data would be 2.6 ^{o}C (occurring on October 23rd) the minimum change would be 0 ^{o}C (occurring on Nov 6th). The mean temperature change described by the plotted data is 1.3 ^{o}C. The mean duration of the required change described by the plotted data is 14 days.

The development of this load allocation, like the TMDL, is an iterative process. This load allocation will remain in effect until such time as additional data and further analysis warrant its reconsideration and the load allocation is changed through an appropriate process. This thermal load is a load allocation; it is not a waste load allocation. By the use of the term load allocation, however, the DEQs do not waive their right to assert in any proceeding related to this TMDL, the Hells Canyon Hydro-Electric Complex or any other TMDL or hydro-electric project, that a hydro-electric project is a point source under the federal Clean Water Act. Should sufficient data become available to allow an accurate determination of natural warming for the Hells Canyon Complex, this information will be reviewed as part of the iterative TMDL process and revisions to the TMDL and the associated load allocation will be made as appropriate.

Data collected by IPCo and USFWS indicate that fall chinook spawning is occurring under existing conditions throughout the 100 mile reach of the Snake River from below Hells Canyon Dam (RM 245) downstream to Asotin WA (RM 145). While this TMDL stops at the confluence of the Salmon River, the entire reach from Hells Canyon Dam downstream to Asotin, WA currently supports (to some extent) salmonid spawning activity. The majority of spawning activity occurs from October 23rd through the first week of December. Currently, the peak of spawning in the river downstream of Hells Canyon Dam occurs when daily mean and maximum water temperatures are between 12 ^{o}C and l6 ^{o}C.

Data currently available (IPCo, 2001c, 2001e, 2001f) do not identify impairment to fall chinook spawning due to water temperatures in excess of the current criteria occurring in the late fall. Moreover, studies undertaken by IPCo suggest that warmer fall and winter water temperatures can lead to accelerated hatching and fry development, which may provide a survival benefit to out-migrating juvenile fall chinook. However, these data, and their interpretation, are preliminary. If additional data or study further clarify the support status of fall chinook and/or the effects of water temperature on spawning, or result in changes to salmonid spawning criteria, this information will be reviewed as part of the iterative TMDL process and revisions to the TMDL and the associated load allocations will be made as appropriate.

4.0.7 Total Dissolved Gas

A detailed discussion of sources, available data, associated water quality-related concerns and loading is available in Sections 2.2.4.7, 2.3.3.2, 2.3.4.2, 2.3.5.2 and 3.7.

4.0.7.1 LOADING

Elevated total dissolved gas levels are the result of releasing water over the spillways of dams. Spill at Brownlee and Hells Canyon Dams is the only source of elevated total dissolved gas in the SR-HC reach. At this time, voluntary spill does not occur within the Hells Canyon Complex.

Spill at dams occurs only involuntarily, usually as a result of flood control constraints. The magnitude of the exceedence (to some extent) and the total distance downstream of the dam where water was observed to exceed the less than 110 percent of saturation target are observed to be directly related to the volume of the spill.

Observed ranges of total dissolved gas loading to the Oxbow Reservoir (RM 285 to 272.5), Hells Canyon Reservoir (RM 272.5 to 247) and Downstream Snake River segment (RM 247 to 188) are shown in Table 4.0.18.

Table 4.0.18. Total dissolved gas waste loads from sources in the Snake River - Hells Canyon TMDL reach.

Load Type	Location	Load	Estimation Method
Spill from Brownlee Reservoir	Oxbow and Hells Canyon Reservoir Segments	114% to 128%	Monitoring
Spill from Hells Canyon Reservoir	Downstream Snake River Segment	108% to 136%	Monitoring

4.0.7.2 LOAD CAPACITY

In order to ensure that designated aquatic life uses are protected, total dissolved gas concentrations cannot exceed 110 percent of saturation. This concentration therefore defines the load capacity for the Oxbow Reservoir (RM 285 to 272.5), Hells Canyon Reservoir (RM 272.5 to 247) and Downstream Snake River segment (RM 247 to 188) of the SR-HC TMDL reach (Table 4.0.19).

Table 4.0.19. Total dissolved gas load capacity for segments in the Snake River - Hells Canyon TMDL reach.

Segment	Annual Load Capacity
Oxbow Reservoir segment (RM 285 to 272.5)	less than 110% of saturation
Hells Canyon Reservoir segment (RM 272.5 to 247)	less than 110% of saturation
Downstream Snake River segment (RM 247 to 188)	less than 110% of saturation

4.0.7.3 MARGIN OF SAFETY

An implicit margin of safety is incorporated into the SR-HC TMDL total dissolved gas target as it is established as a conservative criterion for the protection of aquatic life designated uses.

4.0.7.4 BACKGROUND/NATURAL LOADING

There are no known natural sources of total dissolved gas that result in substantial loading or standards violations in the SR-HC TMDL reach.

4.0.7.5 Reserve

No reserve capacity was built into the calculation of load allocations for total dissolved gas.

4.0.7.6 Load Allocations

Load allocations specific to total dissolved gas exceedences are identified in Table 4.0.20.

Table 4.0.20. Total dissolved gas load allocations for the Hells Canyon Complex reservoirs.

Segment	Load Allocation
Oxbow Reservoir segment (RM 285 to 272.5)	less than 110% of saturation at the edge of the aerated zone below Brownlee Dam*
Hells Canyon Reservoir segment (RM 272.5 to 247)	less than 110% of saturation at the edge of the aerated zone below Oxbow Dam*
Downstream Snake River segment (RM 247 to 188)	less than 110% of saturation at the edge of the aerated zone below Hells Canyon Dam*

* The specific location of compliance points and protocol for monitoring will be determined as part of the Hells Canyon Complex 401 Certification process for each state.

The load allocation can be calculated using the following equation:

Load = (110%)(K)(flow conversion constant)
where K = the gas conversion constant for N_2

This load allocation has been established to ensure that the less than 110 percent of saturation target is attained. This load allocation applies to all discharge flows not exceeding the ten-year, seven-day average flood flow for Brownlee and Hells Canyon Dams, identified by Idaho Power Company as 72,500 cfs. As spill over Brownlee Dam and Hells Canyon Dam (both facilities owned and operated by IPCo) is the sole source of elevated total dissolved gas in the SR-HC TMDL reach, the entire load allocation goes to the Hells Canyon Complex.

If a separate target is established through the FERC, 401 Certification process or other appropriate mechanism, and shown to support the designated beneficial uses, the load allocation will be revised to reflect the new target.

The SR-HC TMDL will proceed toward completing site-specific implementation objectives within 18 months of approval of the TMDL. Data collection is projected to continue throughout the implementation process to determine progress and improve understanding of the SR-HC TMDL system. As this TMDL is a phased process, it is projected that the goals and objectives of this TMDL will be revisited periodically to evaluate new information and assure that the goals and milestones are consistent with the overall goal of meeting water quality standards in the SR-HC TMDL reach.

4.1 Reasonable Assurance

For watersheds that have a combination of point and nonpoint sources where pollution reduction goals can only be achieved by including some nonpoint source reduction, a reasonable assurance that reductions will be met must be incorporated into the TMDL (EPA, 1991). The SR-HC TMDL will rely on nonpoint source reductions to meet the load allocations to achieve desired water quality and to restore designated beneficial uses. The State of Oregon Water Quality Management Plan and the State of Idaho Implementation Plan (Section 6.0) contain more detailed information on implementation programs that will provide reasonable assurance of implementation.

To ensure that nonpoint source reduction mechanisms are operating effectively, and to give some quantitative indication of the reduction efficiency for in-place BMPs, monitoring will be conducted. The monitoring will not be carried out on a site specific basis for each implemented BMP, but rather as a suite of indicator analyses monitored at the inflow and outflow of the segments within the SR-HC TMDL reach and at other appropriate locations such as the inflow of tributaries. For example, a decrease in total phosphorus over time as monitored at the Boise River inflow to the SR-HC TMDL reach would serve as an indicator that BMPs employed within the Boise River watershed were acting to reduce total phosphorus levels within the tributary water column. This data will be further utilized, in conjunction with flow measurements, to evaluate the overall decrease in total pollutant mass being delivered to the SR-HC TMDL reach.

Concurrent monitoring of mainstem water quality will be undertaken to determine the direct effects of the monitored inflowing concentration trends on mainstem water quality. If instream monitoring indicates an increasing pollutant concentration trend (not directly attributable to environmental conditions) or a violation of standards despite use of approved BMPs or knowledgeable and reasonable efforts, then BMPs for the nonpoint sources activity must be modified by the appropriate agency to ensure protection of beneficial uses (Subsection 350.02.b.ii). This process is known as the "feedback loop" in which BMPs or other efforts are periodically monitored and modified if necessary to ensure protection of beneficial uses. With continued instream monitoring, the TMDL will initiate the feedback loop process and will evaluate the success of BMP implementation and its effectiveness in controlling nonpoint source pollution.

All identified point sources discharging to the Snake River within the SR-HC TMDL reach are permitted facilities administered by the US EPA (Idaho facilities) or the State of Oregon (Oregon facilities). Wasteload reductions can be precipitated by modification of the NPDES permit. However, the load reductions needed to achieve desired water quality and restore full support of designated beneficial uses in the SR-HC TMDL reach will not be achieved in their entirety by upgrades of the point sources.

The states have responsibility under Section 401 of the CWA to provide water-quality certification. Under this authority, the states review the projects to determine applicability to local water-quality issues.

Under Section 319 of the CWA, each state is required to develop and submit a nonpoint source management plan. The nonpoint management program describes many of the voluntary and regulatory approaches the state will take to abate nonpoint pollution sources. Since the development of the original Nonpoint Management Programs, revisions of the water-quality standards have occurred. Many of these revisions have adopted provisions for public involvement, such as the formation of Basin Advisory Group (BAGs) and WAGs (Idaho Code 39-3614, 3615, 39-3601, 39-3616), as discussed in section 2.0.5.1. The WAGs (SR-HC PAT) are to be established in high priority watersheds to assist DEQ and other state agencies in developing TMDLs and Watershed Management Plans (WMPs) for those segments.

The State of Idaho and State of Oregon water-quality standards refer to other programs whose mission is to control nonpoint pollution sources. Some of these programs and responsible agencies are listed in Tables 4.1.1 and 4.1.2.

Table 4.1.1 State of Idaho regulatory authority for nonpoint pollution sources.

Citation	IDAPA Citation	Responsible Agency
Rules governing forest practices	16.01.02350.03(a)	Idaho Department of Lands
Rules governing solid waste management	16.01.02350.03(b)	Idaho Department of Health and Welfare
Rules governing subsurface and individual sewage disposal systems	16.01.02350.03(c)	Idaho Department of Health
Rules and standards for stream channel alteration	16.01.02350.03(d)	Idaho Department of Water Resources
Rules governing exploration and surface mining operations in Idaho	16.01.02350.03(e)	Idaho Department of Lands
Rules governing placer and dredge mining in Idaho	16.01.02350.03(f)	Idaho Department of Lands
Rules governing dairy waste	16.01.02350.03(g) or IDAPA 02.04.14	Idaho Department of Agriculture

The State of Idaho uses a voluntary approach to control agricultural nonpoint sources. However, regulatory authority can be found in the state water-quality standards (IDAPA 16.01.02350.01 through 16.01.02350.03). IDAPA 16.01.02054.07 refers to the Idaho Agricultural Pollution Abatement Plan (IAPAP) (IDHW, SCC, EPA; 1993) which provides direction to the agricultural community for approved BMPs. As a portion of the IAPAP, it outlines responsible agencies or elected groups (SCDs) that will take the lead if nonpoint pollution problems need addressing. For agricultural activity it assigns the local SCDs to assist the landowner/operator to develop and implement BMPs to abate nonpoint pollution associated with the land use. If a voluntary approach does not succeed in abating the pollutant problem, the state may provide injunctive relief for those situations that may be determined to present imminent and substantial danger to public health or environment (IDAPA 16.01.02350.02 (a)).

If a nonpoint pollutant(s) is determined to be impacting beneficial uses and the activity already has in-place referenced BMPs, or knowledgeable and reasonable practices, the state may request the BMPs be evaluated and/or modified to determine appropriate actions. If evaluations and/or modifications do not occur, injunctive relief may be requested (IDAPA 16.01.02350.2, ii (1)).

Table 4.1.2 State of Oregon regulatory authority for nonpoint pollution sources.

Citation	Citation	Responsible Agency
Rules governing forest practices	ORS 527.710, ORS 527.765, ORS 183.310, OAR 340-041-0026, OAR 629-635-110, and OAR 340-041-0120	Oregon Department of Forestry
Rules governing solid waste management	ORS 459, ORS 459a, OAR 340-093-0005 through 340-096-0050	Oregon Department of Environmental Quality
Rules governing subsurface and individual sewage disposal systems	ORS 454.600,OAR 340-71, OAR 340-73	Oregon Department of Environmental Quality
Rules and standards for stream channel alteration	ORS 196.800-196.990, ORS 390.805-390.925, OAR 141-085-0005 through 141-085-0666	Oregon Division of State Lands
Rules governing exploration and surface mining operations in Oregon	ORS 517.010-517.950, OAR 632-030-0005 through 0007	Oregon Department of Geology and Mineral Industries
Rules governing placer and dredge mining in Oregon	ORS 517.010-517.950, OAR 141-085-0005 through 0085, OAR 141-100-0000 through 0090	Oregon Division of State Lands
Rules governing dairy waste and other CAFOs	ORS 468B.200-468B.230;OAR 340-51, ORS 603-074-0005 through 603-074-0080	Oregon Department of Agriculture

The Oregon Department of Agriculture has primary responsibility for control of pollution from agriculture sources. This is accomplished through the Agriculture Water Quality Management (AWQM) program authorities granted ODA under Senate Bill 1010 Adopted by the Oregon State Legislature in 1993. The AWQM Act directs the ODA to work with local farmers and ranchers to develop water quality management plans for specific watersheds that have been identified as violating water quality standards and have agriculture water pollution contributions. The agriculture water quality management plans are expected to identify problems in the watershed that need to be addressed and outline ways to correct the problems.

It is expected that a voluntary approach will be able to achieve load allocations needed for the SR-HC TMDL. Public involvement along with the eagerness of the agricultural community has demonstrated a willingness to implement BMPs and protect water quality. In the past, cost-share programs have provided the agricultural community technical assistance, information and education (I & E), and the cost share incentives to implement BMPs. The continued funding of these projects will be critical to achieving the load allocations identified in the SR-HC TMDL.

In 1995 the State of Idaho passed Senate Bill 1284, now incorporated into the Idaho Code Section 39-3613 and Section 39-3615. This bill established the formation of the WAGs and BAGs to assist state and federal agencies with water-quality planning in high priority watersheds. The Snake River – Hells Canyon Public Advisory Team (SR-HC PAT), which functions as the WAG for the SR-HC TMDL reach, was formed in March of 2000 in response to Idaho Code Section 39-3615 and public interest in the development of a TMDL for the SR-HC reach. The SR-HC PAT was recognized as the representative body for the watershed by DEQ in that same year.

4.1.1 Forestry Practices

The Idaho Forest Practices Act was passed in 1974 (revised 1992; Title 38, Chapter 13, Idaho Code). Rules that implement the Act establish required minimum BMPs for forestry practices to protect state water quality. In addition to logging, forestry practices include road construction, slash management and other activities associated with silviculture. The rules, which govern activities on Forest Service, private and state lands, primarily address sediment and erosion of streams impacted by logging activity. Reductions in the export of nutrients are not directly assessed; rather, they are addressed through reduction in sediment and sediment transport. Moreover, forestry BMPs do not address the export of nutrients and sediment caused by land disturbing activities that occurred prior to 1974. However, Boise and Payette National Forests, and Idaho Department of Lands (IDL), in conjunction with Boise Cascade Corporation have jointly developed the Forestry Source Plan (1998) to achieve load reductions. The Forests have also identified a method to determine sediment and phosphorus yield from roads and landslides and have developed a list of forestry practice BMPs and treatments with an estimate of their effectiveness in reducing phosphorus (sediment).

The Oregon Department of Forestry (ODF) is the designated management agency for regulation of water quality on non-federal forested lands in Oregon. The Oregon Board of Forestry has adopted water protection rules, including but not limited to OAR Chapter 629, Divisions 635-660, which describe BMPs for forest operations. These rules are implemented and enforced by ODF and monitored to assure their effectiveness. The Environmental Quality Commission, Board of Forestry, ODEQ, and ODF have agreed that these pollution control measurers will be relied upon to result in achievement of state water quality standards. ODF provides on the ground field administration of the Forest Practices Act (FPA). For each administrative rule, guidance is provided to field administrators to insure proper, uniform and consistent application of the Statutes and Rules. The FPA requires penalties, both civil and criminal, for violation of Statutes and Rules. Additionally, whenever a violation occurs, the responsible party is obligated to repair the damage.

Current forestry BMPs in Oregon and Idaho will remain as each state’s forestry component of the TMDL.

4.1.2 Agricultural Practices

For agricultural activities in Idaho there are no required BMPs. Consequently, agricultural activities must use knowledgeable and reasonable efforts to achieve water-quality standards. Generally, voluntary implementation of BMPs would be considered a knowledgeable and reasonable effort. A list of recommended BMP component practices which when selected for a specific site become a BMP, has been published in the Idaho Agricultural Pollution Abatement Plan (1991). To facilitate use of these practices, a variety of state and federal funding sources are available to provide cost share incentives. Projects are directed at improving water quality through control of nonpoint source pollution at the subwatershed level using BMPs developed by the Natural Resources Conservation Service (NRCS). Cost share funds are dispersed to private landowners through local Soil Conservation Districts. Contracts with landowners require that BMPs be implemented for ten years, but changes in management practices should provide longer-term benefits. Currently, BMPs are directed at changes in irrigation practice, fencing or other access-restriction of riparian areas, creation of wetland habitat, establishment of off-site watering facilities and related practices.

In Oregon it is the Oregon Department of Agriculture's (ODA) statutory responsibility to develop agricultural water quality management (AWQM) plans and enforce rules that address water quality issues on agricultural lands. The AWQM Act directs ODA to work with local farmers and ranchers to develop water quality management area plans for specific watersheds that have been identified as violating water quality standards and having agriculture water pollution contributions. The agriculture water quality management area plans are expected to identify problems in the watershed that need to be addressed and outline ways to correct those problems. These water quality management plans are developed at a local level, reviewed by the State Board of Agriculture, and then adopted into the Oregon Administrative Rules. It is the intent that these plans focus on education, technical assistance, and flexibility in addressing agricultural water quality issues. These plans and rules will be developed or modified to achieve water quality standards and will address the load allocations identified in the TMDL. In those cases when an operator refuses to take action, the law allows ODA to take enforcement action. ODEQ will work with ODA to ensure that rules and plans meet load allocations.

4.1.3 Monitoring

A rigorous monitoring plan and schedule is critical to the SR-HC TMDL. There is no way to determine progress, define trends, fill data gaps or enlarge understanding without an understanding of the changes occurring in the system. The State of Idaho includes a monitoring plan in all TMDL implementation plans prepared in the state. By including this plan in the implementation plan, it allows greater opportunity for ground-truthing and interagency participation. It also allows the monitoring plan to be constructed with a better understanding of the implementation activities that will be undertaken, and where and when these activities will occur so that monitoring can be tailored to the needs of the system as well as tracking the improvements that will be made.

These implementation plans are completed in much the same way as a TMDL is put together, with public, agency and stakeholder input. They are reviewed in a public process and comments are responded to.

Given this understanding, a monitoring plan that is appropriate in scope will be prepared as part of the site-specific implementation plans completed 18 months following the approval of the SR-HC TMDL. IDEQ has an acknowledged role in construction of this plan and oversight of the monitoring activities. In other TMDLs in the State of Idaho, IDEQ monitoring has played a prominent role in progress evaluation. Other entities, such as state and federal agencies have also often been partners in providing monitoring support for TMDL implementation. It is expected that the monitoring accomplished on the SR-HC TMDL will follow a similar pattern of participation. ODEQ has committed to participate to the fullest extent possible contingent on available resources.

The implementation of the SR-HC TMDL and the correlated system response is projected to be a lengthy process lasting several decades. Therefore it is critical that a schedule for long-term monitoring be committed to. In order to accomplish this, the general level of monitoring will need to be tailored in such a way that a sustainable level of routine monitoring can be accomplished while still allowing site-specific response to immediate conditions. For example, routine chlorophyll *a* monitoring should be scheduled at a frequency that will allow trend identification but should not be undertaken at a frequency that will make the assessment of a specific bloom impossible due to budget constraints.

While detailed plans cannot be accurately identified at this time, the monitoring effort on the SR-HC TMDL is expected to include (at minimum):

MONITORING TO FILL DATA GAPS

Constituents:

- Dissolved Oxygen at the sediment/water interface in the Upstream Snake River segment, mercury (water column), pesticides (Oxbow Reservoir), sediment (duration data)

Schedule:

- Final evaluations completed within the first phase of implementation

ROUTINE PROGRESS MONITORING

Constituents:

- Phosphorus, nitrogen, dissolved oxygen, chlorophyll *a*, sediment, temperature

Locations:

- Monitoring points located upstream and downstream in the defined TMDL segments, namely Upstream Snake River (RM 409 to 335), the Reservoir Complex (RM 335 to 247), and Downstream Snake River segments (RM 247 to 188). As Brownlee Reservoir (RM 335 to 285) acts not only as the source water for the downstream reservoirs, but also as the recipient of upstream waters where water quality objectives will have a noticeable influence if attained, it is expected that a greater level of monitoring will be focussed on Brownlee Reservoir than on Oxbow or Hells Canyon reservoirs.
- Monitoring of major tributaries at their inflow to the SR-HC TMDL reach

Schedule:

- Routine monitoring frequency is projected to occur monthly or (at minimum) seasonally as water quality needs require.
- Monitoring of major tributaries at their inflow to the SR-HC TMDL reach on a monthly or (at minimum) a seasonal basis to determine loading trends.

These projected goals of the SR-HC monitoring plan will be a joint effort on the part of many government and private participants. Specific responsibility will be identified as the implementation planning process proceeds.