Pend Oreille River
Total Dissolved Gas
Total Maximum Daily Load

Water Quality Improvement Report

Washington State Department of Ecology

Kalispel Tribe of Indians

U. S. Environmental Protection Agency

December 2007

Prepared jointly by the Washington State Department of Ecology
and the U.S. Environmental Protection Agency,
in cooperation with the Kalispel Tribe

Ecology Publication No. 07-03-003

Publication Information

U.S. Environmental Protection Agency

For a printed copy or a compact disk of this publication, contact:

Helen Rueda
U.S. EPA
811 SW Sixth Avenue
Portland, OR 97204
Phone: (503) 326-3280; E-mail: rueda.helen@epa.gov

Washington State Department of Ecology

This report is available on the Department of Ecology's website at www.ecy.wa.gov/biblio/0703003.html

Environmental Assessment Program
P.O. Box 47600
Olympia, WA 98504-7600
Phone: (360) 407-6764; E-mail: jlet461@ecy.wa.gov

Washington State Department of Ecology - www.ecy.wa.gov/

o Headquarters, Lacey	360-407-6000
o Northwest Regional Office, Bellevue	425-649-7000
o Southwest Regional Office, Lacey	360-407-6300
o Central Regional Office, Yakima	509-575-2490
o Eastern Regional Office, Spokane	509-329-3400

Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search User Study ID, PPIC0007.

Ecology's Study Tracker Code for this study is 04-017-01.

Cover photos: Left side - Box Canyon Dam (photo by Paul Pickett)
Right side - Boundary Dam (photo by City of Seattle)

Pend Oreille River
Total Dissolved Gas
Total Maximum Daily Load

Water Quality Improvement Report

by
Paul J. Pickett[1] *and Jon Jones*[2]

[1]Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

[2]Water Quality Program
Eastern Regional Office
Washington State Department of Ecology
Spokane, Washington 99205

Waterbody Numbers: WA-62-1010 & 1020

This page is purposely left blank

Table of Contents

List of Figures

Page

List of Tables

Abstract

Monitoring of the Pend Oreille River from 2001 through 2004 at the Idaho state line near Newport, and in the forebays and tailraces of Box Canyon and Boundary Dams, shows that total dissolved gas (TDG) frequently exceeds water quality standards. As a result, the Washington State Department of Ecology (Ecology) listed the Pend Oreille River on its 2004 303(d) list of impaired waters and has determined the Total Maximum Daily Load (TMDL) for TDG in the Pend Oreille River.

The U.S. Environmental Protection Agency is issuing a TMDL for the section of the Pend Oreille River that flows through the reservation of the Kalispel Tribe of Indians. Ecology is issuing this TMDL for the Pend Oreille River in Washington State, other than the section flowing through the reservation.

Total dissolved gas was monitored in the Pend Oreille River with datalogging and profiling multi-parameter instruments from March through July 2004 near Newport, Ruby, Box Canyon Dam, and Boundary Dam. Data show that TDG changes over time at these sites. These data also allow comparisons to data collected by other organizations.

TDG data analyzed were from 2001 through 2004 during the high-flow season (mid-March through early August). The analysis shows TDG levels at the Idaho state line, TDG generation processes at Box Canyon and Boundary Dams, and the fate of TDG in the reservoirs of those dams.

- TDG levels from upstream of the state line often exceed standards, most likely due to Cabinet Gorge Dam on the Clark Fork.
- Box Canyon and Boundary Dams both generate TDG that exceeds standards; therefore, gas abatement programs to reduce TDG generation or reduce spill are needed to meet standards.
- Natural processes in the reservoirs – barometric pressure decreases, water temperature increases, increased instream productivity, and lack of wind-induced dissipation – occasionally raise TDG levels, but the frequency of these events are low and the TDG increases are small.

The TMDL for TDG in the Pend Oreille River consists of loading capacity and allocations equal to the excess dissolved gas pressure above ambient barometric pressure, equivalent to 110% saturation at the 95th percentile low barometric pressure.

Acknowledgements

The authors would like to thank the following people for their contribution to this study:

- John Gross, Michele Wingert, and other staff of the Kalispel Tribe for their field support and environmental information.
- Helen Rueda and Don Martin of the U.S. Environmental Protection Agency for their support and coordination of the shared waters of the Pend Oreille River.
- Washington State Department of Ecology staff:
  - Jean Parodi, Karin Baldwin, and Elaine Snouwaert of the Water Quality Program, Eastern Regional Office, for their coordination and support.
  - Jim Ross of the Environmental Assessment Program, Eastern Regional Office, for his many hours of field support.
  - Karol Erickson, Nicoleta Cristea, and Joan LeTourneau of the Environmental Assessment Program for their review and editing of this report and general support for the project.
  - Clint Bowman of the Air Quality Program for data and technical support on meteorological parameters.
- Ed Tulloch of the Idaho Department of Environmental Quality for support and information on conditions upstream “East of the Border”.
- Julia Beatty of the British Columbia Ministry of Environment for useful information on conditions downstream “North of the Border”.
- Pat Buckley, Nathan Jones, and other staff of the Pend Oreille Public Utility District for their support and information about Box Canyon Dam.
- Christine Pratt, Al Solonsky, Kim Pate, Jim Collen, Barbara Greene, and other staff at Seattle City Light for their support and information about Boundary Dam.
- Kent Easthouse and Mike Schneider of the U.S. Army Corps of Engineers for their support and information about Albeni Falls Dam.
- Philip Mote and Josiah Mault at the Office of the State Climatologist for data and technical support on meteorological parameters.
- Kent Doughty of EES Consulting for his help and information.
- Brett Smith, John Gralow, Bob Drzymkowski, and Luis Fuste of the U.S. Geological Survey for providing flow and TDG data.
- Ruth Watkins and the members and staff of the Tri-State Water Quality Council for their work on community outreach.
- Cliff Noxon, Pend Oreille River landowner, for his generosity in allowing access and mooring of monitoring gear from his dock.
- Mark Schneider, Dan Millar, and all the other members of the Transboundary Gas Group for providing a forum for technical discussion of TDG in the Pend Oreille River.

Dedicated to the memory of Nancy Weller, who helped initiate this project and supported many other projects over the years.

Pend Oreille River Total Dissolved Gas Total Maximum Daily Load: Water Quality Improvement Report

Executive Summary

What is a Total Maximum Daily Load (TMDL)?

The federal Clean Water Act requires Washington State to establish water quality standards, to prepare the "303(d) list" of waterbodies not meeting water quality standards, and to prepare a Total Maximum Daily Load (TMDL) for each waterbody on the 303(d) list.

A TMDL includes an analysis of water quality problems, including the causes of those problems, determines the amount of pollutants that can be assimilated in the waterbody and still meet standards, and allocates loading among the various sources.

Why are Ecology and EPA conducting this TMDL?

The Washington State Department of Ecology (Ecology) and EPA are determining the TMDL of total dissolved gas (TDG) in the mainstem Pend Oreille River from the Idaho border to the Canadian border (Figure ES-1). Data show TDG levels above (not meeting) Washington State water quality standards in multiple reaches of the Pend Oreille River, which has resulted in Ecology listing the river on its 2004 303(d) list.

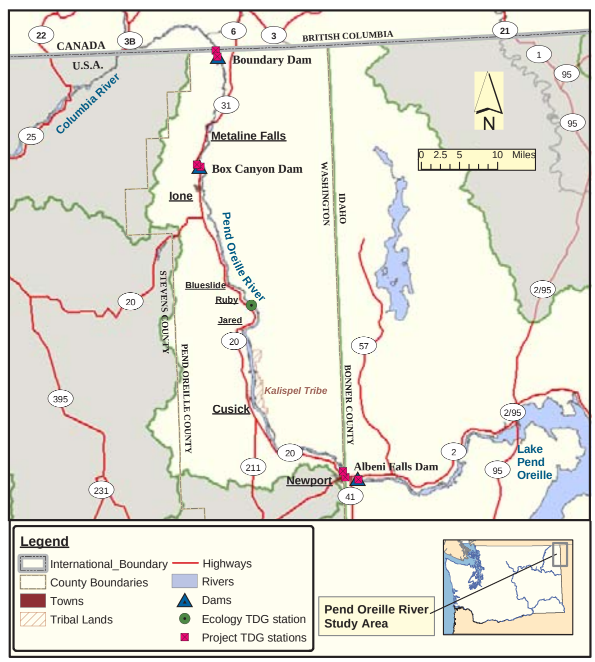


Figure ES-1. Pend Oreille River TDG TMDL study area (Washington), as well as upstream (Idaho) and downstream (British Columbia) neighboring areas.

Ecology is developing this Pend Oreille River TDG TMDL jointly with EPA and the Kalispel Tribe. Ecology will issue this TMDL for state waters and submit the final TMDL to EPA for approval. EPA will approve the TMDL for Washington's waters and issue the TMDL for Kalispel Tribal waters at the same time. TDG monitoring data and sources upstream of Washington will be evaluated, but the waters of Idaho and Montana will not be directly addressed by this TMDL.

Spill events at hydroelectric projects can cause elevated TDG levels. Water pouring over the spillway of a dam and plunging into the tailrace carries air bubbles deep into the dam's stilling basin where hydrostatic pressures force air from the bubbles into supersaturated solution. Typically spill occurs during the snowmelt runoff season in late spring and early summer.

TDG may also be affected by natural phenomena, such as waterfalls, biological primary productivity, decreased ambient barometric pressure, changes in water temperature, and wind-induced turbulence.

Fish may not experience problems with TDG if they are deep enough for higher water pressures to compensate for high TDG pressure. However, if the fish inhabit supersaturated water for extended periods or rise in the water column, TDG may come out of solution within the fish, thus forming bubbles in their body tissues. This gives rise to the condition called "gas bubble trauma."

Water quality standards and beneficial uses

Water quality standards for both the state of Washington and the Kalispel Tribe set a criterion of 110% of TDG saturation for the protection of fisheries. Washington provides an exemption from the standards when flows exceed the 7Q10 flood flow, while Tribal standards apply at all flows.

Watershed description

The Pend Oreille River is part of the Pend Oreille/Clark Fork watershed, which drains western Montana and northern Idaho. The river enters Washington near the city of Newport and flows northward towards the Canadian border. Downstream of Newport, the river passes through the reservation of the Kalispel Tribe of Indians. A short reach of the river flows through Canada to its confluence with the Columbia River just upstream of the international border.

There are two hydroelectric projects in the TMDL area: Box Canyon Dam (Pend Oreille Public Utility District) and Boundary Dam (Seattle City Light). Just upstream of the TMDL area in Idaho is Albeni Falls Dam (U.S. Army Corps of Engineers), which controls downstream flows. There are other major dams in the Clark Fork upstream of Lake Pend Oreille in Idaho, including Cabinet Gorge Dam which has been identified as a source of TDG impairment.

Box Canyon Dam is a run-of-the-river dam with limited storage capacity which manages its reservoir to control water levels at Cusick and Newport. Spill occurs at maximum water elevations when the powerhouse reaches hydraulic capacity. Boundary Dam, which is operated for peak load-following, releases during the day and refills the reservoir at night. Spill occurs at maximum powerhouse capacity when reservoir storage is no longer available. Box Canyon Dam received a new Federal Energy Regulatory Commission (FERC) license in 2005, while Boundary Dam is beginning relicensing for a license expiring in 2011.

Study methods

TDG monitoring data from 2001 through 2004 were obtained for five locations on the Pend Oreille River. TDG data at the Idaho state line near Newport were collected by the Pend

Oreille Public Utility District (PUD) and the U.S. Army Corps of Engineers. Pend Oreille PUD also monitors the Box Canyon Dam forebay and tailrace, and USGS monitors the Boundary Dam forebay and tailrace. In 2004 Ecology conducted additional TDG monitoring near Ruby, about halfway up the Box Canyon reservoir, and took spot readings at the other monitoring locations to assess data comparability.

The TMDL was developed by analyzing TDG generation and dynamics using statistical tools – nonparametric methods (percent exceedances) and regressions (trend lines) – supplemented with special studies and field observations from dam operators.

Study quality assurance evaluation

TDG monitoring at all locations followed standard data quality assurance procedures. Data quality has been reviewed, unacceptable data has been removed from the analysis, and questionable data qualified. The remaining data are credible and representative, and appropriate for use in TMDL development.

TMDL analyses

Flow in the Pend Oreille River typically follows a pattern of peak flows from mid-April to early July, peaking in early June. Flow during this study ranged from extreme low flows in 2001 to high flows in 2002, with average flows in 2003 and low flows in 2004. The 7Q10 flood flow is 105.5 kcfs (1000 cubic feet/second) from Newport to Boundary Dam and 108.3 kcfs below Boundary Dam.

TDG is often already elevated above standards as the river enters Washington. To determine the effect of ambient environmental conditions on TDG in the Box Canyon Dam reservoir, paired data from the Idaho state line and from the Box Canyon forebay were compared. TDG usually dissipates, but sometimes TDG increases. Water temperature effects were removed by recalculation using gas law equations, and differences compared. At times water temperature increases cause TDG increases, but more commonly temperature changes and other effects offset each other.

Ecology data from 2004 illustrate that the variability of TDG changes are much higher in the reach from the Idaho state line to Ruby than in the reach downstream of Ruby. The effect of wind was also evaluated, which shows how high winds narrow the range of TDG changes and eliminate TDG increases through the reservoir.

Over the four years (2001-04) of seasonal monitoring (mid-March through early August), TDG exceeded water quality standards at the Idaho state line about 24% of the time, and at the Box Canyon forebay about 16% of the time. About 9% of the time, impairment was found at the Idaho state line but not at Box Canyon. About 1% of the time, Box Canyon was impaired while the Idaho state line showed no impairment. The median change in TDG under impaired conditions was less than 1% of saturation. Therefore, conditions that increase TDG in the Box Canyon reservoir are rare and the increase is very small, so compliance with an allocation at the upstream end of the reservoir should be adequate to protect the entire reservoir.

TDG generation at Box Canyon Dam was evaluated by comparing forebay and tailrace data. TDG generation increased with increasing flow, reaching peak levels at 30 to 50 kcfs of spill, and then dropping at higher flows. Spills cause impairment at levels of 2.5 to 5 kcfs.

In the Boundary Dam reservoir, TDG data showed impairment about 52% of the time during the four seasons of monitoring, or about 154 days out of 293 days monitored. However, the effect of water temperature was weak and conditions when TDG increased were rare. About 4% of the time, Box Canyon tailrace was impaired and Boundary forebay was unimpaired, while about 5% of the time, Boundary forebay was impaired while Box Canyon tailrace was not. These frequencies are similar and can be explained by travel time. The median net pool effect on TDG was a decrease of over 3% of saturation during all impairments and an increase of about 1% of saturation when Box Canyon tailrace was unimpaired but Boundary forebay was impaired. Therefore, situations where TDG increases in the Boundary reservoir pool were rare, and in these situations the TDG increases are small.

TDG generation at Boundary Dam was analyzed by comparing forebay and tailrace data. Spill at Boundary Dam occurs at higher flows than at Box Canyon Dam, so during the study, forebay conditions were always impaired when Boundary Dam spilled. Boundary Dam spill increased impairment at levels above about 8 kcfs. Since the tailrace is well mixed, TDG generation by spill was back-calculated from flows and TDG levels. This analysis indicates that spill increases TDG above 110% of saturation at spill volumes of about 4 kcfs, and if forebay levels were at or below 110%, this amount of spill would cause impairment at the tailrace monitor.

Tailrace monitoring shows that Boundary Dam also generates TDG when downstream flows are low. Special studies by Seattle City Light show that some of the turbines cause elevated TDG during turbine ramp-up or ramp-down. Data were analyzed to illustrate this phenomenon, which is characterized by TDG which is highest during zero flow and declines as flows rise.

TDG loading capacities and allocations were calculated as excess TDG pressure above ambient barometric pressure (ΔP), based on 110% of saturation and 95^{th} percentile low barometric pressure. Loading capacities and allocations are identical, and were set at ΔP values of (1) 68 mm Hg (mercury) above saturation in compliance areas from the Idaho state line to the Box Canyon Dam forebay and from the Box Canyon tailrace to the Boundary Dam forebay, and (2) 69 mm Hg in the compliance area from the Boundary Dam tailrace to the International Border. If forebay levels exceed allocations, then the dams shall not increase TDG above forebay levels in the downstream compliance areas.

The compliance area will exclude the area immediately below each dam to allow for the dissipation of TDG in the aerated (“bubbly”) zone. The upstream boundaries of compliance areas are defined in the *Implementation Strategy* section of this report.

Several factors in the TMDL analysis introduce a margin of safety. Critical low barometric pressures were used to set TMDL allocations. Criteria are inherently conservative, and the large amount of continuous TDG data available reduces uncertainty in the analysis.

Conclusions and recommendations

TMDL allocations are recommended that are protective of the Pend Oreille River in Washington and the Kalispel Reservation. Allocations should be met at the Idaho state line by implementing actions in Idaho and Montana. TMDL allocations will be met primarily through TDG abatement plans developed under 401 certifications for FERC licensing. Existing monitoring should continue to assess compliance with standards and effectiveness of the TMDL.

What is a Total Maximum Daily Load (TMDL)?

Federal Clean Water Act requirements

The Clean Water Act established a process to identify and clean up polluted waters. Under the Clean Water Act, every state has its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses for protection, such as cold water biota and drinking water supply, and criteria, usually numeric criteria, to achieve those uses.

Every two years, states are required to prepare a list of waterbodies – lakes, rivers, streams, or marine waters – that do not meet water quality standards. This list is called the 303(d) list or water quality assessment. (See Appendix A for definitions of terms and acronyms.) To develop the list, Ecology compiles its own water quality data along with data submitted by local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the 303(d) list.

Ecology publishes its 303(d) list as part of a larger Water Quality Assessment list, which tells a more complete story about the condition of Washington's water. This list divides waterbodies into five categories:

- Category 1 – Meets tested standards for clean water.
- Category 2 – Waters of concern.
- Category 3 – No data available.
- Category 4 – Polluted waters that do not require a TMDL since the problems are being solved in one of three ways:
    - 4a – Has a TMDL approved and it is being implemented
    - 4b – Has a pollution control plan in place that should solve the problem
    - 4c – Impaired by a non-pollutant such as low water flow, dams, culverts
- Category 5 – Polluted waters that require a TMDL – on the 303(d) list.

The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be developed for each of the waterbodies on the 303(d) list. A TMDL identifies how much pollution needs to be reduced or eliminated to achieve clean water. Then the local community works with Ecology to develop (1) a strategy to control the pollution and (2) a monitoring plan to assess the effectiveness of the water quality improvement activities.

Elements required in a TMDL

The goal of a TMDL is to ensure the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of the water quality problems and of the pollutant sources that cause the problem. The TMDL determines the amount of a given pollutant that can be discharged to the waterbody and still meet standards (the loading capacity) and allocates that load among the various sources.

Identifying the contaminant loading capacity for a waterbody is an important step in developing a TMDL. EPA defines the loading capacity as "the greatest amount of loading that a waterbody can receive without violating water quality standards" (EPA, 2001). The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a waterbody into compliance with standards. The portion of the receiving water's loading capacity assigned to a particular source is a load or wasteload allocation. By definition, a TMDL is the sum of the allocations, which must not exceed the loading capacity.

If the pollutant comes from a discrete (point) source such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload allocation*. If it comes from a set of diffuse (nonpoint) sources such as general urban, residential, or farm runoff, the cumulative share is called a *load allocation.*

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A reserve capacity for future loads from growth pressures is sometimes included as well. The sum of the wasteload and load allocations, the margin of safety, and any reserve capacity must be equal to or less than the loading capacity.

Federal coordination

EPA has authority under section 303(d)(2) of the Clean Water Act to approve or disapprove TMDLs submitted by the states and tribes, and to establish its own TMDLs in the event that it disapproves a state or tribal submission. When the TMDL focuses on inter-jurisdictional waters, EPA's involvement can facilitate the resolution of complex cross-jurisdictional problems that might be difficult for an individual state or tribe, acting alone, to resolve. As part of its tribal trust responsibilities, EPA has authority to establish TMDLs for tribal waters.

Therefore, the goal of this project is to provide a single analysis and set of TMDL allocations which will lead to attainment of the standards established for waters of Washington State and the Kalispel Tribe. This report contains the technical analysis that forms the basis for the TMDL and the pollutant allocations that make up the TMDL. The *Implementation Strategy* section of this report, developed by Ecology and the Kalispel Tribe, identifies actions to be taken to achieve the allocated loads.

Why are Ecology and EPA conducting a TMDL study in this watershed?

Overview

The Washington State Department of Ecology (Ecology) and the EPA are developing a TMDL for total dissolved gas (TDG) in the mainstem Pend Oreille River from the Idaho border to the Canadian border (Figure 1). Ecology has reviewed data which show TDG levels above Washington State water quality standards in multiple reaches of the Pend Oreille River. Ecology has included four Category 5 listings (polluted waters that require a TMDL) for the Pend Oreille River on its 2004 water quality assessment list.

The state of Washington is developing this TMDL jointly with EPA, and will be issuing this TMDL for impaired waters of Washington State outside the Kalispel Indian Reservation. Ecology will submit the final TMDL to EPA for approval, and EPA will issue the TMDL for impaired Tribal waters.

Study area

The Pend Oreille River begins at the outlet of Lake Pend Oreille in Idaho. The river enters Washington near the city of Newport and flows northward towards the international border with Canada (Figure 1). Downstream of Newport, the river passes through the reservation of the Kalispel Tribe of Indians. A short reach of the river flows through Canada to its confluence with the Columbia River just upstream of the international border. The principal source of inflow to Lake Pend Oreille is the Clark Fork, which drains a large portion of western Montana (Figure 2).

The TMDL study area encompasses the mainstem Pend Oreille River from the Idaho border to the Canadian border. TDG monitoring data that reflects sources upstream of Washington were evaluated, but the waters of Idaho and Montana are not directly addressed by this TMDL.

Pollutants addressed by this TMDL

Total dissolved gas is the pressure exerted by the air dissolved in water. Air dissolved in water exchanges dynamically with atmospheric air, and TDG pressure seeks equilibrium with the air pressure (barometric pressure) at the air-water interface. Therefore TDG pressure is also measured as “percent of saturation”, which is calculated as the TDG pressure divided by the ambient barometric pressure at the same location and moment in time. When TDG pressure equals the ambient barometric pressure, TDG is at 100% of saturation.

TDG that exceeds water quality criteria is usually not caused by the discharge of pollutants, but rather by physical processes that supersaturate dissolved air. Spill events at hydroelectric projects and natural waterfalls are the most common cause of elevated TDG levels.

Spills at hydroelectric projects can occur for several reasons:

- The powerhouse cannot pass flood flows.
- Powerhouse capacity is not fully utilized due to lack of power demand.
- Powerhouse turbines are off-line for maintenance or repair.

Although dams can spill at any time because of changes in power demand or turbine failure, typically the spill season occurs during the snowmelt-runoff season in late spring and early summer.

During spill at a dam, water pouring over the spillway of a dam and plunging into tailrace waters entrains air bubbles. As these are carried deep into the dam's stilling basin, the higher hydrostatic pressure forces air from the bubbles into solution. The result is water supersaturated with dissolved nitrogen, oxygen, and the other constituents of air.

As the bubbles rise in the aerated zone of the tailrace, some of the gas leaves solution at a relatively rapid rate. However, as the bubbles dissipate and the water enters the downstream reach, the remaining TDG will equilibrate with air pressure at a relatively slow rate unless the process is enhanced by wind or channel-induced turbulence.

As a result of these physical processes, the gas exchange between bubbles and the water column reach a new equilibrium. Therefore, TDG generation by spill is almost always independent of upstream conditions.

Also, at most dams water passing through the powerhouse has virtually the same TDG levels as in the upstream forebay (USACE, 2001). Therefore, downstream conditions will represent a mixture of powerhouse flows at forebay gas levels and spill flows with TDG levels generated independently of forebay conditions.

One other process that often occurs at dams is the entrainment of powerhouse flows into the spill. The hydraulics of the spill may cause eddies that pull the powerhouse flows into the spill plunge area, resulting in additional flows having TDG generated with the spill. The result is an effective spill that includes a fraction of the powerhouse flows. The conditions which allow this to occur are highly site specific, but typically the powerhouse discharge needs to be close to the spill plunge area without any physical structure dividing the flows.

TDG may also be affected by natural phenomena:

- High biological primary productivity can raise TDG by raising dissolved oxygen. This may be occurring in Pend Oreille River due to algal and macrophyte photosynthesis.
- For a constant TDG loading level, the percent saturation of TDG can rise if atmospheric barometric pressure drops or if the water temperature increases. These effects are generally stronger when water travel time is slower.
- Natural waterfalls and cascades can either increase or decrease gas levels. In general, plunging waterfalls generate gas, and cascades passing over rock surfaces can cause degassing. The Albeni Falls project was built on an existing waterfall, which may have affected TDG in the system prior to hydro development. Other waterfalls and areas of

cascades and rapids, such as Box Canyon, Metaline Falls, and Z Canyon, are now submerged under reservoirs.

Fish in water with high TDG levels may not display signs of difficulty if higher water pressures at depth offset high TDG pressure passing through the gills into the blood stream. However, if the fish inhabit supersaturated water for extended periods, or rise in the water column to a lower water pressure at shallower depths, TDG may come out of solution within the fish, thus forming bubbles in their body tissues. This gives rise to the condition called "gas bubble trauma" or "gas bubble disease."

Impaired beneficial uses and waterbodies on Ecology's 303(d) list of impaired waters

The designated beneficial use to be protected by this TMDL is aquatic life, and in particular, trout and other salmonids. TDG criteria have been established to protect this use, and monitoring data have indicated that the use is impaired by elevated TDG. As a result the waterbodies listed in Table 1 have been included in Ecology's 2004 303(d) list.

Table 1. Study area 303(d) TDG listings (2004 list) addressed in this report.

Waterbody	Listing ID	Township, Range, Section
Pend Oreille River – Boundary Dam Tailrace	42516	Township 40N; Range 43E; Section 03
Pend Oreille River – Box Canyon Dam Tailrace	6287	Township 38N; Range 43E; Section 20
Pend Oreille River – Box Canyon Dam Forebay	42517	Township 38N; Range 43E; Section 19
Pend Oreille River – near Newport	42518	Township 31N; Range 46E; Section 07

The Pend Oreille River is listed for TDG on Idaho's 2002 303(d) list of impaired waters. Monitoring data also show that TDG in the Pend Oreille River exceeds water quality criteria in British Columbia and may contribute to impairment of the Columbia River south of the Canadian border (Pickett *et al.*, 2004; NWPCC, 2003).

The Pend Oreille River has been identified as providing critical habitat for bull trout, a species designated as threatened under the federal Endangered Species Act. In September 2005, a final rule was adopted that identified northeast Washington as Recovery Unit 22 for Bull Trout Critical Habitat (USFWS, 2005). In Chapter 23 of the Draft Bull Trout Recovery Plan (USFWS, 2002), recovery measure 1.4.2 identifies the following action:

> ***Design and deploy gas abatement structures.*** *Design and deploy gas abatement structures to reduce gas supersaturation conditions detrimental to bull trout at Albeni Falls, Box Canyon, and Boundary Dams.*

The Pend Oreille watershed in Washington has other water quality issues that will not be addressed in this TMDL. In particular, the following additional 303(d) listings for parameters other than TDG occur in the study area, but are not addressed in this report:

- Aldrin (Listing ID 43357)
- pH (8611)

- pH (8613)
- pH (8609)
- Temperature (11452)
- Temperature (8617)
- Temperature (42512)
- Temperature (42513)
- Temperature (42515)
- Temperature (43539)
- Total PCBs (43383)

Recent publications relevant to these listings include Era-Miller and Kinney (2005) and Whiley *et al.* (2005).

Why are we doing this TMDL now?

There are several compelling reasons for doing this TMDL now:

- Boundary Dam, a major hydroelectric project on the Pend Oreille River, is covered by a Federal Energy Regulatory Commission (FERC) license. The project, owned by Seattle City Light, has a license that is due to expire in 2011, and they are in the early stages of their relicensing efforts. TDG is a key issue of Seattle City Light's FERC process, and this TMDL will help inform the relicensing process and the Section 401 certification issued as part of the process.

- Box Canyon Dam, owned by the Pend Oreille Public Utility District, is another major hydroelectric project on the Pend Oreille River in Washington covered by a FERC license. FERC issued a new license for the project in 2005, and Ecology's 401 certification includes compliance measures for TDG. This TMDL helps guide the implementation of the 401 certification and ensures that the cumulative effects of TDG sources are addressed.

- TMDLs have been completed which address TDG in the mainstem Columbia River from the Canadian border to its mouth at the Pacific Ocean. The entire river is considered impaired for TDG. The Pend Oreille River has been identified as a contributor to elevated TDG in the Columbia River. The Mid-Columbia and Lake Roosevelt TDG TMDL identified a TDG TMDL for the Pend Oreille River as an action that should help meet TDG allocations in the Columbia River TDG TMDLs (Pickett, *et al.*, 2004).

- TDG in the Pend d'Oreille River in Canada exceeds Canadian criteria for environmental protection. TDG from the Pend Oreille River in the United States has been one of the areas of focus for transboundary efforts to control TDG. This TMDL helps address Canadian concerns with high TDG in their downstream waters.

- Because the Pend Oreille River is listed for TDG on Idaho's 303(d) list, this TMDL will set allocations for the Idaho state line which will help guide upstream TDG control efforts.

Water Quality Standards and Beneficial Uses

This TMDL is addressing Pend Oreille River TDG in waters of both Washington State and the reservation of the Kalispel Tribe of Indians. This TMDL is being developed jointly for both jurisdictions, and therefore the standards of both must be met. By current interpretation of law, in shared waters where there is a difference between standards, the more protective standard must apply, and upstream sources must meet downstream standards.

Washington State TDG standards

Chapter 173-201A Washington Administrative Code (WAC) contains the water quality standards for the state of Washington. Pertinent sections are as follows:

WAC 173-201A-200(1)(f): Aquatic life total dissolved gas (TDG) criteria.

TDG is measured in percent saturation. Table 200(1)(f) (see Table 2) lists the maximum TDG criteria for each of the aquatic life use categories.
(i) The water quality criteria herein established for TDG shall not apply when the stream flow exceeds the seven-day, ten-year frequency flood.

Table 2: Aquatic life TDG criteria from the Washington State Code

Table 200(1)(f): Aquatic Life Total Dissolved Gas Criteria in Fresh Water	
Category	Percent Saturation
Char	TDG shall not exceed 110% of saturation at any point of sample collection
Salmon, Steelhead, and Trout Spawning, and Rearing	
Salmon, Steelhead, and Trout Rearing – Only	
Non-anadromous Interior Redband Trout	
Indigenous Warm Water Species	

Kalispel Tribe TDG standards

The Kalispel Tribe of Indians has adopted, and EPA has approved, water quality standards for the waters of the Kalispel Reservation. The Designated Beneficial Uses of the Pend Oreille River in the reservation include Adult Salmonid Migration. The following TDG criterion applies to protect this beneficial use:

12(e) Adult Salmonid Migration

4) Total dissolved gas shall not exceed 110% of saturation in any single sample.

The TDG water quality criterion for Montana, Idaho, Washington, and the Kalispel Tribe are all identical at 110% of saturation. However, the Kalispel Tribal standards do not provide an exemption for flows above the 7Q10 flood flow. Therefore, this TMDL will provide conditions for Washington's waters that are protective of Kalispel Tribal standards. EPA in its oversight role will help facilitate compliance within upstream states (Washington, Idaho, and Montana) with the TDG standards of the Kalispel Tribe.

Watershed Description

Geographic setting

The Pend Oreille/Clark Fork watershed drains the Rocky Mountains of western Montana and the Idaho panhandle (Figure 2). The entire basin encompasses over 25,000 square miles, of which about 1,000 square miles, or 4% of the watershed, is in Washington. About 88% of the watershed is in Montana. Therefore, flow in the river is dominated by snowmelt in the late spring and early summer, with low streamflows in the late summer and mid-winter.

The climate of the Pend Oreille River watershed is characterized by cold, snowy winters followed by hot, dry summers, although rainfall is somewhat higher than other areas of Washington east of the Cascade Mountains.

Land uses in the river basin are primarily farming, ranching, mining, and forestry. Pend Oreille County is sparsely populated with most of the residents living in the towns of Newport, Cusick, Ione, Metaline, and Metaline Falls. The Kalispel Tribal reservation includes sections of the river near Cusick.

The Pend Oreille River in Washington can be divided into three reaches:

1. From Newport to Jared (upstream of the mouth of LeClerc Creek and the old town site of Ruby), the river runs wide with a broad flood plain through a wide valley.
2. From Jared to Ione, the river valley is narrower and more forested, although the valley widens a bit near Tiger.
3. From Ione northwards, the river valley again is fairly narrow, and reservoirs cover the former features of Box Canyon, Metaline Falls, and Z Canyon.

Pollutant sources

There are two hydroelectric projects in the TMDL area (Figure 1): Box Canyon Dam (Pend Oreille Public Utility District, or PUD) and Boundary Dam (Seattle City Light). Just upstream of the TMDL area in Idaho is Albeni Falls Dam (Army Corps of Engineers – Seattle District), which regulates Lake Pend Oreille water levels and controls downstream flows. Other major dams in the Clark Fork upstream of Lake Pend Oreille in Idaho include Noxon and Cabinet Gorge Dams (Avista), and Hungry Horse Dam (U.S. Bureau of Reclamation). Cabinet Gorge Dam has been identified as a source of TDG impairment, and the Federal Energy Regulatory Commission (FERC) license issued in 2001 includes measures Avista will be undertaking to control TDG (Avista, 1999).

Box Canyon Dam is a run-of-the-river dam with very little active storage capacity. Reservoir water levels are managed to maximum heights at Cusick and Newport. Spill occurs when that elevation is reached or when the powerhouse has reached hydraulic capacity. At high flows, spill gates are pulled and tailwater elevations increase, reducing the head difference through the dam, and therefore decreasing the plunging of the spill. As this occurs, powerhouse capacity drops, and the powerhouse ultimately shuts at about river flows of about 83 kcfs. At the highest flows the river flows through the spillway with almost no drop in elevation.

Boundary Dam has a small amount of active reservoir storage and is operated for peak load-following and providing operating reserves, meaning water is most often released during the day and the reservoir refills at night. Therefore, reservoir levels experience fluctuations. Spill occurs when powerhouse capacity is at a maximum and reservoir storage is no longer available.

Box Canyon and Boundary Dams are each covered by a FERC license. Pend Oreille PUD received a new license for Box Canyon Dam in July 2005, which made the Section 401 certification received from Ecology in 2003 legally binding. Boundary Dam's license expires in 2011; therefore, Seattle City Light is just beginning the relicensing process.

Study Methods

The Pend Oreille River TDG TMDL evaluates the effects of dams, hydroelectric projects, and natural features on TDG in the river. TDG has been monitored by Pend Oreille PUD at Newport, Box Canyon Dam forebay, and Box Canyon Dam tailrace since 2001 (Pend Oreille PUD, 2001; 2002; 2003). Monitoring was conducted above and below Box Canyon Dam in 2004 and 2005. The U.S. Geological Survey (USGS) has monitored TDG in the Boundary Dam forebay and tailrace continuously since 2000 (Kimbrough *et al.,* 2000; 2001; 2002; and USGS, 2006a). Monitoring was conducted in 2004 and 2005 by the Army Corps of Engineers at the USGS flow gage just upstream of the Idaho state line near Newport and in the forebay of Albeni Falls Dam (Easthouse and Klein, 2004; 2005). These monitoring locations are shown in Figure 1 ("Project TDG Stations"). The seasonal window for monitoring generally fell between mid-March and early August during 2001 through 2004.

Ecology conducted monitoring in 2004 to complement the TDG monitoring described above by filling potential data gaps and assessing comparability of data. A data-logging multiparameter meter was deployed near Ruby, about halfway up the impoundment behind Box Canyon Dam (Appendix Figure B-1). In addition, Ecology took grab measurements at Newport, Box Canyon Dam, and Boundary Dam for comparison to continuous monitoring at those sites. The methods and results of Ecology's monitoring are described in Appendix B.

The approach for the TMDL analysis was to compare these data sets from 2001 through 2004 to evaluate TDG dynamics in the Box Canyon Dam reservoir, above and below Box Canyon Dam during spill events, in the Boundary Dam reservoir, and above and below Boundary Dam during spill events and non-spill conditions. The principal analytical tools have been nonparametric statistical analysis and univariate regressions. Nonparametric metrics (e.g., percentiles of data sets) have the merit of being simple to use, robust with non-standard distributions of data, and powerful for large data sets. Linear and nonlinear regressions were used to highlight trends in the data. These analyses have been supplemented with special studies and field observations from the dam operators. These methods are described in greater detail in the *TMDL Analysis* section below.

This page is purposely left blank

Study Quality Assurance Evaluation

All TDG data used in this study were collected through monitoring that followed similar data quality assurance (QA) procedures. Monitoring is based on Standard Method Number 2810 (APHA, AWWA, and WEF, 2005). All meters are manufactured by either Common Sensing or Hydrolab. Pressure sensors are tested against pressures measured according to National Institute of Standards and Technology standards, and the membranes are tested for integrity by immersion in seltzer, pressure testing, paired field observations, and/or other methods. Raw data are reviewed, and outliers or data failing other quality tests are removed. Suspect data may be qualified. Data gaps also may exist from equipment malfunction, low water levels, or when meters were pulled for maintenance or to protect from vandalism.

QA methods and results for Ecology's monitoring study are presented in Appendix B. Detailed procedures were described in the Quality Assurance Project Plan for this study (Ecology, 2004). The QA analysis found that data for TDG and temperature collected by Ecology from May through July 2004 at Newport, Ruby, Box Canyon Dam, and Boundary Dam are of good quality and can be used in TMDL development. Conductivity, pH, and dissolved oxygen data are of poor quality and will not be reported or used.

The Army Corps of Engineers have documented their QA procedures in their annual reports on TDG monitoring (Easthouse and Klein, 2004; 2005). The tailrace monitoring location is on the left bank above the state highway bridge near Newport, and is representative of river conditions with a bias towards spill conditions from Albeni Falls Dam. Therefore, during Albeni Falls spill the Corps tailrace monitor will tend to read the higher TDG levels in the river and overestimate the average TDG in the river. Therefore, use of these data will tend to be implicitly conservative and introduce a margin of safety. In 2004, 90% of data were recovered and reported. All data are usable without qualification, except for data collected during the July 14 to August 19, 2004 time period; these data have been flagged as suspect.

QA procedures for Pend Oreille PUD TDG monitoring are documented in their annual reports (Pend Oreille PUD, 2001; 2002; 2003). The site near Newport (Kelly Island) is in a narrow, swift, and turbulent channel and probably represents fully mixed conditions, although this cannot be confirmed due to the lack of transect data. The Box Canyon Dam forebay site is located on the upstream nose of the dam and is representative of river conditions arriving at the dam. The tailrace site is located on the right bank downstream of the dam, and is representative of river conditions with a bias towards spill conditions from Box Canyon Dam. Therefore, use of these data will tend to be implicitly conservative and introduce a margin of safety. All data reported passed QA tests and are usable, except that tailrace data from May 22 through June 5, 2001 were deemed conditional.

USGS follows extensive QA procedures that are documented through internal procedures (USGS, 2006b). Only data passing QA tests are published. The Boundary Dam forebay monitoring site is in the powerhouse intake channel, and is representative of river conditions arriving at the dam. The tailrace monitoring site is about a mile downstream of the dam near the international border. Studies have shown that the tailwater site shows some variability across the channel, but the differences are small and distribution across the channel is inconsistent. Given the high energy of this location and variability of readings, this site can be considered to be fully mixed for all but the lowest flows.

To evaluate comparability of data between Ecology and the three other monitoring programs, paired measurements were made during the 2004 spill season at the Newport bridge (close to the Army Corps of Engineers monitoring station at the Idaho state line); at Box Canyon Dam forebay; and at Boundary Dam forebay.

Table 3 compares dissolved gas pressure, total dissolved gas as percent of saturation, and temperature for the Newport site. All pairs compared well except for TDG measurements in July. As mentioned above, the Army Corps of Engineers identified problems with their data in late July 2004, so a poor comparison is not unexpected. With that pair removed, pairs and the root mean square error of pairs compared well. Data at Newport after June 23, 2004 were not used in the TMDL analysis.

The comparison of data at Box Canyon Dam forebay is shown in Table 4. The overall root mean square error of pairs met the data quality targets, despite April values slightly exceeding targets for TDG. Data pairs at Boundary Dam forebay (Table 5) compared very well for all pairs and for the root mean square error of pairs, with minor exception for a pair of temperature readings.

Overall, all TDG data used for the TMDL analysis are of acceptable quality and show good agreement for paired readings.

TMDL Analyses

Flow conditions

As described above, flow in the Pend Oreille River is the primary condition that determines spill. Although spill occasionally occurs due to reasons other than flow, the vast majority of the time high flows trigger the spill. Therefore, the timing and amount of runoff will determine the magnitude of spill.

Figure 3 shows 22 years of flows at Newport (1984 through 2005), and Figure 4 shows the 90^{th}, 50^{th}, and 10^{th} percentile flows for each day. Figures 5 and 6 show the same information for flows below Box Canyon Dam. These graphs show several key features:

- Peak flows occur during the season of snowmelt runoff. Spring freshet flood flows typically begin in mid-April, peak in early June, and are dropping by early July.
- 1996 was unusual for its high flows in December and February.
- 1997 was an exceptionally high run-off year.

Figures 7 through 11 show the flows for each year from 2001 through 2005 at Newport, below Box Canyon Dam, and at the international boundary. Out of 32 years of data (based on the annual maximum 7-day flow), 2001 had very low flows (3^{rd} place), 2002 had relatively high flows (26^{th} place), 2003 had average flows (15^{th} place), 2004 had low flows (7^{th} place), and 2005 had average flows (13^{th} place). Comparing flows for the three gages, Newport and Box Canyon Dam have similar flows, consistent with its operation as a run-of-the-river project, while flows at the International Boundary show greater variation, consistent with Boundary Dam's operation for peak load-following generation.

The TDG standards in Washington State do not apply when flows are greater than the 7Q10 flood flow. The 7Q10 flood flows for the three gages, as calculated from 1974-2005 data, are 105.5 kcfs at Newport and below Box Canyon Dam, and 108.3 kcfs at the International Boundary. Within this period of analysis, flows in the Pend Oreille River exceeded the 7Q10 flood flow for 15 to 16 days in 1974, and for 38 to 39 days in 1997.

Idaho state line to Box Canyon Dam

Table 6 shows the distribution of data at the upstream and downstream ends of the Box Canyon Dam reservoir for the 2001-2004 spill seasons for times when data were available at both sites. TDG data from Newport indicate that criteria were exceeded due to conditions upstream of the Idaho state line a little less than 25% of the time for the periods monitored. At the Box Canyon forebay, TDG criteria were exceeded at a slightly lower frequency.

To determine the effect of ambient conditions in the reservoir on TDG levels, data for the same time were paired, and the difference was calculated between the value at the Box Canyon Dam forebay and Newport sites. Because of the travel time of water between the sites, which is typically 10-12 hours (Pend Oreille PUD, 2000), the difference between pairs will vary if TDG levels are increasing or decreasing. So a spread of data around the central tendency is to be expected, but a bias in the symmetry of the data around zero will indicate physical or biological processes that are altering TDG levels as they pass through the reservoir.

Note that the values in the columns labeled “Difference” or “Diff.” in Table 6 and subsequent similar tables in this report are the values for the percentile distribution of the differences between paired measurements from the two stations being compared. The values reported in the “Difference” column will not usually be the same as the difference between the respective percentile values in the neighboring columns for the two stations.

Figure 12 plots the paired TDG data for the Newport versus Box Canyon sites. Visually the data have a tendency to fall below the 1:1 line, suggesting the reservoir tends to reduce TDG. TDG during 2001, which was a very low-flow year, tends to show an increase through the reservoir; while TDG during 2002, a relatively high-flow year, tends to show a decrease.

In Table 6, the fifth column from the left marked “Diff.” shows the distribution of the paired differences. The median value of -0.7 percent of saturation suggests that overall a slight decline in TDG is typical.

Changes in water temperature, changes in ambient barometric pressure, primary productivity in the water column, and wind-induced gas exchange can all affect TDG levels. Often these processes offset each other, such as windy conditions occurring during a period of increasing temperature. On the other hand, conditions can align to increase TDG levels as percent of saturation, worst case being if the following occurred simultaneously: increasing water temperatures, falling barometric pressures, no wind, and high aquatic plant and algae productivity.

To separate the effects of temperature from other effects, a method was employed to standardize the paired data to the same temperature. Gas law equations allow for a simple adjustment of TDG pressure by assuming the same partial pressures of constituent gases while only changing temperature (Colt, 1984). TDG percent saturation values for the Box Canyon forebay station were recalculated using the temperature for the paired value at Newport.

Table 6 shows the temperatures at the two stations, the recalculated value at Box Canyon forebay, and the recalculated difference. The median TDG decline with temperature effects removed is -2.2 percent of saturation, which indicates that conditions other than temperature tend to reduce TDG in the river and that temperature tends to have the net effect of increasing TDG in the reach. These patterns can also be observed in the distribution of total gas pressure in millimeters of mercury (mm Hg).

Figures 13 though 16 show, for each of the years 2001-2004, TDG as percent of saturation for the two stations, the difference of pairs overall, and the difference with standardized temperatures. The graphs show that the TDG levels at the Idaho state line are generally elevated above the Box Canyon forebay values. In comparing the two time series for differences, the gap between the line marked “Difference” and the line marked “Difference (temperature effect removed)" represents the effect of temperature changes on TDG, which is typically an increase in TDG from seasonal warming of the river.

Ecology collected TDG data from a dock near Ruby in 2004, which allows an evaluation of differences between the broad, open reach upstream of that site and the narrower channel downstream. Table 7 shows the distribution of TDG between Newport and Ruby, and Table 8 shows the distribution of data between Ruby and the Box Canyon forebay. Figures 17 and 18 also show TDG patterns in these reaches. Both reaches show a tendency for TDG to decline, but in the Ruby-Box Canyon reach changes are much smaller and the TDG time series more similar to each other. The Newport-Ruby reach shows greater heating and a broader range of temperatures. When the effect of temperature is removed, the Newport-Ruby reach shows a greater temperature effect. These patterns are consistent with the upstream reach being more susceptible both to heating and to wind-induced degassing.

For a more exact, quantitative evaluation of impairment, data were filtered for stable data. During dynamic TDG conditions, sensors may not be equilibrating adequately between readings. The calibration criterion for reading stability is less than 1 mm Hg change over 2 minutes after 15 minutes equilibration. Therefore, a "steady state" data set was developed that included only TDG data that had changed less than 1 mm Hg per 15 minutes from the previous reading.

Table 9 shows the distribution of this stable data set for the Newport to Box Canyon reach. When compared to Table 6 (the same data set unfiltered), the range of data is slightly reduced and the median slightly closer to zero. Similar patterns can be seen in Tables 10 and 11, which show the filtered stable data from 2004 in the reaches from the Idaho state line to Ruby, and from Ruby to Box Canyon forebay.

The data were then evaluated more closely to characterize conditions when impairment occurred (TDG > 110% of saturation). Table 12 summarized the results of that evaluation. Over the four seasons of monitoring, the river was impaired when crossing the state line from Idaho to Washington about 24% of the time. This impairment rate ranged from 33% of the 2002 data to 1.5% of the 2004 data. At the Box Canyon forebay, the river was impaired overall about 16% of the time monitored, with the highest rate of 23% seen in 2002 and no impairment found in 2004.

About 25% of the time monitored during 2001-05, impairment was found at either the Idaho state line or the Box Canyon forebay (or both). About 9% of the time, the Idaho state line was impaired but not Box Canyon forebay, and about 1% of the time, Box Canyon forebay was impaired but not the Idaho state line, leaving about 15% of readings when both were impaired.

Tables 13 and 14 provide a similar summary for 2004 in the two reaches upstream and downstream of Ruby. About 2% of the time, TDG impairment was found at the Idaho state line, but during those times Ruby and the Box Canyon forebay were never impaired.

To illustrate instream TDG with respect to impairment, the difference between the measured TDG as percent of saturation and the criterion of 110% was calculated for all times when TDG exceeded 110% of saturation at either the Idaho state line or Box Canyon forebay station. Figures 19 through 21 show these time series, along with the difference in TDG between paired values due to the net pool effect, temperature, and effects other than temperature (most likely productivity and wind). The interaction of temperature and other effects to produce the net pool effect can be clearly seen in these figures. In Figure 19, early on May 28, 2001 (the gridline with the date marks the beginning of that day) one can observe that the pool effect is dominated by temperature, but later that same day the non-temperature effects dominate and the net pool effects become negative. Similarly, Figures 20 and 21 show that the net pool effect in 2002 and 2003 was usually negative, despite the temperature effect being usually positive.

The effect of wind on the net TDG change in the pool was examined in more detail. Wind data for the Deer Park Airport National Weather Service station were compared to the calculated non-temperature pool effect. Since the wind data are from a point several miles outside the Pend Oreille River valley, only general patterns based on regional wind conditions can be discerned.

Figure 22 shows the distribution of TDG change in the pool for all data due to non-temperature effects (wind or productivity) compared to wind speed. When winds are low, TDG changes cover a broader range, most likely reflecting the effect of macrophytes and algae productivity on TDG, as well as TDG dissipation across the air-water interface. At higher wind speeds the range decreases, and positive changes disappear above 20-knot wind speeds. This is consistent with the effect of wind – to increase equilibration of TDG to ambient levels – which narrows the range of observed TDG changes. At the highest wind speeds, the effect becomes solely one of decreasing elevated TDG.

Figure 23 shows a similar graph using only data during impaired conditions. Again, as winds increase, positive differences disappear, the ranges of differences narrow, and the net effect becomes negative.

The final step in this analysis is to determine whether the net pool effect is large enough to merit inclusion in pollutant allocations. At the bottom of Table 12, the median net pool effect is shown. The key question is whether the pool causes impairment when the river otherwise would not be impaired, or increases impairment when conditions at the Idaho state line are already impaired. In 2001, 25% of the data showed impairment, but the median change in TDG in the pool was less than 1% of saturation. The combination of Idaho being unimpaired while Box Canyon was impaired occurred 11% of the time, and the median TDG change was just over 1% of saturation. For all four years, the rate and magnitude of impairment was similar to 2001: impairment occurred 25% of the time monitored, with a median change less than 1% of TDG saturation in the pool. However, less than 1% of the time Idaho was unimpaired and Box Canyon was impaired, and the median TDG change was again less than 1%.

To summarize, conditions in the pool (temperature changes, wind, and productivity) can affect TDG levels. However, most of the time wind effects appear to offset temperature effects. A small fraction of the time, effects may combine to increase TDG in the pool to cause or increase impairment. However, the percentage of time this represents is very small, and the change in TDG is within the error of TDG measurements and of the analysis. Therefore, a separate allocation for the Box Canyon reservoir pool is unnecessary, and an allocation at the Idaho state line equal to the criterion of 110% will be adequate to protect Washington's water quality.

Box Canyon Dam TDG generation

TDG data for the 2001-2004 monitoring seasons were evaluated from the forebay and tailrace stations at Box Canyon Dam to characterize TDG generation processes. TDG data from spill conditions were filtered to include only stable readings (as described above). Table 15 shows the distribution of flow, barometric pressure, TDG as percent of saturation, and dissolved gas pressure for this data set. Figure 24 illustrates these data.

Power production and spill operations are affected by several factors. The powerhouse typically passes flows between 24 and 29 kcfs. At low river flows, all flow passes through the powerhouse, but spill begins either to pass river flows in excess of powerhouse capacity or to keep river levels below the flood stage at Cusick. As river flows rise, the downstream tailrace elevation also rises, resulting in a head loss that reduces powerhouse capacity. In Figure 24 this can be seen to occur for spills of about 32 kcfs and higher. As river flows increase, eventually the powerhouse must be shut down. At the highest flows, all spill gates are opened and the river flows with little drop through the dam.

At lower spill flows, TDG levels increase steadily with increasing flows as a result of both increasing spill volumes and tailrace depths. TDG generation peaks during spills of about 30 to 50 kcfs. Then TDG generation begins to drop off with higher spills as a result of the decreasing height of the spill's fall. At the highest flows, TDG generation is negligible. Spill at Box Canyon Dam begins to generate TDG above 110% of saturation at around 2.5 kcfs and exceeds the criterion consistently at spills above 5 kcfs. Studies by Pend Oreille PUD (2005) indicate that gate configurations can affect TDG generation, which partially explains the variability of TDG generation versus flow.

Box Canyon Dam to Boundary Dam

The analysis of TDG processes in the Boundary Dam reservoir uses similar methodology to the analysis discussed above for the Box Canyon Dam reservoir. Data from the Box Canyon Dam tailrace were paired with data from the Boundary Dam forebay. Table 16 shows the distribution of that data, and Figure 25 compared TDG data from the two stations. As compared to the Box Canyon reservoir, TDG levels show a much greater tendency to decline between Box Canyon and Boundary Dams, and there is less of a temperature effect.

Figures 26 through 29 show the time series for TDG at these sites for the 2001 through 2004 seasons, along with the TDG differences, as well as the TDG difference with temperature effects removed. Again, other than a short period in the extreme low-flow year of 2001, TDG tends to dissipate between Box Canyon and Boundary Dams, and relatively little temperature effect can be seen.

Tables 17 and 18 and Figures 30 through 33 show the results of an analysis of stable TDG readings. Again, the typical pattern is for impairments at the Box Canyon tailrace to translate downstream with little temperature effect and a net dissipation of TDG. The percent of time impairment found was fairly consistent at the two stations (Table 18), ranging from 14% of the data in 2001 to 67% in 2002, and about 52% for the four seasons combined.

Overall, about 4% of the time the Box Canyon tailrace was impaired but the Boundary Dam forebay was unimpaired. This situation occurred less than 1% of the time in 2001 and about 8% of the time in 2002.

About 5% of the time monitored, the Box Canyon tailrace was unimpaired but Boundary Dam forebay was impaired, with annual rates varying from 10% of the time in 2001 to less than 3% |of the time in 2003. The median net pool effect in these situations for the four years was an increase of around 1% of saturation, with a median effect in 2003 of slightly over 2% of saturation increase. This effect was strongest in 2001, and the diurnal pattern of the data suggests that an algae bloom in the reservoir may have contributed to the impairments, although some other data anomaly related to the daily cycling of power generation may also cause the patterns.

During all periods of impairment in the four monitoring seasons, the net pool effect was a decrease of over 3% of saturation. Only in 2001 was the median increase in TDG positive but still less than 1% of saturation. Therefore, conditions that caused TDG to increase in the pool were rare, and the effect on TDG when it occurred was small.

Boundary Dam TDG generation

TDG data from the forebay and tailrace of Boundary Dam were analyzed to determine TDG generation from dam operations. Using a similar process to the Box Canyon Dam analysis, data were segregated as spill and non-spill and then filtered for stable data. The results for TDG during spills are shown in Table 19 and Figure 34.

Boundary Dam operates quite differently from Box Canyon Dam. Boundary is a "load-following" dam which generates power in the morning and evening, and typically shuts down during the night, storing water for the next day. Spill only occurs when flows exceed 50 kcfs, while generation continues during all river flows during peak load times.

Studies conducted for Seattle City Light have indicated that the river is well mixed at the tailwater monitoring station (SCL, 1998; 2003). Therefore, because forebay TDG is already elevated when Boundary Dam begins to spill, at low spill levels the amount of TDG generated by spill may be small, and its effect on tailrace TDG levels may be masked by dilution.

Another complicating factor is the possibility that powerhouse flows are entrained into the spill, which means that the amount of powerhouse flow retaining forebay levels is reduced and a fraction of the powerhouse flow has TDG generated at levels similar to spill flows. A study of controlled spill in 2002 (SCL, 2003) evaluated entrainment in the tailrace and came to the conclusion that entrainment "was not occurring or represented a small volume if it did exist."

However, a review of that study by the U.S. Army Corps of Engineers (Schneider, 2006) reached preliminary conclusions that significant entrainment was occurring, but the proportion of flow being entrained at different spill volumes and flows was not determined. Therefore the approach taken in this analysis of illustrating TDG generation processes was to assume no entrainment, with the understanding that, as further analysis occurs, the generation processes will be better understood and the models more predictive.

In Figure 34 the graph for the forebay-tailrace difference shows a decrease (negative values) at low spill levels. This suggests that low volumes of spill generate lower levels of TDG than forebay values, causing the fully mixed levels at the tailrace station to be less than the forebay. As spill levels rise above 8 kcfs, the increase in TDG from Boundary Dam spill between the forebay and tailrace becomes more apparent.

To determine the TDG generation characteristics of the Boundary Dam spill, TDG levels from spill were back-calculated by assuming that (1) total flow and TDG at the tailrace monitoring site represented total loading, (2) forebay TDG and the generation flows represented the generation loading, (3) TDG generation by the spill is independent of forebay levels, and (4) no entrainment of powerhouse flows into the spill was occurring.

The distribution of back-calculated spill TDG is shown in Table 19. Below the 25th percentile, Boundary Dam spill TDG is lower than forebay TDG, but above the 25th percentile TDG generation by spill is far higher than forebay levels, which is consistent with the pattern of the forebay-tailrace difference curve. The exclusion of powerhouse entrainment from the back-calculation could explain the very low TDG values at low spill levels.

In Figure 34 the calculated spill generation values were fitted to a power (log-log) curve. Based on this curve, the Boundary Dam spill begins to produce TDG above 110% at about 8 kcfs.

During the four years of monitoring, forebay TDG levels were always above 110% during a Boundary Dam spill. To determine the effect of the Boundary Dam spill on fully mixed conditions at the tailrace monitor with upstream conditions in compliance, tailrace TDG was recalculated with the assumption that forebay TDG equaled 110% of saturation. These values, shown in Table 19 and Figure 34, indicate that Boundary Dam spill above 4 kcfs would elevate TDG above 110% if the forebay were in compliance. At the highest spills downstream, TDG levels are dominated by TDG generation from the Boundary Dam spill.

Evaluation of tailrace TDG data indicates that Boundary Dam sometimes exceeds the 110% criterion when no spill is occurring. Table 20 shows the distribution of non-spill flow, barometric pressure, and dissolved gas when forebay TDG is below 110% (to avoid the masking effect of high upstream levels). Under these conditions, the 95th percentile TDG is just below the 110% criterion, and the maximum level is well above the criterion. In Figure 35, at the lower range of flows, a portion of the data exceeds 100% at the tailrace monitor and a similar portion of data shows a large increase from forebay to tailrace.

These elevated TDG levels at low flows are caused by air injection into several turbines to prevent cavitation when the turbines ramp up and down. Several studies conducted by consultants for Seattle City Light have documented this effect (SCL 2000; 2001), and the utility has been researching how to eliminate it. Not all turbines have this problem, so the effect is not consistently observed.

To illustrate this issue, Figure 36 zooms in on the period of January 23-31, 2001. This graph clearly shows how TDG climbs when flow is low (powerhouse generation stopped), and then drops as flows rise (powerhouse operating). Taking only the flow and TDG data from January 24 through 30, 2001, Figure 37 shows a strong relationship between flow and TDG, with TDG dropping as flow increases.

Loading capacity

As discussed above, the fundamental process that elevates TDG is gas transfer between the air and water at the boundary of entrained bubbles, driven by differential gas pressures. For any given spill volume and tailwater depth, the excess pressure over ambient barometric pressure, ΔP, can be predicted. The mass loading of air that is associated with any given ΔP will depend on water temperature. However, this mass loading is of less importance than ΔP, since it is ΔP that drives whether gas bubble trauma in fish will occur. For these reasons, using excess pressure rather than mass loading to express loading capacity is appropriate for this TMDL and is supported by the Clean Water Act's allowance for the use of "other appropriate measures" in developing TMDLs.

The use of critical barometric pressure to set a value of ΔP to meet the criterion of 110% saturation is appropriate because of the need to meet the criteria throughout the river as conditions change downstream of the dams and away from the upstream end of the compliance areas.

To determine the TMDL loading capacity, ΔP can be directly related to the TDG water quality criteria as described in this equation:

$$S_{tdg} = \frac{(P_{atm} + \Delta P)}{P_{atm}} * 100$$

Where:

S_{dtg} = TDG percent saturation
P_{atm} = barometric pressure
ΔP = excess pressure over ambient barometric pressure

If S_{tdg} is set at the criterion of 110% saturation, the equation can be rearranged to establish a ΔP loading capacity (ΔP_{lc}):

$$\Delta P_{lc} = P_{atm} * 0.1$$

To choose a critical barometric pressure (P_{atm}) for establishing the loading capacity, the 95th percentile low barometric pressure was determined during the spring and summer spill season for each dam. This pressure varies from 678 mm Hg at the Idaho state line to 686 mm Hg in the

Boundary Dam tailrace. At a TDG of 110% of saturation, ΔP equals 10% of the ambient barometric pressure. Therefore, 10% of critical barometric pressure results in the loading capacities for the Pend Oreille River in terms of ΔP shown in Table 21.

Table 21: Loading capacities for the Pend Oreille River

Reach of Pend Oreille River	Loading Capacity*
Idaho state line to Box Canyon Dam forebay	68 mm Hg above saturation (ΔP)
Box Canyon Dam tailrace† to Boundary Dam forebay	68 mm Hg above saturation (ΔP)
Boundary Dam tailrace† to International Border	69 mm Hg above saturation (ΔP)

*maximum instantaneous
†upstream end of the compliance area as identified in the *Implementation Strategy* section of this document.

Compliance areas

The compliance area boundaries for the tailrace of each dam were chosen from several options, illustrated in Figure 38:

1. By a strict interpretation of Washington State water quality standards without any consideration of applying the mixing zone provisions of the water quality standards, the compliance area would be the entire river from the dam downstream. This includes the area of maximum TDG immediately below the spillway. However, this area is difficult to identify and monitor in real time, and this area does not take into account the rapid degassing in the aerated zone.

2. If Washington State mixing zone provisions were applied to the aerated zone (the area of bubble entrainment and dissipation), then the compliance area would begin in the tailrace at the end of the aerated zone. This location would be easier to identify for regulatory purposes, but monitoring in this location may not be feasible.

3. The area of compliance could begin at the tailwater TDG monitoring sites, with mixing zone provisions applied to the entire river, including powerhouse flow. The locations of the tailwater monitoring sites are clearly identified, and the time of travel from the end of the aerated zone may be very brief. However, the monitoring sites may be inconsistent with respect to the amount of mixing they represent between water gassed by the spill and water unchanged from the forebay.

The upstream boundaries of tailwater compliance areas will be based on application of the mixing zone provisions of the water quality standards to the aerated zone immediately below the spillways of the two Pend Oreille River dams. The water quality standards for the state of Washington provide an allowance for a mixing zone. Within a mixing zone, water quality can exceed standards, but compliance with standards is required at the boundary of the mixing zone. In this context, the area excluded from compliance with the standards is the aerated zone, and not literally a mixing zone.

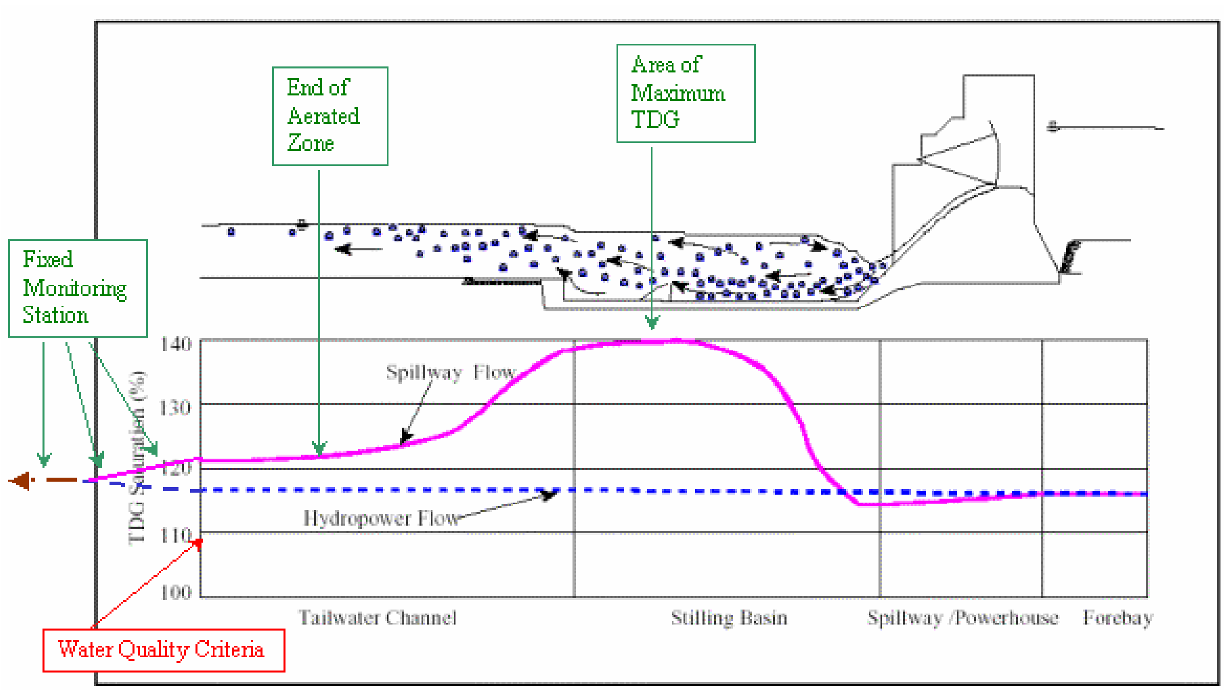


Figure 38. Key features of potential tailwater compliance area boundaries.

There are several reasons that it is appropriate in this situation to exclude an area from compliance with the standards through use of the mixing zone provisions of the standards:

- TDG levels rise immediately below the spillway, but then degas for some distance downstream. The tailrace compliance area boundaries were determined from field observations or research which identified the location where degassing was mostly complete. This is a local area of impact with very dynamic conditions.
- Because the area below the spillway is highly turbulent and aerated, TDG levels are difficult to accurately assess.
- Extensive fisheries research has shown that most fish are able to pass through this area below the spillway quickly, without ill effects.
- Because of the turbulent flow associated with the spill above the compensation depth (the depth where hydrostatic pressure equals ΔP), little or no resident fish habitat is available in this area. (The zone below the compensation depth is by definition in compliance with standards.)
- Provision of a mixing zone and deviation from the size requirements are appropriate because of the public interest in ensuring that water quality standards are applied appropriately to the dam projects.

The upstream boundaries of compliance areas are determined on a case-by case basis for each dam. The compliance areas for load allocations will either begin at the end of the aeration zone in the tailrace or at another designated location such as the tailrace monitoring site. These locations will be determined using the best available information based on:

- Measurements from a near-field study which show the location where rapid degassing has ceased;
- Visual field observations of where significant bubble rising has ceased; and/or
- The "footprint" of the project, where the natural channel has been modified.

The location where the compliance area begins, as determined by current information, is shown in the *Implementation Strategy* section in this document. If additional information becomes available that supports a different location for the upstream end of the compliance area, Ecology can modify how the location of the compliance area is defined through amendment of the *Water Quality Implementation Plan.*

Pollutant allocations

Under the Clean Water Act, pollutant allocations are categorized as "wasteload allocations" when they apply to NPDES-permitted point sources and "load allocations" for all other sources. For the purpose of this TMDL, each dam will be included in a load allocation based on a river reach, because no NPDES permits will be issued to the dams to regulate TDG caused by spills[1]. This approach is also reasonable for several reasons:

- Spills entrain air to reach a polluted condition, much like a high-energy release of water might erode a streambank.
- Dams are essentially very large instream structures that may require modifications to achieve attainment of water quality standards.
- The level of improvement expected from any specific structural or operational modification is uncertain, and therefore a series of modifications may be needed to achieve the desired outcome, with effectiveness monitoring to assess results.
- Discharges from non-federal dams are usually regulated through water quality certifications issued under Section 401 of the Clean Water Act.

The wasteload allocation in this TMDL is zero because there are no NPDES-permitted point sources that contribute to elevated TDG in the Pend Oreille River.

Table 22 shows the load allocations for the Pend Oreille River from the Idaho state line to the international boundary. As noted previously, because of the unique nature of TDG, load allocations are not directly expressed in terms of mass loading.

Many dams in the Columbia River system have been studied for TDG exchange processes. These studies have shown that typically TDG concentrations created by spills are independent of upstream conditions. This is because the spilled water and entrained air rapidly reach a new

[1] The Courts have determined the characterization of dams as point sources for which NPDES permits will not be issued for certain parameters. The current policies of the state of Washington and EPA are to not issue NPDES permits for TDG.

equilibrium under the hydrostatic pressures of the stilling basin. Exceptions occur when spill volumes are very low or the plunge height is short, so that the time for gas absorption is short. Therefore, it is a fairly accurate generalization to say that under most conditions each dam's spill "resets" the TDG levels for the water that passes over the spillway and for any entrained powerhouse water.

For this reason, the primary approach of this TMDL is that each dam is responsible for the TDG generated by its spill, and not for TDG levels upstream. Each dam has the obligation to meet the load allocation below the dam and downstream to the forebay of the next dam or to the international boundary if possible. If conditions upstream of a dam exceed allocations and prevent meeting allocations downstream, then that dam should manage its spill to at least make TDG conditions in the downstream compliance area no worse than forebay conditions and perhaps at times to improve TDG levels downstream.

Downstream levels are a simple mass balance of each dam's TDG generation from spill plus powerhouse flows that pass forebay levels from upstream. Therefore, if TDG comes from Idaho at 110%, and each dam does not increase the gas in its spill above 110%, the river will always meet 110% except for brief intermittent increases above 110% due to natural influences.

As with loading capacity, allocations are stated in terms of ΔP at all other times and locations. Load allocations are equal to loading capacity throughout the TMDL area, including each dam's forebay and tailrace. When this TMDL is fully implemented, spills from dams downstream of the Idaho state line must meet the allocations (except during flows above a 7Q10 flood). The allocation at the Idaho state line must be met under all flow conditions, to ensure compliance with Kalispel Tribal standards.

The load allocation for the upstream boundary at the Idaho state line will need to be met by the states of Idaho and Montana, with EPA playing a role for interstate compliance. Implementation of TDG TMDLs, FERC license conditions, and other TDG abatement programs at dams in the Pend Oreille and Clark Fork Rivers in Idaho and Montana should also reduce TDG levels in the Pend Oreille River entering Washington.

Table 22: TDG allocations for the Pend Oreille River

Reach of Pend Oreille River	TDG Allocation[1]
Idaho state line to Box Canyon Dam forebay	68 mm Hg above saturation (ΔP)
Box Canyon Dam tailrace[2] to Boundary Dam forebay	68 mm Hg above saturation (ΔP)[3]
Boundary Dam tailrace[2] to International Border	69 mm Hg above saturation (ΔP)[3]

[1]Maximum instantaneous

[2]Upstream boundary of the compliance area identified in *Implementation Strategy* section of this report.

[3] Not applicable during flows above the 7Q10 flood flow. If upstream forebay levels exceed the load allocation, then TDG levels in the downstream compliance area shall not exceed upstream forebay levels.

Margin of safety

The margin of safety for this TMDL is implicit in the TMDL analysis through the use of conservative assumptions. A detailed analysis of how the margin of safety is included is provided below.

Critical conditions

No specific high-flow or low-flow critical conditions exist for this TMDL. Although most spills occur during the late spring/early summer runoff season (April through July), spills that generate high gas levels can occur in any season. Load allocations are applicable to spills at all flow levels from the Idaho state line to the Kalispel Reservation, and at all flows below the 7Q10 flood downstream of the Kalispel Reservation to the Canadian border.

Certain parameters that are necessary to develop load allocations were established at levels equivalent to critical conditions. As described above, loading capacity and allocation are based on barometric pressures at critical levels. This approach introduces several conservative assumptions that provide a margin of safety to the TMDL.

Criteria versus site-specific conditions

The criterion of 110% to be met at any point of measurement is extremely protective. Fish are mostly fairly mobile and experience TDG more as an average value than as a maximum value at any one location, and fish below the compensation depth will not experience adverse effects from TDG. In addition, review of EPA guidance and other background information on the 110% criteria suggest that this level will incur no chronic effects on fish for extended time periods. It appears that the 110% criterion could be applied with an averaging period, rather than as an instantaneous value. Therefore, the current standards include an implicit margin of safety when applied to this river system.

Data quality and quantity

A margin of safety is usually identified in a TMDL to recognize uncertainty in the data used to produce the TMDL. Due to the continuous monitoring programs conducted by the dam operators over the last several years, there is a large amount of data for TDG, barometric pressure, water temperature, tailwater elevation, forebay elevation, as well as total river flow and spill quantity at hourly, and sometimes quarter-hourly, frequencies. Operators follow data quality procedures for monitoring at the sites for which they are responsible. The complete continuous data sets and data quality assurance information are available from the dam operators or from Ecology.

Conclusions

The analysis of TDG in the Pend Oreille River in Washington State during the 2001 through 2004 spill seasons led to the following conclusions:

- TDG at the Idaho state line exceeded the 110% criterion slightly less than 25% of the time for the periods monitored, most likely from spills at upstream dams in Idaho and Montana.
- Ambient (environmental) conditions that can change TDG in the Box Canyon Dam reservoir – barometric pressure, water temperature, instream productivity, and wind – usually offset each other but occasionally combined to increase TDG. However, TDG increases that cause or increase impairment (relative to Washington State water quality standards) were rare, and the magnitudes of the TDG increases in those situations were small.
- TDG generation at Box Canyon Dam began to exceed Washington State standards at spills of 2.5 to 5 kcfs, and maximum TDG generation occurred during spills of 30 to 50 kcfs, above which TDG generation decreased.
- Ambient conditions in the Boundary Dam reservoir rarely increased TDG, and the magnitude of increases that caused or increased impairment were very small.
- When spill occurred at the Boundary Dam forebay, TDG was already above standards. The Boundary Dam impairment increased at spills of about 9 to 12 kcfs and higher. If forebay conditions were meeting standards, TDG standards would be exceeded at spill levels above 4 kcfs.
- Turbines at Boundary Dam occasionally caused TDG impairment due to air injection during turbine startup or shutdown; therefore, these impairments were observed at very low downstream flows.
- Loading capacity and allocations are established equal to the excess dissolved gas pressure above ambient barometric pressure equivalent to 110% saturation at the 95th percentile low barometric pressure.
- Compliance with TDG allocations is required during all times when flow is below the 7Q10 flood flows, except in waters of the Kalispel Reservation where compliance is required during all flows.
- Compliance with TDG allocations is required in compliance areas which include the entire Pend Oreille River in Washington except for aerated portions of the tailrace areas immediate downstream of Box Canyon and Boundary Dams. The location of the upstream boundary of the compliance areas below the dams is identified in the *Implementation Strategy* section of this report.
- At Box Canyon Dam or Boundary Dam, if the upstream forebay TDG levels at the dam exceed the load allocation, then TDG levels in the compliance area downstream of the dam shall not exceed upstream forebay levels.

Recommendations

As a result of this study, the following actions are recommended:

- TDG allocations should be met at the Idaho state line by implementing actions in Idaho and Montana. This could include implementing the 401 certification at Cabinet Gorge Dam, additional analysis of TDG generation by Albeni Falls Dam, and if necessary, developing and enacting a gas abatement strategy for Albeni Falls Dam. EPA will provide oversight of interstate compliance.
- The TDG abatement plan under the Box Canyon Dam 401 certification should be implemented.
- A TDG abatement plan for Boundary Dam should be developed and implemented as part of the 401 certification process for Federal Energy Regulatory Commission (FERC) relicensing.
- TDG should be monitored continuously at the Idaho state line, at the forebay and tailrace of Box Canyon Dam, and at the forebay and tailrace of Boundary Dam.

This page is purposely left blank

Implementation Strategy

Introduction

The Total Maximum Daily Load (TMDL) study, conducted by the Washington State Department of Ecology (Ecology) in 2006, evaluated areas of the Pend Oreille River known to have excess total dissolved gas (TDG).

This *Implementation Strategy* is intended to describe the framework for improving water quality. It describes the roles and authorities of cleanup partners (i.e., those organizations with jurisdiction, authority, or direct responsibility for cleanup) and the programs or other means through which they will address these water quality issues.

The Pend Oreille River is part of the Pend Oreille/Clark Fork watershed, which drains western Montana and northern Idaho. The river enters Washington near the city of Newport and flows northward towards the Canadian border. Downstream of Newport, the river passes through the reservation of the Kalispel Tribe of Indians. A short reach of the river flows through Canada to its confluence with the Columbia River just upstream of the international border.

Much of the land in the Pend Oreille River basin in Washington State falls within the boundaries of the Kaniksu National Forest. Two-thirds of the northern and central parts of Pend Oreille County are government owned; the southern portion is mostly privately owned. The basin's topography consists of river-bottom flatlands in a long and narrow trough between ridges of the Selkirk Mountains. Agriculture on the lowland plains includes grain crops, hay, pasture, and livestock. The area is largely forested with rough mountainous terrain. Private land ownership is concentrated on river and lake shorelines as strip development.

There are two hydroelectric projects in the TMDL area: Box Canyon Dam (Pend Oreille Public Utility District) and Boundary Dam (Seattle City Light). Just upstream of the TMDL area in Idaho is Albeni Falls Dam (Army Corps of Engineers), which controls downstream flows. There are other major dams in the Clark Fork watershed upstream of Lake Pend Oreille in Idaho, including Cabinet Gorge Dam which has been identified as a source of TDG impairment.

Box Canyon Dam is a run-of-the-river dam with limited storage capacity. The dam manages its reservoir to control water levels at Cusick and Newport. Spill occurs at maximum water elevations when the powerhouse reaches hydraulic capacity.

Boundary Dam is operated for peak load-following and to provide operating reserves. As a result, water is most often released during the day and the reservoir refills at night. Therefore, reservoir levels experience daily fluctuations. Spill occurs when powerhouse capacity is at a maximum and reservoir storage is no longer available.

Box Canyon and Boundary Dams are each covered by a Federal Energy Regulatory Commission (FERC) license. The Pend Oreille Public Utility District (PUD) received a new license for Box Canyon Dam in July 2005 which made the Section 401 certification received from Ecology in 2003 legally binding. Boundary Dam's license expires in 2011, and Seattle City Light is beginning the relicensing process.

The issuance of a new license by FERC allows the dams to continue generating electricity for the term of that license. FERC assesses the effects associated with the operation of the project as well as alternatives to the proposed project and determines the terms and conditions that become a part of any license issued. In deciding whether to issue any license, FERC must determine that the project would be best adapted to a comprehensive plan for improving or developing a waterway. In addition to the power and developmental purposes for which licenses are issued (e.g., flood control, irrigation, and water supply), the Commission must give equal consideration to the purposes of energy conservation; protection of, mitigation of damage to, and enhancement of fish and wildlife (including related spawning grounds and habitat); protection of recreational opportunities; and the preservation of other aspects of environmental quality.

In general, this is the FERC process:

- At least five years before their FERC license expires, the utility sends FERC a notice of intent (NOI) to apply for a new license.
- The utility then files proposed and revised study plans with FERC. The studies are designed to analyze environmental and other effects of the dam and generally take about two years to complete. The results of the studies will lead to proposals for solving any problems caused by the dam and its operations.
- The utility requests a new FERC license at least two years before the existing license expires.
- Concurrently the utility requests a water quality certification from the state (Ecology) and/or affected tribes.
- The state has one year to issue the water quality certification from the date the request is made. The state then sends the water quality certification to the utility and FERC.
- FERC then puts the conditions of the water quality certification into the FERC license.

There is a high degree of interest in the Pend Oreille River and surrounding watershed. A number of public and private organizations have established programs for monitoring, protection, and restoration of the natural water resources. This voluntary support for maintaining water quality is vital to maintaining the quality and function of the river.

For purposes of this TMDL, the upstream boundary of the compliance areas for the TMDL below both Box Canyon and Boundary Dams is the existing tailrace TDG monitoring sites. If Ecology, because of improved knowledge of conditions in the river, determines that the upstream boundary of the compliance area should be in a different location, this *Implementation Strategy* will be revised to identify that location.

After EPA approves this TMDL, interested and responsible parties will work together to develop a *Water Quality Implementation Plan*. That plan will describe and prioritize specific actions planned to improve water quality and achieve water quality standards.

What needs to be done?

This section of the report outlines an *Implementation Strategy* that will be used to achieve the necessary TDG water quality improvements.

Spill events at hydroelectric projects can cause elevated TDG levels. Water pouring over the spillway of a dam and plunging into the tailrace carries air bubbles to depth in the dam's stilling basin, where hydrostatic pressure forces air from the bubbles into supersaturated solution. Typically spill occurs during the snowmelt runoff season in late spring and early summer.

TDG may also be affected by natural phenomena, such as biological primary productivity, decreased ambient barometric pressure, changes in water temperature, and wind-induced turbulence.

Because the Pend Oreille River basin encompasses portions of Idaho and Montana, actions of those states have the potential to significantly alter the quality of water coming into Washington. However, the Idaho Department of Environmental Quality (DEQ) is currently conducting a TMDL for TDG in the Clark Fork River, and a 401 Certification is in place for Cabinet Gorge Dam. The Idaho TMDL and the Cabinet Gorge 401 Certification will help ensure that water quality crossing the state boundaries will meet Washington's standards. In addition, the United States EPA has ultimate responsibility for ensuring that upstream states meet Washington's standards. EPA's oversight will further ensure success of this TMDL.

Washington has no jurisdiction over other states, so timeframes and solutions outside the geographic boundaries of Washington are beyond the scope of this TMDL.

Box Canyon Dam

On January 5, 2002, the Pend Oreille PUD applied to Ecology for water quality certification for the Box Canyon Project in Washington State. On December 30, 2002, Ecology issued a water quality certification for the project, which Ecology amended slightly on February 21, 2003 to better line up the due dates for the various water quality attainment plans required by certification with the pending FERC license. The certification contains conditions relating to TDG abatement to ultimately bring TDG levels into compliance.

FERC granted a new license for the Box Canyon Project on July 11, 2005. The PUD filed a draft TDG abatement plan with Ecology shortly thereafter. After gaining approval from Ecology, the final *Total Dissolved Gas Abatement Plan for the Box Canyon Hydroelectric Project* was issued in November 2005.

The TDG abatement plan includes:

1. Upgrading all four turbines at the dam, thereby increasing the hydraulic capacity of the powerhouse. This will allow the PUD both to generate more electricity and reduce gas-producing spills, especially during high spring flows.

2. Install an auxiliary spillway bypass. As planned, the bypass will be able to route up to an additional 27,600 cubic feet per second (cfs) of water through the dam rather than over the dam as spill.

The PUD estimates that upgrading turbines and adding the spillway bypass will further reduce TDG production and bring the PUD into compliance with state water quality standards. The PUD will also:

1. Analyze and identify spill gate settings that reduce gas generation for both the dam as it is now and after completion of the turbine upgrades and construction of the bypass. Actual on-ground experimentation with the gates will be needed to determine how much gas is reduced by manipulating gate settings.

2. Monitor TDG both upstream and downstream of the dam as described in the *Water Quality Monitoring Plan for the Box Canyon Hydroelectric Project* (November 2005). The results of this monitoring will be reported annually to Ecology.

Copies of the TDG abatement plan and water quality monitoring plan, as well as a complete copy of the new license for Box Canyon Dam, can be found on the PUD's website: www.popud.com/license.htm.

Boundary Dam

By contrast to Box Canyon Dam, Boundary Dam is in the relatively early stages of FERC relicensing. Seattle City Light will need to apply for the new FERC license for Boundary Dam and water quality certification from Ecology by September 2009.

The utility is currently designing and conducting studies to sort out the environmental and other effects of the dam. The results of these studies will help guide development of protection, mitigation and enhancement measures for the FERC license, and will help identify water quality conditions that need to be incorporated into Ecology's 401 certification. Seattle City Light filed their Draft Study Plan with FERC in October 2006 and their Revised Study Plan in February 2007. The electronic version of Seattle City Light's study plan for Boundary Dam is available on the web at: www.ci.seattle.wa.us/light/news/isssues/bndryRelic/br_document.asp.

The Revised Study Plan (Appendix D) identifies 24 individual study plans. One of these plans, *Evaluation of TDG and Potential Abatement Measures,* is relevant to this TMDL. SCL developed the TDG study plan in consultation with the Water Quality Work Group set up to help SCL with their relicensing project. Organizations participating in the work group include:

- British Columbia Hydro.
- Columbia Power Corporation.
- Columbia River Intertribal Fisheries Commission.
- Confederated Tribes of the Colville Reservation.
- Pend Oreille County Noxious Weed Control Board.
- Pend Oreille County Public Utility District (PUD).
- Ponderay Newspring.
- Teck Cominco.
- The Kalispel Tribe of Indians.
- U.S. Fish and Wildlife Service.
- USDA Forest Service.
- Washington Department of Fish and Wildlife.
- Washington State Department of Ecology.

In 2003 and 2004, approximately 30 alternatives to reduce TDG were identified by SCL. Twenty-four of the original 30 alternatives were preliminarily assessed by SCL as documented in the July 2005 options matrix. These 24 options were further evaluated, ranked, and narrowed down based on a set of criteria which included potential reduction in TDG; how easy the alternative would be to construct, operate, and maintain; cost; dam safety; plus effects on fish and other resources.

Based on this analysis, the six most technically promising alternatives were placed on the shortlist for more detailed evaluation. One or several of these alternatives may ultimately become part of SCL's final TDG Abatement Plan for Boundary Dam. These six alternatives are (See Revised Study Plan on SCL's website listed previously):

- Throttle sluice gates.
- Roughen Sluice Gate Discharge.
- New Right Abutment Tunnel with Submerged Discharge.
- New left Abutment tunnel Intercepts Diversion Tunnel.
- Penstock/Draft Tube By-Pass.
- New Short Left Abutment Tunnel.

Who needs to participate?

Box Canyon Dam: Pend Oreille PUD will be responsible for implementing provisions of their FERC license. To access the PUD's FERC license, go to: www.popud.com/license.htm. The Pend Oreille PUD should keep the public, as well as the Kalispel Tribe, Idaho DEQ, Ecology, the Tri-State Water Quality Council, and the EPA informed of the status of the project.

Boundary Dam: Seattle City Light will be responsible for implementing provisions of their study plan and provisions of their new FERC license. Seattle City Light should keep the public, as well as the Kalispel Tribe, Idaho DEQ, Ecology, the Tri-State Water Quality Council, and the EPA informed of the status of the project.

What is the schedule for achieving water quality standards?

The goal of this TMDL is to reduce TDG concentrations in the Pend Oreille River so that levels meet Washington State water quality standards. Interim targets and milestones are necessary measures of success to meeting that end.

Box Canyon Dam

The schedule for implementing the various elements of the TDG abatement plan for Box Canyon Dam is designed to reach compliance with the state's TDG standard within 10 years of the date FERC issued the new license for the project (July 11, 2005). This is consistent with the 401 certification and WAC 173-201A-510(5) *Compliance Schedules for Dams.*

Table IS-1 lists milestones and shows the schedule for implementing the TDG abatement plan for Box Canyon Dam.

Boundary Dam

The study plan elements will be completed from 2007 through 2009. Depending on the actual duration to conduct specific tasks within the study plan, completion of specific tasks may extend beyond 2009. The attached Appendix D contains projected interim and final timelines for the achievement of the target load reductions identified in the technical sections of this report. Seattle City Light's Revised Study Plan for TDG is a flexible approach designed to complete a sequence of tasks based on current knowledge of gas abatement measures. The FERC has issued their study plan determination (March 2007) and approved Study No. 3 as the TDG study plan (Appendix D). Seattle City Light will commit to the elements of the Revised Study Plan The Revised Study Plan is designed to significantly reduce TDG by changing operations consistent with the 401 certification application process. Ten years from EPA's approval of this TMDL is the time frame given to meet clean water standards for TDG on the Pend Oreille River.

Table IS-1. Schedule for implementing PUD's gas abatement plan

Start Date	Completion Date	Activity
Phase 1 (Years 2005-2012)		
Year 1	Year 7	--
Year 1	Year 3	Testing of alternate gates settings for existing gates; testing schedule is dependent on river flow
Year 1	Year 1	Final design turbine upgrades
Year 2	Year 7	Install turbine upgrades
Year 3	Year 7	Final design for auxiliary bypass
	Annually 4/1 – 10/31	TDG monitoring in Box Canyon forebay
	Annually 4/1 – 7/15	TDG monitoring 1 mile downstream of spillway
May Year 7	June Year 7	Short duration TDG monitoring in turbine tailrace
December Year 1	December Year 7	Annual progress and monitoring report
Phase 2 (Years 2011-2013)		
Year 6	Year 9	Schedule will be accelerated if phase 1 requires less than 7 years
Year 6	Year 7	Final design auxiliary bypass. Prepare and submit Hydraulic Permit Application
Year 8	Year 10	Auxiliary bypass construction
	Annually 4/1 – 10/31	TDG monitoring in Box Canyon forebay
	Annually 4/1 – 7/15	TDG monitoring in tailrace
December Year 8	December Year 9	Annual progress and monitoring report
Phase 3 (Years 2015-2020)		
Year 10	Life of license	
Year 10	Annually 4/1 – 10/31	TDG monitoring in Box Canyon forebay during spill season until Ecology determines monitoring is no longer needed
Year 10	Annually 4/1 – 7/15	TDG monitoring within auxiliary spillway tailwater, turbine tailwater, and 1 mile downstream of spillway
Year 13	Life of license	TDG monitoring at only one downstream location; subject to Ecology confirmation of abatement measures achieving compliance
Year 11	Year 15	Evaluate the need and options for other reasonable TDG abatement measures
Year 12	Year 15	Design and implement any necessary additional TDG abatement measures
December Year 10	Life of license	Annual progress and monitoring reports until Ecology notifies PUD that TDG monitoring is no longer necessary
Year 13	Year 13	TDG monitoring on downstream spatial grid if compliance is not met
Year 15		Prepare Use Attainability Analysis (UAA) if compliance not met

Reasonable assurances

When establishing a TMDL, reductions of a particular pollutant are allocated among the pollutant sources (both point and nonpoint) in the waterbody. For the Pend Oreille River TDG TMDL, only nonpoint sources exist. TMDLs (and related Action Plans) must show "reasonable assurance" that these sources will be reduced to their allocated amount. FERC license administration and enforcement will be used to ensure that the goals of this water cleanup plan are met.

Ecology believes that activities in the Pend Oreille River watershed are already supporting this TMDL and add to the assurance that TDG in the Pend Oreille River will meet conditions provided by Washington State water quality standards. This assumes that activities contained in this report and in the FERC licenses of Box Canyon and Boundary Dams are continued and maintained.

Box Canyon Dam: The TDG abatement plan and its implementation schedule map out a strategy for bringing Box Canyon Dam into compliance with the state's water quality standards for TDG. Preparing and following a TDG abatement plan is one requirement included in the 401 certification for the dam. Since the conditions of the 401 certification are also conditions of the new FERC license, the TDG abatement plan is a license requirement. License conditions are mandatory and enforced by FERC. A copy of the new license for Box Canyon Dam can be found on the PUD's website: www.popud.com/license.htm.

Boundary Dam: The goal of this Pend Oreille Water Quality Improvement Report for TDG is for the waters of the Pend Oreille River to meet the state's water quality standards. Seattle City Light is in the process of FERC relicensing, and conditions for the license obligate Seattle City Light to take steps to address the TDG issue in the Pend Oreille River. In response to license requirements, Seattle City Light drafted a study plan (Appendix D). The study plan outlines possible approaches to reduce TDG.

In addition to the measures Box Canyon and Boundary Dams agreed to, there is considerable interest and local involvement toward resolving other water quality problems in the Pend Oreille River. Numerous organizations and agencies are already engaged in stream restoration and source correction actions that will help resolve water quality issues. Depending on the actual duration to conduct specific tasks within Phases 1 and 2 of the study plan (Appendix D), completion of specific tasks may extend beyond 2009.

While Ecology is authorized under Chapter 90.48 RCW to impose strict requirements or issue enforcement actions to achieve compliance with Washington State water quality standards, it is the goal of all participants in the Pend Oreille River TDG TMDL process to achieve clean water through voluntary control actions. However, Ecology will consider and issue notices of noncompliance in accordance with the Regulatory Reform Act in situations where the cause or contribution of cause of noncompliance with load allocations can be established.

Location of compliance areas

During a spill, aerated zones exist below Box Canyon and Boundary Dams. The size of that zone varies with flow and the amount of spill. However, current information suggests that the existing monitoring stations are placed appropriately to determine compliance with the water quality standards in the area immediately below the aerated zones. Therefore:

1. The compliance area below Box Canyon will begin approximately 3000 feet downstream of the dam spillways near the current tailwater monitoring stations.
2. The compliance area below Boundary Dam will begin approximately 4,500 feet below the dam spillways at the current tailwater monitoring stations.

The area of the river from each dam to the beginning of the compliance area below the dam is excluded from compliance with the allocations in this TMDL.

Adaptive management

TMDL reductions should be achieved within ten years of completion of the Water Quality Implementation Plan (WQIP). However, if water quality standards are met before the load reductions are met, the purpose of this TMDL shall be satisfied. The status of this TMDL will be reevaluated every five years.

Adjustments will be made to the cleanup strategy as needed. It is ultimately Ecology's responsibility to ensure that cleanup is being actively pursued and water standards are achieved.

Adaptive management is defined in state law as "*reliance on scientific methods to test the results of actions taken so that the management and related policy can be changed promptly and appropriately*" (RCW 79.09.020).

The key stages of the adaptive management cycle are to "monitor", "evaluate", and "respond." Adaptive management is a continuing attempt to adapt to uncertainty associated with management actions.

Adaptive management is used if water quality monitoring data show that the TMDL targets are not being met. A feedback loop is implemented consisting of the following three steps:

Step 1. The water quality implementation plan and associated action items are put into practice. Programs and on-site best management practices (BMPs) are evaluated for technical adequacy of design and installation.

Step 2. The effectiveness of the water quality implementation plan in achieving the goal and objectives is evaluated by comparison to water quality monitoring data. If the goal and objectives are achieved, the implementation efforts are adequate as designed, installed, and maintained. If not, the plan is modified and objectively reevaluated.

Step 3. Project success and accomplishments should be publicized and reported to continue project implementation and support.

Summary of public involvement methods

This is a multi-state, multi-agency TMDL. Idaho DEQ, the Kalispel Tribe, the Tri-State Water Quality Council, and the Washington State Department of Ecology, with assistance from the EPA, are cooperating in the development of TMDLs in the Pend Oreille/Clark Fork watershed. An advisory group, made up of citizens and agencies from Idaho and Washington, met on October 20, 2005, May 25, 2006, and January 25 and March 20, 2007. The Tri-State Water Quality Council is coordinating and facilitating the public involvement portion of this TMDL.

Seattle City Light held workshops on the Boundary Dam Project relicensing in Spokane, Washington, on November 30, 2005, and February 16, 2006. Water Quality Workgroup meetings were held in Spokane on May 22, July 25, and August 16, 2006, and in Metaline Falls, Washington, on June 29, 2006. Parties attending the Water Quality Workgroup meetings included Ecology, U.S. Forest Service, U.S. Fish and Wildlife Service, Confederated Tribes of the Colville Reservation, the Kalispel Tribe of Indians, Columbia River Intertribal Fisheries Commission, BC Hydro, Pend Oreille County PUD, and Columbia Power Corporation.

Prior to filing the application for their new license, and for 401 water quality certification, the Pend Oreille PUD organized a Water Quality Work Group to provide comments on the various water quality studies as feedback on related protection and enhancement measures. The group met periodically from approximately early 1997 through 1999. Participants included representatives from several state and federal agencies, the Kalispel Tribe, Pend Oreille County government, and the public.

This Water Quality Improvement Plan went through a 30-day public comment period from August 6 until September 5. The comment period was advertised in the following papers:

- Newport Miner
- Miner Extra

A news release was also issued to area newspapers. Appendix C has more information concerning public involvement.

Potential funding sources

Funding for carrying out provisions of Box Canyon's FERC license will come from the Pend Oreille PUD.

Funding for the Boundary Dam study project will come from Seattle City Light's budget.

Next steps

Following edits and responses to public comments (Appendix E), the final version of this draft report will be submitted to the EPA for formal review and approval. Once EPA approves the TMDL, a *Water Quality Implementation Plan* must be developed within one year. Elements of this plan include who will commit to do what, how will we measure effectiveness, what if it doesn't work, and potential funding sources.

Box Canyon Dam: Staff with Box Canyon Dam will be responsible for adhering to the provisions set forth in their FERC license. It will be Ecology's responsibility to monitor Box Canyon Dam's progress, through the permit process.

Boundary Dam: Ecology usually works with local citizens to create this plan, but in this instance, Ecology will work primarily with Seattle City Light for Boundary Dam, choosing the combination of possible solutions that will be most effective in the Pend Oreille River.

Once this TMDL is in place, Ecology will strive to coordinate with other agencies and entities involved with implementation activities in the Pend Oreille River watershed.

Effectiveness monitoring plan

A TMDL must include monitoring to measure achievement of targets and water quality standards. Monitoring also provides evidence that actions taken by the Pend Oreille PUD and Seattle City Light are having the desired results.

A quality assurance project plan (QAPP) should be prepared for whatever effectiveness monitoring is conducted. The QAPP should follow Ecology guidelines (Lombard and Kirchmer, 2004), paying particular attention to consistency in sampling and analytical methods.

Seattle City Light plans to adopt an effectiveness monitoring plan for Boundary Dam to verify the TDG exchange process and uptake mechanisms in the forebay, turbine discharge area (afterbay), tailwater channel, and other locations will be adopted. This will require planning, procuring, installation, collection of TDG data, and retrieval of TDG monitoring transects. The collected TDG data will comply with or exceed current USGS quality assurance/quality control methods for water quality instruments, calibration, maintenance, and precision.

The purpose of effectiveness monitoring is to discover if management activities and BMPs are improving water quality. Effectiveness monitoring results are used to determine if the interim targets and/or water quality standards are being achieved. Ecology usually performs this monitoring five years after the *Water Quality Implementation Plan* is finished.

Ecology should conduct effectiveness monitoring for TDG levels after five years. The ability for Ecology to conduct the monitoring in five years depends on the availability of resources. If the streams are found to not meet the interim targets and/or water quality criteria, an adaptive management strategy will be adopted and future effectiveness monitoring will need to be scheduled.

Entities with enforcement authority will be responsible for following up on any enforcement actions. Those conducting restoration projects or installing BMPs will be responsible for effectiveness monitoring as well as maintaining improvements and structures.

References

APHA , AWWA, and WEF, 2005. Standard Methods for the Examination of Water and Wastewater, 21st Edition. American Public Health Association, American Water Works Association , and Water Environment Federation, Alexandria, VA.

Avista, 1999. Appendices to the Clark Fork Settlement Agreement: Protection, Mitigation and Enhancement Measures. Appendix F5: Dissolved Gas Supersaturation Control, Mitigation, and Monitoring. Avista Utilities, Spokane, WA. www.avistautilities.com/resources/hydro/clarkfork/assets/02-1999_Clark_Fork_Settlement_Agreement.pdf

Colt, John, 1984. Computation of Dissolved Gas Concentrations in Water as Functions of Temperature, Salinity, and Pressure. American Fisheries Society Special Publication No. 14.

Easthouse, K.B. and A.S. Klein, 2004. Total Dissolved Gas and Temperature Monitoring at Chief Joseph Dam, Washington, Albeni Falls Dam, Idaho and Libby Dam, Montana 2004: Data Review and Quality Assurance. Draft Report, U.S. Army Corps of Engineers, Seattle District, Hydrology and Hydraulics Section, Seattle, WA.

Easthouse, K.B. and A.S. Klein, 2005. Total Dissolved Gas and Temperature Monitoring at Chief Joseph Dam, Washington, Albeni Falls Dam, Idaho and Libby Dam, Montana 2005: Data Review and Quality Assurance. Draft Report, U.S. Army Corps of Engineers, Seattle District, Water Management Section, Seattle, WA.

Ecology, 2004. Quality Assurance Project Plan, Pend Oreille River Total Dissolved Gas Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-107. www.ecy.wa.gov/biblio/0403107.html

EPA, 2001. Overview of Current Total Maximum Daily Load - TMDL - Program and Regulations. U.S. Environmental Protection Agency. www.epa.gov/owow/tmdl/overviewfs.html

Era-Miller, B. and K. Kinney, 2005. Verification of 303(d) Listings for Fish Tissue in the Skagit and Pend Oreille Rivers. Washington State Department of Ecology, Olympia, WA. Publication No. 05-03-017. www.ecy.wa.gov/biblio/0503017.html

Kimbrough, R.A., R.R. Smith, G.P. Ruppert, W.D. Wiggins, S.M. Knowles, and V.F. Renslow, 2000. Water Resources Data, Washington, Water Year 2000. Water-Data Report WA-00-1, U.S. Geological Survey, Tacoma, WA.

Kimbrough, R.A., G.P. Ruppert, W.D. Wiggins, R.R. Smith, S.M. Knowles, and V.F. Renslow, 2001. Water Resources Data, Washington, Water Year 2001. Water-Data Report WA-01-1, U.S. Geological Survey, Tacoma, WA.

Kimbrough, R.A., W.D. Wiggins, R.R. Smith, G.P. Ruppert, S.M. Knowles, and V.F. Renslow, 2002. Water Resources Data, Washington, Water Year 2002. Water-Data Report WA-02-1, U.S. Geological Survey, Tacoma, WA.

NWPCC, 2003. "Follow-up to Columbia Basin Trust Presentation." Memorandum from Tom Karier, Vice Chair, Northwest Power and Conservation Council, November 12, 2003, Portland OR. www.nwcouncil.org/news/2003_11/12.pdf

Pend Oreille PUD, 2000. Box Canyon Hydroelectric Project Application for New License, Federal Energy Regulatory Commission No. 2042. Public Utility District No. 1 of Pend Oreille County, Newport, WA.

Pend Oreille PUD, 2001. Total Dissolved Gas Monitoring, 2001, Box Canyon Hydroelectric Project (No. 2042). Prepared by Duke Engineering & Services, Bellingham, WA.

Pend Oreille PUD, 2002. Total Dissolved Gas Monitoring, Final Report 2002, Box Canyon Hydroelectric Project (No. 2042). Prepared by Framatome ANP DE&S, Inc., Bellingham, WA.

Pend Oreille PUD, 2003. Total Dissolved Gas Monitoring, Final Report 2003, Box Canyon Hydroelectric Project (No. 2042). Prepared by Devine Tarbell & Associates, Bellingham, WA.

Pend Oreille PUD, 2005. Total Dissolved Gas Abatement Plan. Prepared by EES Consulting, Bellingham, WA.

Pickett, P., H. Rueda, and M. Herold, 2004. Total Maximum Daily Load for Total Dissolved Gas in the Mid-Columbia River and Lake Roosevelt. Washington State Department of Ecology, U.S. Environmental Protection Agency, and the Spokane Tribe of Indians. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-002. www.ecy.wa.gov/biblio/0403002.html

Schneider, M., 2006. Report Review Comments on "Boundary 2002 Spill Evaluation" and "TDG Analysis During the 2002 Spill Event". Memorandum For Record, dated 21 June 2006, City of Seattle, Seattle City Light Department (SCL), U.S. Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS.

SCL, 1998. Dissolved Gas Assessment, Boundary Dam 1998. Prepared by Parametrix, Kirkland, WA, for Seattle City Light, Seattle, WA.

SCL, 2000. Boundary Dam Total Dissolved Gas Evaluation: TDG Dynamics Associated with Power Generation, 23 June - 23 July 2000. Prepared by Columbia Basin Environmental, The Dalles, Oregon, for Seattle City Light, Seattle, WA.

SCL, 2001. Boundary Dam Total Dissolved Gas Study, 24 to 25 September 2001. Prepared by Columbia Basin Environmental, The Dalles, Oregon, for Seattle City Light, Seattle, WA.

SCL, 2003. Boundary Dam Spillway Evaluation, 1 May – 25 July 2002, Pre-decision Draft Report. Prepared by Columbia Basin Environmental, The Dalles, Oregon, for Seattle City Light, Seattle, WA.

USACE, 2001. Dissolved Gas Abatement Study - Phase II Draft Final. U.S. Army Corps of Engineers, Portland District and Walla Walla District.

USFWS, 2002. Bull Trout (Salvelinus confluentus) Draft Recovery Plan, Chapter 23. U.S. Fish and Wildlife Service, Region 1, Portland, OR.

USFWS, 2005. 50 CFR Part 17, Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Bull Trout; Final Rule. U.S. Fish and Wildlife Service. Federal Register, September 26, 2005, Part II, Washington D.C.

USGS, 2006a. National Water Information System, Washington Water Science Center, U.S. Geological Survey, Tacoma, WA.

USGS, 2006b. Personal communication. Brett Smith, Hydrologic Technician, U.S. Geological Survey, Spokane, WA.

Whiley, A., K. Baldwin, B. Cleland, 2005. Colville National Forest Temperature, Bacteria, and pH Total Maximum Daily Load (Water Cleanup Plan): Submittal Report. Washington State Department of Ecology, Olympia, WA. Publication No. 05-10-047. www.ecy.wa.gov/biblio/0510047.html

This page is purposely left blank

Figures

This page is purposely left blank

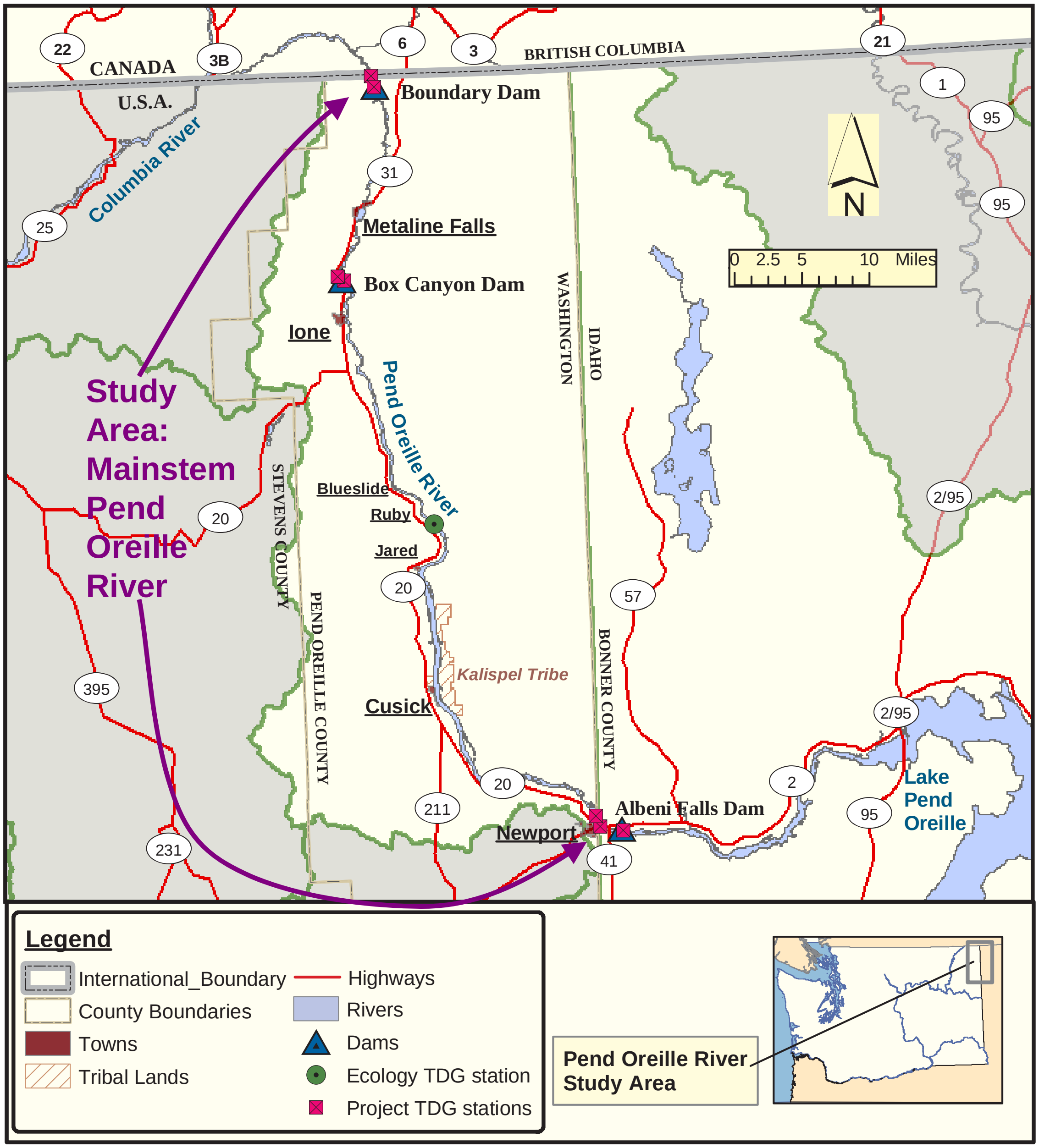


Figure 1. Pend Oreille River TDG TMDL study area (Washington), as well as upstream (Idaho) and downstream (British Columbia) neighboring areas.

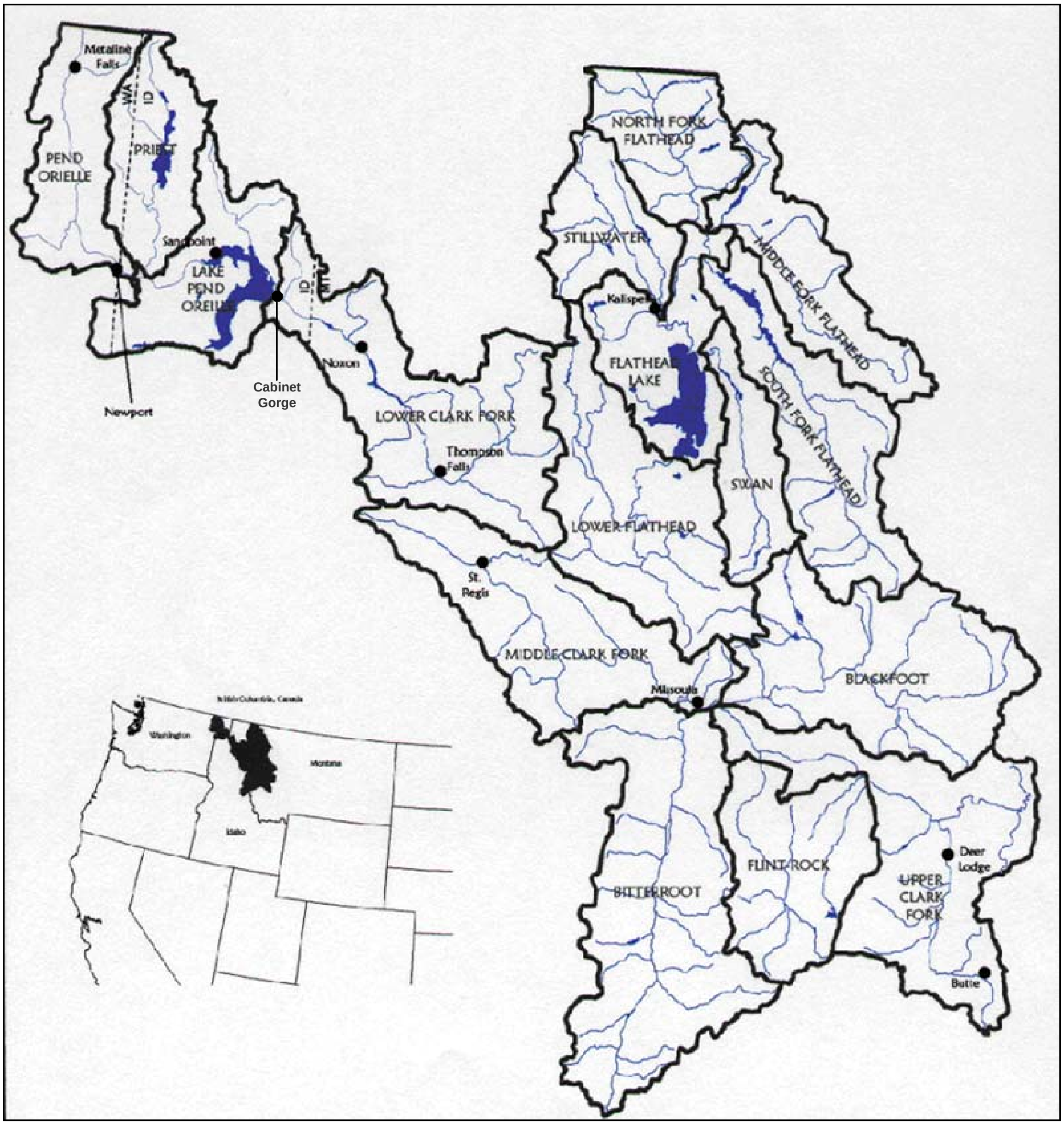


Figure 2. Clark Fork – Pend Oreille watershed boundaries.

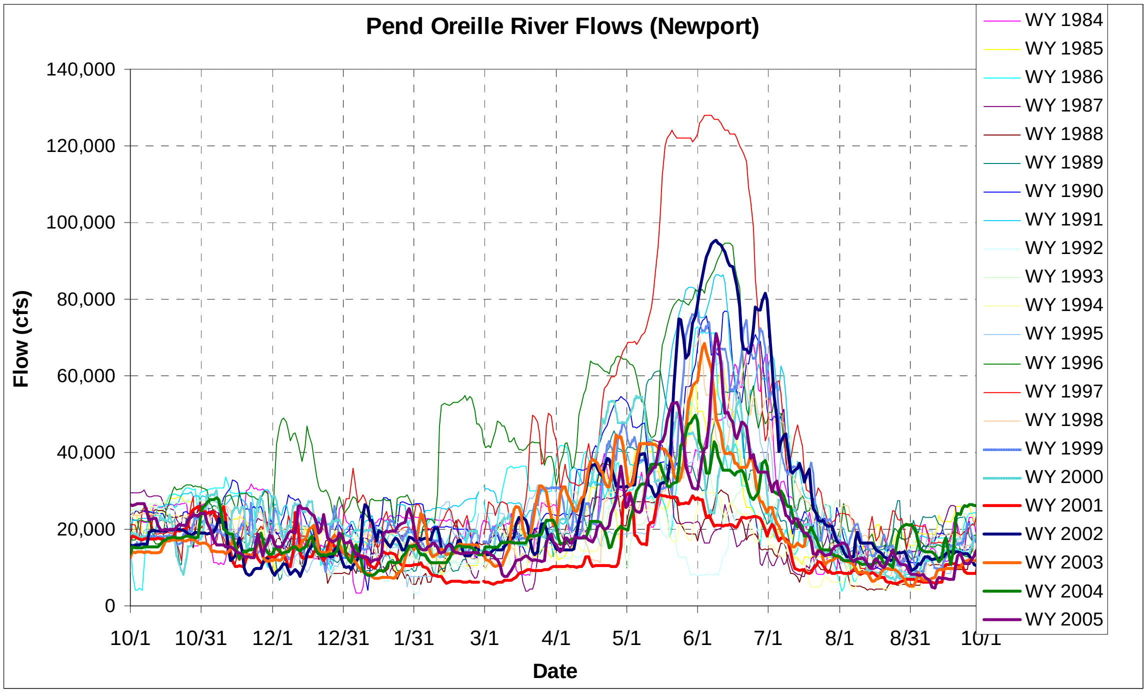


Figure 3. Pend Oreille River at Newport flows, 1984-2005.

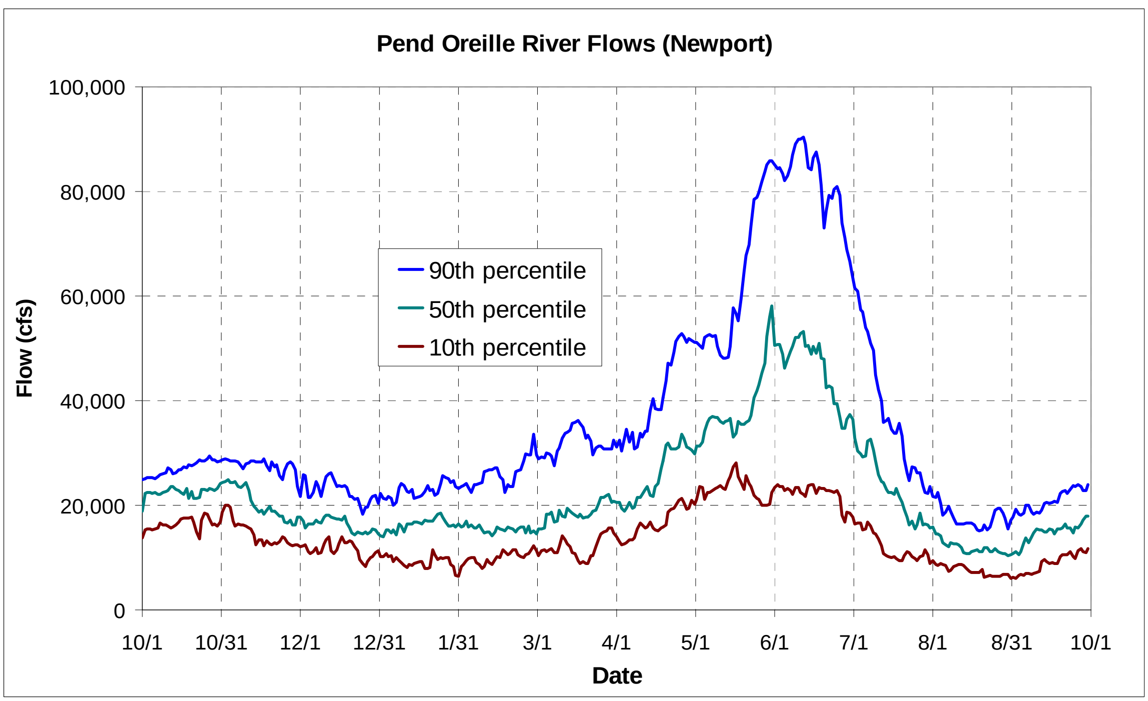


Figure 4. Distribution of daily flows, Pend Oreille River at Newport, 1984-2005.

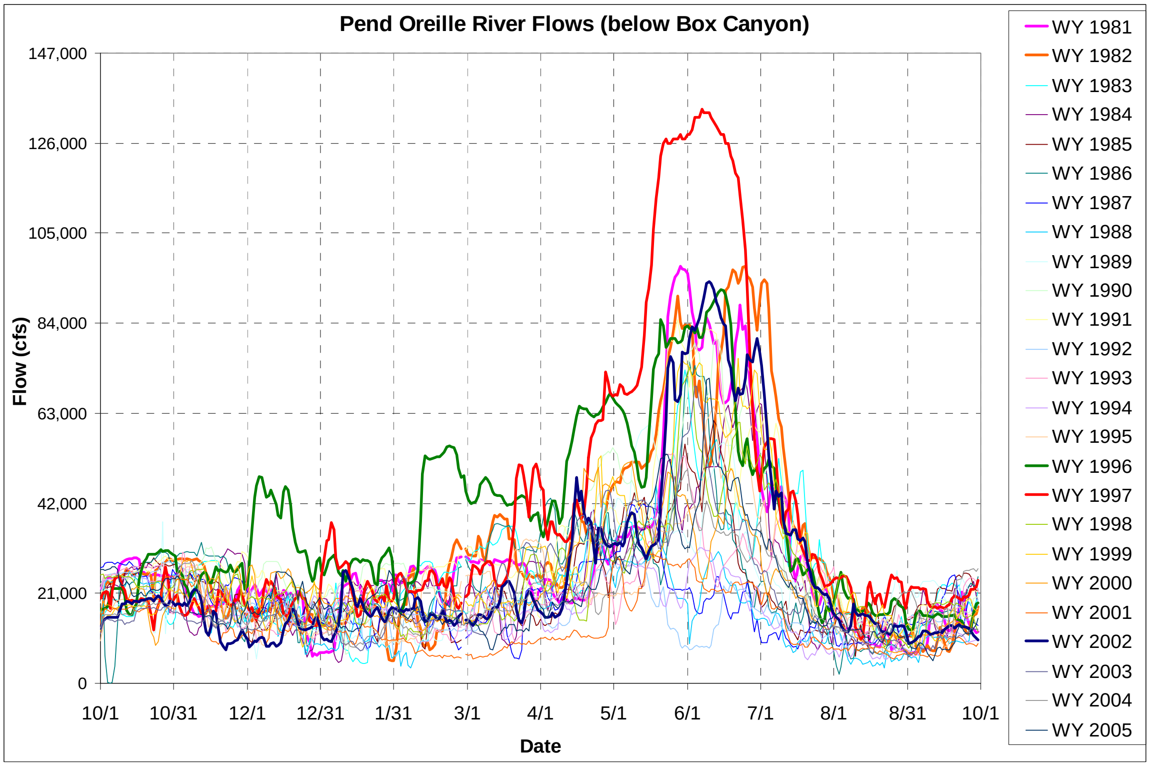


Figure 5. Flows in the Pend Oreille River below Box Canyon near Ione, 1984-2005.

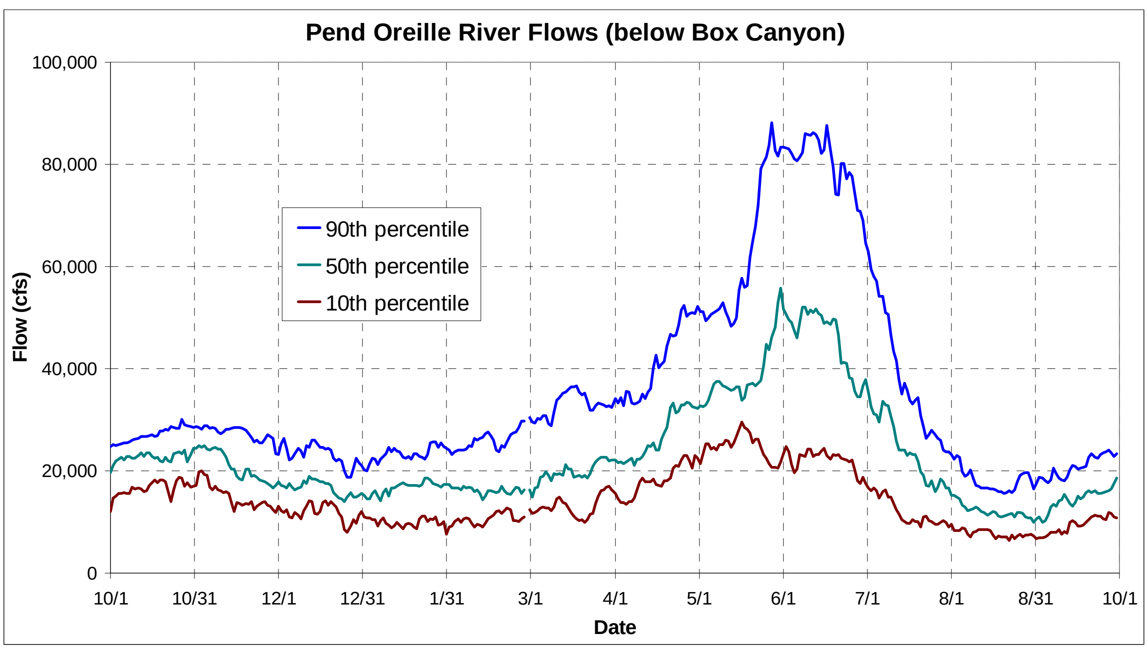


Figure 6. Distribution of daily flows, Pend Oreille River below Box Canyon near Ione, 1984-2005.

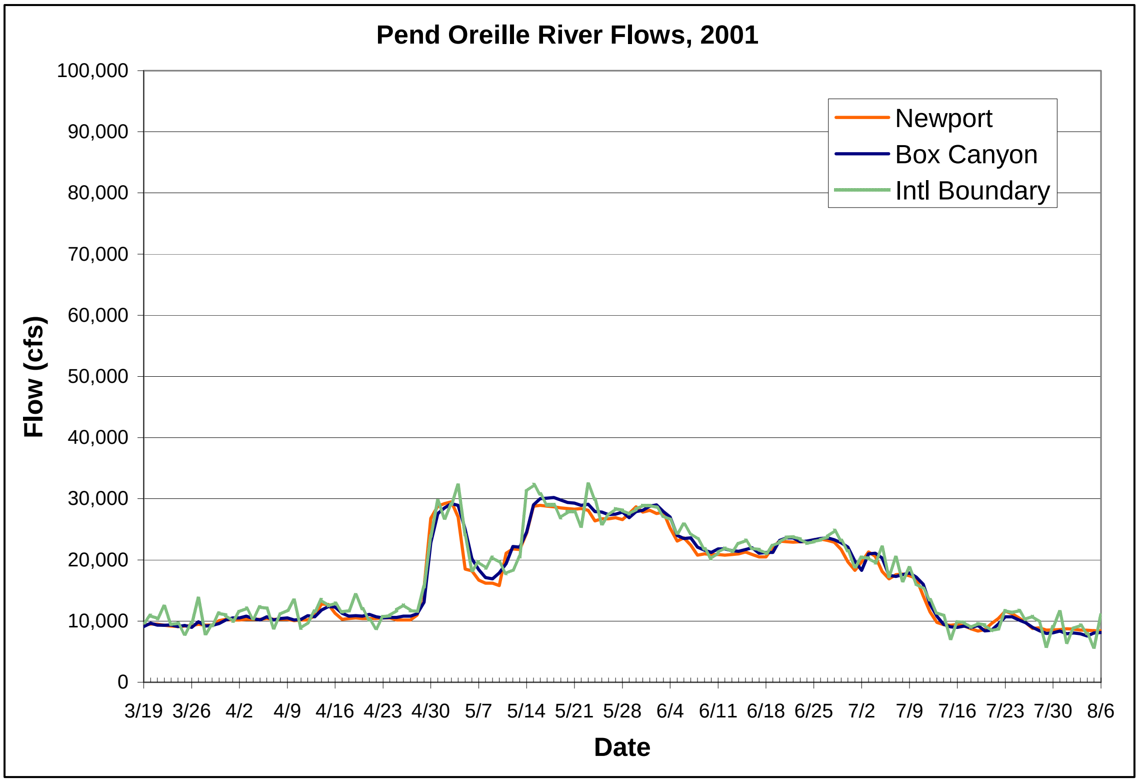


Figure 7. Pend Oreille River spill season flows, 2001.

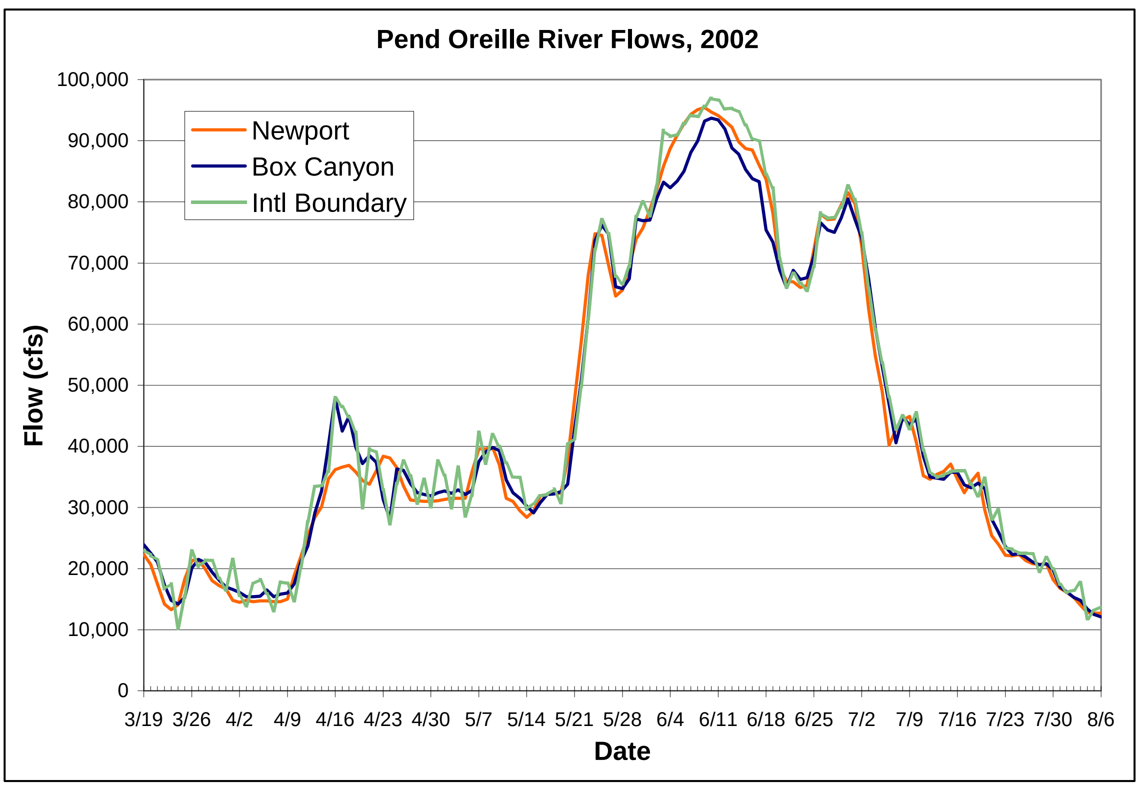


Figure 8. Pend Oreille River spill season flows, 2002.

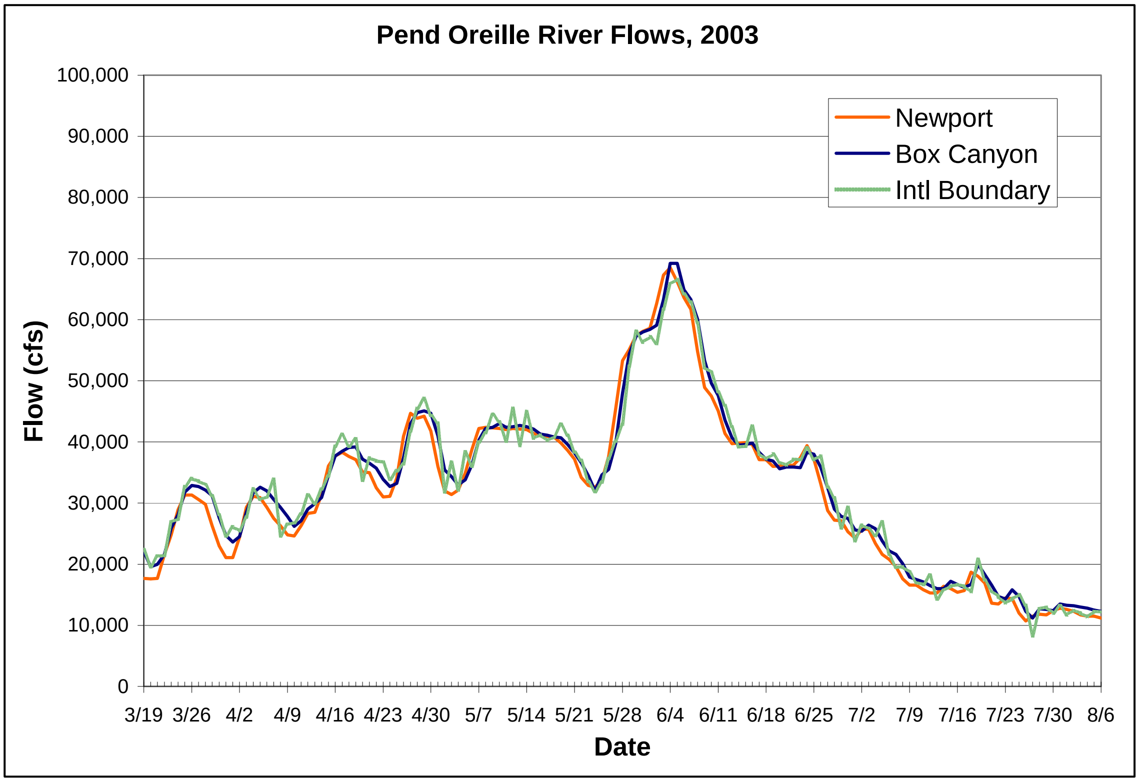


Figure 9. Pend Oreille River spill season flows, 2003.

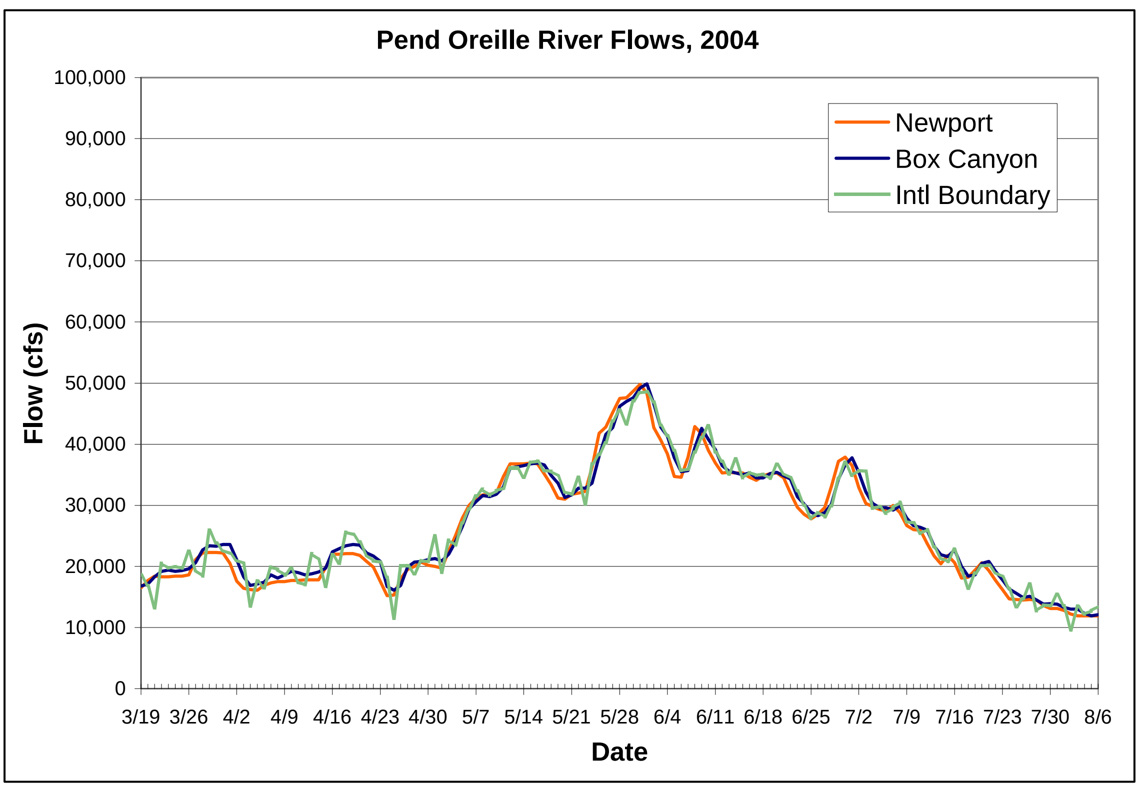


Figure 10. Pend Oreille River spill season flows, 2004.

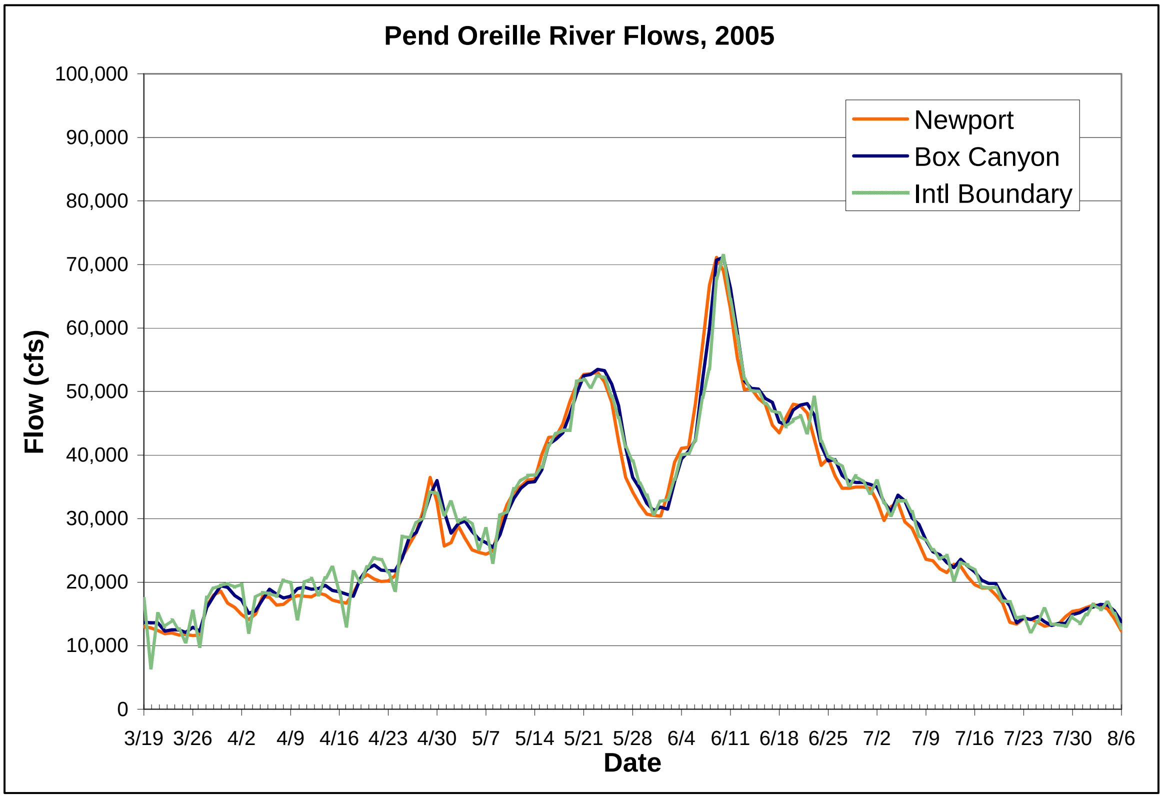


Figure 11. Pend Oreille River spill season flows, 2005.

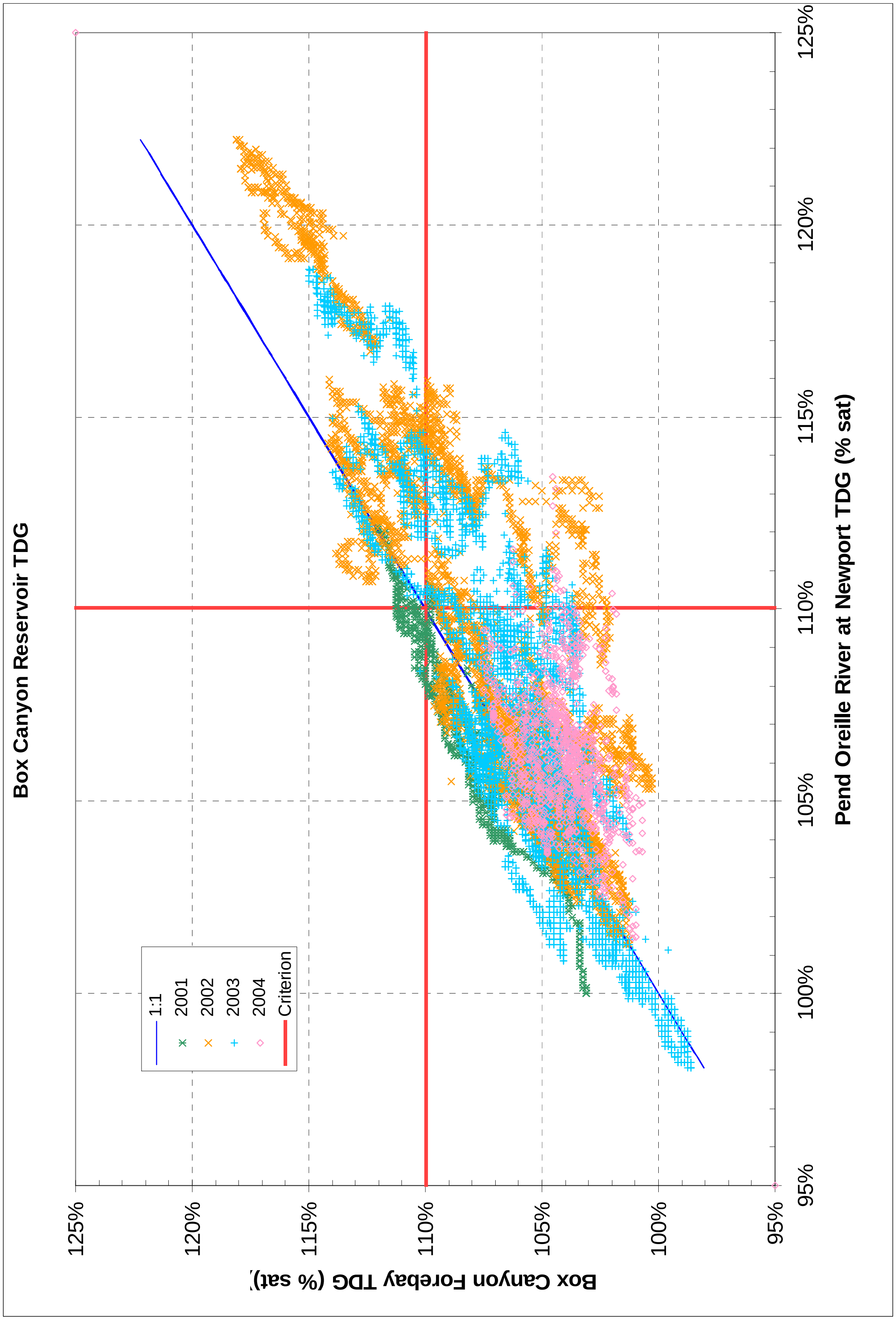


Figure 12. Pend Oreille River TDG, Newport vs. Box Canyon Dam forebay.

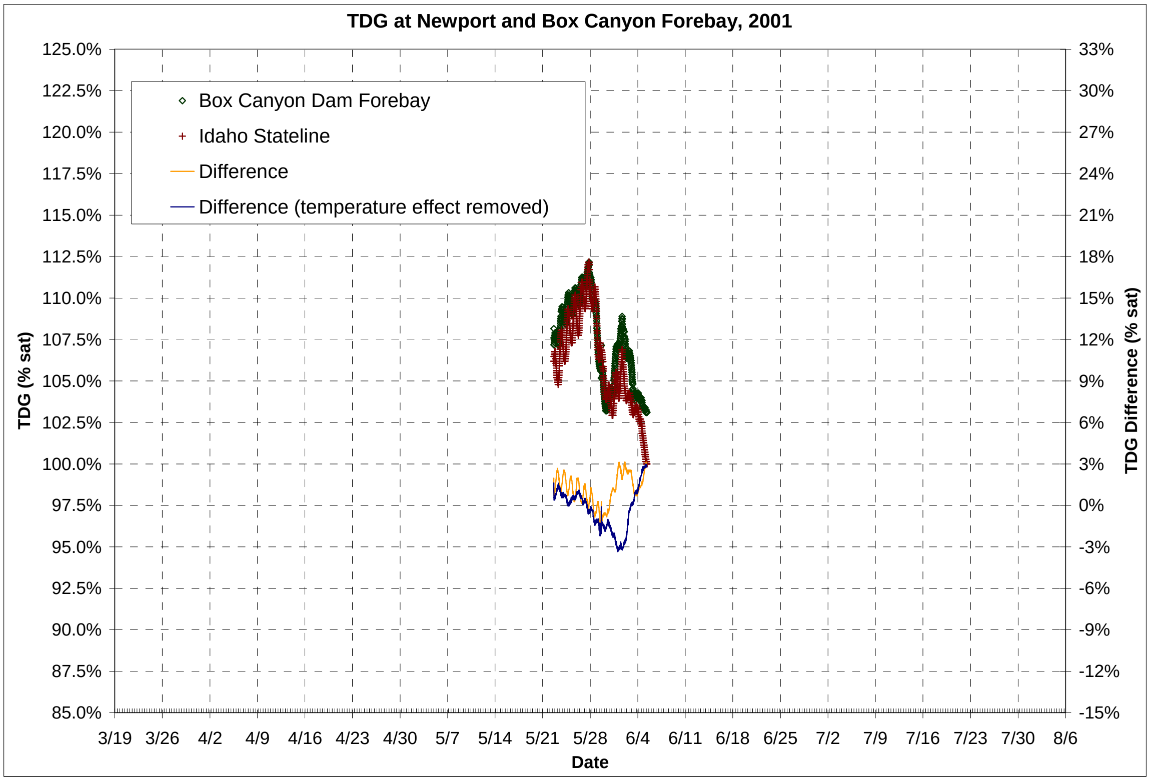


Figure 13. Pend Oreille River TDG, Newport and Box Canyon Dam, 2001.

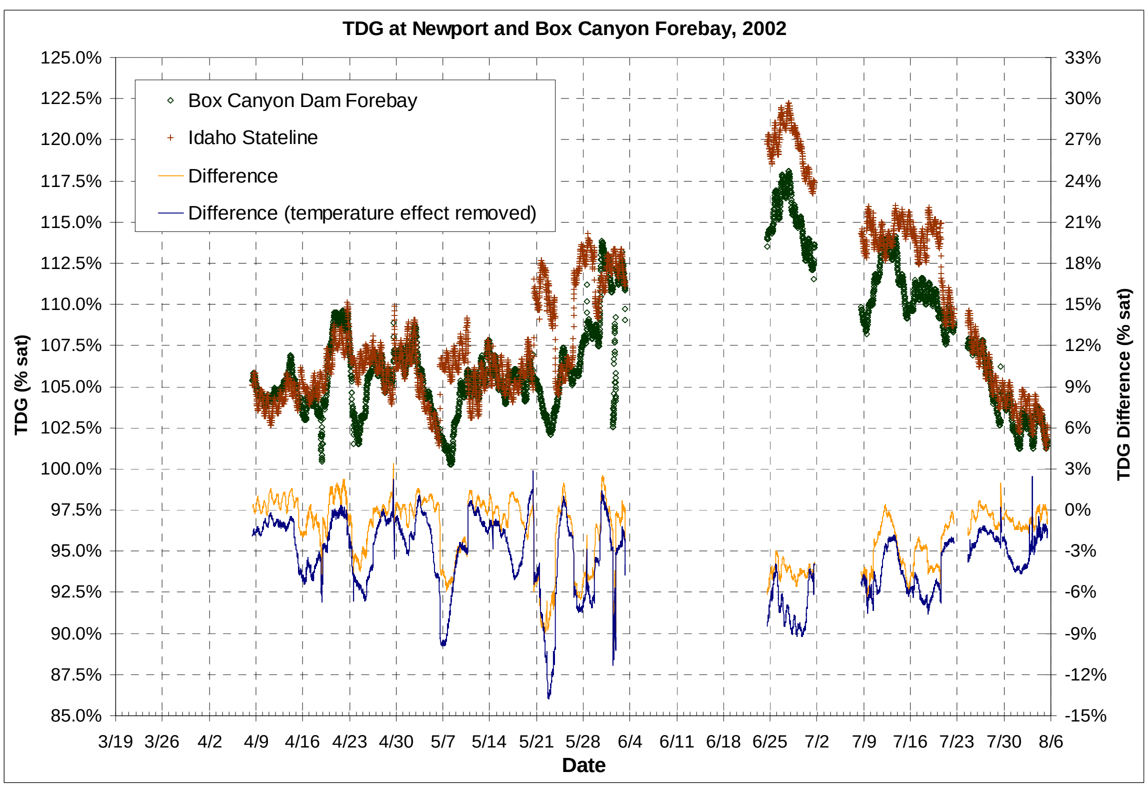


Figure 14. Pend Oreille River TDG, Newport and Box Canyon Dam, 2002.

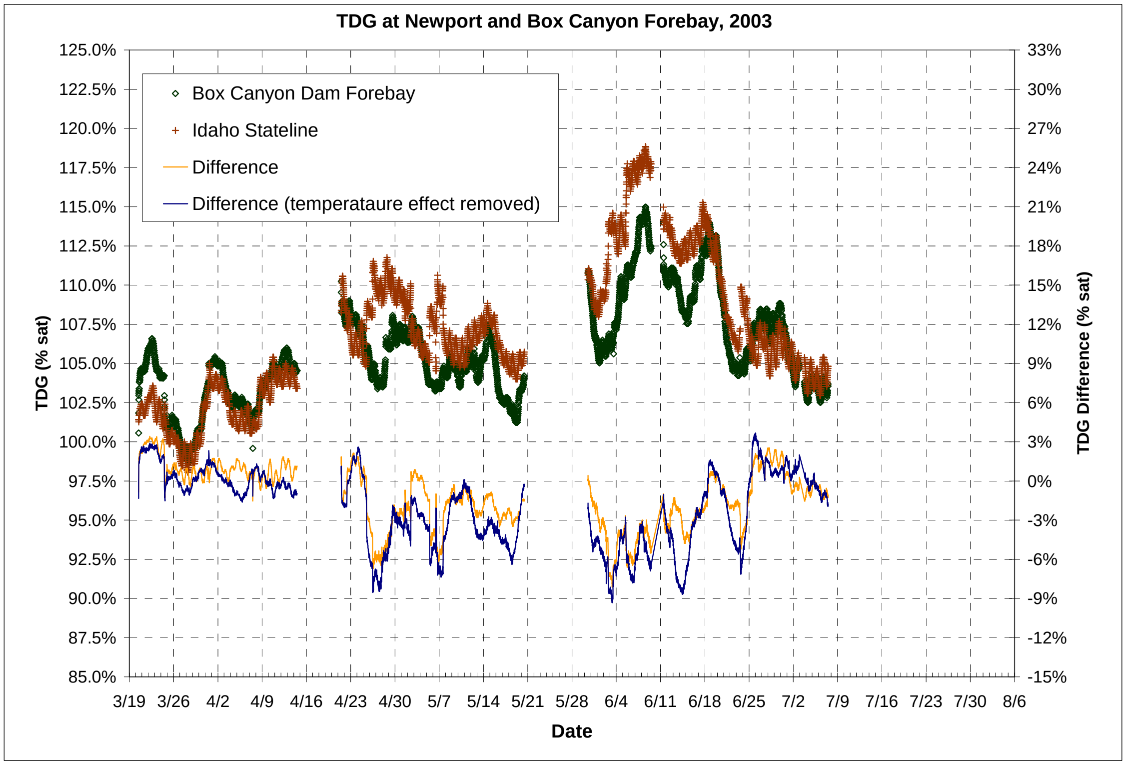


Figure 15. Pend Oreille River TDG, Newport and Box Canyon Dam, 2003.

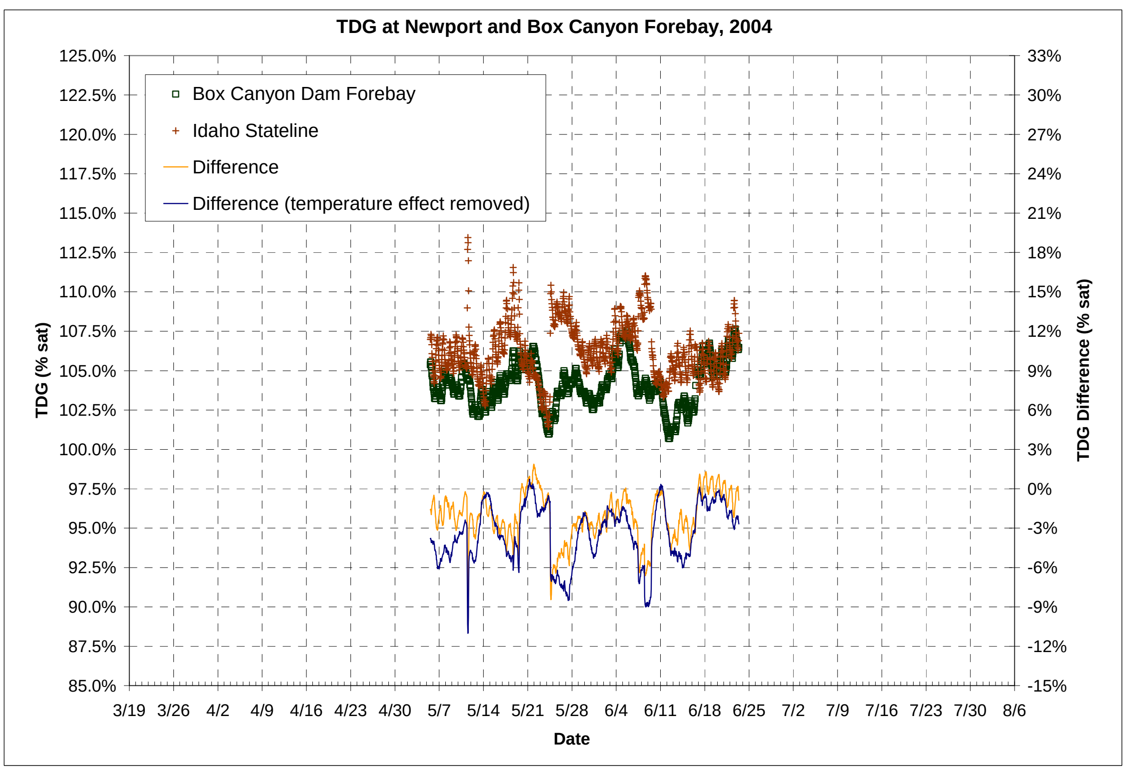


Figure 16. Pend Oreille River TDG, Newport and Box Canyon Dam, 2004.

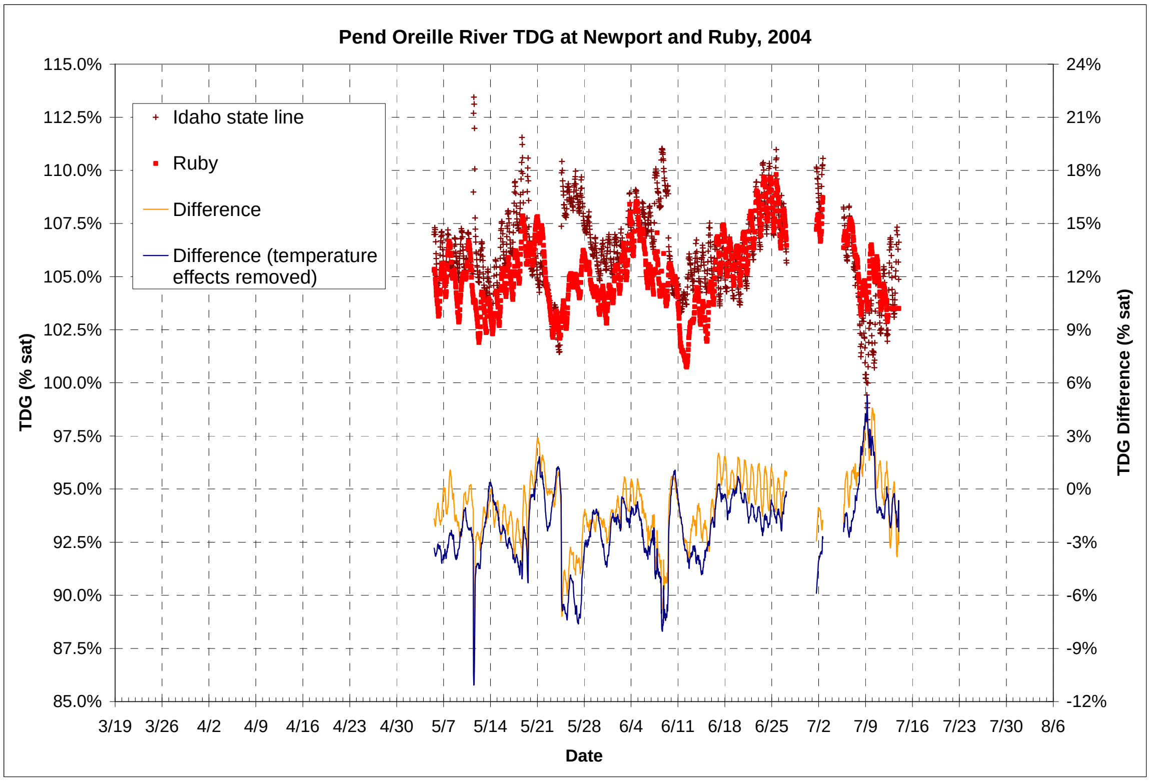


Figure 17. Pend Oreille River TDG, Newport and Ruby, 2004.

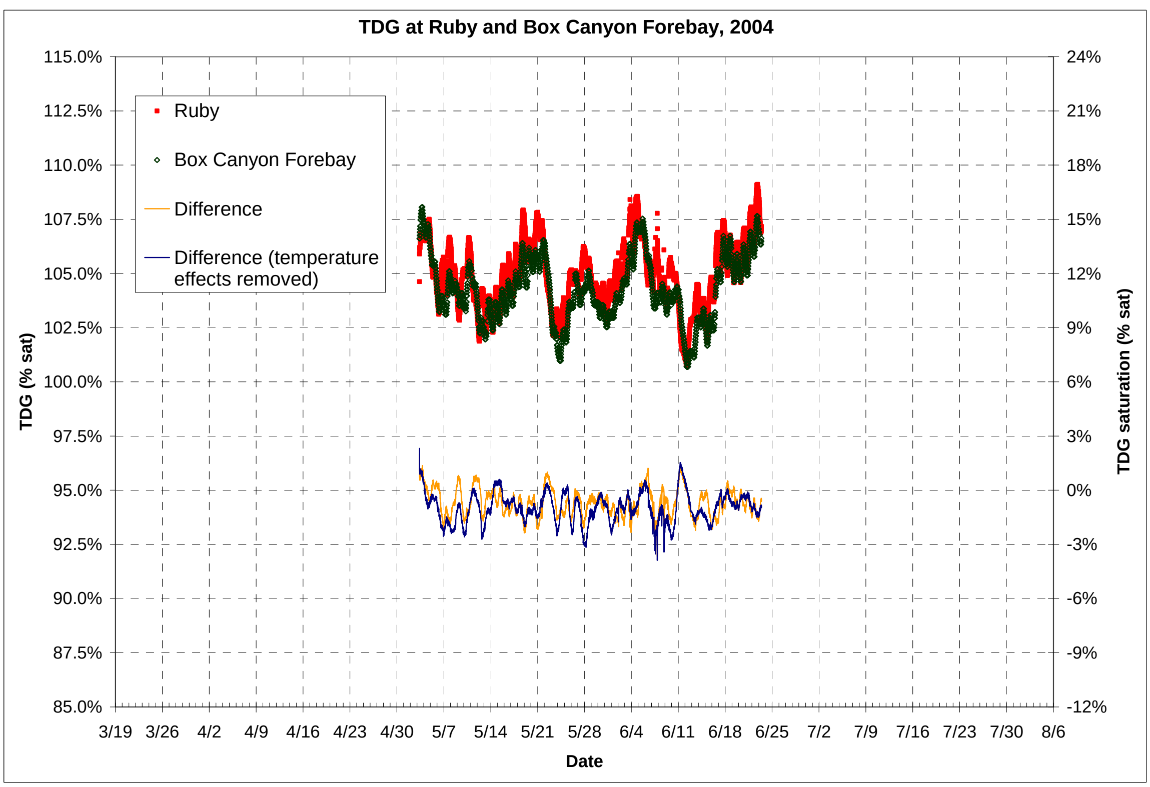


Figure 18. Pend Oreille River TDG, Ruby and Box Canyon Dam, 2004.

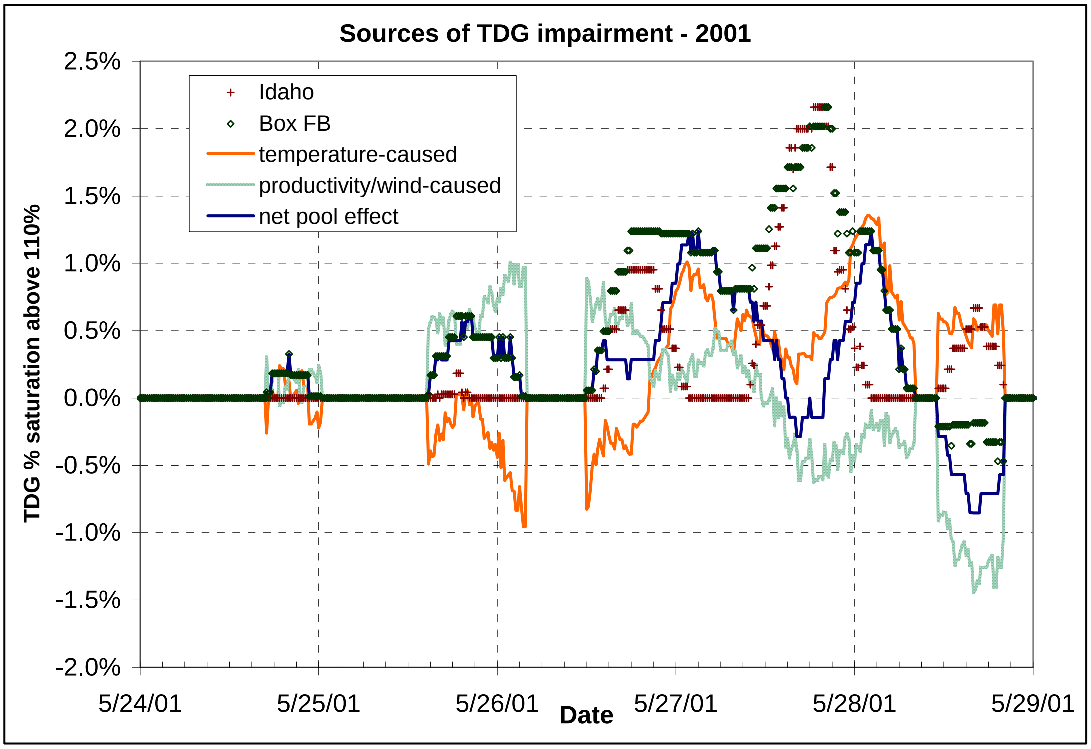


Figure 19. Pend Oreille River TDG sources of impairment, Newport and Box Canyon Dam, 2001, stable data.

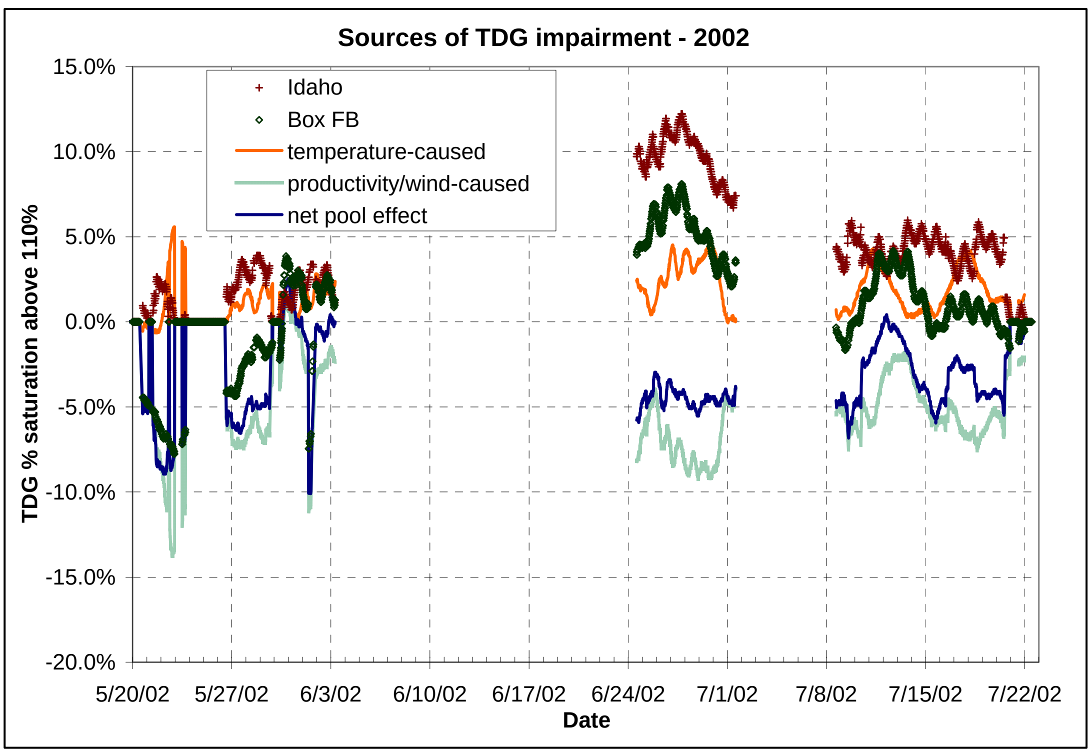


Figure 20. Pend Oreille River TDG sources of impairment, Newport and Box Canyon Dam, 2002, stable data.

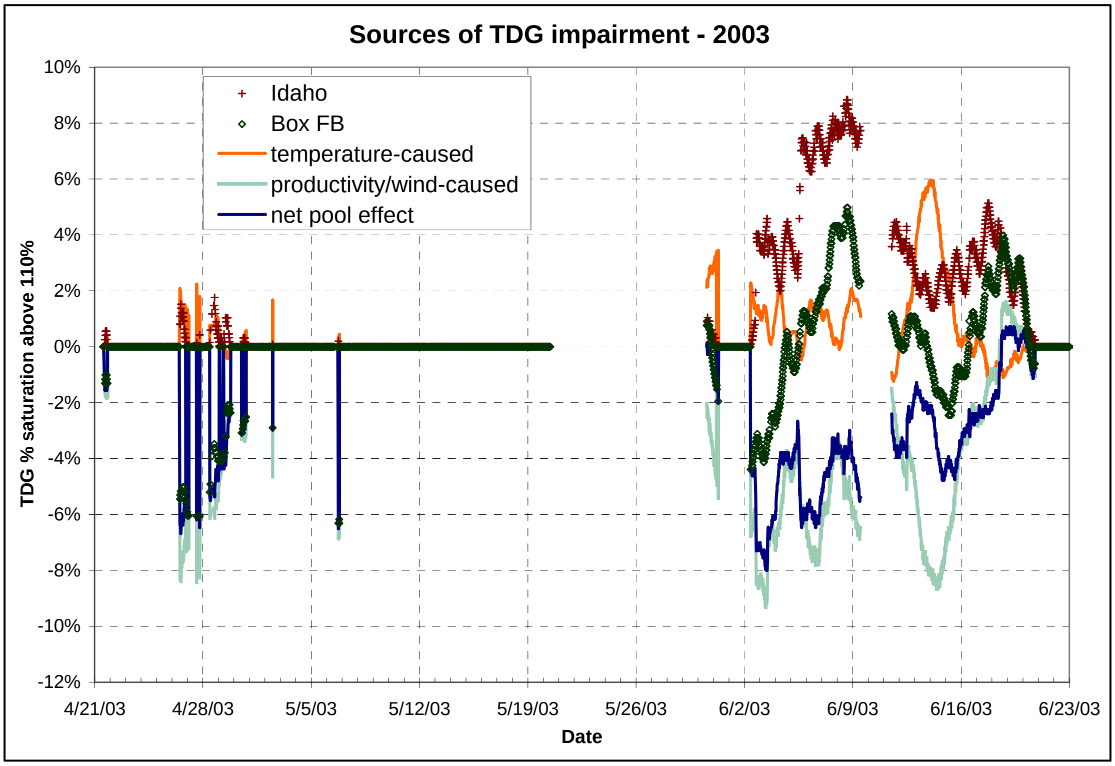


Figure 21. Pend Oreille River TDG sources of impairment, Newport and Box Canyon Dam, 2003, stable data.

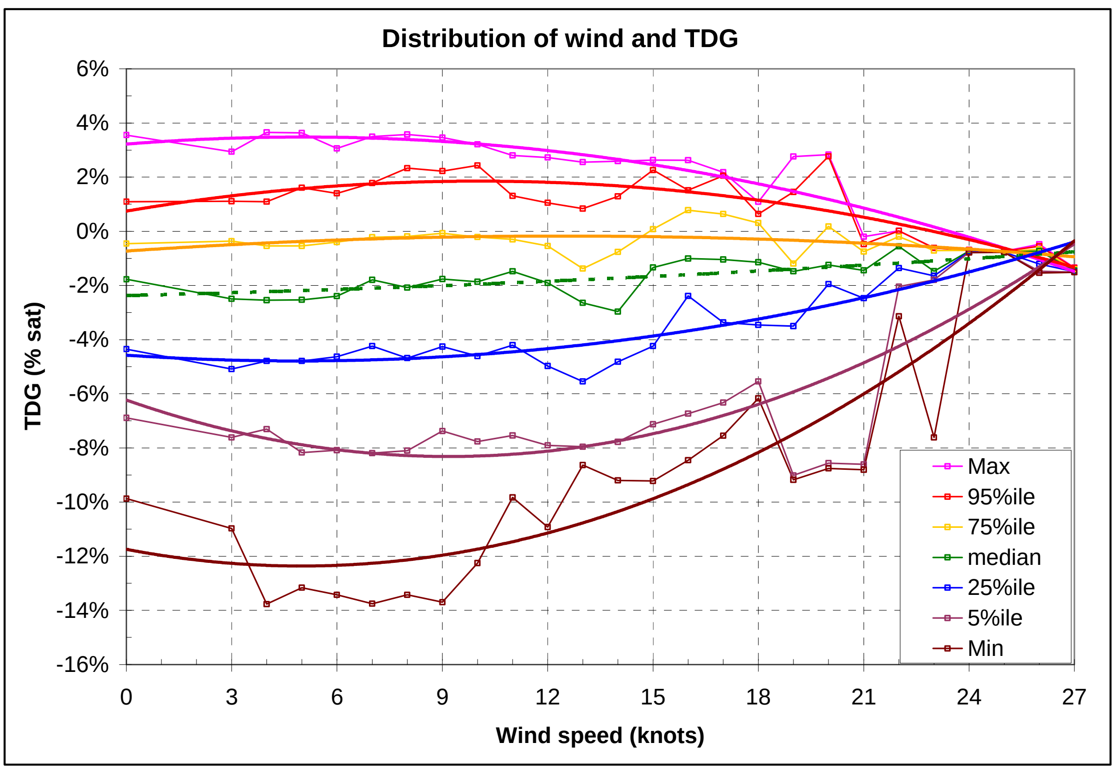


Figure 22. Distribution of TDG change due to wind or productivity, by wind speed.

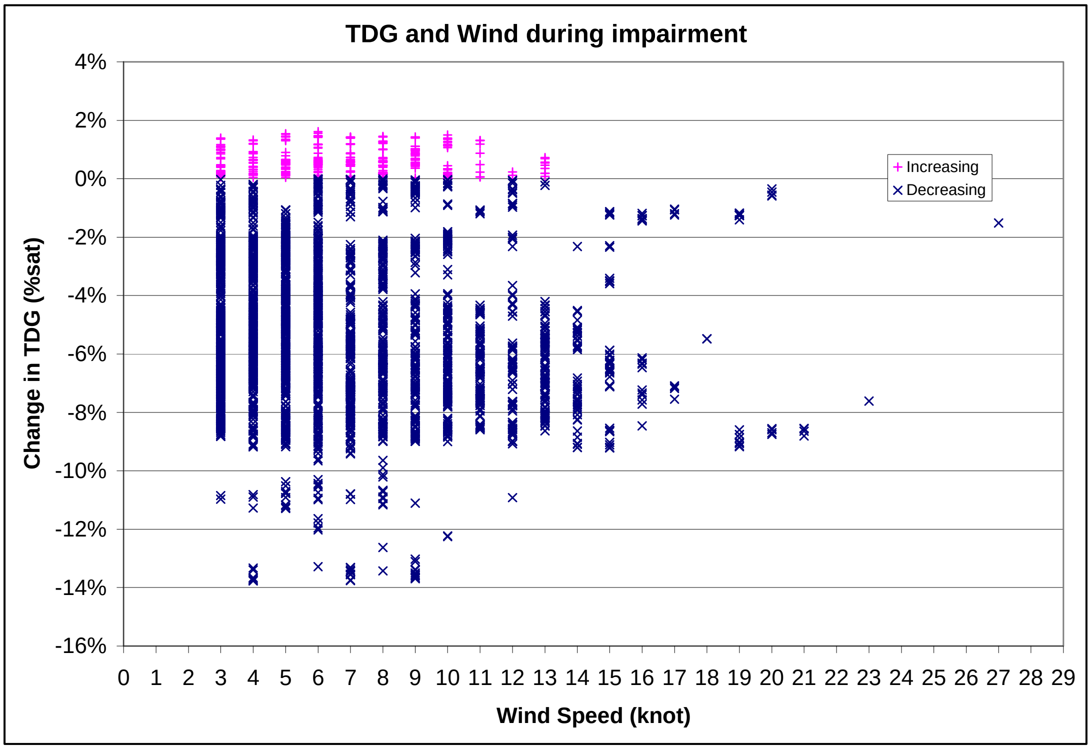


Figure 23. TDG change due to wind or productivity while impaired, by wind speed.

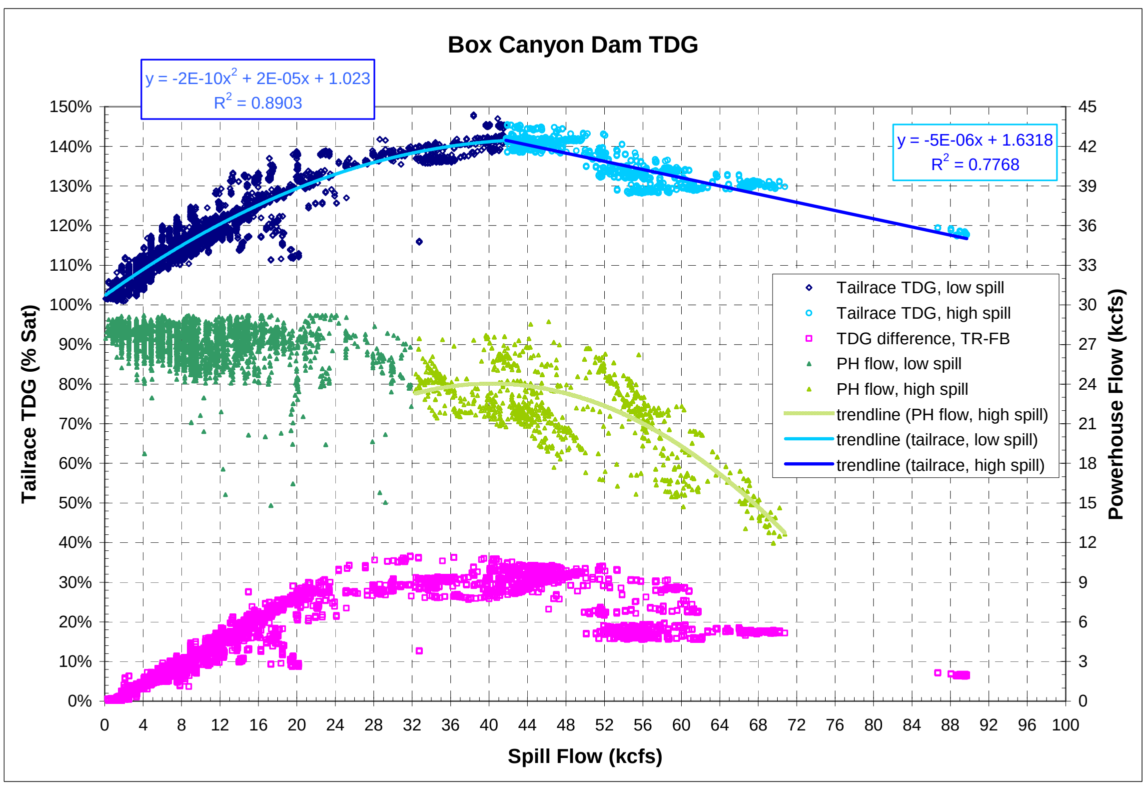


Figure 24. TDG generation at Box Canyon Dam, 2001-2004.

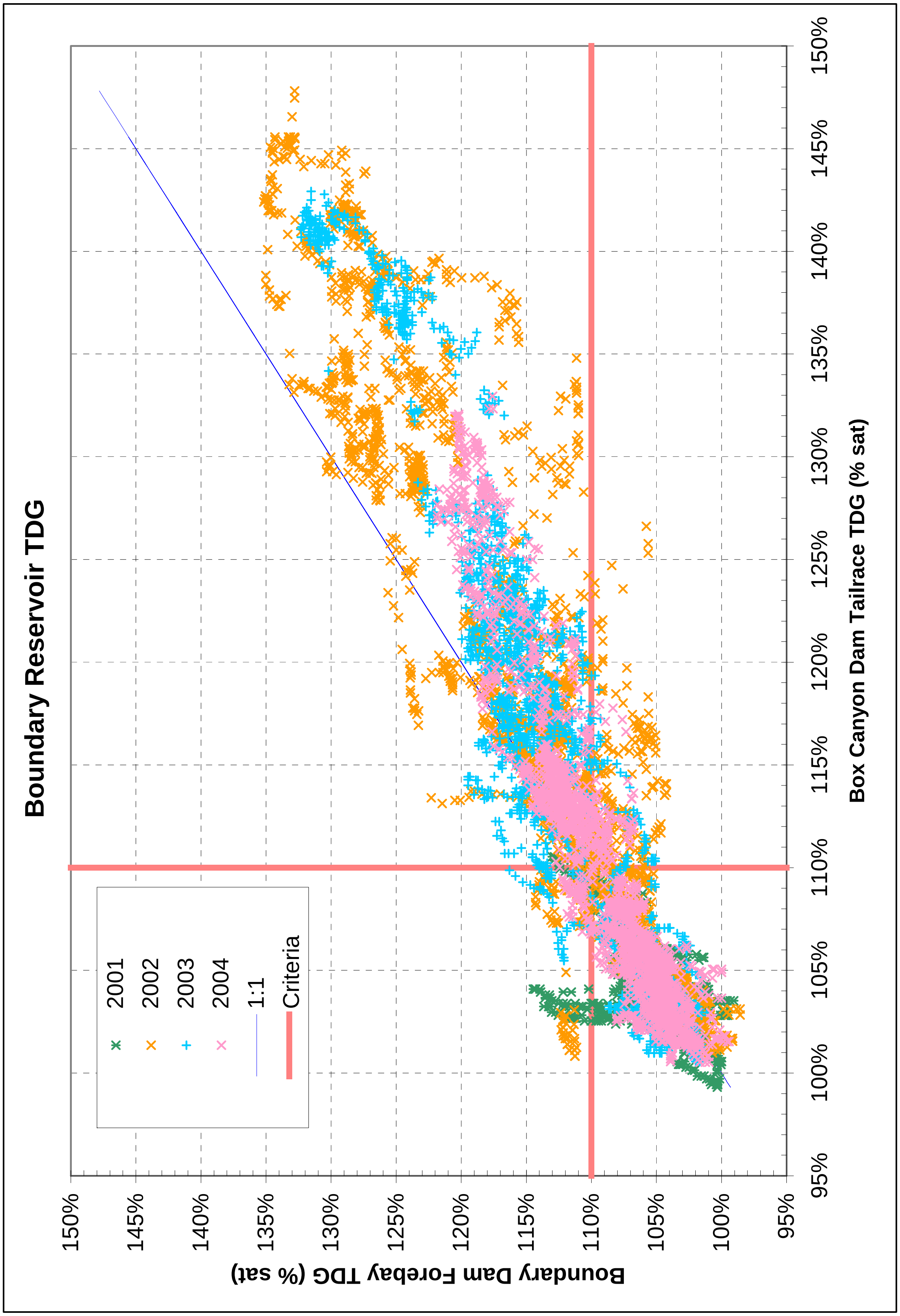


Figure 25. Pend Oreille River TDG, Box Canyon tailrace vs. Boundary Dam forebay.

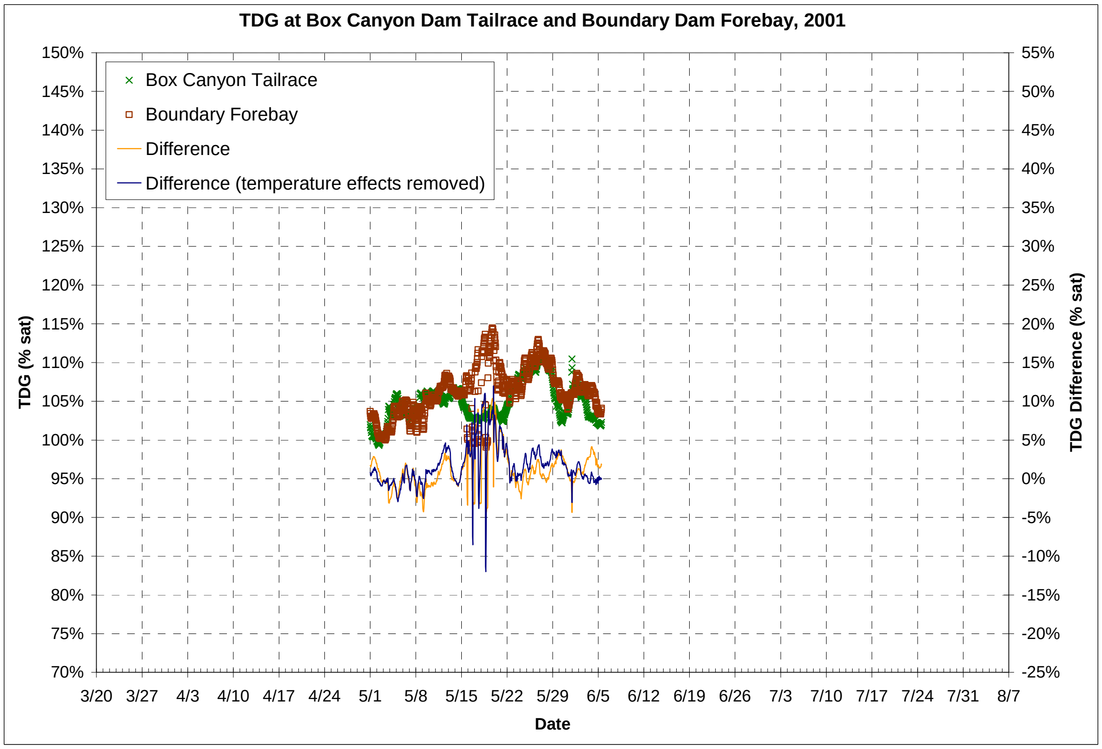


Figure 26. Pend Oreille River TDG, Box Canyon Dam tailrace and Boundary Dam forebay, 2001.

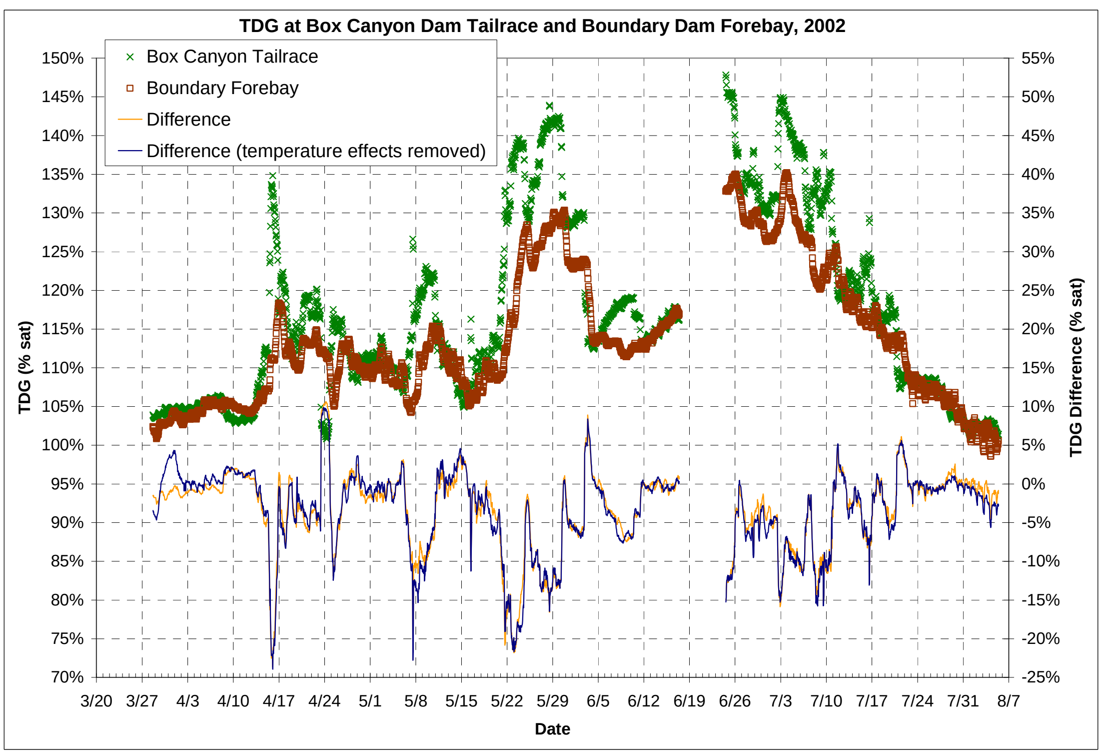


Figure 27. Pend Oreille River TDG, Box Canyon Dam tailrace and Boundary Dam forebay, 2002.

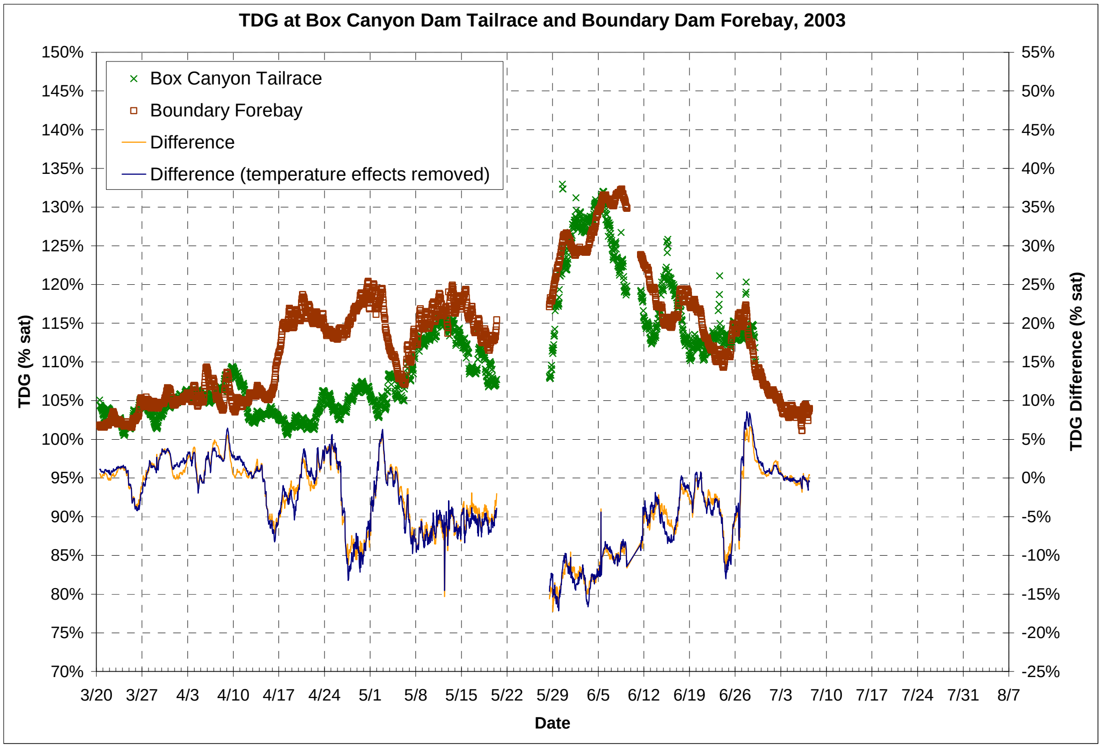


Figure 28. Pend Oreille River TDG, Box Canyon Dam tailrace and Boundary Dam forebay, 2003.

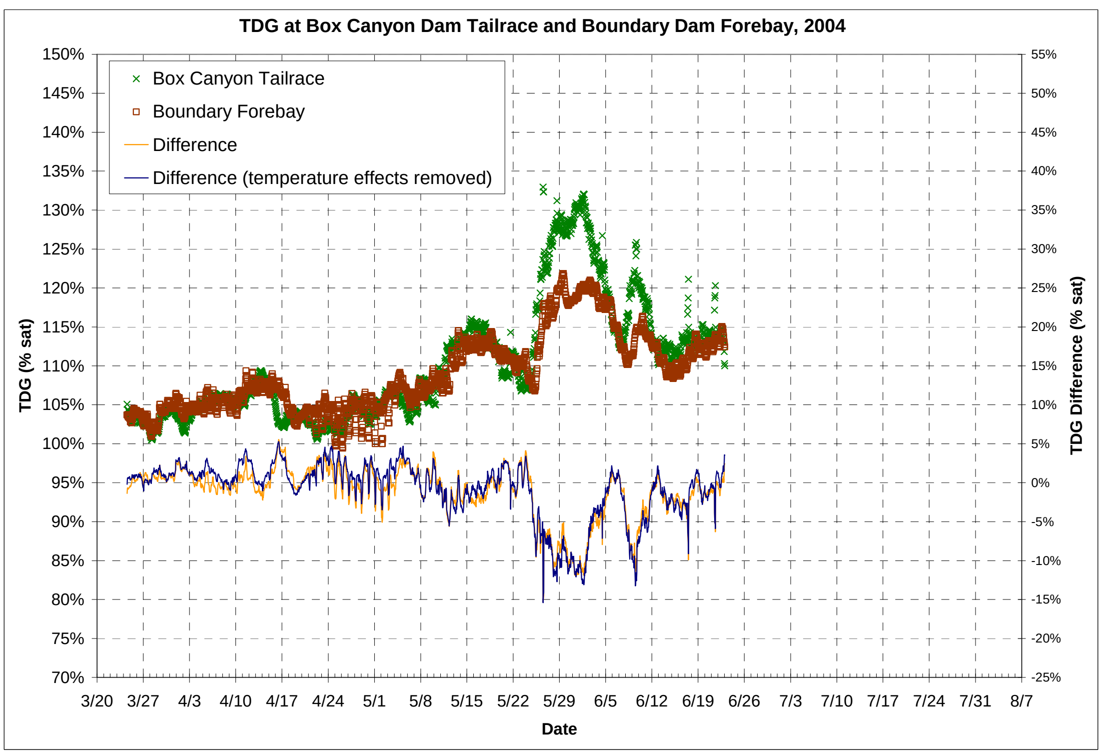


Figure 29. Pend Oreille River TDG, Box Canyon Dam tailrace and Boundary Dam forebay, 2004.

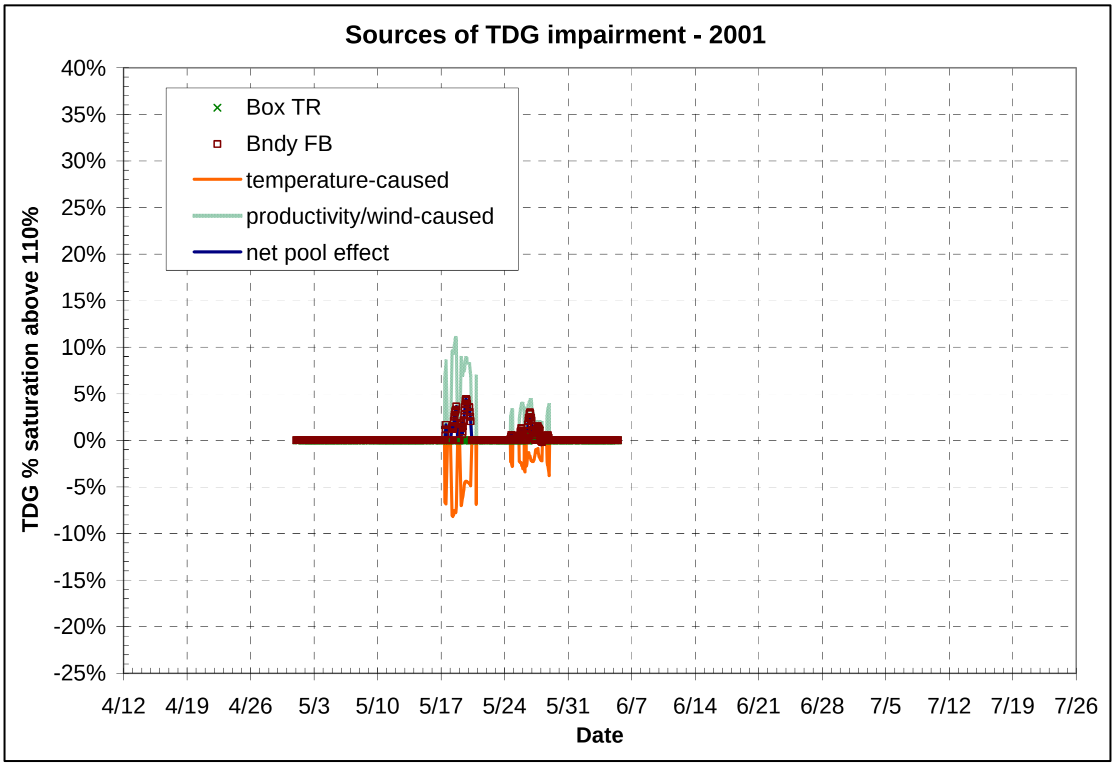


Figure 30. Pend Oreille River TDG sources of impairment, Box Canyon Dam tailrace and Boundary Dam forebay, 2001, stable data.

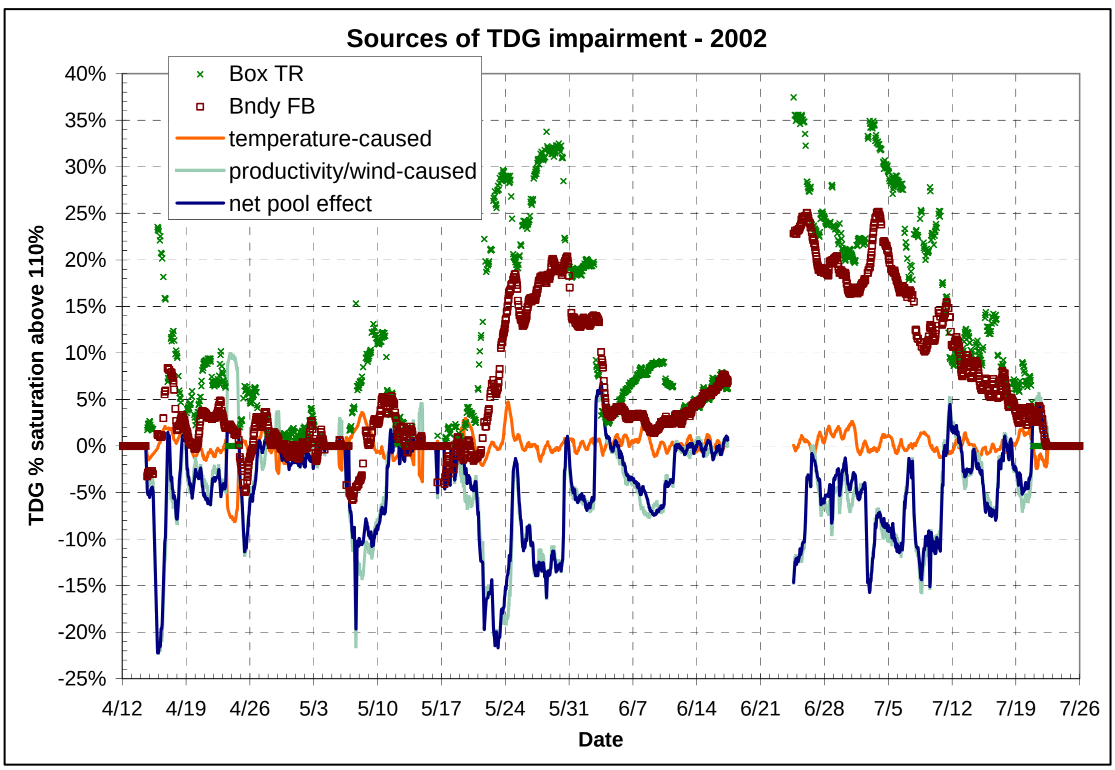


Figure 31. Pend Oreille River TDG sources of impairment, Box Canyon Dam tailrace and Boundary Dam forebay, 2002, stable data.

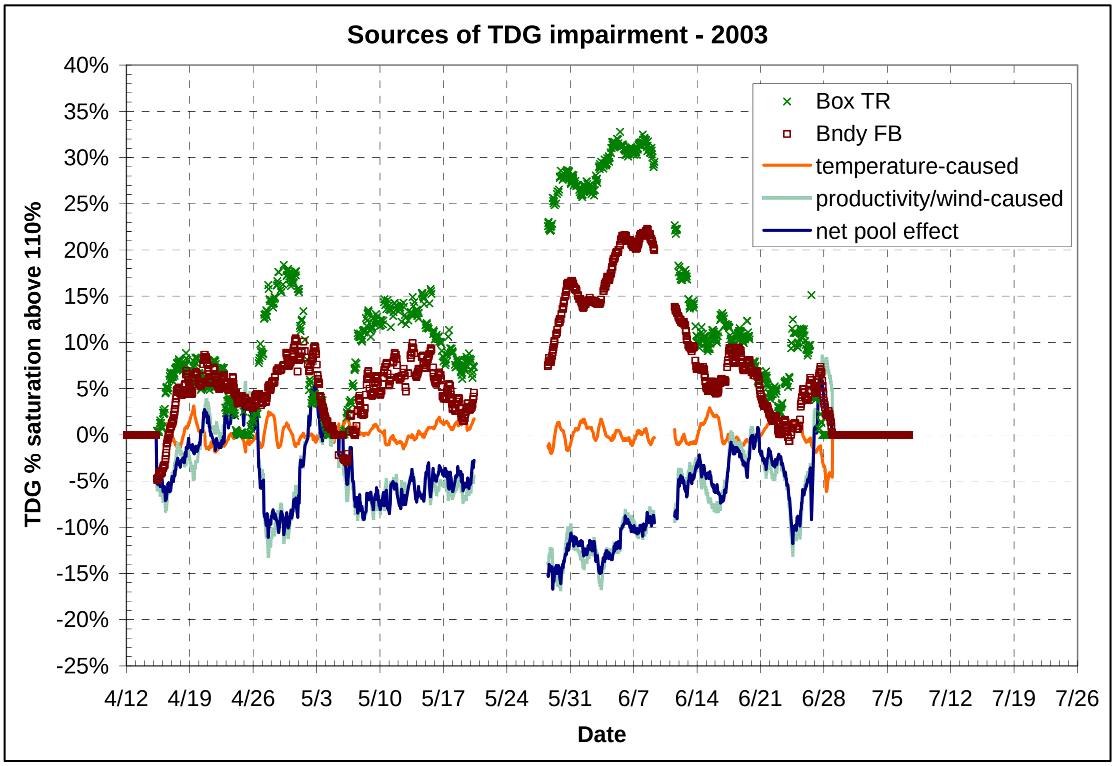


Figure 32. Pend Oreille River TDG sources of impairment, Box Canyon Dam tailrace and Boundary Dam forebay, 2003, stable data.

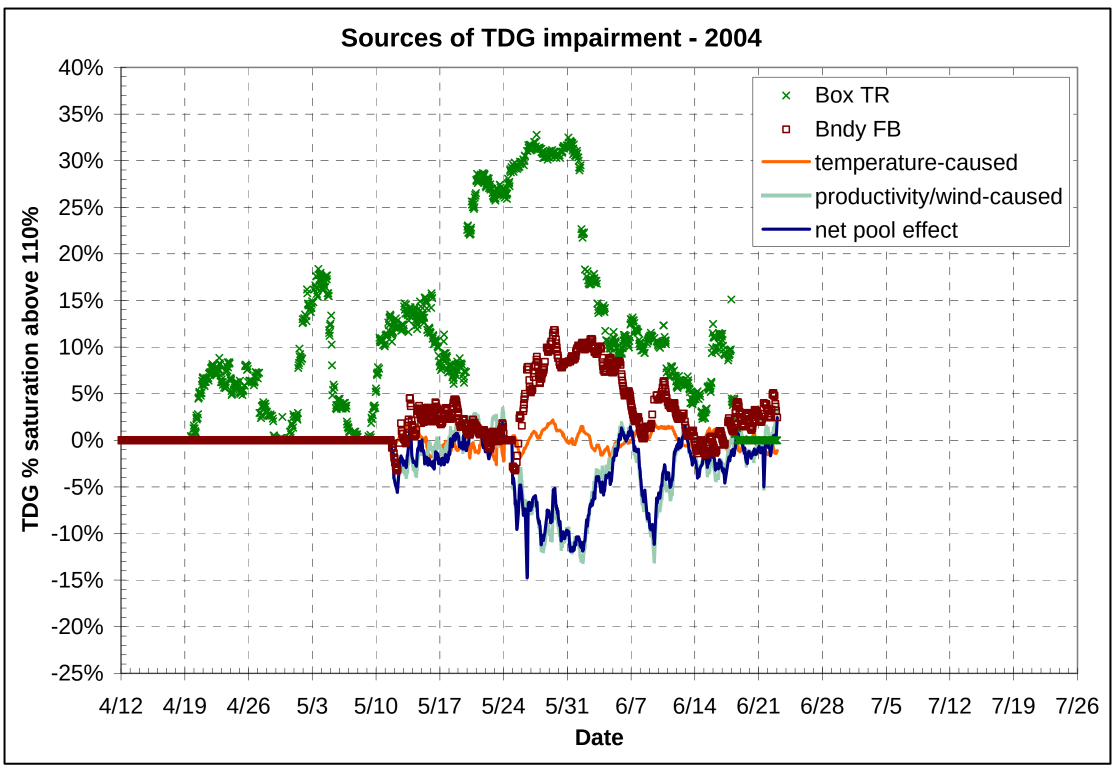


Figure 33. Pend Oreille River TDG sources of impairment, Box Canyon Dam tailrace and Boundary Dam forebay, 2004, stable data.

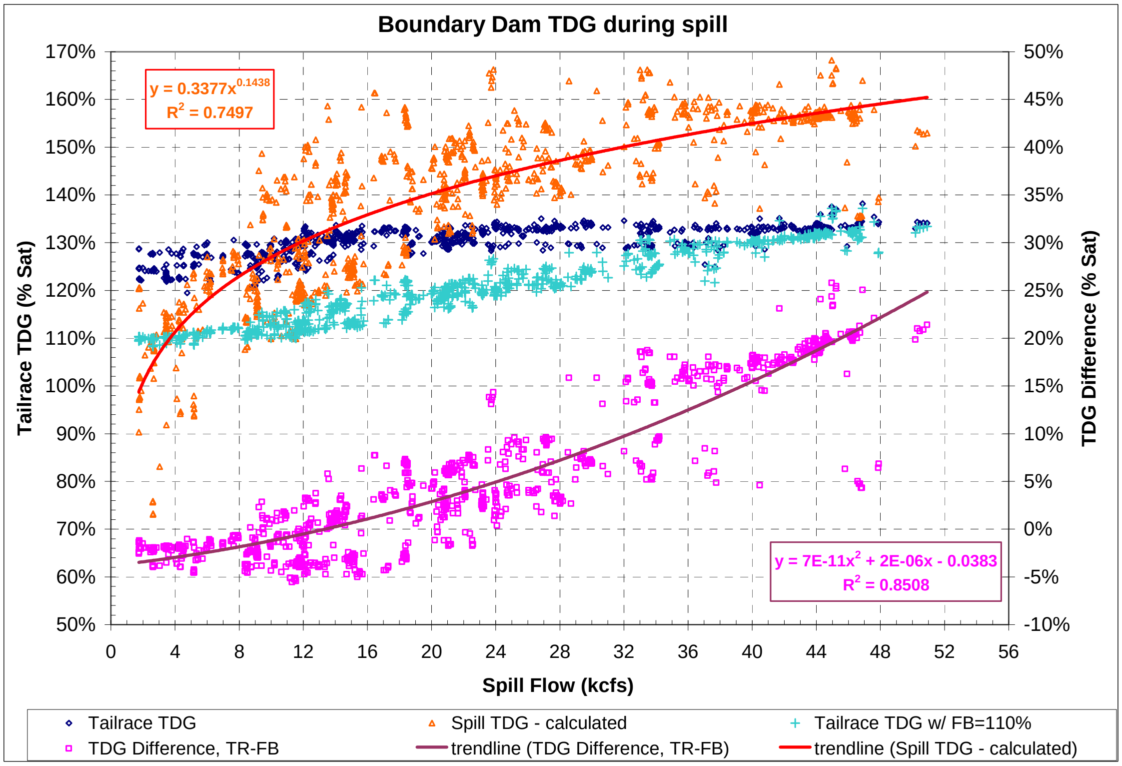


Figure 34. TDG generation by spill at Boundary Dam, 2001-2004.

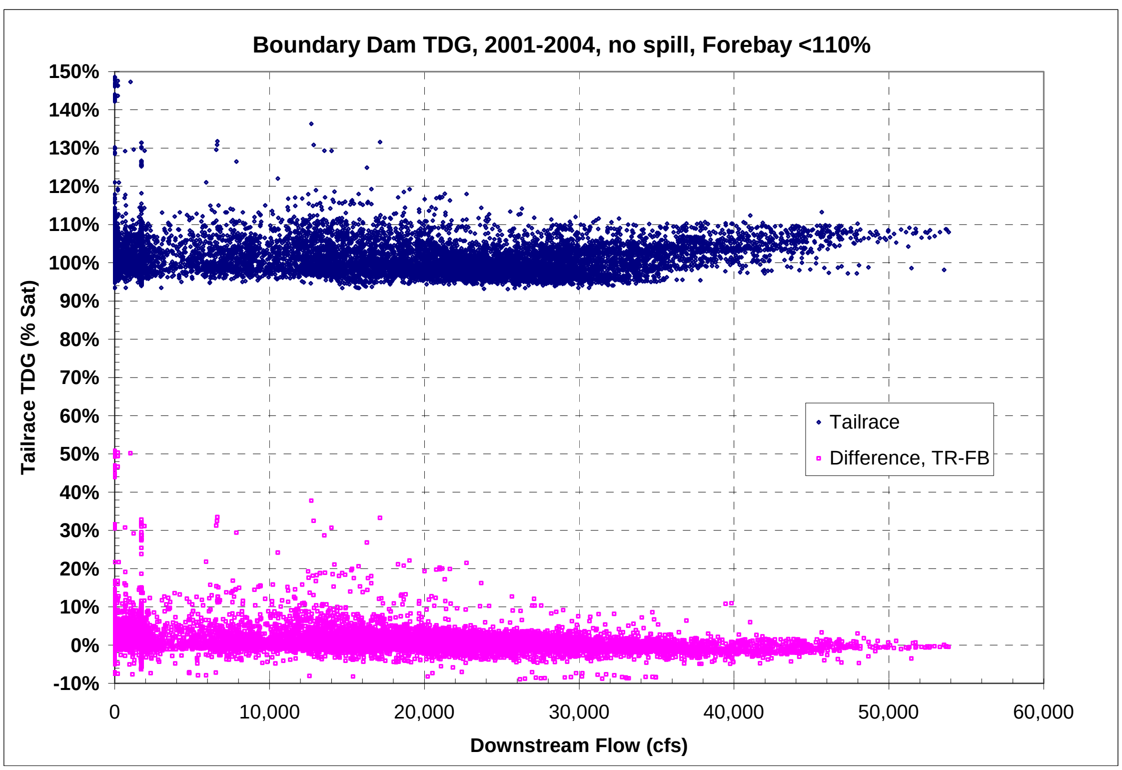


Figure 35. TDG at Boundary Dam, 2001-2004, no spill, forebay <110% of saturation.

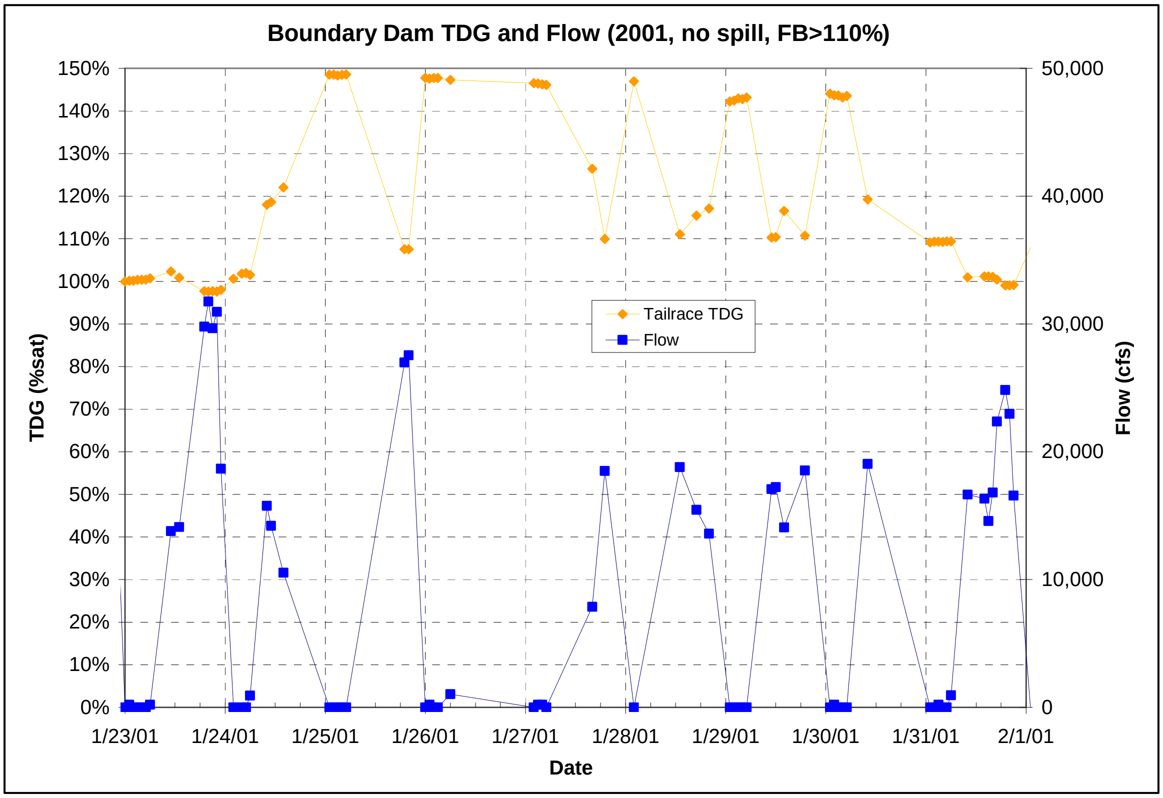


Figure 36. Boundary Dam tailrace TDG and flow, 23-31 January 2001 (no spill).

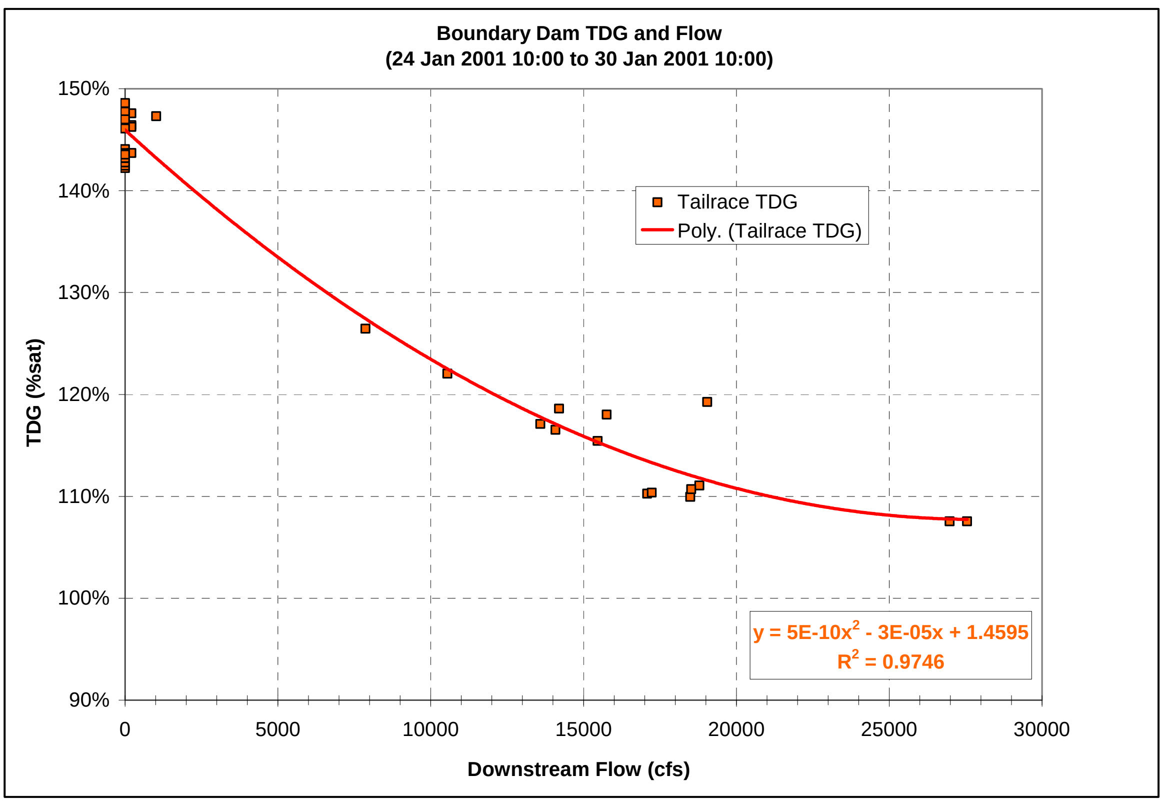


Figure 37. Boundary Dam tailrace TDG vs flow, 24-30 January 2001 (no spill).

This page is purposely left blank

Tables

This page is purposely left blank

Table 3. Field water quality measurement comparisons: Ecology-U.S. Army Corps of Engineers pairs.

TDG (mm Hg)				Difference
Date	Time	Ecology	USACE	(Target = ±5)
13-May-2004	08:48	736	741	**-5**
27-May-2004	09:21	757	761	**-4**
9-Jun-2004	09:58	765	766	**-1**
17-Jun-2004	09:19	744	744	**0**
9-Jul-2004	09:40	733	712	*21*
Root Mean Square Error (RMSE) :				*9.8*
RMSE without 9-July :				**3.2**

TDG (% of saturation)				Difference
Date	Time	Ecology	USACE	(Target = ±1%)
13-May-2004	08:48	103.8%	104.3%	**-0.5%**
27-May-2004	09:21	108.1%	108.5%	**-0.4%**
9-Jun-2004	09:58	108.8%	109.1%	**-0.3%**
17-Jun-2004	09:19	104.6%	104.4%	**0.2%**
9-Jul-2004	09:40	104.6%	101.3%	*3.2%*
Root Mean Square Error (RMSE) :				*1.5%*
RMSE without 9-July :				**0.4%**

Temperature (deg C)				Difference
Date	Time	Ecology	USACE	(Target = ±0.5)
13-May-2004	08:48	11.4	11.3	**0.1**
27-May-2004	09:21	12.3	12.2	**0.1**
9-Jun-2004	09:58	13.0	12.9	**0.1**
17-Jun-2004	09:19	14.0	13.9	**0.1**
9-Jul-2004	09:40	19.1	19.2	**-0.1**
Root Mean Square Error (RMSE) :				**0.1**

Bold = meets MQOs
Shaded italics = exceeds MQOs
See Appendix A for abbreviations

Table 4. Field water quality measurement comparisons: Ecology-Pend Oreille Public Utility District pairs.

TDG (mm Hg)				Difference
Date	Time	Ecology	POPUD	(Target = ±5)
20-Apr-2004	13:55	734	728	*6*
27-Apr-2004	11:10	757	747	*10*
13-May-2004	12:02	734	734	**0**
27-May-2004	12:35	730	731	**-1**
9-Jun-2004	13:15	730	732	**-2**
17-Jun-2004	12:34	754	755	**-1**
Root Mean Square Error (RMSE) :				**4.9**

TDG (% of saturation)				Difference
Date	Time	Ecology	POPUD	(Target = ±1%)
27-Apr-2004	11:10	107.7%	106.0%	*1.7%*
13-May-2004	12:02	103.4%	102.8%	**0.6%**
27-May-2004	12:35	104.1%	103.7%	**0.4%**
9-Jun-2004	13:15	104.0%	103.8%	**0.2%**
17-Jun-2004	12:34	106.0%	105.6%	**0.5%**
Root Mean Square Error (RMSE) :				**0.9%**

Temperature (deg C)				Difference
Date	Time	Ecology	POPUD	(Target = ±0.5)
20-Apr-2004	13:55	9.7	9.7	**0.0**
27-Apr-2004	11:10	11.2	11.2	**0.0**
13-May-2004	12:02	11.7	11.7	**0.0**
27-May-2004	12:35	13.9	13.8	**0.1**
9-Jun-2004	13:15	14.1	14.0	**0.1**
17-Jun-2004	12:34	14.6	14.6	**0.0**
Root Mean Square Error (RMSE) :				**0.0**

Bold = meets MQOs
Shaded italics = exceeds MQOs
See Appendix A for abbreviations

Table 5. Field water quality measurement comparisons: Ecology-Seattle City Light/ U.S. Geological Survey pairs.

TDG (mm Hg)				Difference
Date	Time	Ecology	SCL/USGS	(Target = ±5)
30-Mar-2004	15:59	740	738	**2**
20-Apr-2004	15:27	736	735	**1**
27-Apr-2004	12:50	739	742	**-3**
13-May-2004	13:10	793	796	**-3**
27-May-2004	14:15	828	832	**-4**
9-Jun-2004	15:10	801	804	**-3**
17-Jun-2004	13:47	794	795	**-1**
9-Jul-2004	14:01	741	742	**-1**
Root Mean Square Error (RMSE) :				**2.5**

TDG (% of saturation)				Difference
Date	Time	Ecology	SCL/USGS	(Target = ±1%)
30-Mar-2004	15:59	105.3%	105.3%	**0.0%**
20-Apr-2004	15:27	104.2%	104.3%	**-0.1%**
27-Apr-2004	12:50	105.4%	106.0%	**-0.6%**
13-May-2004	13:10	111.7%	112.0%	**-0.3%**
27-May-2004	14:15	117.9%	118.5%	**-0.6%**
9-Jun-2004	15:10	114.1%	114.5%	**-0.4%**
17-Jun-2004	13:47	111.7%	111.7%	**0.0%**
9-Jul-2004	14:01	105.4%	105.4%	**0.0%**
Root Mean Square Error (RMSE) :				**0.3%**

Temperature (deg C)				Difference
Date	Time	Ecology	SCL/USGS	(Target = ±0.5)
30-Mar-2004	15:59	6.8	6.8	**0.0**
20-Apr-2004	15:27	10.0	10.0	**0.0**
27-Apr-2004	12:50	10.8	10.8	**0.0**
13-May-2004	13:10	13.1	12.4	*0.7*
27-May-2004	14:15	14.1	14.1	**0.0**
9-Jun-2004	15:10	14.7	14.8	**-0.1**
17-Jun-2004	13:47	14.2	14.2	**0.0**
9-Jul-2004	14:01	19.7	19.8	**-0.1**
Root Mean Square Error (RMSE) :				**0.2**

Bold = meets MQOs
Shaded italics = exceeds MQOs
See Appendix A for abbreviations.

Table 6. Distributions of TDG and temperature between Idaho state line (ID-SL) and Box Canyon Dam forebay (Box FB), 2001-2004, all data.

	BP	TDG (% sat)			Temperature (°C)			TDG (% sat)		TDG (mm Hg)			TDG (mm Hg)	
	Box FB	ID-SL	Box FB	Diff.	ID-SL	Box FB	Diff.	Box FB (T@ID)	Diff.	ID-SL	Box FB	Diff.	Box FB (T@ID)	Difference
Maximum	724	122.2%	118.1%	3.4%	22.9	23.5	2.9	116.3%	3.7%	861	830	24	824	26
95%ile	716	116.9%	113.2%	2.0%	21.1	22.1	1.8	112.1%	1.4%	830	800	14	792	10
75%ile	711	109.9%	108.2%	0.6%	15.9	16.7	0.9	107.1%	-0.4%	778	766	4	758	-3
Median	708	106.4%	105.6%	-0.7%	11.1	11.7	0.5	104.4%	-2.2%	755	748	-5	740	-15
25%ile	706	104.5%	104.0%	-2.8%	8.4	9.0	0.2	102.5%	-4.7%	740	736	-20	726	-33
5%ile	702	101.4%	101.7%	-5.5%	5.2	5.3	-0.4	99.6%	-7.7%	720	723	-39	707	-54
Minimum	694	98.1%	98.6%	-10.4%	4.4	4.9	-1.8	96.2%	-13.8%	705	709	-73	683	-98

T@ID = adjusted for temperatures from the Idaho state line monitoring station. Diff. = Distribution of differences between pairs.
See Appendix A for other abbreviations.

Table 7. Distributions of TDG and temperature between Idaho state line (ID-SL) and Ruby, 2004, all data.

	BP	TDG (% sat)			Temperature (°C)			TDG (% sat)		TDG (mm Hg)			TDG (mm Hg)	
	Ruby	ID-SL	Ruby	Diff.	ID-SL	Ruby	Diff.	Ruby (T@ID)	Diff.	ID-SL	Ruby	Diff.	Ruby (T@ID)	Diff.
Maximum	714	113.4%	109.8%	5.2%	20.11	20.25	1.78	109.1%	5.3%	797	775	37	770	37
95%ile	711	109.5%	108.1%	1.8%	19.17	19.67	1.25	106.6%	1.1%	772	764	12	754	8
75%ile	708	107.4%	106.4%	0.3%	15.56	16.18	0.81	105.1%	-0.9%	757	751	2	742	-6
median	706	106.0%	105.0%	-1.0%	13.44	13.82	0.52	104.1%	-1.9%	749	739	-7	734	-13
25%ile	703	104.8%	103.9%	-2.1%	12.56	13.09	0.22	102.9%	-3.4%	741	733	-15	725	-24
5%ile	700	102.8%	102.5%	-4.4%	11.50	12.05	-0.31	101.2%	-6.5%	725	725	-31	714	-46
Minimum	697	98.3%	100.7%	-9.6%	10.89	11.18	-0.97	100.2%	-11.1%	0	0	-67	0	-78

T@ID = adjusted for temperatures from the Idaho state line monitoring station. Diff. = Distribution of differences between pairs.
See Appendix A for other abbreviations.

Table 8. Distributions of TDG and temperature between Ruby and Box Canyon forebay (Box FB), 2004, all data.

	BP	TDG (% sat)			Temperature (°C)			TDG (% sat)		TDG (mm Hg)			TDG (mm Hg)	
	Ruby	Ruby	Box FB	Diff.	Ruby	Box FB	Diff.	Box FB (T@Ruby)	Diff.	Ruby	Box FB	Diff.	Box FB (T@Ruby)	Diff.
Maximum	714	109.1%	108.1%	2.0%	17.51	17.35	0.78	107.8%	2.3%	768	763	14	763	16
95%ile	711	107.5%	107.0%	0.6%	16.05	15.86	0.60	107.0%	0.4%	759	754	4	755	3
75%ile	707	106.1%	105.4%	-0.2%	14.22	14.15	0.34	105.2%	-0.5%	749	744	-1	743	-3
Median	705	104.9%	104.1%	-0.7%	13.55	13.72	0.10	103.8%	-1.0%	739	733	-5	730	-7
25%ile	703	103.9%	103.2%	-1.3%	12.96	13.11	-0.13	102.7%	-1.5%	733	728	-9	724	-11
5%ile	699	102.4%	101.8%	-1.8%	11.91	12.08	-0.37	101.2%	-2.3%	724	720	-13	716	-16
Minimum	697	100.7%	100.7%	-3.7%	11.18	11.37	-0.67	100.2%	-3.9%	712	711	-26	710	-27

T@Ruby = adjusted for temperatures from the Ruby monitoring station. Diff. = Distribution of differences between pairs.
See Appendix A for other abbreviations.

Table 9. Distributions of TDG and temperature between Idaho state line (ID-SL) and Box Canyon Dam forebay (Box FB), 2001-2004, stable data.

	BP	TDG (% sat)			Temperature (°C)			TDG (% sat)		TDG (mm Hg)			TDG (mm Hg)	
	Box FB	ID-SL	Box FB	Diff.	ID-SL	Box FB	Diff.	Box FB (T@ID)	Diff.	ID-SL	Box FB	Diff.	Box FB (T@ID)	Difference
Maximum	720	122.2%	118.1%	3.1%	19.2	20.0	2.9	116.3%	3.0%	861	830	22	824	21
95%ile	716	119.7%	115.0%	2.0%	16.6	17.6	2.2	112.6%	0.8%	848	814	14	797	6
75%ile	711	110.9%	109.2%	0.7%	14.2	14.8	1.1	108.1%	-0.7%	784	773	5	766	-5
median	708	106.5%	105.9%	-0.3%	10.0	10.8	0.6	104.8%	-2.0%	756	751	-2	743	-14
25%ile	705	104.9%	104.5%	-3.1%	7.7	8.4	0.3	102.8%	-4.9%	745	741	-22	729	-35
5%ile	702	103.3%	102.5%	-5.6%	6.5	7.3	-0.1	99.3%	-8.7%	730	728	-40	702	-61
Minimum	694	100.0%	100.3%	-10.1%	5.4	6.9	-0.8	96.2%	-13.8%	707	718	-71	683	-98

T@ID = adjusted for temperatures from the Idaho state line monitoring station. Diff. = Distribution of differences between pairs.
See Appendix A for other abbreviations.

Table 10. Distribution of TDG and temperature between Idaho state line (ID-SL) and Ruby, 2004, stable data.

	BP	TDG (% sat)			Temperature (^oC)			TDG (% sat)		TDG (mm Hg)			TDG (mm Hg)	
	Ruby	ID-SL	Ruby	Diff.	ID-SL	Ruby	Diff.	Ruby (T@ID)	Diff.	ID-SL	Ruby	Diff.	Ruby (T@ID)	Diff.
Maximum	714	113.1%	109.8%	5.2%	20.06	20.25	1.78	109.1%	5.3%	795	775	37	770	37
95%ile	711	109.3%	108.1%	1.7%	19.06	19.66	1.27	106.5%	1.0%	770	764	12	753	7
75%ile	708	107.3%	106.3%	0.4%	15.24	15.57	0.83	105.0%	-0.8%	757	751	2	742	-6
median	706	106.0%	105.0%	-0.9%	13.39	13.79	0.53	104.0%	-1.9%	748	739	-7	733	-13
25%ile	703	104.8%	103.9%	-2.0%	12.50	13.07	0.24	102.8%	-3.4%	740	733	-14	725	-24
5%ile	700	102.9%	102.5%	-4.2%	11.50	11.99	-0.26	101.2%	-6.4%	726	725	-30	714	-45
Minimum	697	98.3%	100.7%	-9.3%	10.89	11.18	-0.92	100.2%	-10.8%	691	712	-65	706	-76

T@ID = adjusted for temperatures from the Idaho state line monitoring station. Diff. = Distribution of differences between pairs.
See Appendix A for other abbreviations.

Table 11. Distributions of TDG and temperature between Ruby and Box Canyon forebay (Box FB), 2004, stable data.

	BP	TDG (% sat)			Temperature (^oC)			TDG (% sat)		TDG (mm Hg)			TDG (mm Hg)	
	Ruby	Ruby	Box FB	Diff.	Ruby	Box FB	Diff.	Box FB (T@Ruby)	Diff.	Ruby	Box FB	Diff.	Box FB (T@Ruby)	Diff.
Maximum	714	109.0%	108.1%	1.4%	17.51	17.35	0.78	107.8%	1.5%	767	763	10	763	11
95%ile	711	107.5%	107.0%	0.6%	16.07	15.86	0.61	107.0%	0.4%	759	753	4	755	3
75%ile	707	106.1%	105.3%	-0.2%	14.17	14.14	0.34	105.2%	-0.5%	749	744	-1	743	-3
median	706	104.9%	104.1%	-0.7%	13.53	13.71	0.10	103.8%	-1.0%	739	733	-5	731	-7
25%ile	703	103.9%	103.2%	-1.3%	12.94	13.10	-0.13	102.7%	-1.5%	732	728	-9	724	-10
5%ile	699	102.3%	101.8%	-1.8%	11.90	12.12	-0.37	101.2%	-2.3%	724	719	-13	716	-16
Minimum	697	100.7%	100.7%	-2.4%	11.18	11.37	-0.67	100.2%	-3.2%	712	711	-17	710	-22

T@Ruby = adjusted for temperatures from the Idaho state line monitoring station. Diff. = Distribution of differences between pairs.
See Appendix A for other abbreviations.

Table 12. Summary of TDG impairments, Idaho state line (ID-SL) to Box Canyon Dam forebay (Box FB).

		2001	2002	2003	2004	All years
1.	Total number of data points	1179	7589	7857	1028	17653
2.	ID-SL impaired (% of all)	13.7%	33.5%	19.6%	1.5%	24.1%
3.	Box FB impaired (% of all)	22.0%	23.2%	11.0%	0.0%	16.3%
4.	Data points with impairment (% of all)	25.0%	33.5%	19.6%	1.5%	24.9%
5.	ID-SL impaired, Box FB not impaired (% of all)	3.1%	10.4%	8.6%	1.5%	8.6%
6.	ID-SL not impaired, Box FB impaired (% of all)	11.3%	0.0%	0.0%	0.0%	0.8%
7.	Number of data points with impairment	295	2546	1539	15	4395
8a.	Temperature increases impairment (% of points with impairment)	68.5%	96.8%	75.0%	93.3%	87.2%
8b.	Productivity and wind increases impairment (% of points with impairment)	58.6%	2.7%	11.2%	0.0%	9.4%
8c.	Net pool effect increases impairment (% of points with impairment)	80.7%	4.9%	10.1%	0.0%	11.8%
9.	Net pool effect increases impairment (% of all)	20.2%	1.6%	2.0%	0.0%	2.9%
10.	Temperature increases TDG (% of all)	84.3%	96.2%	76.9%	90.8%	86.5%
11.	Productivity and wind increases TDG (% of all)	54.3%	4.6%	31.3%	2.8%	19.7%
12.	Net pool effect increases TDG (% of all)	81.4%	27.1%	40.7%	12.9%	36.0%
13.	Pool effect, ID-SL not impaired, Box FB impaired (median percent of saturation)	***0.4%***	--	--	--	***0.4%***
14.	Pool effect, all impairments (median percent of saturation)	***0.3%***	**-4.2%**	**-3.5%**	**-6.4%**	**-3.8%**
15.	Pool effect, all measurements (median percent of saturation)	***1.1%***	**-0.8%**	**-0.7%**	**-2.0%**	**-0.7%**

Shaded italics = a positive percent of saturation value.
See Appendix A for abbreviations.

Table 13. Summary of TDG impairments, Idaho state line (ID-SL) to Ruby

		2004
1.	Total number of data points	1280
2.	ID-SL impaired (% of all)	2.1%
3.	Ruby impaired (% of all)	0.0%
4.	Data points with impairment (% of all)	2.1%
5.	ID-SL impaired, Ruby not impaired (% of all)	2.1%
6.	ID-SL not impaired, Ruby impaired (% of all)	0.0%
7.	Number of data points with impairment	27
8a.	Temperature increases impairment (% of points with impairment)	96.3%
8b.	Productivity and wind increases impairment (% of points with impairment)	0.0%
8c.	Net pool effect increases impairment (% of points with impairment)	0.0%
9.	Net pool effect increases impairment (% of all)	0.0%
10.	Temperature increases TDG (% of all)	86.6%
11.	Productivity and wind increases TDG (% of all)	11.8%
12.	Net pool effect increases TDG (% of all)	32.0%
13.	Pool effect, ID-SL not impaired, Ruby impaired (median percent of saturation)	--
14.	Pool effect, all impairments (median percent of saturation)	**-0.9%**
15.	Pool effect, all measurements (median percent of saturation)	***3.7%***

Shaded italics = a positive percent of saturation value.
See Appendix A for abbreviations.

Table 14. Summary of TDG impairments, Ruby to Box Canyon Dam forebay (Box FB).

		2004
1.	Total number of data points	4203
2.	Ruby impaired (% of all)	0.0%
3.	Box FB impaired (% of all)	0.0%
4.	Data points with impairment (% of all)	0.0%
5.	Ruby impaired, Box FB not impaired (% of all)	0.0%
6.	Ruby not impaired, Box FB impaired (% of all)	0.0%
7.	Number of data points with impairment	0
8a.	Temperature increases impairment (% of points with impairment)	--
8b.	Productivity and wind increases impairment (% of points with impairment)	--
8c.	Net pool effect increases impairment (% of points with impairment)	--
9.	Net pool effect increases impairment (% of all)	--
10.	Temperature increases TDG (% of all)	63.3%
11.	Productivity and wind increases TDG (% of all)	10.3%
12.	Net pool effect increases TDG (% of all)	18.7%
13.	Pool effect, Ruby not impaired, Box FB impaired (median percent of saturation)	--
14.	Pool effect, all impairments (median percent of saturation)	--
15.	Pool effect, all measurements (median percent of saturation)	***1.0%***

Shaded italics = a positive percent of saturation value.
See Appendix A for abbreviations.

Table 15. Distributions of tailrace flow and TDG between Box Canyon Dam forebay and tailrace, 2001-2004, stable data.

	Flow (cfs)			BP (mm Hg)	TDG (% sat)			TDG (mm Hg)		
	Spill	Total	Powerhouse	Forebay	Forebay	Tailrace	Difference	Forebay	Tailrace	Difference
Maximum	89712	89712	29200	724.0	118.1%	148.0%	36.6%	830.0	1049.0	261.0
95%ile	56036	77541	28600	716.0	113.9%	139.9%	30.3%	806.0	992.0	215.0
75%ile	14888	42390	28040	711.0	108.3%	123.4%	16.8%	768.0	875.0	119.0
median	7562	34823	27320	708.0	105.5%	114.3%	8.5%	748.0	811.0	61.0
25%ile	4141	32038	26120	706.0	103.8%	110.1%	4.8%	736.0	779.0	34.0
5%ile	1765	29815	20440	702.0	101.3%	104.3%	0.8%	721.0	741.0	6.0
Minimum	107	22866	0	694.0	98.6%	101.0%	-1.1%	709.0	721.0	-8.0

Difference = Distribution of differences between pairs.
See Appendix A for abbreviations.

Table 16. Distributions of TDG and temperature between Box Canyon Dam tailrace (Box TR) and Boundary Dam forebay (Bndry FB), 2001-2004, all data.

	BP	TDG (% sat)			Temperature (°C)			TDG (% sat)		TDG (mm Hg)			TDG (mm Hg)	
	Bndry FB	Box TR	Bndry FB	Diff.	Box TR	Bndry FB	Diff.	Bndry FB (T@BTR)	Diff.	Box TR	Bndry FB	Diff.	Bndry FB (T@BTR)	Diff.
Maximum	722.0	147.8%	135.2%	10.6%	23.06	23.50	6.37	135.7%	12.0%	1048.0	956.0	75.0	952.2	85.1
95%ile	714.4	137.9%	127.9%	3.4%	21.26	21.50	0.63	127.6%	3.7%	979.0	903.0	22.0	899.8	24.2
75%ile	710.0	119.4%	115.5%	0.7%	14.97	14.90	0.18	115.5%	1.1%	847.0	816.0	3.0	815.5	6.2
median	707.0	111.0%	110.2%	-0.9%	11.72	11.60	-0.14	110.3%	-0.6%	786.0	779.0	-8.0	779.7	-6.3
25%ile	704.0	104.7%	105.4%	-4.5%	9.01	8.70	-0.43	106.0%	-4.8%	741.8	746.0	-34.0	748.6	-36.8
5%ile	701.0	102.1%	102.4%	-11.6%	5.75	5.40	-0.83	102.4%	-12.2%	726.0	725.0	-86.0	724.6	-89.2
Minimum	692.0	99.3%	98.6%	-23.7%	2.72	2.90	-5.69	91.4%	-23.9%	714.0	694.0	-167.0	648.8	-169.0

T@BTR = adjusted for temperatures from the Box Canyon Dam tailrace monitoring station. Diff. = Distribution of differences between pairs.
See Appendix A for other abbreviations.

Table 17. Distribution of TDG and temperature between Box Canyon Dam tailrace (Box TR) and Boundary Dam forebay (Bndry FB), 2001-2004, stable data.

	BP	TDG (% sat)			Temperature (°C)			TDG (% sat)		TDG (mm Hg)			TDG (mm Hg)	
	Bndry FB	Box TR	Bndry FB	Diff.	Box TR	Bndry FB	Diff.	Bndry FB (T@BTR)	Diff.	Box TR	Bndry FB	Diff.	Bndry FB (T@BTR)	Diff.
Maximum	722.0	147.5%	135.2%	10.6%	23.1	23.5	3.4	135.7%	11.0%	1047.0	956.0	75.0	952.2	79.2
95%ile	714.6	138.1%	128.1%	3.4%	21.5	21.7	0.6	127.7%	3.7%	980.0	904.0	22.0	900.5	24.3
75%ile	709.0	118.1%	114.9%	0.9%	14.9	14.8	0.2	114.9%	1.3%	839.0	812.0	4.0	810.6	7.5
median	707.0	109.0%	109.0%	-0.7%	11.5	11.3	-0.1	109.3%	-0.3%	771.0	769.0	-6.0	772.3	-4.3
25%ile	704.0	104.3%	105.1%	-3.9%	8.4	8.0	-0.4	105.6%	-4.2%	740.0	744.0	-30.0	746.8	-31.6
5%ile	700.6	102.0%	102.3%	-11.3%	5.5	5.3	-0.9	102.3%	-11.6%	726.0	724.0	-83.0	723.9	-85.1
Minimum	692.0	99.3%	98.6%	-22.2%	2.7	2.9	-5.7	94.3%	-22.3%	714.0	694.0	-158.0	668.3	-157.2

T@BTR = adjusted for temperatures from the Box Canyon Dam tailrace monitoring station. Diff. = Distribution of differences between pairs.
See Appendix A for other abbreviations.

Table 18. Summary of TDG impairments, Box Canyon Dam tailrace (Box TR) to Boundary Dam forebay.

		2001	2002	2003	2004	All years
1.	Total number of data points	766	2509	1942	1808	7025
2.	Box TR impaired (% of all)	3.9%	62.9%	56.5%	39.7%	48.7%
3.	Boundary FB impaired (% of all)	13.6%	58.9%	56.7%	37.7%	47.9%
4.	Data points with impairment (% of all)	14.0%	66.7%	59.2%	42.7%	52.7%
5.	Box TR impaired, Boundary FB not impaired (% of all)	0.4%	7.8%	2.4%	5.0%	4.8%
6.	Box TR not impaired, Boundary FB impaired (% of all)	10.1%	3.8%	2.7%	3.0%	4.0%
7.	Number of data points with impairment	107	1674	1149	772	3702
8a.	Temperature increases impairment (% of points with impairment)	0.0%	50.3%	51.8%	40.9%	47.4%
8b.	Productivity and wind increases impairment (% of points with impairment)	100.0%	18.2%	19.5%	24.6%	22.3%
8c.	Net pool effect increases impairment (% of points with impairment)	93.5%	18.8%	17.4%	19.7%	20.7%
9.	Net pool effect increases impairment (% of all)	13.1%	12.6%	10.3%	8.4%	10.9%
10.	Temperature increases TDG (% of all)	32.8%	49.8%	49.8%	36.7%	44.6%
11.	Productivity and wind increases TDG (% of all)	74.3%	28.9%	42.4%	57.1%	44.8%
12.	Net pool effect increases TDG (% of all)	63.8%	23.8%	42.2%	46.9%	39.2%
13.	Pool effect, Box TR not impaired, Boundary impaired (median percent of saturation)	***1.0%***	***1.3%***	***2.3%***	***0.9%***	***1.3%***
14.	Pool effect, all impairments (median percent of saturation)	***0.8%***	**-3.6%**	**-4.9%**	**-1.9%**	**-3.3%**
15.	Pool effect, all measurements (median percent of saturation)	***0.7%***	**-1.5%**	**-1.1%**	**-0.2%**	**-0.7%**

Shaded italics - a positive percent of saturation value.
See Appendix A for abbreviations.

Table 19. Distributions of tailrace flow and of TDG between Boundary Dam forebay and tailrace, 2001-2004 spill only, stable data.

	Flow (cfs)			Barometric Press. (mm Hg)		TDG (% sat)			TDG (mm Hg)				TDG (% sat)	
	Spill	Total	Power-House	Bndry FB	Bndry TR	Bndry FB	Bndry TR	Diff.	Bndry FB	Bndry TR	Diff.	Bndry Spill (calc.)	Bndry Spill (calc.)	Bndry TR (calculated, FB=110%)
Maximum	50911	102039	57930	713.0	720.0	137.4%	138.2%	25.8%	969.0	988.0	192.0	1200.9	168.2%	137.2%
95%ile	44953	95710	57187	711.0	718.0	134.5%	133.8%	19.9%	948.0	955.0	150.0	1131.0	158.5%	132.0%
75%ile	31012	83985	55443	708.0	715.0	130.0%	132.8%	8.5%	917.0	946.0	68.0	1091.1	153.1%	124.6%
median	18505	70431	53418	707.0	714.0	126.6%	130.7%	2.4%	896.0	932.0	26.0	1004.4	141.2%	118.5%
25%ile	10855	64025	51567	704.0	711.0	122.9%	127.9%	-1.9%	868.0	912.0	-5.0	874.2	122.6%	111.9%
5%ile	3143	55836	45644	701.0	708.0	113.0%	122.6%	-3.8%	801.0	879.0	-18.0	778.2	109.2%	110.0%
Minimum	1741	50065	9879	699.0	706.0	111.6%	119.5%	-5.5%	-22.3%	714.0	694.0	520.2	73.1%	108.3%

Diff. = Distribution of differences between pairs. Bndry = Boundary Dam. Calc. = calculated. See Appendix A for other abbreviations.

Table 20. Distributions of tailrace flow and of TDG between Boundary Dam forebay and tailrace, 2001-2004 without spill, stable data.

	Flow (cfs)	BP (mm Hg)		TDG (% sat)			TDG (mm Hg)		
	Total	Bndry FB	Bndry TR	Bndry FB	Bndry TR	Diff.	Bndry FB	Bndry TR	Diff.
Maximum	53856	728.0	735.0	110.0%	148.6%	50.8%	784.1	1063.0	369.8
95%ile	35063	719.0	726.0	106.9%	108.3%	6.3%	755.0	774.0	52.0
75%ile	22459	712.1	719.4	102.5%	103.4%	1.7%	726.0	739.0	19.0
median	2103	708.8	715.8	99.3%	100.4%	0.1%	703.0	719.0	8.0
25%ile	1724	705.0	712.0	97.6%	98.2%	-0.7%	693.0	702.0	2.0
5%ile	0	699.7	706.0	95.8%	95.8%	-1.7%	683.0	689.0	-5.0
Minimum	0	634.0	641.0	91.0%	93.2%	-9.0%	647.0	675.0	-56.0

Diff. = Distribution of differences between pairs. Bndry = Boundary Dam. See Appendix A for other abbreviations.

This page is purposely left blank

Appendices

This page is purposely left blank

Appendix A. Glossary, Acronyms, and Abbreviations

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State periodically to prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards, and are not expected to improve within the next two years.

401 certification: Section 401 of the federal Clean Water Act allows Washington State to set conditions in federal permits that ensure that water quality standards will be met by the project. For non-federal hydropower dams, Washington issues a 401 certification as part of licensing by the Federal Energy Regulatory Commission.

Ambient: Background or away from local sources of contamination or other variability. Refers to large-scale or area-wide conditions, including conditions not associated with a specific point source, facility, or property.

Barometric pressure (BP and ΔP): Ambient atmospheric air pressure.

Best management practices (BMPs): Physical, structural, and/or operational practices that, when used singularly or in combination, prevent or reduce pollutant discharges.

Clean Water Act: Federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Calibration: The process of establishing the relationship between the response of a measurement system and the value of the parameter being measured.

Cubic feet per second (cfs): A measure of flow in English units. The abbreviation "kcfs" is used for one thousand cubic feet per second, for convenience in large rivers.

Degree centigrade (^{o}C, or deg C): A temperature scale defined by 0°C at the ice point and 100°C at boiling point of water at sea level.

DEQ: Department of Environmental Quality. See "Idaho DEQ."

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each waterbody or segment, regardless of whether or not the uses are currently attained.

Ecology: Washington State Department of Ecology.

Federal Energy Regulatory Commission (FERC): The United States agency that regulates non-federal hydroelectric dams through the issuance of licenses for the projects.

Forebay (FB): The area of a reservoir immediately upstream of a dam.

Hg: Mercury

Idaho Department of Environmental Quality (IDEQ): A state department created by the Idaho Environmental Protection and Health Act (Idaho Code 539-101 et seq) to ensure clean air, water, and land in the state and protect Idaho citizens from the adverse impacts of pollution.

kcfs: One thousand cubic feet per second. See "cfs" above.

Load allocation: The portion of a receiving waters' loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading capacity: The greatest amount of a substance that a waterbody can receive and still meet water quality standards.

Margin of safety: Required component of TMDLs that accounts for uncertainty about the relationship between pollutant loads and quality of the receiving waterbody.

Measurement quality objectives (MQOs): The performance or acceptance criteria for individual data quality indicators, including precision, bias, and sensitivity.

Millimeters of mercury (mm Hg): A unit of pressure used for gasses.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including, but not limited to, atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the National Pollutant Discharge Elimination System Program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Pend Oreille Public Utility District (POPUD): The publicly-owned utility that owns and operates Box Canyon Dam and supplies electricity to Pend Oreille County.

Percent of saturation (% of saturation, or % sat): The pressure of dissolved gas measured as the percent of the saturation pressure, which for environmental measurements is calculated as the measured dissolved gas pressure divided by the ambient local barometric pressure.

Percentile (%ile): A value in the x^{th} percentile ($0 \leq x \leq 100$) is a value within a given distribution or ranked data set that is greater than x% of the values and less than (1-x)% of the values.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state as will or is likely to create a nuisance or render such waters harmful, detrimental, or injurious to the public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish, or other aquatic life.

Pool: The reservoir behind a dam.

Powerhouse: The area of a hydroelectric project containing the power generation turbines.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

PUD: Public utility district.

Quality assurance (QA): Adherence to a system for assuring the reliability of measurement data.

Quality Assurance Project Plan: A document that describes the objectives of a project and the procedures necessary to acquire data that will serve those objectives.

Root mean square error (RMSE): A measure of total error determined by calculating the difference of paired values, squaring each difference, and then taking the square root of the average of the set of squared differences.

Seattle City Light (SCL): The City of Seattle, a municipal corporation of the State of Washington, acting by and through its City Light Department (SCL), owns and operates Boundary Dam.

Spill: The release of water through a dam by means other than through the powerhouse when storage and powerhouse hydraulic capacity are inadequate to manage inflows to the dam's reservoir. Used as a verb ("the dam spilled"), a generic noun ("when spill occurs"), or a specific noun ("several spills occurred").

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, saltwaters, wetlands and all other surface waters and water courses within the jurisdiction of the State of Washington.

Tailrace (TR): The area of a river just downstream of a dam.

Total dissolved gas (TDG): The total amount of constituent gases from the atmosphere dissolved in the water column. TDG is typically measured as pressure (e.g. in millimeters of mercury [mm Hg]) or as percent of saturation with respect to ambient barometric pressure. TDG is also referred to as Total Gas Pressure (TGP).

Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody designed to protect the waterbody from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

U.S. Army Corps of Engineers (USACE): The federal agency that owns and operates Albeni Falls Dam and other dams in the Columbia River system. They are also responsible for the overall coordination of dam operation in the Columbia River system, and provide technical expertise for the water quality and other environmental effects of dams and hydroelectric operations.

U.S. Environmental Protection Agency (EPA): The federal agency responsible for implementation of the Clean Water Act, including oversight of the states and tribes and coordination of issues with shared waters (interstate, state-tribal, and international).

U.S. Geological Survey (USGS): The federal agency whose duties include monitoring of river flow and water quality.

Washington Administrative Code (WAC): The promulgated Rules and Regulations of the State of Washington.

Washington State Department of Ecology (Ecology): The State of Washington's principal environmental management agency.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocations constitute one type of water quality-based effluent limitation.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Appendix B. Total Dissolved Gas Monitoring Results, Pend Oreille River, May - July 2004

Methods

The methods used for the TDG surveys followed the Quality Assurance Project Plan (Ecology, 2004), with the changes and exceptions noted below. Overall project planning was managed by Paul Pickett of Ecology's Environmental Assessment Program headquarters office in Olympia, while field operations were conducted by Jim Ross of Ecology's Eastern Regional Office in Spokane.

Figure 1 shows the TMDL study area, including Pend Oreille River dams and the continuous TDG monitoring locations used historically and in 2004. Ecology's monitoring location is described under *Results* and is shown at a smaller scale in Figure B-1. Monitoring was conducted from a local landowner's dock on the west bank.

Daily average river flows prior to, during, and following the survey are shown in Figure B-2 (USGS Station 12396500, Pend Oreille River below Box Canyon). The survey captured conditions during the 2004 spring freshet flows. However, flows in 2004 were relatively low, with peak flows the fifth lowest in 20 years.

Continuous data were collected by lowering the meter in a protective tube to the river bottom, secured by cable from the dock. The site was chosen because of the relatively swift currents and lack of milfoil at that location, which provided a representative measurement of river conditions. Brief gaps in the data occurred when the meter was serviced.

Eight surveys were conducted between late March and mid-July at intervals of one to three weeks. Three reconnaissance surveys were conducted prior to installation of the datalogging meter. During four of the following five surveys, the datalogging meter was removed and replaced with a calibrated meter. At the time of meter replacement, paired readings were made with a meter to be replaced, the replacement meter, and on most surveys with a third meter. After removal, data were retrieved, and the meter was serviced and calibrated.

During each survey, spot measurements were taken from the state highway bridge in Newport, the forebay of Box Canyon Dam, and the forebay of Boundary Dam. Spot measurements from the tailrace of the two dams were determined to be too difficult logistically, and the forebay measurements were deemed adequate to meet the objectives of the study.

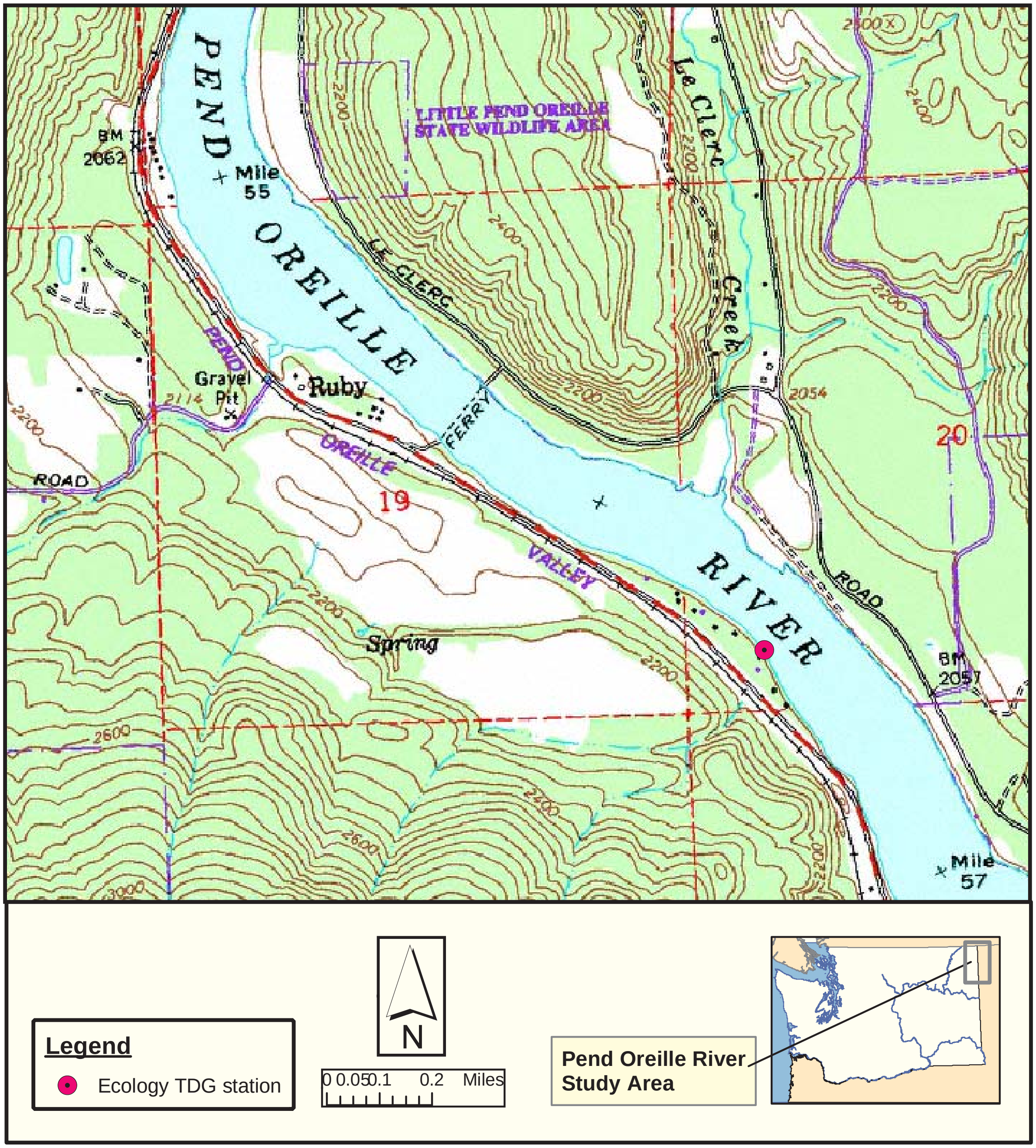


Figure B-1. TDG Monitoring Locations

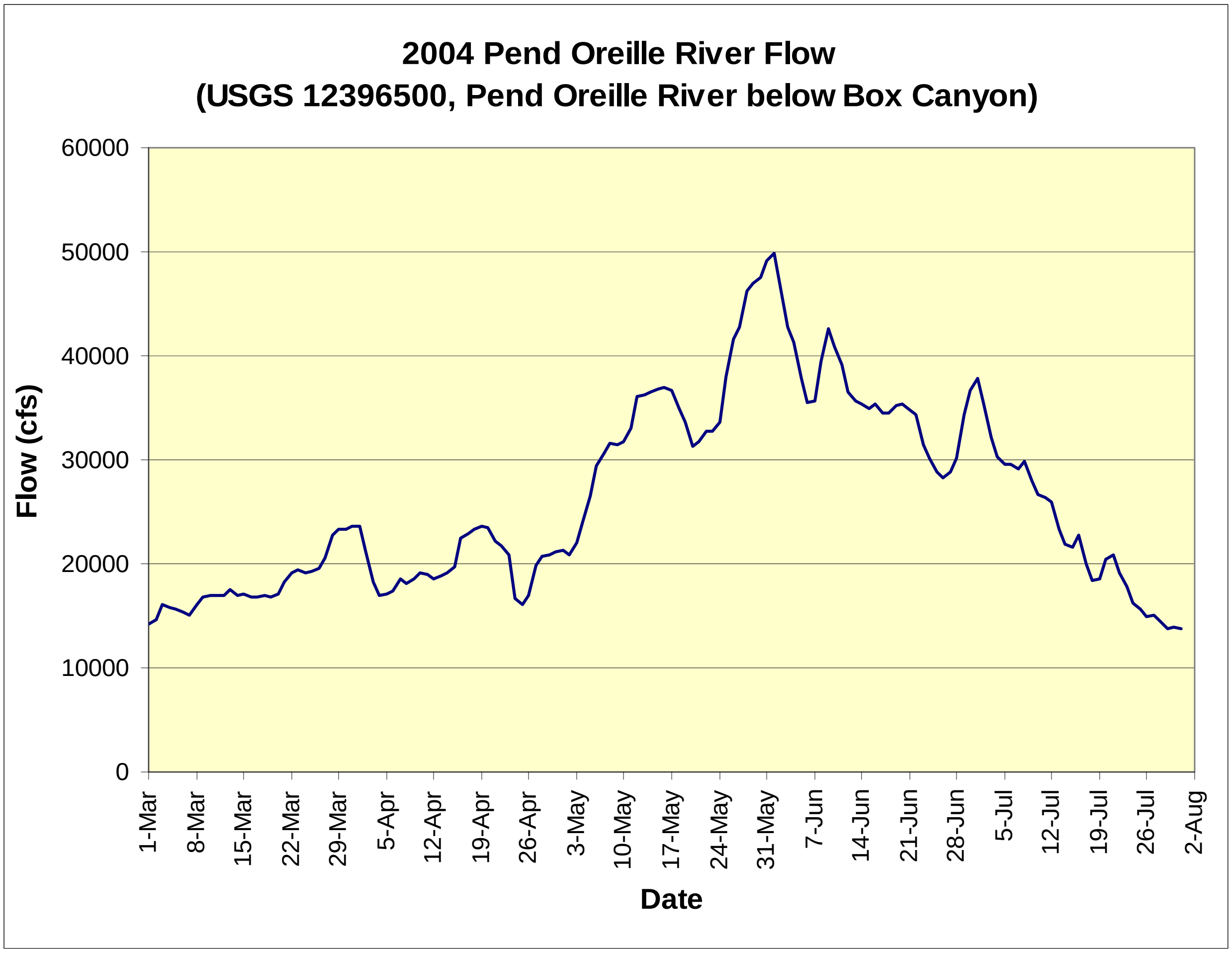


Figure B-2. Pend Oreille River Flows During the Monitoring Period, March – July 2004

Spot measurements of barometric pressure were made at each grab monitoring location and at the datalogging location during meter servicing using a digital barometer or the meters' pressure sensors with the TDG membrane removed. Two meteorological stations were evaluated for continuous barometric pressure data: the National Weather Service station at Deer Park Airport, and a station maintained by the Kalispel Tribe at their headquarters. Regressions to estimate barometric pressure at the Ruby site were developed from the two meteorological stations, and the most accurate method was chosen to generate a pressure time series to calculate TDG percent saturation.

Results

Data Quality

The analyses of monitoring data quality are shown in Tables B-1 through B-3. The root mean square error (RMSE) of measurements that meet Measurement Quality Objectives (MQOs) are shown in bold, while RMSEs that exceed the MQOs are shaded.

With one exception, all three meters met the MQOs defined in the Quality Assurance Project Plan for TDG during calibration and post-calibration (+/- 5 mm Hg) both in terms of individual calibration results and the RMSE for the season (Table B-1). The sole exception was post-calibration of meter DS15 on May 27, when the meter was visibly fouled with slime and the meter response was very slow.

Spot barometric pressure (BP) readings paired with meteorological station readings met the MQOs at Deer Park but not at the Kalispel station (top section of Table B-2). However, the meteorological station data were examined more closely to determine whether the Kalispel data could be usable, since it is located much closer to Ruby. A comparison of data sets indicated a temperature effect on the station pressure values. Figure B-3 shows how the Deer Park data show very little temperature effect, while the Kalispel data show a relationship between temperature and pressure.

When evaluating regression equations for estimating barometric pressure at Ruby, a two-parameter linear regression to temperature and Kalispel station pressure was evaluated along with linear regressions to Deer Park pressure and Kalispel pressure alone. The results are shown in the lower section of Table B-2. Deer Park showed a better relationship for a regression to station pressure alone (R^2 of 0.936 versus 0.764), but with temperature included the regression to Kalispel data showed the strongest relationship (R^2 of 0.988). The RMSE of this regression (0.5 mm Hg) met the MQO for barometric pressure and was the lowest of the three methods. Therefore, a time series for barometric pressure at Ruby was developed from this regression.

The RMSE of paired Ecology meter readings (Table B-3) met the MQOs for TDG pressure, percent saturation, and temperature for all meters at all times. Meter DS15, which post-calibrated poorly on May 27, met the MQO for paired readings on that date. Therefore, the TDG and temperature data meets MQOs and is considered acceptable for use in the TMDL.

Paired data between the Ecology spot measurements and the three continuous monitors will be evaluated in this TMDL report, because those data are not yet available from the responsible parties.

Quality assurance (QA) procedures (pre- and post-calibration and standards checks) were followed only sporadically for dissolved oxygen, specific conductance, and pH during this study. The QA data that were collected showed poor compliance with MQOs. Therefore, these data are not considered of sufficient quality to report or use in the study. However, since these data were of secondary importance, their poor quality is of only minor importance and will not prevent attainment of study objectives.

Field Data

The TDG pressures measured in the Pend Oreille River are shown in Figure B-4, while the TDG percent saturation values from monitoring are shown in Figure B-5. Also shown in these figures are the total flow and spill discharges from Albeni Falls Dam. Pressures show little relationship to river flows or spill at Albeni. Possible explanations for this include the effect of conditions upstream of Albeni Falls and the effect of changes in river water temperature on TDG levels. With the exception of 2 spurious outliers, maximum TDG levels remained below 110% saturation for all measurements.

Figure B-6 shows the pattern of temperature readings during monitoring. Values generally increased over time, as would be expected, and daily variation in temperature could also be observed.

Figure B-7 shows a shorter period of data for TDG and temperature, where the pattern of diurnal TDG variation can be seen more clearly, with minimum levels in the morning and maximum levels in the evening. Temperature shows a similar pattern, indicating that the diurnal temperature pattern is at least partially the cause of the diurnal TDG pattern.

Conclusions and Recommendations

Data for TDG and temperature collected by Ecology from May through July at Newport, Ruby, Box Canyon Dam, and Boundary Dam are of good quality, and therefore can be used in TMDL development. Conductivity, pH, and dissolved oxygen data are of poor quality and will not be reported or used.

TDG levels did not exceed the state standard of 110% saturation, but the relatively low flows in 2004 must be taken into account. TDG levels did not correspond to flow, but TDG patterns appear related to water temperatures, and especially to diurnal temperature cycles.

The data reported here will be used in combination with TDG monitoring by the U.S. Army Corps of Engineers, Pend Oreille PUD, and the City of Seattle for development of a TMDL for the Pend Oreille River in Washington State.

This page is purposely left blank

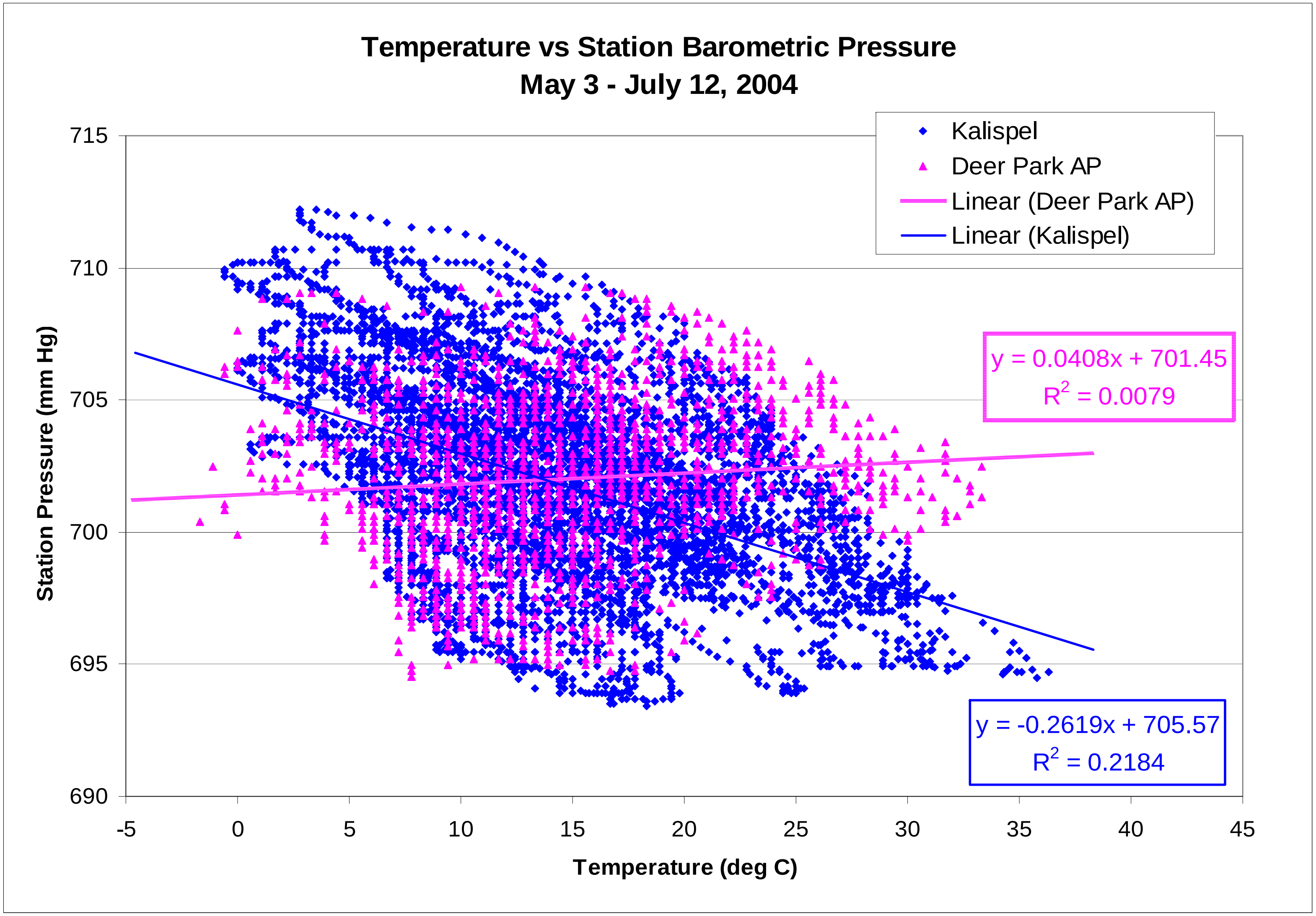


Figure B-3. Air Temperature vs Station Pressure, Kalispel and Deer Park Stations

This page is purposely left blank

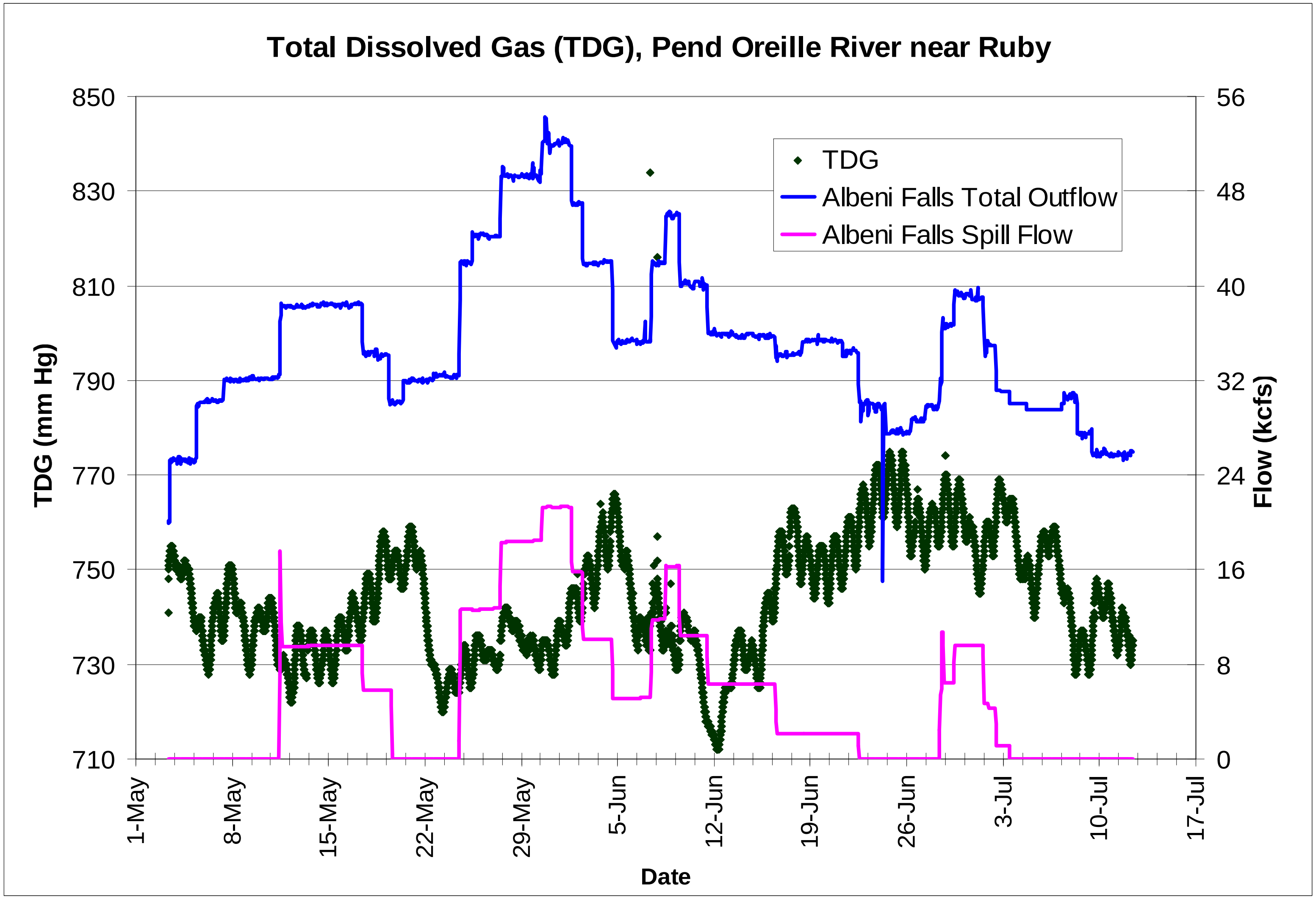


Figure B-4. Pend Oreille River TDG Pressure

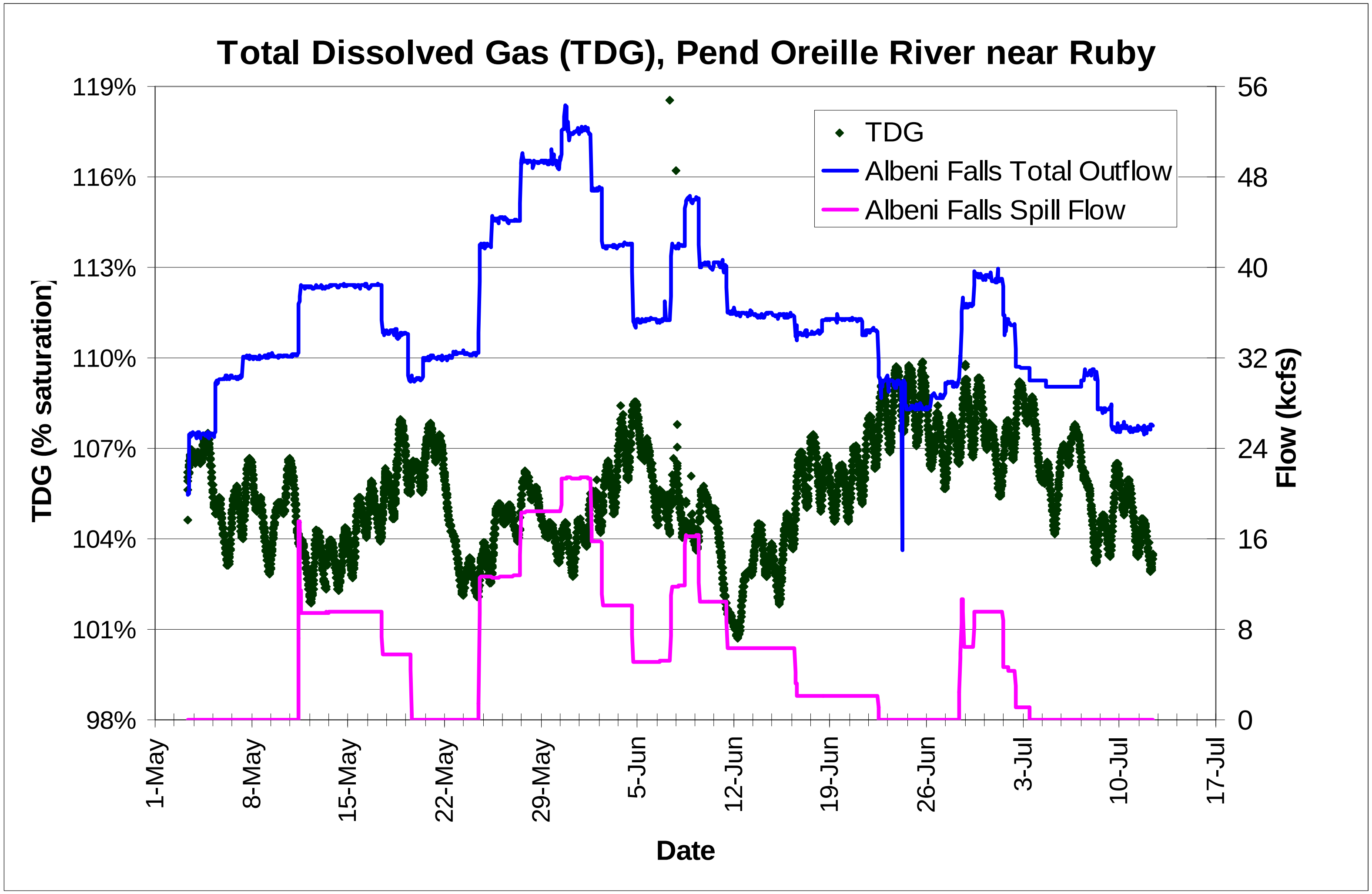


Figure B-5. Pend Oreille River TDG Percent Saturation

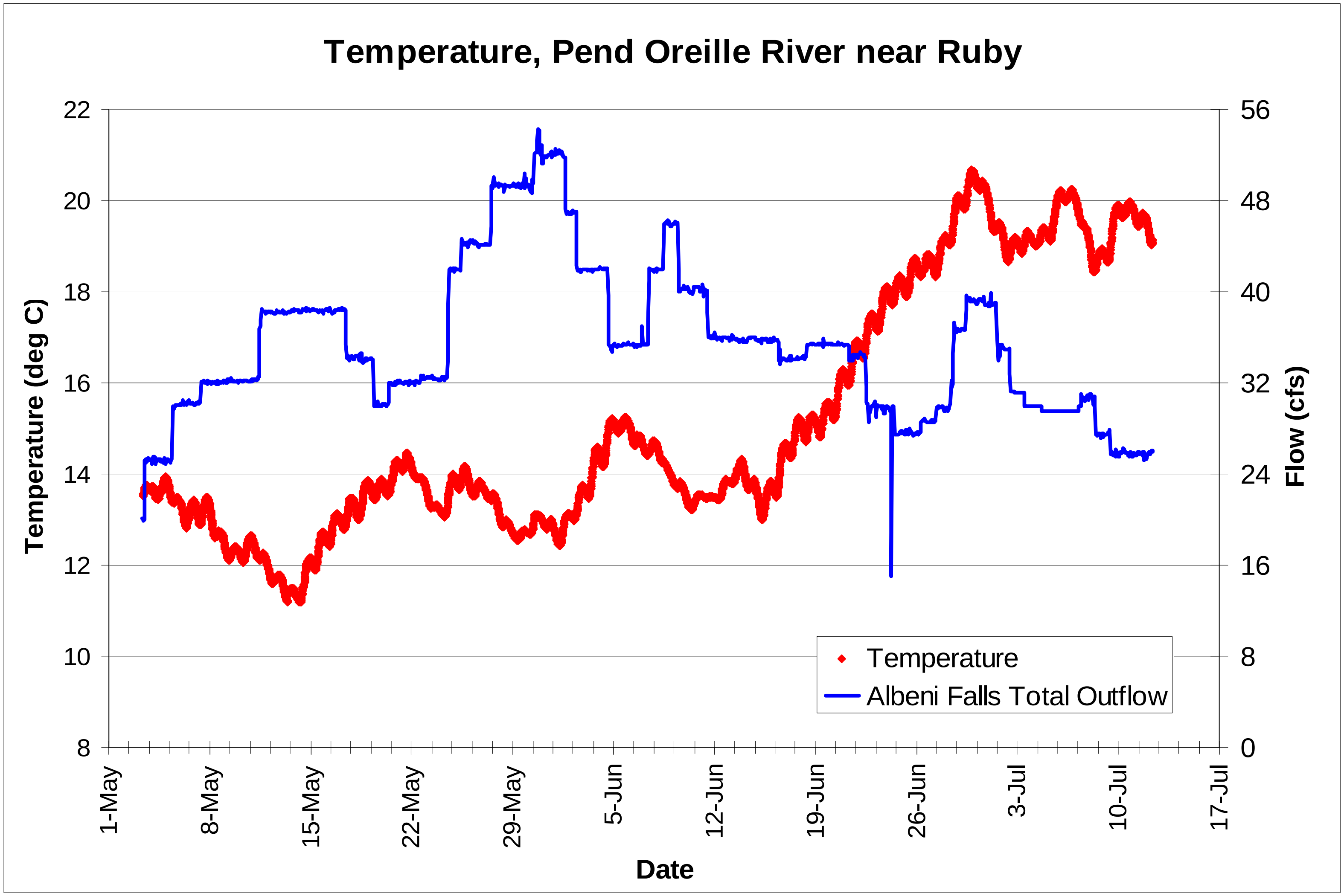


Figure B-6. Pend Oreille River Temperature

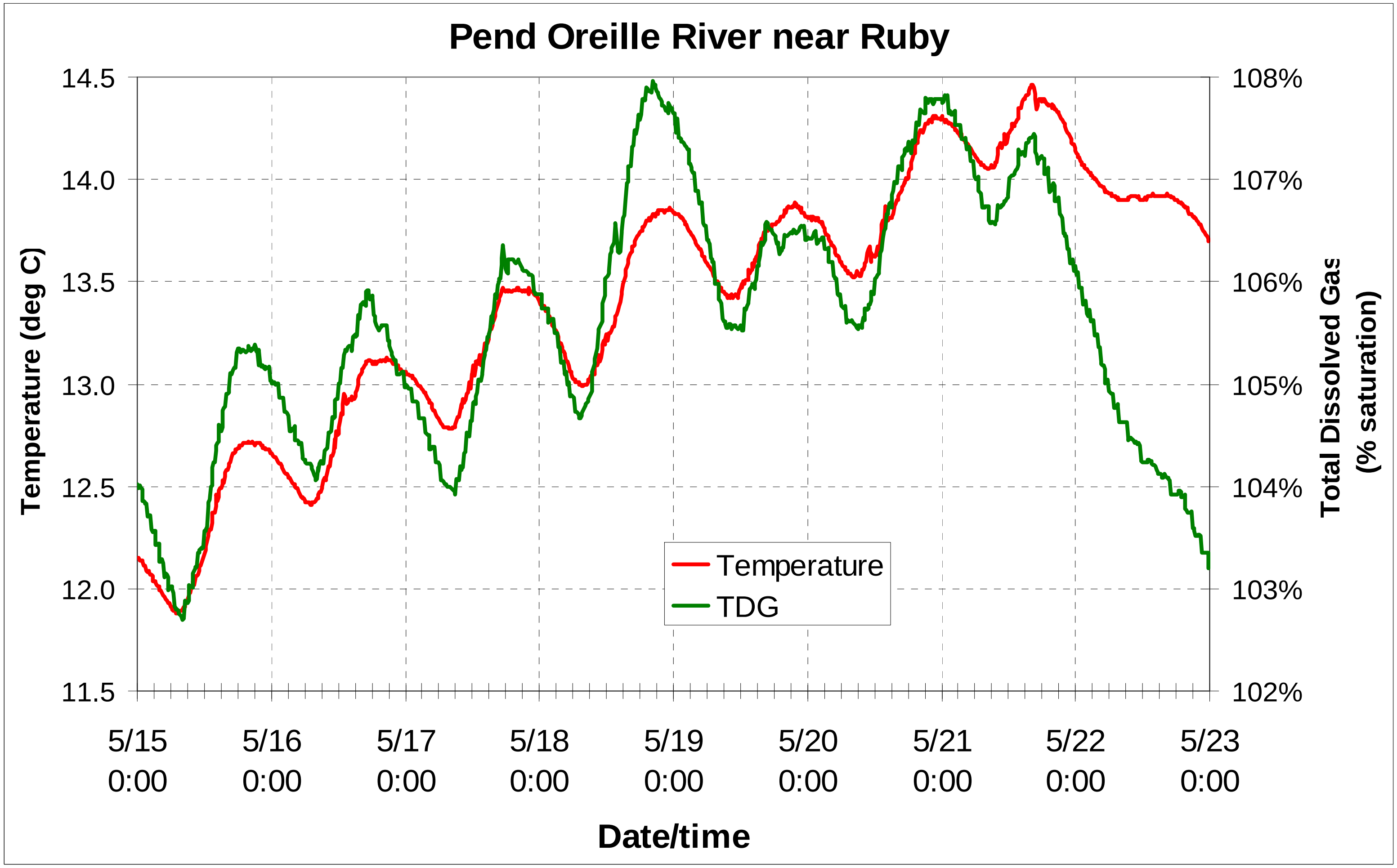


Figure B-7. Pend Oreille River Temperature and TDG, May 15-22, 2004

Table B-1. Data Quality Assessment of Laboratory Total Dissolved Gas: Pre- and post-survey comparison to reference standard

Date	DS15		DS16		DS21		Difference (Target = ±5)		
	Meter	Std	Meter	Std	Meter	Std	DS15 -Std	DS16 -Std	DS21 -Std
3/29/2004	711	711	711	711	711	711	**0**	**0**	**0**
3/29/2004	911	911	909	911	910	911	**0**	**-2**	**-1**
4/20/2004	703	703					**0**		
4/20/2004	905	903					**2**		
4/21/2004	709	706					**3**		
4/21/2004	908	906					**2**		
4/26/2004	715	714					**1**		
4/26/2004	914	914					**0**		
4/28/2004	710	708	710	711			**2**	**-1**	
4/28/2004	903	908	909	911			**-5**	**-2**	
5/12/2004	709	708			708	708	**1**		**0**
5/12/2004	907	908			907	908	**-1**		**-1**
5/14/2004			712	709	711	709		**3**	**2**
5/14/2004			910	909	908	909		**1**	**-1**
5/27/2004	704	699	701	699	699	699	**5**	**2**	**0**
5/27/2004	890	899	899	899	898	899	-9	**0**	**-1**
5/27/2004					701	700			**1**
5/27/2004					899	900			**-1**
6/8/2004	705	705			705	705	**0**		**0**
6/8/2004	904	905			904	905	**-1**		**-1**
6/9/2004			704	702	702	702		**2**	**0**
6/9/2004			901	902	900	902		**-1**	**-2**
6/16/2004			714	713	712	713		**1**	**-1**
6/16/2004			912	913	911	913		**-1**	**-2**
6/18/2004	710	709			710	709	**1**		**1**
6/18/2004	908	909			908	909	**-1**		**-1**
7/9/2004	704	703					**1**		
7/9/2004	903	903					**0**		
7/10/2004			705	705				**0**	
7/10/2004			904	905				**-1**	
7/15/2004	707	706					**1**		
7/15/2004	904	906							
Root Mean Square Error (RMSE)							**2.0**		

Bold meets MQOs, shaded exceeds MQOs. All units in mm Hg. Std = check standard.
See Appendix A for other abbreviations. DS14, DS16, and DS21 are meters.

Table B-2. Data Quality Assessment of Field Barometric Pressure Monitoring

Barometric Pressure (BP) at Meteorological Station (mm Hg): Ecology versus Station Paired Measurements					
Date	Time	Station Name	Station BP	Ecology BP	Difference (Target = ±2)
4/20/2004	17:24	Deer Park	699	701	**-1.7**
4/27/2004	15:10	Deer Park	695	696	**-1.3**
5/13/2004	15:15	Deer Park	707	706	**0.5**
5/27/2004	9:21	Deer Park	699	698	**0.7**
6/9/2004	17:58	Deer Park	698	698	**0.3**
7/9/2004	17:01	Deer Park	699	697	**2.0**
Root Mean Square Error (RMSE)					**1.3**
4/20/2004	12:01	Kalispel	702	704	-2.5
5/27/2004	16:30	Kalispel	695	699	-4.0
6/9/2004	16:56	Kalispel	697	700	-3.5
Root Mean Square Error (RMSE)					3.4

Barometric Pressure (BP) at Ruby (mm Hg): Paired Ecology measurements versus values from regression					
Date	Time	Ecology BP	(from Deer Park BP)	(from Kalispel BP only)	(from Kalispel BP & Temp)
4/30/2004	11:53	712	712	710	712
5/13/2004	10:06	710	711	713	711
5/27/2004	11:05	702	702	703	702
6/9/2004	11:00	703	703	704	702
6/17/2004	10:35	713	712	710	713
7/9/2004	15:30	702	702	701	703
			Difference (Target = ±1)		
4/30/2004	11:53		**0.1**	**1.6**	**0.4**
5/13/2004	10:06		**-1.1**	-2.8	**-0.7**
5/27/2004	11:05		**0.0**	**-1.1**	**0.1**
6/9/2004	11:00		**0.5**	**-1.4**	**0.7**
6/17/2004	10:35		**0.8**	2.6	**0.3**
7/9/2004	15:30		**-0.4**	**1.0**	**-0.7**
Root Mean Square Error (RMSE)			**0.6**	**1.9**	**0.5**
R^2			0.936	0.764	0.988

Bold meets MQOs, shaded exceeds MQOs. All units in mm Hg. See Appendix A for abbreviations.

Table B-3. Data Quality Assessment of Field Water Quality Monitoring: Ecology paired measurements of total dissolved gas (TDG) and temperature.

TDG (mm Hg)					Difference (Target = ±5)		
Date	Time	DS15	DS16	DS21	DS15 -DS16	DS15 -DS21	DS16 -DS21
30-Apr	12:15	747	748		**-1.0**		
13-May	10:21		731	731			**0.0**
13-May	10:45	729		731		**-2.0**	
27-May	11:20	732	733	734	**-1.0**	**-2.0**	**-1.0**
27-May	11:36	731		734		**-3.0**	
9-Jun	11:26	732	732	732	**0.0**	**0.0**	**0.0**
17-Jun	10:56	753	756	755	**-3.0**	**-2.0**	**1.0**
9-Jul	15:45	744	743		**1.0**		
Root Mean Square Error (RMSE) :							**1.6**

TDG (% Saturation)					Difference (Target = ±1%)		
Date	Time	DS15	DS16	DS21	DS15 -DS16	DS15 -DS21	DS16 -DS21
30-Apr	12:15	104.9%	105.1%		**-0.1%**		
13-May	10:21		103.0%	103.0%			**0.0%**
13-May	10:45	102.7%		103.0%		**-0.3%**	
27-May	11:20	104.3%	104.4%	104.6%	**-0.1%**	**-0.3%**	**-0.1%**
27-May	11:36	104.1%		104.6%		**-0.4%**	
9-Jun	11:26	104.1%	104.2%	104.1%	**-0.1%**	**0.0%**	**0.1%**
17-Jun	10:56	105.6%	106.0%	105.9%	**-0.4%**	**-0.3%**	**0.1%**
9-Jul	15:45	106.0%	105.8%		**0.1%**		
Root Mean Square Error (RMSE) :							**0.2%**

Temperature (deg C)					Difference (Target = ±0.5)		
Date	Time	DS15	DS16	DS21	DS15 -DS16	DS15 -DS21	DS16 -DS21
30-Apr	12:15	12.0	12.0		**0.0**		
13-May	10:21	11.4	11.2	11.3	**0.2**	**0.1**	**-0.1**
13-May	10:45	11.3		11.3		**0.0**	
27-May	11:20	13.5	13.4	13.5	**0.1**	**0.0**	**-0.1**
27-May	11:36	13.5		13.5		**0.0**	
9-Jun	11:26	13.7	13.7	13.7	**0.0**	**0.0**	**0.0**
17-Jun	10:56	14.6	14.6	14.6	**0.0**	**0.0**	**0.0**
9-Jul	15:45	19.6	19.6		**0.0**		
Root Mean Square Error (RMSE) :							**0.1**

Bold meets MQOs, shaded exceeds MQOs. See Appendix A for abbreviations. DS14, DS16, and DS21 are meters.

This page is purposely left blank

Appendix C. Record of Public Participation

Introduction

Public involvement is vital in any TMDL. Nonpoint TMDLs are successful only when the watershed landowners and other residents are involved. They are the closest to and most knowledgeable of the watershed resources. The Pend Oreille River watershed has a host of local, state, federal, and tribal agencies as well as non-governmental organizations involved in water resource protection. Many private landowners in the area are intimately involved with these efforts.

An advisory group, made up of citizens representing interests of Idaho groups and citizens with parallel representation from Washington, was formed. The Tri-State Water Quality Council has been facilitating meetings and coordinating the two-state effort. The Kalispel Tribe has been participating in meetings and is an important part of the process.

Ecology's *technical report* was reviewed by the Pend Oreille Advisory Committee, and a presentation of the findings was given by Paul Pickett at the May 25, 2006 Advisory Group meeting held in Sandpoint, Idaho. All Advisory Group meetings are open to the public. Meeting announcements and past meeting notes are sent to a mailing list of approximately 50 people, representing a cross-section of the public. Ecology maintains a website at www.ecy.wa.gov/programs/wq/tmdl/pend_oreille/index.htm

Comments to the responses received during the public comment period are found in Appendix E.

List of public meetings

Advisory group meetings, open to the public, were held at locations alternating between Newport and Sandpoint on the following dates:

January 20 and October 20, 2005; May 25 and October 26, 2006; and January 25, March 20, May 10, June 25, August 16, and September 28, 2007.

Outreach and announcements

A 30-day public comment period for this report was from August 6 through September 5, 2007. A news release was sent to all local media in the Pend Oreille watershed area. Advertisements were placed in the following publications:

- Newport Miner
- Miner Extra

This page is purposely left blank

Appendix D. Revised Study Plan for the Boundary Hydroelectric Project, Study No. 3, Evaluation of Total Dissolved Gas and Potential Abatement Measures, Seattle City Light FERC Project #2144, October 3, 2006

This page is purposely left blank

Revised Study Plan

Boundary Hydroelectric Project (FERC No. 2144)

Study No. 3
Evaluation of Total Dissolved Gas and Potential Abatement Measures

Seattle City Light

February 2007

TABLE OF CONTENTS

List of Tables

List of Figures

Study No. 3 – Evaluation of Total Dissolved Gas and Potential Abatement Measures

1.0 INTRODUCTION

The FERC relicensing process and the related application for certification under Section 401 of the federal Clean Water Act (401 certification) requires characterization of existing water quality conditions in the Boundary Project area and a determination of whether water quality meets the Washington Department of Ecology (Ecology) regulatory standard of 110 percent total dissolved gas (TDG) saturation for aquatic biota. Based on existing information, the Project at times does not meet this standard and increases levels of TDG in the Pend Oreille River downstream of Boundary Dam. The purpose of this study is to better define the relationship between TDG levels and Boundary Project (Project) operations and to identify and evaluate potential operational and/or structural measures that could reduce elevated TDG levels that can impair beneficial uses for fish and other aquatic species downstream of the dam. The study will involve monitoring of TDG and detailed assessment of potential abatement measures. This study plan was developed in consultation with USDA Forest Service (USFS), U.S. Fish and Wildlife Service (USFWS), Washington State Department of Ecology (Ecology), Washington Department of Fish and Wildlife (WDFW), Confederated Tribes of the Colville Reservation, Kalispel Tribe of Indians, BC Hydro, and Teck Cominco, Ltd., as described in section 2.8, below.

The Pend Oreille River system (which includes the Clark Fork River basin upstream of Lake Pend Oreille) is highly regulated, with operations controlled at dams associated with several energy production and/or storage projects. Flows into Boundary Reservoir are controlled by flows from upstream projects, including the Box Canyon Project (Pend Oreille County PUD), Albeni Falls Project (U.S. Army Corps of Engineers [USACE]), and other upstream projects such as Hungry Horse (U.S. Bureau of Reclamation).

Boundary Reservoir has a small useable storage capacity relative to the average daily river flow, as illustrated in Figure 1.0-1. As a result, instream flow releases to the Pend Oreille River from Boundary Dam on annual, seasonal, or monthly time intervals are largely controlled by the amount of water delivered from upstream projects such as Albeni Falls and Hungry Horse. Load-following operations at Boundary Dam primarily affect instream flow releases on a daily or hourly interval.

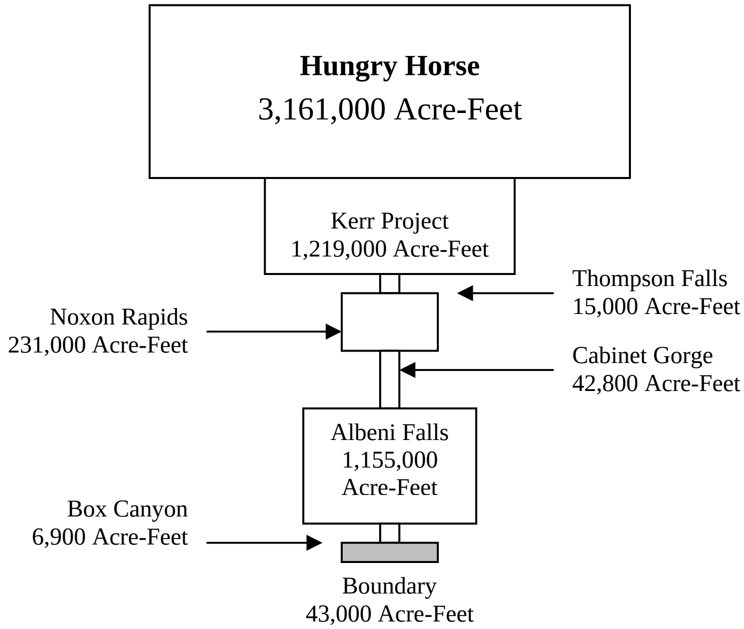


Figure 1.0-1. Hungry Horse to Boundary useable storage (acre-feet).

2.0 STUDY PLAN ELEMENTS

2.1. Nexus between Project Operations and Effects on Resources

TDG is a water quality constituent of concern in relation to the Project because past monitoring has shown that TDG measurements upstream and downstream of Boundary Dam exceeded the Ecology standard (110 percent saturation). Based on this monitoring, it has been determined that during times of spill, the Project increases TDG concentrations above this standard or increases TDG concentrations above upstream levels when upstream levels already exceed the standard.

2.2. Agency Resource Management Goals

In addition to providing information needed to characterize Project effects, this study will provide information to help agencies with jurisdiction primarily over water quality and aquatic resources in the Project area identify appropriate conditions for the new Project license pursuant to their respective mandates. The Evaluation of TDG and Potential Abatement Measures is specifically designed to meet 401 certification and relicensing requirements, but may also be relevant to recent or ongoing management activities by other agencies. A brief description of relevant resource management goals follows.

Washington Department of Ecology (Ecology) and the U.S. Environmental Protection Agency (EPA)

Washington State water quality standards related to TDG are summarized in Table 2.2-1. This table presents two sets of standards: the 1997 federally approved standards and revised standards adopted by Ecology in July of 2003. The 2003 revised standards cannot be used for regulating federal Clean Water Act actions until approved by the U.S. Environmental Protection Agency (EPA). EPA is in the process of reviewing these standards and in February 2005 provided a partial approval. Ecology is currently using the 2003 rule for the parts that EPA has approved (including TDG), but employs the 1997 rule for the parts that EPA has not yet approved (i.e., temperature). The last column of Table 2.2-1 identifies the TDG standard that is currently applicable. Both standards specify that all reservoirs with a mean detention time of 15 days or less are classified the same as the river section in which they are located. Boundary Reservoir has a residence time of less than 4 days, and is therefore categorized under the Pend Oreille River water quality standards.

Table 2.2-1. Applicable Washington State surface water total dissolved gas (TDG) standards for the Pend Oreille River between the Idaho border and the Canadian border (WAC 1997; WAC 2003).

1997 Standard (Class A) [1]	2003 Standard (salmon and trout spawning, non-core rearing, and migration) [2]	Applicable Standard
Not to exceed 110 percent of saturation at any point of sample collection	Not to exceed 110 percent of saturation at any point of sample collection	2003 Standards

1 Chapter 173-201A WAC Water Quality Standards for Surface Waters of the State of Washington. November 1997.

2 Chapter 173-201A WAC Water Quality Standards for Surface Waters of the State of Washington. July 2003.

From 2001 through 2004, the USACE and Pend Oreille County Public Utility District (PUD) monitored TDG at the Idaho state line near Newport. The U.S. Geological Survey (USGS) has been monitoring in the forebay and tailrace of Boundary Dam, with supplemental monitoring performed by Ecology. Data from this monitoring show that total TDG frequently exceeds the State of Washington water quality standards. As a result, Ecology listed the Pend Oreille River on its 2002/2004 303(d) list of impaired waters and is in the process of developing the total maximum daily load (TMDL) for TDG in the Pend Oreille River jointly with the EPA and the Kalispel Tribe. The EPA is issuing this TMDL for all waters of the Kalispel Tribe of Indians, and Ecology is issuing this TMDL for all waters in the state (A TMDL identifies how much pollution needs to be reduced or eliminated to achieve applicable water quality standards and establishes acceptable loads to achieve this end.).

Water quality standards established by both the State of Washington and the Kalispel Tribe set a criterion of 110 percent of saturation designed for the protection of fish and other aquatic organisms. Washington provides an exemption from the standards when flows exceed the seven-day, ten-year frequency (7Q10) flood flow, while Tribal standards apply at all flows.

Ecology's Water Quality Improvement Report documenting the Pend Oreille River TMDL for TDG, currently scheduled to be filed by March 2007, will consist of two parts: Volume I, Study Findings, and Volume II, Implementation Strategy. TMDL allocations will be met primarily through TDG abatement plans developed under 401 certifications for FERC relicensing. Monitoring will continue to assess compliance with standards and effectiveness of the TMDL.

The 401 certification process will consider the Project's compliance with the Clean Water Act, water quality standards, and other appropriate requirements of state law, including what measures can be employed to protect the beneficial use of the waters associated with the Project (Ecology 2005). These beneficial uses include water supply, fish and wildlife habitat, generation of electricity, and recreation. Ecology, through the 401 certification process, may require that specific actions or measures be included in the Project's license to support beneficial uses.

Water Resource Inventory Area (WRIA) 62

Numerous agencies and stakeholders in 1998 formed the Water Resource Inventory Area (WRIA) 62 planning unit, the goal of which is to "develop strategies that will balance competing demands for water, while at the same time addressing local concerns, preserving and enhancing the health of the watershed and considering the economic stability of the watershed." In January 2005, a Watershed Management Plan for WRIA 62 was completed (Golder and Associates 2005). This plan identified the following five goals and related objectives for water quality:

- WQUAL-1: WRIA-wide coordination of water quality monitoring.
- WQUAL-2: Watershed Planning Implementing Body support of actions that aim to reduce Eurasian watermilfoil and other aquatic nuisance weeds in WRIA 62.

  Objective: Reduce Eurasian watermilfoil and other aquatic nuisance weeds in WRIA 62.
- WQUAL-3a: Watershed Planning Implementing Body to participate in (interact and provide input to) the TMDL process for tributary streams that originate within WRIA 62.

  Objective: Remove tributary streams in WRIA 62 from the 3030(d) list of impaired waters by meeting State and tribal (where appropriate) water quality standards in impaired tributary streams.
- WQUAL-3b: Watershed Planning Implementing Body to participate in (interact and provide input to) the TMDL process for the mainstem of the Pend Oreille River.

  Objective: Meet State and tribal (where appropriate) water quality standards in the mainstem Pend Oreille River.
- WQUAL-5: Protect water bodies of high water quality and improve water quality of impaired water bodies.

  Objective: Maintain compliance with state water quality standards and prevent degradation of waters that meet or exceed state water quality standards in WRIA 62.

Columbia River Subbasin Plans

In 2004, the Northwest Power Planning Council completed the Intermountain Province Subbasin Plan. This plan identifies recommended management actions that will be used to guide the review, selection, and funding of projects in Columbia River subbasins (GEI 2004). The relevant management plan objectives identified in the subbasin plan as related to the Pend Oreille River are outlined below:

- Subbasin Objective 1B2: Improve water quality to meet or exceed applicable water quality standards in the Subbasin.

  Strategy c: Identify pollution sources, causes, and constituents on tributaries and mainstem Pend Oreille River; determine and implement actions necessary to eliminate or mitigate effects.

  Proposed Strategy e: Continue monitoring the water quality of Lake Pend Oreille, Clark Fork River and Pend Oreille River to insure it meets State and Federal standards.

The Evaluation of TDG and Potential Abatement Measures for the Project will provide information relevant to the objectives and strategies described above.

USDA Forest Service (USFS)

The Colville National Forest is located within the Pend Oreille River basin and as such, the USFS is a participating stakeholder in the relicensing of the Project. The USFS developed and completed the Land and Resource Management Plan for the Colville National Forest in 1988 (USFS 1988). Specific standards and guidelines in this plan related to TDG include:

1. Maintain water quality parameters within the range of good fish habitat conditions, and within State water quality standards, including the following:
   - *Total dissolved gas* – not to exceed 110 percent of saturation
2. Complying with State of Washington requirements in accordance with the Clean Water Act for protection of waters of the state through planning, application, and monitoring of Best Management Practices in conformance with the Clean Water Act, regulations, and federal guidance issued thereto.
3. In watersheds where project scoping identifies an issue or concern regarding the cumulative effects of activities on water quality or stream channels, a cumulative effects assessment will be made. This will include land in all ownerships in the watershed. Activities on National Forest System lands in these watersheds should be dispersed in time and space to the extent practicable, and at least to the extent necessary to meet management requirements. On intermingled ownerships, coordinate scheduling efforts to the extent practicable.

US Fish and Wildlife Service (USFWS)

The US Fish and Wildlife Service is responsible for some federally listed species, including threatened bull trout (*Salvelinus confluentus*), migratory birds, and the habitats that support them.

A short reach of Sullivan Creek, commencing at its confluence with the Pend Oreille River, has been designated as critical habitat for bull trout. The draft Bull Trout Recovery Plan identifies as a recovery objective, "restore and maintain suitable habitat conditions for all bull trout life history stages and strategies," and identifies investigation and improvement of water quality as a specific action to address this objective.

2.3. Study Goals and Objectives

The goal of the proposed Evaluation of TDG and Potential Abatement Measures is to identify all "reasonable and feasible" (Ecology 2005) improvements that could be used to meet the 110 percent standard by evaluating operational and/or structural modification alternatives to reduce TDG impairment at the Project in support of the Pend Oreille River TMDL for TDG and application for 401 certification. This goal will be accomplished by the following eight primary objectives for this study, which will be accomplished in two phases (with Phase 1 initiated in 2007 and Phase 2 following, as early as 2008):

1. Analyze hourly and 15-minute interval TDG data reported by the USGS from 1999 to 2005 for the forebay and tailrace fixed monitoring stations (FMS) relative to Pend Oreille River flow data, Project discharge and spill volumes to assess gas saturation.
2. Continue to monitor and collect Project forebay and tailrace FMS TDG data and assess the dissipation of TDG downstream of the Project.
3. Identify and provide brief summaries of the scope and results of the various TDG-related studies and evaluations that have been conducted since 1998 concerning gas supersaturation at the Project.
4. Evaluate methods and controls to reduce air admission requirements for generating units #55 and #56 to reduce total dissolved gas.
5. Identify, describe, and evaluate a shortlist of alternatives and potential combinations of alternatives consisting of operational and structural control measures for reducing TDG production relative to the established criteria.
6. Conduct a comparative analysis of the shortlist of operational and/or structural modification alternatives based on TDG reduction performance, hydraulic engineering methods, field testing, and modeling.
7. Identify the "preferred alternative modification strategy" (preferred alternative) for controlling and mitigating for TDG impairment based on the results of this study.
8. Identify the TDG and other monitoring and reporting activities that will be undertaken during the new license term, including those needed to evaluate the effectiveness of TDG control measures or other mitigation.

The following sections of this document provide a more detailed description of the study plan for addressing these objectives in association with the Pend Oreille River TMDL for TDG, application for 401 certification, and economic feasibility analysis (Ecology 2006) processes.

2.4. Need for Study

Many hydroelectric projects in the state of Washington — including the Grand Coulee Dam (USBR 1998), Cabinet Gorge Dam (Avista 2000), Chief Joseph Dam (USACE 2000), Priest Rapids Dam (Grant County PUD 2002), and Rocky Reach Project (Chelan County PUD 2003) — have conducted various TDG-related studies to assess operational and structural alternative measures. The need for this study and development of this study plan is informed by and benefits from these previous evaluations to ascertain a reasonable and feasible approach for assessing TDG impairment and potential abatement measures at the Project.

Summary of Existing Project Information

TDG has been documented in exceedance of Ecology standards throughout the Pend Oreille River. TDG levels in the river often exceed these standards during spill events at the hydropower facilities. TDG exceedances have been documented at the Albeni Falls, Box Canyon, and Boundary projects on the Pend Oreille River system.

Seattle City Light (SCL) has carried out numerous investigations and peer reviews from 1998 through 2006 to initially assess and characterize the effect of existing operations at the Project on TDG levels in the Pend Oreille River downstream of the Project. These investigations consisted of collection and analysis of dissolved gas data and preliminary assessment of potential alternatives to reduce TDG supersaturation in the river below the Project. In addition, several steps were performed to determine the objectives of this study plan. SCL collected relevant data, information on the TDG measurements, drawings of Boundary Dam, and regional reports. SCL then retained several consultants experienced with regional gas abatement techniques to participate in brainstorming sessions to identify potential operational and structural alternatives for reducing TDG. The list of potential alternatives was conceptually reviewed by SCL to assess the applicability of solutions previously studied at other projects. Finally, SCL has consulted with Ecology and other relicensing participants regarding the objectives for this study.

TDG data collected by the USGS since 1999 in the Boundary Dam forebay and tailrace are available on the USGS online NWIS website at http://waterdata.usgs.gov/nwis/qw. Spill and non-spill testing reports from 1998 through 2003, which comprise SCL's historic TDG assessment activities collected prior to initiating assessment of potential operational and structural alternatives in 2004, are also available in the online Information Library on the Boundary Project relicensing website (www.seattle.gov/light/news/issues/bndryRelic/), as is the subsequent peer review of Columbia Basin Environmental's (CBE) 2002 spill testing (CBE 2003), conducted by Michael Schneider (USACE 2006). For a more detailed discussion regarding existing TDG data, please refer to section 4.4.5.3.7 of the Boundary Project relicensing Pre-Application Document (PAD; SCL 2006a), filed by SCL with FERC on May 5, 2006, and available on the Documents page of the relicensing website.

As described in Attachment 1, section 3.1 of this RSP, compilation and analyses of existing hydrology data have been undertaken by SCL to produce the reliable hydrologic dataset that is needed to conduct environmental and energy production analyses (as described in Attachment 1, section 3.2 of this RSP) for FERC relicensing of the Project. This hydraulic dataset will serve as the Project hydrologic record to be used consistently for evaluations of Project operations, resource effects, and potential alternative operational scenarios, and is therefore integral to the evaluation of TDG conditions and potential abatement measures as described in this study plan. The hydrologic record for the Pend Oreille River system and the Boundary Project will be completed by March 2007 and will also be available in the Information Library on the Boundary Project relicensing website.

USGS Data for the Boundary Project

Since 1999, a continuous data logger has been recording TDG at a USGS gage (#12398600) located approximately 0.75 miles downstream of Boundary Dam. SCL has an ongoing contract with the USGS for station maintenance and daily TDG data management for this TDG station. From 1999 to 2005, exceedances of the 110 percent standard occurred in five of the six years during 5.3 percent of the total number of days monitored (primarily from April through the beginning of July). Daily TDG values for this period, estimated assuming a barometric pressure of 760 mmHG, are presented in Figure 2.4-1.

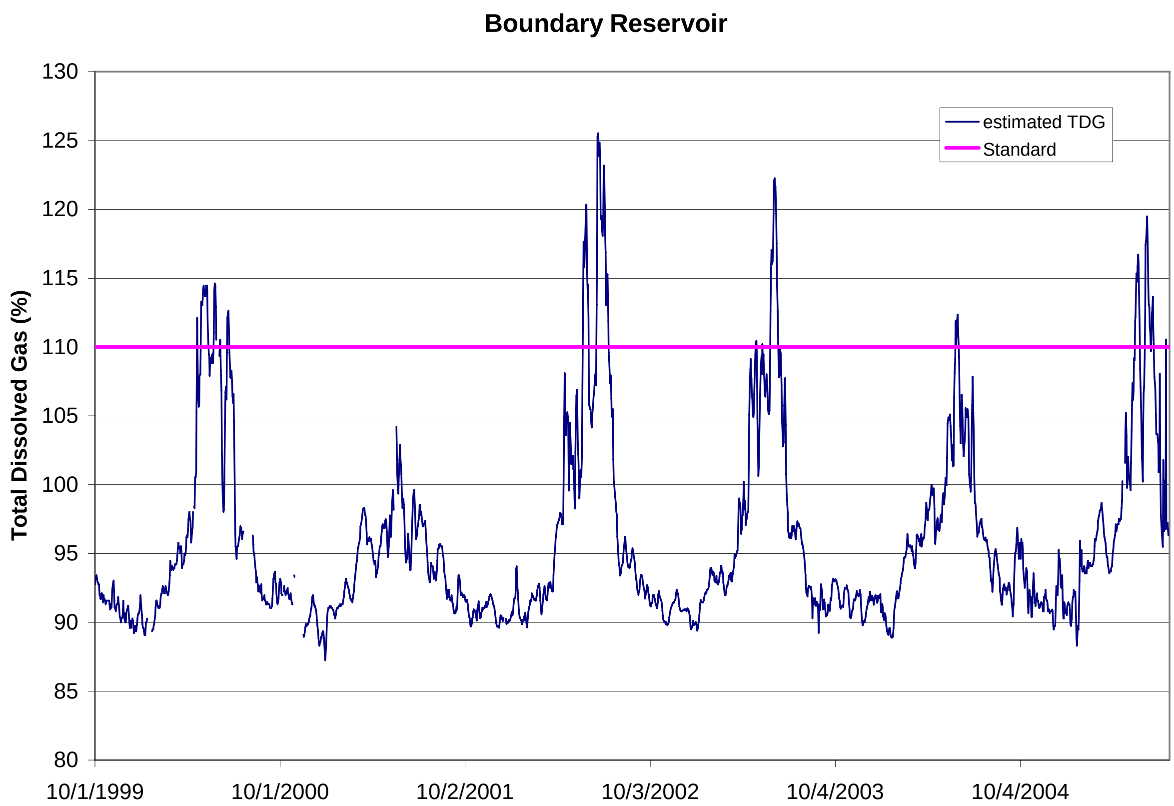


Figure 2.4-1. Measured TDG just downstream of Boundary Dam from 1999–2005 (Gage # 12398550). Note: Assumes an atmospheric pressure of 760 mmHg for the percent calculation (USGS 2005).

The elevated TDG measurements above the 110 percent standard occurring between the months of April through early July in Figure 2.4-1 correlate to approximately 4 days of spill in 2000, 1 hour of spill in 2001 (drought year), 43 days of spill in 2002 due to high flows and spillway testing (CBE 2003), 11 days of spill in 2003, and 1 hour of spill in 2004 based on SCL System Control Center dispatch data.

Pend Oreille River TMDL for TDG

The Pend Oreille River was listed on the Ecology 2002/2004 303(d) list, based on TDG in exceedance of the 110 percent saturation criterion at multiple locations. This standard is to be met for all river flows downstream of the Kalispel Reservation up to the seven-day average, ten-year high flow (7Q10 flow), which is about 108,300 cfs for the Pend Oreille River in Washington state below the Project. As a result of this listing, Ecology will take action in accordance with its memorandum of understanding with EPA, and will develop a water cleanup plan for TDG based on establishment of a TMDL. A project schedule for the TDG TMDL was reported in the Quality Assurance Project Plan (Pickett 2004) and updated (J. Jones, WDOE, personal communication, January 22, 2007; included in Attachment 4) as listed in Table 2.4-1.

Table 2.4-1. Pend Oreille River Total Maximum Daily Load for Total Dissolved Gas Schedule.

Report	**Schedule**
TMDL Report Submittal:	
Draft Technical Report (Vol. I, Study Findings)	May 16, 2006 (completed)
Draft TMDL (Vol. I and Vol. II, Implementation Strategy)	January 2007
Final TMDL (Volumes I and II)	March 2007

In completing the TDG TMDL, Ecology expects to rely heavily on historical and current data collected by the Pend Oreille County PUD, USGS, and USACE. Data from these sources and additional data collected by the USGS in 2004 will be used by Ecology to perform a simple spreadsheet-based analysis and, if necessary, a more complex modeling analysis of TDG in the Pend Oreille River system. Ecology's analysis will help determine loading capacity, pollutant allocations, and TMDL implementation to address the effects of TDG from hydroelectric projects and natural phenomena on the Pend Oreille River.

TDG Objective for the Project

State of Washington regulations require that the Project pass the 7Q10 flow while preventing the TDG concentration from exceeding 110 percent saturation. SCL is assuming that the Project will only be responsible for the TDG added relative to the difference between forebay and tailrace FMS TDG levels for flows less than the 7Q10. Depending on review of Project outage records, the 401 certificate may require SCL to accommodate the 7Q10 during a single unit outage; therefore, for a conservative design, SCL will assume that one generating unit (8,000 to 10,000 cfs) has an outage decreasing the total capacity of the plant from approximately 55,000 cfs to 45,000 cfs during high flows. This assumption creates a *design flow rate* of approximately 63,300 cfs, or the difference between the 7Q10 (108,300 cfs) and the assumed plant capacity of 45,000 cfs, for assessing an alternative or combination of alternatives without adding TDG when the level exceeds the 110 percent standard.

Need for Additional Information

Additional testing and ongoing TDG data collection is needed to further characterize Project effects on TDG in the Pend Oreille River downstream of the dam. Information is also needed to further evaluate potential measures that could be undertaken to help the Project achieve compliance with the Ecology standard for TDG. The potential gas abatement alternatives will require further analysis or evaluation to predict TDG performance and reduction benefits associated with specific flow(s) relative to the percent of the 7Q10 flow. Further investigation will also include assessment of and need for the following:

1. Potential combination of alternatives.
2. Additional field testing and monitoring.
3. Identify TDG predictive tools (numerical analysis, etc.).
4. Physical and computational modeling methods.

The study may identify significant structural modifications that will require further evaluation and refinement prior to construction. Such additional work may include on-site geotechnical investigations, physical and computer hydraulic modeling, and final design work. The major uncertainties, anticipated future evaluations, and potential actions may include:

- Sources of incoming TDG and the ability, likelihood, and implications/results of any upstream TDG reduction efforts (e.g., at upstream hydroelectric developments).
- Estimated TDG abatement performance for potential alternatives.
- Numerous engineering design and construction issues and associated requirements (e.g., bedrock integrity and other characteristics, tunnel lining and/or strengthening needs, and flow regulation capabilities [e.g., specific gate structure requirements, optimal inlet, outlet, and other optimal shaping and design considerations]).
- Potential impacts to other resources due to construction and operation.
- Benefits to the target resources as a result of the TDG Monitoring and Abatement Plan (401 certification).
- Actual TDG abatement performance of the implemented alternative by monitoring and other methods.

Assessment of Fish for Gas Bubble Trauma

TDG concentrations in excess of 110 percent saturation have been shown to cause gas bubble trauma in fish. Symptoms of gas bubble trauma vary from blistering beneath the skin when fish are exposed to low exceedances of the TDG standard to mortality when fish are exposed to extreme exceedances. Bubbles on external surfaces of juvenile salmonids have been shown to persist for up to 4 days (Hans et al. 1999).

SCL will examine fish for external signs of gas bubble trauma during surveys conducted downstream of the Project, as part of the Fish Distribution, Timing, and Abundance Study (Attachment 2, Study No. 9 of this RSP). This evaluation would only occur if a scheduled fish sampling event occurs within one week of spill; no sampling events will be scheduled specifically to address the effects of TDG on fish in the tailrace. Although a systematic appraisal of all fish captured will only be conducted during the one-week period following spill, records will be kept of any fish showing obvious signs of gas bubble trauma, regardless of when those fish are captured in relation to spill. The following information will be recorded for each fish showing signs of trauma: species, life-stage, and capture location, time, and date. All fish showing signs of trauma will be photographed.

2.5. Detailed Description of Study

Study Area

The total reach of the Pend Oreille River from Boundary Dam (river mile [RM] 17.0) upstream (southerly direction) to Box Canyon Dam (RM 34.5) is the Boundary Reservoir. There are no major tributaries to the Pend Oreille River between Boundary Dam and Box Canyon Dam, but minor flows are contributed to the reservoir from creeks such as Sullivan and Slate. For the purposes of this study, the reach of the Pend Oreille River from Boundary Dam downstream (northerly direction) to the U.S.-Canada border is considered the Project tailrace.

The study area extends from the Box Canyon tailrace FMS (#12396500) downstream through the Project area to the US-Canada border along the Pend Oreille River mainstem. TDG monitoring will be conducted at the existing USGS FMSs in the Project forebay (#12398550) and tailrace (#12398600) locations as shown in Figure 2.5-1.

SCL Efforts to Date to Assess Potential TDG Abatement Measures

Historic and current efforts to identify, describe, preliminarily assess and rank operational and structural alternatives for gas abatement controls are presented in Appendix 1. Building on the results of the assessment presented in Appendix 1, the following sections discuss the possible TDG abatement measures that have been identified and describe the Phase 1 and Phase 2 study efforts.

Identification and Preliminary Assessment

Approximately 30 alternatives to reduce TDG were identified by SCL in 2003 and 2004. Twenty-four of the original 30 alternatives were preliminarily assessed by SCL as documented in the July 2005 options matrix (see Appendix 3). The 24 alternatives are categorized in the options matrix as follows:

- Operational Alternatives
- Structural Alternatives:
  - Spillway Structural Modification Alternatives
  - Sluice Gate Structural Alternatives
  - New Structure Alternatives
- Lower River Modification Alternatives

Figure 2.5-1. Project Forebay and Tailrace Total Dissolved Gas Monitoring Locations.

Many of the alternatives were further assessed by SCL in late 2005 and early 2006 as further described in this study plan. Initial findings from this exercise included the following:

- No 'Operational Alternatives' were considered to have the potential to significantly reduce TDG levels. This initial finding was stated prior to conducting sluice gate testing in April 2006. A combination of operational and structural alternatives will be considered in this study.
- No 'Spillway Structural Modification Alternatives' were selected for further consideration. These alternatives are currently not promising due to the inability to predict the effect on TDG levels before the alternative is constructed. Previous spill test reports and subsequent peer review in 2006 support this general conclusion.
- Most of the 'Sluice Gate Structural Alternatives' were discarded, except for one option. These alternatives were rejected over concerns about reducing the sluice gate capacity to pass the required Probable Maximum Flood (PMF), inability to predict the effect on TDG levels, and constructability issues.
- Changes to the river channel downstream of the Boundary Project were initially considered, but were eliminated in early 2006 because they would be largely ineffective in reducing downstream TDG levels as measured at the tailrace FMS. The addition of new powerhouse capacity as a significant means of reducing downstream TDG was also dismissed due to the limited amount of new capacity that could be reasonably achieved and economically justified due to the relatively short period of high flows.

Only the operational and structural alternatives proposed for further evaluation are described in this study plan.

Ranking of Alternatives

SCL further assessed the 2006 list of operational and structural alternatives based on nine specific criteria prior to the June 2006 Water Quality work group meeting. These criteria, described in Table 2.5-1, are as follows:

- Hydraulic Capacity: Percent of 7Q10 (108,300 cfs)
- Effect on Ability of Project to Pass the PMF
- Potential TDG Benefit
- Constructability
- Operation and Maintenance (O&M) Challenge
- Cost
- Dam Safety
- Effects on Other Resources
- Effects on Fish (exclusion/passage)

Table 2.5-1. Criteria used for filtering TDG abatement alternatives for the Project.

Criterion	Description and Matrix Scoring
Hydraulic capacity (percent of 7Q10 flow)	How much flow can the alternative pass? A score of 10 implies the option can pass the remainder of the 7Q10 after powerhouse flows (about 64,000 cfs). A 9 implies it can pass 90%, etc.
Effect on Ability to of Project to Pass PMF	The current FERC license requires that the Project be capable of passing the probable maximum flood (PMF) of 316,000 cfs through a combination of generation discharge, spillway and sluiceway discharges. The Project is currently capable of passing a total flow of approximately 360,000 cfs. Theoretically, the difference of approximately 44,000-cfs is the maximum impairment due to a modification. A score of 10 means the option will have no affect on the Project's ability to pass the PMF. A score of 1 means the option will certainly prevent the Project from passing the PMF. A score between 1 and 10 would be assessed if there is some uncertainty as to the effect of the option. An option should also be given a score between 1 and 10 if it will reduce the Project's capacity to pass water but it is yet unknown how much flow it will impair.
Potential TDG Benefit	One of the most challenging criteria to determine and the primary objective of the study. Would the option add gas to the river? No impairment (a score of 10) means that the water passed through this option would maintain at the same TDG level as the forebay level or if the structure will strip gas (tailrace TDG levels are lower than incoming).
Constructability	How has this type of alternative been constructed before? Is construction fairly standard or is this alternative difficult to construct due to other factors? A score of 1 would be assigned if the option required new, innovative, uncertain or risky construction methods that have not been industry tested. An option would be assigned a 10 if it required little or no construction such as an operational alternative.
Operation and Maintenance (O&M) Challenge	If the alternative consists of components not typically encountered at hydroelectric projects, does it require other training by City crew to maintain? Is access to the alternative or specific areas of the alternative problematic? This score reflects if the option requires typical O&M or requires new skills not currently available at the Project. A score of 10 would indicate a very small or non-existent O&M challenge, and a 1 would indicate a large O&M challenge.
Cost	What is a reasonable cost relative to the benefits? How does initial Capital Improvement Project (CIP) cost compare to on-going O&M cost? Total costs (minus fish exclusion/passage cost) of designing, building, operating and maintaining the option (above existing plant O&M costs). An option would be assigned a 10 if there were little or no costs involved, and a 1 if costs were very high.
Dam Safety	Does the alternative modify the structure of the dam and/or powerhouse? Would the alternative affect current dam safety monitoring equipment? If so, how? What is the potential of the option to impact the structural integrity of the dam? An option that has no potential impact to the dam structure is given a score of 10.
Effect on Other Resources	Will this alternative adversely affect or conflict with other environmental and operational resources? Is so, how? This criterion is a measure of how the option affects other Project or utility resources such as the recreation areas, habitat, access roads, head on Project, aesthetics, etc. An alternative would be assigned a 10 if it had little or no effect on other resources, and a 1 for highly significant adverse effects.
Effects on Fish (exclusion/passage)	Will be informed by the findings of the Fish and Aquatic Resources studies. A score of 10 implies that no additional cost is required for fish exclusion or passage, nor will the option impair fish.

A matrix was developed using these nine criteria to compare TDG options to each other as shown in Appendix 1, Alternatives Matrix and Ranking Criteria. These criteria are the basis for filtering and identifying the most promising alternatives for further evaluation as described in this study plan.

The criteria were given relative importance factors. For example, the ability to reduce TDG and effects on fish were given full weight or 100 percent, while constructability factors were weighted at 70 percent. Following the July 2006 Water Quality Workgroup meeting, the operational and structural alternatives were ranked by muting the "Cost" criteria to assess the sensitivity of the options to specific non-cost criteria and eventually, with other criteria filtering methods, provide a technical basis for further assessing alternatives as listed in Appendix 1, Matrix #1.

Sensitivity Analysis

Method

A sensitivity analysis was performed using Matrix #1, Matrix #2, and Matrix #3 in Appendix 1. Matrix #1 (see Appendix 1) assesses if one or more of the criteria were having a more dominant effect on the relative ranking of the alternatives. The analysis was accomplished in two steps. First, the options were ranked according to individual criteria and compared to the ranking positions using all the criteria as presented in Matrix #2 in Appendix 1. Second, each criterion was muted successively and the option ranks were compared to the ranking positions using all the criteria as presented in Matrix #3 in Appendix 1. The results of the muted rankings in Matrix #3 use a color coding scheme. If the option rank order increased, it is shown in yellow. If the option rank order remained the same, it is shown in green. If the option rank order decreased, it is shown in blue. The bottom table on Matrix #3 only sorts the upper table to numerically list the six proposed alternatives for further evaluation in this study.

Observations

As a result of the sensitivity analysis, the following observations are noted among alternatives on Matrix #2 and enlarged as the first table on Matrix #3 relative to assessing the influence of each of the nine criteria on the *Rank with All Criteria*:

- Rank without *Hydraulic Capacity* criterion:

  Muting this criterion replaced only one of the top six alternatives, Option 4-8A, with Option 4-1, Underwater Outlet through Midsection of Dam, since Option 4-1 has a lower score of "4" relative to Option 4-8A's score of "10." Muting the lower score of Option 4-1 increased its overall rank.

- Rank without *Effect on Ability of Project to Pass the PMF* criterion:

  Muting this criterion only switched the rankings of two alternatives, Options 3-2 and 4-9, yet all six alternatives remained in the top six rankings. This result assumes that Option 3-2, Roughen Sluice Gate Discharge, will not significantly reduce the current, total discharge capacity of seven gates. Again, Option 3-2's score of "9" was muted relative to Option 4-9's score of "10," causing the switch in rank between 1 and 2.

- Rank without *Potential TDG Benefit* criterion:

  Muting this criterion elevated the ranking of Option 2-1, Spillway Modifications, to the top six alternatives with Option 4-8A dropping to a rank of 8. Option 2-1's score of "2.5" was muted relative to other channel/tunnel options. All scores listed for this criterion are based on industry experience and judgment reflecting on an alternative's proven ability to reduce TDG. This is the primary criterion to be further evaluated in Phase 1 of the study.

- Rank without *Constructability* criterion:

  Muting this criterion allows the lower scores of Options 4-7A and 4-8 to increase rank into the top six alternatives, yet Option 1-3, Throttle Sluice Gates and Option 4-8A, New Left Abutment Tunnel Intercepts Diversion Tunnel, maintain high ranks. This criterion creates a broad distribution of scores. The apparent consistency of high ranking tunnel options may reflect more confidence in this construction method.

- Rank without *O&M Challenge* criterion:

  Muting this criterion switches the ranking of Option 4-7A with Option 4-8A, and reorders the top 2 through 4 ranking alternatives due to relatively close scores. This option has a broad distribution of scores reflecting the challenge of assessing the O&M impact due to new structures.

- Rank without *Dam Safety* criterion:

  Muting this criterion did not change any of the top six ranks based on all criteria because many alternatives scored a "10" that, when muted, does not appreciably change the overall rank.

- Rank without *Effects on Other Resources* criterion:

  Muting this criterion allowed Option 4-10 to increase in rank due to a lower score relative to Option 3-2, yet both options remain in the top six alternatives. The subtle rank change is perceived as more potential for Option 4-10 to create some impacts at the inlet and/or outlet versus the sluice gate discharge. Option 4-10 has a lower score, indicative of potentially more impacts downstream. The study will assess the potential impacts of tunnel options on other resources including habitats and changing circulation patterns in the forebay and tailrace.

- Rank without *Effects on Fish (exclusion/passage)* criterion:

  Muting this criterion only switched the top six alternative rankings. The two shorter tunnel alternatives, Option 4-9 and Option 4-10, both rank as "1." The apparent rank movement between Option 4-7 and Option 4-8A may indicate a higher sensitivity for tunnels originating in the forebay (left bank) versus tunnels on the right bank.

Conclusions

Based on the sensitivity analysis of the assessment criteria, four criteria have the greatest potential to reorder the options. These include *O&M Challenge*, *Effects on Other Resources*, *Constructability*, and *Effects on Fish*. Currently, only minor changes in ranking are observed when individual criteria are muted. This suggests that no single criterion is keeping any options out of the upper ranking. As more information is developed through the course of implementing this study plan, the options' sensitivity to specific criteria will be better understood.

Possible Alternatives for TDG Abatement

As a result of the sensitivity analysis and ranking the alternatives (see Appendix 1), the following six alternatives (in numerical option order, not rank) appeared most technically promising:

- Option 1-3. Throttle Sluice Gates
- Option 3-2. Roughen Sluice Gate Discharge
- Option 4-7. New Right Abutment Tunnel with Submerged Discharge
- Option 4-8A. New Left Abutment Tunnel Intercepts Diversion Tunnel
- Option 4-9. Penstock/Draft Tube By-Pass
- Option 4-10. New Short Left Abutment Tunnel Next to Unit #51

Conceptual drawings of the six alternatives are presented in Appendix 2 to this study plan. Additional alternatives may be added to this shortlist as potential replacements for any alternatives discarded based on further evaluation; as a result of new information; or, to complete a viable combination of alternatives. Reasons for discarding an alternative will result from conducting Phase 1 or Phase 2 activities described in this study plan, as applicable.

The "undeveloped" options listed in Appendix 3 result from the initial brainstorming and preliminary assessment sessions and include reasons for discarding the options based on preliminary hydraulic capacity assessment, constructability, dam safety, and potential effects on fish similar to the listed criteria in previous sections. None of these options are anticipated to be evaluated in the study; however, the possibility exists that these options could be revisited in the future to create a combination alternative (i.e., two or more options to achieve TDG reduction). Most of the undeveloped alternatives have limited or no practical industry applications at other projects. Unless one of these options can be combined with another option to create a more viable alternative as identified in Phase 1 of this study, SCL will recommend that all of these undeveloped alternatives be discarded from consideration.

The six most promising alternatives on the shortlist, as illustrated in Appendix 2, are further described in the following sections.

Operational Alternative

Generally, the identified operational alternatives would be simpler to implement than structural alternatives. A detailed description of each option, with conceptual drawings, is presented in the *Alternatives to Reduce Total Dissolved Gas Supersaturation* document. Only the single operational alternative proposed to be further evaluated in this study is described in this study plan.

Option 1-3. Throttle Sluice Gates

As originally designed and constructed, the sluice gates normally operate either fully opened or fully closed. The objective of this operational alternative is to operate a sluice gate at a throttled position to determine the maximum possible flow that may be passed while not causing TDG impairment.

This alternative appears more promising than originally anticipated based on observations during the April through June 2006 testing periods. During this testing period, sluice gates No. 3, No. 4, and No. 5 were throttled to 2-, 3-, 4-, and 5-foot openings for 2 to 4 hours with fairly consistent plant discharge (cfs). The results of the 2006 testing will be completed by March 2007 and will be available in the Information Library on the Boundary Project relicensing website at: www.seattle.gov/light/news/issues/bndryRelic/). Michael Schneider (USACE) will peer review the 2006 testing protocol, data analysis, and results.
To throttle the sluice gates on a permanent short- or long-term basis, design modifications must be implemented and may require enclosing the sluice gate to minimize vibration and leakage, and installation of a redundant or auxiliary gate on the upstream side of the dam to seal off the existing sluice gate (downstream side of dam). The auxiliary gate is an anticipated modification to prevent an uncontrolled release of water due to a potential malfunction of the existing sluice gate(s) in accordance with the FERC dam safety requirements. The current ranking of this option assumes few or no fish are present at elevation 1,800 feet NGVD 29 (1,804 feet NAVD 88), or approximately 190 feet below the normal pool elevation of 1,990 feet NGVD 29 (1,994 feet NAVD 88).

Structural Alternatives

The most promising shortlist of structural alternatives are generally described below relative to each conceptual idea to reduce TDG and illustrated in Appendix 2. A detailed description of each option, with conceptual drawings, is presented in the *Alternatives to Reduce Total Dissolved Gas Supersaturation* document.

Option 3-2. Roughen Sluice Gate Discharge

The intended results would be to break up the jet and increase the surface area of the jet impact zone in the tailrace, thereby limiting the depth of plunge. Modifications for this option included adding deflectors. The sluiceways have been designed to enhance flow by minimizing any disturbance to the flowline. The bulbous piers at the entrance to the sluiceways are designed to minimize flow separation. The introduction of roughening blocks and flow deflectors would disrupt the original design capabilities of the sluiceway. Any modification cannot reduce the flow more than approximately 40,000 cfs, which is the difference between the total hydraulic capacity (approximately 360,000 cfs) and the PMF (approximately 316,000 cfs). The current ranking of this option assumes few or no fish are present at elevation 1,800 feet NGVD 29 (1,804 feet NAVD 88).

Option 4-7. New Right Abutment Tunnel with Submerged Discharge

This tunnel alternative[1] would have an inlet on the right side of the lake and discharge at some point below the dam at a submerged elevation. There are many parameters requiring consideration and include, but are not limited to, the following: routing based on structural integrity analysis and abutment geotechnical analysis; inlet and outlet locations and elevations dependent on submergence requirements, topography, and bathymetry; and, optimized hydraulic capacity. Two smaller-diameter, right abutment tunnels may be a variation of this option.

Option 4-8A. New Left Abutment Tunnel Intercepts Diversion Tunnel

The tunnel inlet would be in the existing forebay near the intake tunnel and emergency generator building on the left side of the dam, and discharge would be deeper than the diversion tunnel below the tailwater for submerged discharge. There could be a number of routing alternatives for the tunnel. The outlet for the existing diversion tunnel would require enlargement and re-alignment for optimal submergence and TDG reduction performance.

Option 4-9. Penstock / Draft Tube By-Pass

This option assumes evaluation of different size tunnels that bifurcate from the existing penstock and bypass the water around the turbine within the boundaries of the headgate and the draft tube gate. SCL anticipates modeling of the test turbine bypass option either with a new turbine design or with existing turbines with a new turbine design potentially designed for maximum capacity and flow, not peak efficiency. If implemented, the standard approach is to design (including hydraulic modeling) and construct one bypass, then monitor for TDG reduction performance, followed by potential design modification to further reduce TDG, then construct the second bypass. A plant outage will be required for construction, and if the construction and testing of a new bypass takes longer than approximately 9 months, excess spill may be produced due to the outage.

Option 4-10. New Short Left Abutment Tunnel Next to Unit #51

The tunnel inlet would be in the existing forebay on the left side of the generating unit #51 intake and conceptually be a seventh penstock. This option would require re-sizing the existing forebay to accommodate this new intake. There may be a couple of routing alternatives for the tunnel. This option would require hydraulic modeling to optimize resizing the forebay for all existing generating units including this new tunnel. This option may present an opportunity to improve capacity, efficiency, and reduce TDG production through the penstocks and turbines.

---

[1] For all tunnel options, it is assumed that conventional drill and shoot methods would be used to excavate the rock from the tunnel outlet. The shafts for the gate controls and accessory equipment would employ the "drop raise" mining technique of drilling closely spaced holes from the ground surface, vertically down to and intersecting the tunnel. The drill holes outline the perimeter of the shaft and are loaded with charge delays from the bottom, then sequentially detonate, moving up the shaft from the tunnel, to release rock material into the tunnel where it can be mucked out.

Proposed Methodology

The methodology proposed for this study is to describe existing conditions within the study area including hydrology, hydraulics, operations, water quality, and environmental resources as the basis for evaluating the benefits of each alternative. The nine criteria for screening TDG abatement measures discussed previously (as presented in Appendix 1) provide the basis for the initial comparison of potential benefits of each alternative.

The Phase 1 and Phase 2 components of this study will focus on the most promising alternatives and identify potential alternative combinations that may be promising to achieve the highest attainable level of improvement to TDG impairment at the Project, with the goal of determining an alternative or combination of alternatives to maximize gas abatement up to the 7Q10 (108,300 cfs) flow.

Desktop analysis, field studies, hydraulic analysis, and hydraulic modeling efforts are needed to complete Phase 1 and Phase 2 identification and detailed design of the alternatives. These efforts include topographic, bathymetric and geologic surveys; physical and numerical modeling of the Project and specific features of the alternatives; and, constructability analyses that may include geotechnical investigations.

Depending on review of the Project outage record, SCL may assume that one generating unit (8,000 to 10,000 cfs) has an emergency outage decreasing the total capacity of the plant from approximately 55,000 cfs to 45,000 cfs during high flows. This assumption creates a *design flow rate* of approximately 63,300 cfs, or the difference between the 7Q10 (108,300 cfs) and the assumed plant capacity of 45,000 cfs, for assessing an alternative or combination of alternatives that would not add TDG when the level exceeds the 110 percent standard.

In addition to the documents that have been developed to date (as available on the Boundary Project relicensing website and referenced in this study plan), this study will use the following sources of TDG-related data to further evaluate gas abatement alternatives:

- TDG forebay and tailrace FMS data from mid-1999 through 2005 (USGS 2006) for Gage Nos. 12398550 and 12398600.
- Hourly flow data from the U.S. Geological Survey for the Pend Oreille River below Box Canyon Dam (Gage No. 12396500) and below Boundary Dam (Gage No. 12398600) near the U.S.-Canada border.
- Hourly flow data from SCL for total flow release from Boundary Reservoir (energy generation plus spill) from 1987 through 2005.
- Hydrologic Record (dataset and statistics) for Boundary Project (March 2007) as referenced in Attachment 1, section 3.1 of this RSP.
- 2006 Sluice Gate Operational and TDG Testing Assessment (March 2007).
- SCL Drawings of Pertinent Project Features such as Plans and Sections of the Dam, Forebay, Powerhouse, Diversion Tunnel, Geology, and Rock Cores.

This study will be conducted in two phases in close coordination with relicensing participants and Ecology. Together, the Phase 1 and Phase 2 components of the study will represent a progressively more detailed and refined assessment of the operational and structural alternatives for reducing TDG levels downstream of the Project.

Phase 1 Activities and Content for Study Report

Phase 1 of this study will generally consist of the ongoing, desktop, and fieldwork tasks listed and described below.

Ongoing Activities

- The USGS will continue to collect and perform QA/QC on the forebay and tailrace FMS data. One probe exists at the forebay FMS and two probes exist at the tailrace FMS. One forebay probe and one tailwater probe have recorded hourly data from 1999 to 2005. In 2005, a second tailwater probe was added to provide redundant data in case of meter outage; in addition, the frequency of readings for all three probes changed from hourly to 15-minute intervals. The two tailwater probes are closer to the left bank. A third probe was installed by SCL at the tailrace FMS closer to the right bank in spring 2006 to better assess mixing characteristics across the tailrace transect during high flows and retrieved in late summer 2006. Deployment of a third probe in the tailrace is expected to be repeated in 2007.
- Throttle testing of two or more sluice gates is not anticipated to continue in 2007. Depending on the Phase 1 results and TDG TMDL process, throttle testing may be planned for 2008/2009.

Tasks for Phase 1 of Study

Task 1.1 Familiarization with Existing TDG-related Studies and Reports

Review and provide brief summaries of the scope and results of the various TDG-related studies and evaluations that have been conducted since 1998 (through early 2007) concerning gas supersaturation at the Project to serve as part of background information for 2007 study report. The studies and reports will include documents prepared by internal staff and consultants. Study and report references in this document include Parametrix (1998), Lemons (2000), Columbia Basin Environmental (2001, 2003), SCL (2003, 2005), and Schneider (2006). Documents related to the Ecology Pend Oreille River TMDL for TDG will require review and familiarization.

Task 1.2 Detailed Scope of Work for Phase 1 and Phase 2 Tasks

Based on the results of the review conducted in Task 1.1, develop a detailed scope of work for performing the remaining Phase 1 tasks and Phase 2 tasks including deliverables, cost estimates, and schedule in accordance with current SCL requirements relative to FERC, Ecology, and other regulatory processes. Performing Task 1.1 may suggest the need for additional investigations to address unresolved conditions such as: the effect of operational alternatives on spill through the various structures; the effect of the submerged cofferdam in the tailrace from original construction; and the conditions creating, and the amount of, powerhouse flow entrainment into the spill.

Task 1.3 Existing Conditions – Data Collection, Analysis, Graphs and Tables

This task requires the Technical Consultant to work closely with SCL staff experienced with analyzing spill and non-spill related TDG impairment at the Project.

1.3.1 Analyze hourly and 15-minute interval TDG data reported by the USGS for the forebay and tailrace FMSs relative to Pend Oreille River flow data, Project discharge and spill volumes to provide gas saturation duration, frequency and related statistics for the 2007 study report. Describe and present data and statistics in tables and graphs.

1.3.2 Identify and describe TDG uptake mechanisms and hydrodynamics in the tailrace.

1.3.3 Briefly summarize the Project hydrologic record (March 2007) for the 2007 study report.

1.3.4 Evaluate methods and controls to reduce air admission requirements to decrease total dissolved gas. Under specific operating conditions, generating units #55 and #56 add TDG due to air admission at low gate openings (Lemons 2000; SCL 2003). This potential TDG impairment will be evaluated to identify gas abatement control measures.

1.3.5 Develop and implement 2007 TDG Monitoring Plan. The purpose of this task is to describe and/or verify the TDG exchange process and uptake mechanisms in the forebay, turbine discharge area (afterbay), and tailwater channel. This task will require planning, procuring, installation, collection of TDG data, and retrieval of TDG monitoring transects. The collected TDG data will be properly reduced to comply with or exceed current USGS QA/QC methods for water quality instruments, calibration, maintenance, and precision. Collect Acoustic Doppler Current Profiler (ADCP) velocity data in the Project tailrace for calibrating analyses.

Task 1.4 7Q10 Flow Conditions

Evaluate 7Q10 flow relative to forebay elevations, generation, and tailwater ranges. The powerhouse capacity will decrease during extreme flood events due to increased tailwater elevations. This reduction in capacity will be estimated to refine the estimated required capacity of the TDG abatement alternatives (differences between 7Q10 and plant discharge flow).

Task 1.5 Estimate TDG Performance for Alternatives, Identify and Assess Potential Alternative Combinations

Parts A and B of this Task will occur concurrently to identify a potentially reasonable alternative or alternative combination that satisfies particular engineering analysis and design goals.

Task 1.5.A. Estimate TDG Performance for Alternatives or Alternative Combinations

Part A of Task 1.5 is to estimate TDG performance for the shortlist of most promising alternatives.

1.5.A.1 Propose and describe rationale for utilizing a specific method or analytical approach for estimating TDG performance based on existing information considering the unique characteristics of the Project.

1.5.A.2 Estimate or predict gas abatement performance for the shortlist of operational and structural alternatives including potential alternative combinations.

1.5.A.2 (1) Briefly describe specific field-testing, surveys, and numerical techniques (DGAS-type of regression analysis, CRiSP methods, etc.) to estimate or predict TDG reduction performance to further assess each alternative based on previous analyses and professional judgment.

1.5.A.2 (2) Provide alternatives comparison of TDG performance relative to existing conditions and variable, forebay TDG levels.

1.5.B. Selecting Gas Abatement Alternatives

Part B of Task 1.5 is to assess whether a selected alternative or combination has a greater potential for gas abatement based on the following design goals defined for Alternative #1, #2, and #3:

Alternative #1 Maximum gas abatement measure to achieve the highest attainable level of improvement resulting in downstream TDG levels that are at least equal to or less than the TDG level at the forebay FMS during the 7Q10 flow, assuming the forebay TDG level is greater than 110 percent. This alternative shall reflect the alternative or alternative combination that comes closest to achieving the 110 percent standard.

Alternative #2 No net increase in TDG relative to forebay FMS TDG levels. This alternative shall pass the *design flow rate* (63,300 cfs) resulting in downstream TDG levels similar to the forebay FMS TDG levels during the 7Q10 flow.

Alternative #3 Account for other potential resource impacts. This alternative shall significantly reduce downstream TDG compared to existing conditions, while minimizing environmental impact, and cost of construction and operation of this alternative.

Task 1.6 Preliminary Design and Construction Approach

For the alternatives and alternative combinations resulting from Task 1.5, briefly identify and describe geologic conditions at the Project, and identify potential location(s) and/or alignment(s) using existing SCL drawings and related documents, as applicable. Identify and describe design and construction approach, constraints, and limitations associated with each alternative.

Task 1.7 Field Reconnaissance, Surveys, and Hydraulic Analysis

Summarize existing topography, bathymetry, depositional areas, and geologic characteristics where significant construction activities will occur based on assessing alignment or location of an alternative or alternative combination as a result of performing Tasks 1.5 and 1.6. This information is required to better estimate gas abatement performance and cost.

1.7.1 Provide design details required to minimize gas uptake at the discharge of any new alternative.

1.7.2 Estimate survival rates of fish passing through a new alternative to minimize potential negative effects on fish passing through the new structure.

1.7.3 Assess flow interactions downstream during a major flood event due to existing and new alternative discharge.

1.7.4 Assess effects of the new alternative on the operational efficiency of the powerplant.

Task 1.8 Preliminary Cost Estimates for Design and Construction

Prepare preliminary cost estimates for design and construction of the alternatives resulting from Tasks 1.5 through 1.7; identify applicable risk assessment methodologies relative to dam safety concerns (Hartford 2004); and conduct economic feasibility analysis (Ecology 2006). Identify and describe all assumptions, constraints, and limitations to inform the Phase 2 and SCL planning efforts.

Task 1.9 Proposal for Phase 2 Activities

Propose activities for Phase 2 of this study effort to review with relicensing participants as a result of performing Tasks 1.1 through 1.8. Further refinement of the alternatives developed in Phase 1 are anticipated to require field reconnaissance studies and hydraulic modeling to identify and resolve uncertainties associated with the alternative designs and specific application at the Project.

Task 1.10 Draft and Final Phase 1 Reports

Prepare Draft and Final Phase 1 study reports for review by relicensing participants including photographs, graphs, tables, and other illustrations needed to effectively describe the tasks, methodologies, and their results.

Phase 2 Activities and Content for Study Report

Phase 2 of this study will generally consist of the following ongoing, desktop, and fieldwork tasks as listed and described below. The Phase 1 report will inform refinements to the Phase 2 tasks listed in this study plan and as a result, the Phase 2 tasks will be updated in 2007/2008.

On-going Activities

- The USGS will continue to collect and perform QA/QC on the forebay and tailrace FMS data.
- Results will be developed and made available from other studies in 2007 that inform the TDG study process.

Tasks for Phase 2 of Study

Task 2.1 2008 TDG Monitoring Plan

The purpose of this task is to describe and/or verify the TDG exchange process and uptake mechanisms in the forebay, turbine discharge area (afterbay), tailwater channel, and other locations identified as a selected Alternative Nos. 1, 2, and 3 (refer to Phase 1, Task 1.5). This task will require planning, procuring, installation, collection of TDG data, and retrieval of TDG monitoring transects. The collected TDG data will be properly reduced to comply with or exceed current USGS QA/QC methods for water quality instruments, calibration, maintenance, and precision.

2.1.1 Evaluate mixing zone dynamics for the USGS tailrace FMS based on 2006 and 2007 monitoring data for the two probes.

Task 2.2 Phase 2 Report Content for Executive Summary

Summarize Phase 1 study efforts and existing dissolved gas conditions for 2008/2009 Study report. Identify and describe operational, structural and/or combination of gas abatement measures resulting from Phase 1 efforts.

Task 2.3 Conceptual and Feasibility Analysis of Alternatives

Perform and present results of hydraulic analysis, total dissolved gas evaluation, surveys, specific field testing, and hydraulic modeling for each applicable gas abatement alternative. The hydraulic analyses for the penstock bypass and tunnel alternatives primarily consist of determining acceptable tunnel/pipe, valve, gates, and submergence requirements. Potential cavitation will need to be accounted for in the analysis. The feasibility level of evaluation will include hydraulic model studies to assist with the final feasibility level designs and evaluation of TDG abatement measures.

2.3.1 Field Surveys and Hydraulic Modeling. Computational and/or physical hydraulic modeling is anticipated to characterize existing conditions and to optimize new proposed modifications. The hydraulic modeling will provide a better understanding of gas transfer mechanisms where the plant and spill flow interact, and contribute to testing and optimizing the design of an alternative or alternative combination. A reasonable assumption is that model testing continues for at least one year.

Task 2.4 Effects of Alternatives on Other Resources

Describe and estimate potential effects on resources due to gas abatement alternative(s) selected as a result of Phase 1 tasks. Resources include water quality, fish and aquatics, operations, in-river construction, plant and wildlife, air quality, cultural, and aesthetics. (Refer to the criteria used to screen alternatives). Based on other resource study results, the evaluation and determination of a "preferred alternative" may need to assess the effects on fish (Neitzel 2000).

Task 2.5 Cost Estimates for Design and Construction

Refine and update Phase 1 cost estimates for design and construction based on final Phase 1 report and results of Phase 2, Tasks 2.1 through 2.4. An economic feasibility analysis (Ecology 2006), dam safety risk assessment (Hartford 2004), or other pertinent analysis of alternatives may need to be performed based on Phase 2 study results.

Task 2.6 Planning the TDG Elements of Application for 401 Certification

Discuss evaluation and implementation of TDG alternative(s) relative to 401certification process. This task includes proposed schedule, licensing, permitting, and environmental reviews required by Ecology, USACE, EPA, USFWS, WDFW, SHPO, and other agencies as applicable.

Task 2.7 Gas Abatement Plan

Draft a gas abatement plan for the 401 certification application including monitoring and reporting activities that will be undertaken during the new license term, such as those needed to evaluate the effectiveness of TDG control measures or other mitigation. This is a separate document from the study reports.

Study Implementation Planning

TDG study efforts and associated evaluations may extend into 2009 and beyond during development of the application for 401 certification, Preliminary Licensing Proposal (PLP), and License Application.

As described in Attachment 1, section 2.2 of this RSP, SCL has selected and retained the Technical Consultant that will implement the relicensing study program. Prior to initiation of the studies, the Technical Consultant will participate, with SCL and relicensing participants, in developing and refining any remaining details related to implementation of the studies.

2.6. Work Products

The following official work products are required for completion of this study:

- *Draft and Final Phase 1 study reports*—The Phase 1 report is expected to include (but not be limited to) the following contents:
    - Section 1: Executive Summary. Background, study goals, and summarize existing and Phase 1 information.

  - Section 2: Existing Project Conditions and Facilities. Describe existing hydrologic and TDG conditions relative to Project facilities. Include existing drawings of Project features, graphs and tables showing rating curves, generation, flow and TDG data. Describe TDG uptake mechanisms and hydrodynamics in the tailrace.
  - Section 3: Gas Abatement Alternatives. Summarize identification and development of alternatives. Identify and present rationale for determination of top three ranked alternatives (i.e., Alternative Nos. 1, 2, and 3).
  - Section 4: Gas Abatement Performance. Describe estimated gas abatement performance for the most promising alternatives and Alternative Nos. 1, 2, and 3. Describe and graphically provide a comparison and summary of the results.
  - Section 5: Field Reconnaissance, Surveys, and Hydraulic Analysis. Summarize existing topography, bathymetry, depositional areas, and geologic characteristics where significant construction activities will occur based on assessing alignments or locations of alternatives listed in Section 3.
  - Section 6: Design and Construction Cost Estimates. Preliminary estimates for design and construction costs including O&M will be developed for Alternative Nos. 1, 2, and 3 resulting from performing Phase 1, Task 1.5. All assumptions will be identified and described for each specific cost line item. Line items will include, but not be limited to: (1) survey(s), potential land acquisition, engineering design, analysis and modeling required to design the alternative; (2) construction materials and installation cost including taxes and contingencies; (3) permitting and environmental review document preparation and meetings; and (4) City of Seattle and SCL contracting administration and overhead.

- *Draft and Final Phase 2 study reports*—The Phase 2 report is expected to consist of similar contents as the final Phase 1 report, with updates and modifications, and the addition of the following work efforts and report contents:
  - Environmental Effects of Alternative and Alternative Combination
  - Identification of environmental resources and how they may be affected by the alternatives, including potential impacts during construction and longer-term operational effects
  - Field Surveys, Hydraulic Modeling and Prototyping
  - Revised Gas Abatement Performance
  - Revised Design and Construction Estimates
  - Identification of Permits and Environmental Review for the 401 certification process
  - Gas Abatement Plan for the 401 certification application

2.7. Consistency with Generally Accepted Scientific Practice

The methods described herein have been developed based on review of regional TDG-related efforts (USBR 1998, Avista 2000, USACE 2000, Grant County PUD 2002, and Chelan County PUD 2003) and in consultation with relicensing participants. The study approach and methods are consistent with Ecology's Water Quality Certifications for Existing Hydropower Dams, Guidance Manual (Ecology 2005).

2.8. Consultation with Agencies, Tribes, and Other Stakeholders

As indicated above, SCL met with Ecology in 2005 to identify issues to be addressed as part of the 401 certification process. Workshops on the Project relicensing were held in Spokane, Washington, on November 30, 2005, and February 16, 2006. Water Quality Workgroup meetings were held in Spokane on May 22, 2006, July 25, 2006 and August 16, 2006, and in Metaline Falls, Washington, on June 29, 2006. Parties attending the Water Quality Workgroup meetings included Ecology, USFS, USFWS, Confederated Tribes of the Colville Reservation, the Kalispel Tribe of Indians, Columbia River Intertribal Fisheries Commission, BC Hydro, Pend Oreille County PUD, and Columbia Power Corporation.

At the May 22, 2006 Water Quality Workgroup meeting, SCL and relicensing participants discussed SCL's proposed TDG monitoring, testing, and study plan development process including 1) existing TDG operational testing and assessment, 2) Ecology's approach to the Pend Oreille River TDG TMDL, 3) gas abatement measures applied at other dams in the region, 4) SCL's TDG abatement measures matrix, and 5) potential PSP study plan elements. SCL confirmed that the eventual solution to TDG abatement at the Project could consist of a combination of structural and operational elements.

At the June 29, 2006 Water Quality Workgroup meeting, SCL and relicensing participants discussed the process by which SCL had developed a series of potential TDG abatement alternatives and preliminarily assessed the application and function of those alternatives. SCL explained that when a shortlist of potential alternatives was identified, study plans would be developed to fully evaluate the effectiveness of the alternatives on the list. SCL provided an overview of potential TDG abatement alternatives from the four following categories: operational alternatives for existing structures, spillway structural modification alternatives, sluice gate structural alternatives, and new structure alternatives. SCL then presented a system developed to rank potential alternatives based on a range of weighted criteria.

At the July 25, 2006 Water Quality Workgroup meeting, SCL and relicensing participants discussed the ongoing preliminary assessment of the concepts and function of potential TDG abatement alternatives identified at the June 29 meeting. SCL described the criteria used to preliminarily evaluate the effectiveness of the alternatives and the ranking of the alternatives based on the criteria. SCL explained that it was currently performing a sensitivity analysis to assess the effect of individual criteria on the overall ranking of alternatives. SCL stated that a proposed shortlist of alternatives — that would be subjected to more detailed analysis — would be presented at the August 2006 workgroup meeting. SCL solicited comments from relicensing participants on the TDG alternatives matrix, including suggestions for additional or improved criteria for evaluating potential alternatives. SCL suggested that relicensing participants share the matrix of alternatives and assessment criteria with engineers in their respective organizations.

At the August 16, 2006 Water Quality Workgroup meeting, SCL and relicensing participants discussed the process by which a shortlist of potential TDG abatement measures for the Boundary Project was identified. SCL explained that the cost criterion had been muted so that abatement measures had been evaluated solely on the basis of technical merit. SCL outlined the sensitivity analysis undertaken to assess the degree to which individual evaluation criteria had affected the overall ranking of potential measures and noted that the results of the sensitivity analysis showed that the following, most promising alternatives selected by SCL for further analysis were consistently indicated as the best potential approaches by the ranking criteria:

- Throttle Sluice Gates
- Roughen Sluice Gate Discharge
- New Right Abutment Tunnel with Submerged Discharge
- New Left Abutment Tunnel Intercepts Diversion Tunnel
- Penstock/Draft Tube By-Pass
- New Short Left Abutment Tunnel Next to Unit #51

Comments provided by relicensing participants on the draft study plan are summarized in the PSP Attachment 3-5 (SCL 2006b) and can also be found in the workgroup meeting summaries available on SCL's relicensing website (http://www.seattle.gov/light/news/issues/bndryRelic/). Written comments provided on this study plan are also included in PSP Attachment 3-5 (SCL 2006b).

In its PAD/Scoping comment letter (USFS 2006), the USFS requested that "Any fish captured below the dam, in conjunction with other studies and during the spill periods, should be analyzed for characteristics of gas bubble trauma and documented with location, date, species, life stage and photo." SCL plans to conduct this analysis as described in section 2.4 (under Need for Additional Information) of the Fish Distribution, Timing, and Abundance Study plan (Study No. 9).

Since filing the PSP, SCL has continued to work with relicensing participants on its proposed study plans. Comments made during the November 15 study plan meeting and comments filed with FERC by the USFS (2007) stated that "The Forest Service agrees with SCL's proposed Evaluation of Total Dissolved Gas and Potential Abatement Measures. This study plan is very well organized and provides the needed detail for the issue. The agency [USFS] appreciates SCL's collaborative effort to provide a consensus based study proposal." No other PSP comments were filed with FERC regarding this study. (Comments are summarized in Attachment 3 and consultation documentation is included in Attachment 4 of this RSP). As a result, SCL has made only minor modifications to this plan to add clarification and detail.

2.9. Schedule

The schedule for completing this study is provided in Table 2.9-1 and includes the current FERC deadlines and potential opportunities (tentative dates) for relicensing participants to review study plans and study results with SCL.

Table 2.9-1. Project Schedule for Evaluation of Total Dissolved Gas and Potential Gas Abatement Measures.

Phase	Target Date
Phase 1 of study — Data Collection and Alternatives Assessment	March 2007 – October 2007
Prepare draft Phase 1 study report (first-year results)	November–December 2007
Distribute draft Phase 1 study report for relicensing participant review	January 2008
Meet with relicensing participants to review first year efforts and results and discuss plans for second year efforts	February 2008
Include final Phase 1 report in Initial Study Report (ISR) filed with FERC	March 2008
Hold ISR meeting and file meeting summary with FERC	March 2008
Phase 2 of study — Evaluation of Alternatives	February–October 2008
Prepare draft Phase 2 study report	October–November 2008
Distribute draft Phase 2 study report for relicensing participant review	December 2008
Meet with relicensing participants to review study efforts and results and “cross-over” study results	January 2009
Include final Phase 2 study report in Updated Study Report (USR) filed with FERC	March 2009
Hold USR meeting and file meeting summary with FERC	March 2009

2.10. Progress Reports, Information Sharing, and Technical Review

Both the draft and final study reports will be available to relicensing participants. Prior to release of the Initial and Updated Study Reports (which will include the results of this study), SCL will meet with relicensing participants to discuss the study results, as described in Attachment 1, section 2.3 of this RSP.

2.11. Anticipated Level of Effort and Cost

The estimated effort and cost for performing Phase 1 of the study ranges from $450,000 to $600,000, subject to review and revisions as additional details are developed. The estimated effort and cost for performing Phase 2 of the study and developing a gas abatement plan for the Boundary Project ranges from $1,300,000 to $1,800,000.

3.0 LITERATURE CITED

Avista Corporation. 2000. Gas Supersaturation Abatement Alternatives, Cabinet Gorge Hydroelectric Project, Phase 3 Study Report, December 2000. Report prepared by Duke Engineering & Services in association with Oakwood Consulting, Inc.

Chelan County, Public Utility District No. 1. 2003. Gas Abatement Techniques at Rocky Reach Hydroelectric Project (Final Report), prepared by MWH. August 2003.

Columbia Basin Environmental. 2001. Boundary Dam Total Dissolved Gas Study, Draft Report.

Columbia Basin Environmental. 2003. Boundary 2002 Spill Evaluation, 1 May – 25 July 2002. Draft Report dated January 2003, The Dalles, Oregon.

Ecology (Washington State Department of Ecology). 2005. Water Quality Certifications for Existing Hydropower Dams, Guidance Manual. March 2005, Revised April 2005.

Ecology. 2006. *Draft* Guidance for Evaluating the Feasibility of Controls to Meet Water Quality Standards for Dams in Washington. August 2006.

EPA. 1993. Clark Fork - Pend Oreille Basin water quality study: A summary of findings and a management plan. United States Environmental Protection Agency Regions VIII and X. Report for Section 525 of the Clean Water Act of 1987.

Golder Associates. 2005. Pend Oreille River Watershed Management Plan. Report prepared for the WRIA 62 Watershed Planning Unit. March 2005. Available at URL: http://www.pocd.org/wmp/plan/WRIA%2062%20WMP%20032305.pdf. Accessed October 25, 2005.

GEI Consultants, Inc. 2004. Intermountain Province Subbasin Plan, Pend Oreille Subbasin. Submitted to: Northwest Power and Conservation Council, Portland, Oregon, on behalf of: Intermountain Province Oversight Committee and Intermountain Province Subbasin Work Teams.

Grant County, Public Utility District No. 2. 2003. Total Dissolved Gas Exchange at Priest Rapids Dam, July 21 – August 4, 2002, prepared by U.S. Army Corps of Engineers. August 14, 2003.

Hans, K. M., and M. G. Mesa, and A. G. Maule. 1999. Rate of disappearance of gas bubble trauma signs in juvenile salmonids. Journal of Aquatic Animal Health, Volume 11(4), pages 383–390.

Hartford, Desmond N.D. and Gregory B. Baecher. 2004. Risk and Uncertainty in Dam Safety. CEA Technologies, Inc., Dam Safety Interest Group.

Lemons, J. and M. Gunter. 2000. Boundary Dam Total Dissolved Gas Evaluation: TDG Dynamics Associated with Power Generation.

Neitzel, Duane A., et. al. 2000. Laboratory Studies on the Effects of Shear on Fish, Pacific Northwest National Laboratory. DOE/ID-10822 published September 2000.

Parametrix. 1998. Dissolved Gas Assessment, Boundary Dam.

Pickett, P.J. 2004. Quality Assurance Project Plan. Pend Oreille River Total Dissolved Gas Total Maximum Daily Load Technical Study. Washington State Department of Ecology Environmental Assessment Program, Olympia.

Schneider, Michael L. 2006. Report Review Comments on “Boundary 2002 Spill Evaluation” and “TDG Analysis During the 2002 Spill Event,” City of Seattle, Seattle City Light Department (SCL) dated June 21, 2006.

SCL (Seattle City Light). 2003. Seattle City Light Memorandum to Mike Harrison, Mike Haynes, and Mike Sinowitz, and the Boundary Relicensing Team regarding Recommendations to reduce total dissolved gas levels at Boundary.

SCL. 2005. Seattle City Light TDG Analysis During the 2002 Spill Event. July 13, 2005.

SCL. 2006a. Pre-Application Document for the Boundary Hydroelectric Project (FERC No. 2144). Seattle, Washington. May 2006. Available online at http://www.seattle.gov/light/news/issues/bndryRelic/br_document.asp

SCL. 2006b. Proposed Study Plan for the Boundary Hydroelectric Project (FERC No. 2144). Seattle, Washington. October 2006. Available online at http://www.seattle.gov/light/news/issues/bndryRelic/br_document.asp

U.S. Army Corps of Engineers. 2000. Chief Joseph Dam, Columbia River, Washington, Gas Abatement Study, General Reevaluation Report (Final). May 2000.

U.S. Bureau of Reclamation. 1998. Structural Alternatives for TDG Abatement at Grand Coulee Dam, Conceptual Design Report prepared by Kathleen H. Frizell and Elizabeth Cohen for USBR, Pacific Northwest Region. October 1998.

USFS (USDA Forest Service). 1988. Alternative maps, final environmental impact statement for the land and resource management plan, Colville National Forest. USDA Forest Service, Pacific Northwest Region.

USFS. 2006. Boundary Hydroelectric Project, FERC No. 2144-035, Response to Scoping Document 1, Comments on Pre-Application Document, and Study Requests. Colville National Forest. August 31, 2006.

USFS. 2007. Boundary Hydroelectric Project, No. 2144-035, comments to Proposed Study Plan. Letter dated January 9, 2007.

USGS (U.S. Geological Survey). 2005. Gages #12398550 and #12398600. Tacoma, Washington.

USGS. 2006. Online NWIS web data for the nation. http://waterdata.usgs.gov/nwis/qw.

Washington Administrative Code Chapter 173-201A. 1997. Water Quality Standards for Surface Waters of the State of Washington. Olympia, Washington.

Washington Administrative Code Chapter 173-201A. 2003. Water Quality Standards for Surface Waters of the State of Washington. Olympia, Washington.

Appendix 1: Total Dissolved Gas Abatement Alternatives Matrix and Ranking Criteria

Matrix #1 - Original Matrix with Scores and Overall Rank, and Muted "Cost" Column

Top Six Alternatives Based on "Rank" Column (1 through 6)

No.	Option	Hydraulic Capacity: Percent of 7Q10	Effect on Ability of Project to pass PMF	Potential TDG benefit (no impairment)	Construct-ability	Cost (capital and O&M)	O&M Challenge	Dam Safety	Effect on Other Resources	Effects on Fish (exclusion / passage)	Weighted Score	Normalized Score	Rank
		1	1	1	0.7	0.7	0.5	1	0.5	0.8			
1-1	Existing Spillway Limited Ops	TBD	TBD	TBD	TBD		TBD	TBD	TBD	TBD	0	0.0%	25
1-2	Existing Skimmer Gate Limited Ops	TBD	TBD	TBD	TBD		TBD	TBD	TBD	TBD	0	0.0%	25
1-3	Throttle Sluice Gates	6	10	7	10		8	10	10	9	56.2	96.9%	5
1-4	Operate Gates #1 and #7	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	0	0.0%	25
2-1	Spillway Modifications	10	10	2.5	9		10	10	10	1	49.6	85.5%	10
2-2	Skimmer Gate Modifications	0.5	10	8	7		9	8	10	4	44.1	76.0%	17
2-3A	Raise Plunge Floor--Spillway	10	10	2	5		4	10	10	1	43.3	74.7%	21
2-3B	Raise Plunge Floor--Sluiceway	10	10	2	5		4	10	10	1	43.3	74.7%	21
2-7	Floating Spill Dissipater	10	10	5	3		3	10	9	1	43.9	75.7%	18
3-1	Armor Area Downstream of Sluice #1 and #7	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	0	0.0%	25
3-2	Roughen Sluice Discharge	10	9	7	9		8	10	10	8	57.7	99.5%	2
3-4	Add Fixed-Cone Valves to Sluices	6	10	9	1		4	10	10	7	48.3	83.3%	11
3-5A	Add Branch Outlet to Sluice Liner (submerged discharge)	5	10	10	4		7	1	10	8	43.7	75.3%	20
3-7	Floating Barge Deflector	10	10	5	3		3	10	9	1	43.9	75.7%	18
4-1	Underwater Outlet through Midsection of Dam	4	10	10	4		5	7	7	10	47.8	82.4%	12
4-4	Bridge-type Spillway Apron	10	10	3	3		3	9	10	1	41.4	71.4%	23
4-4A	New Right Abutment Spillway w/Tunnel Outlet	8	10	6	6		8	10	9	1	47.5	81.9%	13
4-4B	New Right Abutment Spillway w/Long Flume	8	10	6	4		8	10	9	2	46.9	80.9%	14
4-4C	New Right Abutment Spillway with Natural Rock Shoot	6	10	10	2		7	9	10	1	45.7	78.8%	16
4-4D	New Right Abutment Long Side-Channel Spillway	3	10	8	2		7	9	10	1	40.7	70.2%	24
4-5	New Left Abutment Spillway w/Flume along Road	10	10	6	2		7	10	7	3	46.8	80.7%	15
4-5B	New Left Abutment Spillway Along Road, Forebay Intake	10	10	6	2		8	10	7	7	50.5	87.1%	9
4-7	New Right Abutment Tunnel w/Submerged Discharge	10	10	10	5		5	10	8	8	56.4	97.2%	4
4-7A	New Right Abutment Tunnel w/Fixed Cone Valve	10	10	10	2		3	10	8	8	53.3	91.9%	7
4-8	Open Existing Diversion Tunnel and Add Control Struct	10	10	10	1		1	10	7	8	51.1	88.1%	8
4-8A	New Left Abutment Tunnel Meeting Diversion Tunnel	10	10	10	5		5	10	7	5	53.5	92.2%	6
4-9	Penstock/Draft Tube ByPass	10	10	10	7		8	10	7	7	58	100.0%	1
4-10	New Short Left Abutment Tunnel Next to U51	10	10	10	7		8	10	7	6	57.2	98.6%	3
											58	**100%**	

Matrix #2 - Rank of Alternatives Muting Each Criteria Based on Matrix #1

No.	Options	Hydraulic Capacity: Percent of 7Q10	Effect on Ability of Project to pass PMF	Potential TDG benefit (no impairment)	Construct-ability	Cost (capital and O&M)	O&M Challenge	Dam Safety	Effect on Other Resources	Effects on Fish (exclusion / passage)	Weighted Score	Normalized Score	Rank Based on All Criteria, Except Cost	Rank w/o Hydraulic Capacity	Rank w/o PMF	Rank w/o TDG Benefit	Rank w/o Construct-ability	Rank w/o O&M	Rank w/o Dam Safety	Rank w/o Other Resource Effects	Rank w/o Fish Effects
		1	1	1	0.7	0.7	0.5	1	0.5	0.8											
1-1	Existing Spillway Limited Ops	TBD	TBD	TBD	TBD		TBD	TBD	TBD	TBD	0	0.0%	25	25	25	25	25	25	25	25	25
1-2	Existing Skimmer Gate Limited Ops	TBD	TBD	TBD	TBD		TBD	TBD	TBD	TBD	0	0.0%	25	25	25	25	25	25	25	25	25
1-3	Throttle Sluice Gates	6	10	7	10		8	10	10	9	56.2	96.9%	5	1	5	2	8	5	5	5	6
1-4	Operate Gates #1 and #7	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	0	0.0%	25	25	25	25	25	25	25	25	25
2-1	Spillway Modifications	10	10	2.5	9		10	10	10	1	49.6	85.5%	10	14	10	5	15	12	12	10	7
2-2	Skimmer Gate Modifications	0.5	10	8	7		9	8	10	4	44.1	76.0%	17	7	17	21	24	23	18	19	20
2-3A	Raise Plunge Floor--Spillway	10	10	2	5		4	10	10	1	43.3	74.7%	21	22	21	11	20	19	21	21	18
2-3B	Raise Plunge Floor--Sluiceway	10	10	2	5		4	10	10	1	43.3	74.7%	21	22	21	11	20	19	21	21	18
2-7	Floating Spill Dissipater	10	10	5	3		3	10	9	1	43.9	75.7%	18	20	18	17	17	16	19	17	15
3-1	Armor Area Downstream of Sluice #1 and #7	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A	0	0.0%	25	25	25	25	25	25	25	25	25
3-2	Roughen Sluice Discharge	10	9	7	9		8	10	10	8	57.7	99.5%	2	3	1	1	5	3	2	3	3
3-4	Add Fixed-Cone Valves to Sluices	6	10	9	1		4	10	10	7	48.3	83.3%	11	10	11	16	10	10	13	12	17
3-5A	Add Branch Outlet to Sluice Liner (submerged discharge)	5	10	10	4		7	1	10	8	43.7	75.3%	20	17	20	23	19	21	8	20	24
3-7	Floating Barge Deflector	10	10	5	3		3	10	9	1	43.9	75.7%	18	20	18	17	17	16	19	17	15
4-1	Underwater Outlet through Midsection of Dam	4	10	10	4		5	7	7	10	47.8	82.4%	12	6	12	20	12	11	10	11	23
4-4	Bridge-type Spillway Apron	10	10	3	3		3	9	10	1	41.4	71.4%	23	24	23	19	22	22	23	23	21
4-4A	New Right Abutment Spillway w/Tunnel Outlet	8	10	6	6		8	10	9	1	47.5	81.9%	13	15	13	10	15	13	14	14	9
4-4B	New Right Abutment Spillway w/Long Flume	8	10	6	4		8	10	9	2	46.9	80.9%	14	16	14	14	14	15	15	15	10
4-4C	New Right Abutment Spillway with Natural Rock Shoot	6	10	10	2		7	9	10	1	45.7	78.8%	16	13	16	22	13	18	17	16	11
4-4D	New Right Abutment Long Side-Channel Spillway	3	10	8	2		7	9	10	1	40.7	70.2%	24	18	24	24	22	24	24	24	22
4-5	New Left Abutment Spillway w/Flume along Road	10	10	6	2		7	10	7	3	46.8	80.7%	15	19	15	15	11	14	16	13	14
4-5B	New Left Abutment Spillway Along Road, Forebay Intake	10	10	6	2		8	10	7	7	50.5	87.1%	9	12	9	7	9	9	11	9	11
4-7	New Right Abutment Tunnel w/Submerged Discharge	10	10	10	5		5	10	8	8	56.4	97.2%	4	5	4	6	2	2	4	4	4
4-7A	New Right Abutment Tunnel w/Fixed Cone Valve	10	10	10	2		3	10	8	8	53.3	91.9%	7	9	7	9	4	6	7	7	8
4-8	Open Existing Diversion Tunnel and Add Control Struct	10	10	10	1		1	10	7	8	51.1	88.1%	8	11	8	13	6	8	9	8	13
4-8A	New Left Abutment Tunnel Intercepts Diversion Tunnel	10	10	10	5		5	10	7	5	53.5	92.2%	6	8	6	8	7	7	6	6	5
4-9	Penstock/Draft Tube ByPass	10	10	10	7		8	10	7	7	58	100.0%	1	2	2	3	1	1	1	1	1
4-10	New Short Left Abutment Tunnel Next to U51	10	10	10	7		8	10	7	6	57.2	98.6%	3	4	3	4	3	4	3	2	1
											58	**100%**									

Matrix #3 - Rank of Alternatives Muting Each Criteria and Comparison to Overall Rank

Green - Unchanged; Yellow - Increased; Blue - Decreased.

No.	Option	Rank w/o Hydraulic Capacity	Rank w/o PMF	Rank w/o TDG Benefit	Rank w/o Constructability	Rank w/o Cost	Rank w/o O&M	Rank w/o Dam Safety	Rank w/o Other Resource Effects	Rank w/o Fish Effects	Rank w/all Criteria
1-1	Existing Spillway Limited Ops	25	25	25	25		25	25	25	25	25
1-2	Existing Skimmer Gate Limited Ops	25	25	25	25		25	25	25	25	25
1-3	Throttle Sluice Gates	1	5	2	8		5	5	5	6	5
1-4	Operate Gates #1 and #7	25	25	25	25		25	25	25	25	25
2-1	Spillway Modifications	14	10	5	15		12	12	10	7	10
2-2	Skimmer Gate Modifications	7	17	21	24		23	18	19	20	17
2-3A	Raise Plunge Floor--Spillway	22	21	11	20		19	21	21	18	21
2-3B	Raise Plunge Floor--Sluiceway	22	21	11	20		19	21	21	18	21
2-7	Floating Spill Dissipater	20	18	17	17		16	19	17	15	18
3-1	Armor Area Downstream of Sluice #1 and #7	25	25	25	25		25	25	25	25	25
3-2	Roughen Sluice Discharge	3	1	1	5		3	2	3	3	2
3-4	Add Fixed-Cone Valves to Sluices	10	11	16	10		10	13	12	17	11
3-5A	Add Branch Outlet to Sluice Liner (submerged discharge)	17	20	23	19		21	8	20	24	20
3-7	Floating Barge Deflector	20	18	17	17		16	19	17	15	18
4-1	Underwater Outlet through Midsection of Dam	6	12	20	12		11	10	11	23	12
4-4	Bridge-type Spillway Apron	24	23	19	22		22	23	23	21	23
4-4A	New Right Abutment Spillway w/Tunnel Outlet	15	13	10	15		13	14	14	9	13
4-4B	New Right Abutment Spillway w/Long Flume	16	14	14	14		15	15	15	10	14
4-4C	New Right Abutment Spillway with Natural Rock Shoot	13	16	22	13		18	17	16	11	16
4-4D	New Right Abutment Long Side-Channel Spillway	18	24	24	22		24	24	24	22	24
4-5	New Left Abutment Spillway w/Flume along Road	19	15	15	11		14	16	13	14	15
4-5B	New Left Abutment Spillway Along Road, Forebay Intake	12	9	7	9		9	11	9	11	9
4-7	New Right Abutment Tunnel w/Submerged Discharge	5	4	6	2		2	4	4	4	4
4-7A	New Right Abutment Tunnel w/Fixed Cone Valve	9	7	9	4		6	7	7	8	7
4-8	Open Existing Diversion Tunnel and Add Control Struct	11	8	13	6		8	9	8	13	8
4-8A	New Left Abutment Tunnel Intercepts Diversion Tunnel	8	6	8	7		7	6	6	5	6
4-9	Penstock/Draft Tube ByPass	2	2	3	1		1	1	1	1	1
4-10	New Short Left Abutment Tunnel Next to U51	4	3	4	3		4	3	2	1	3

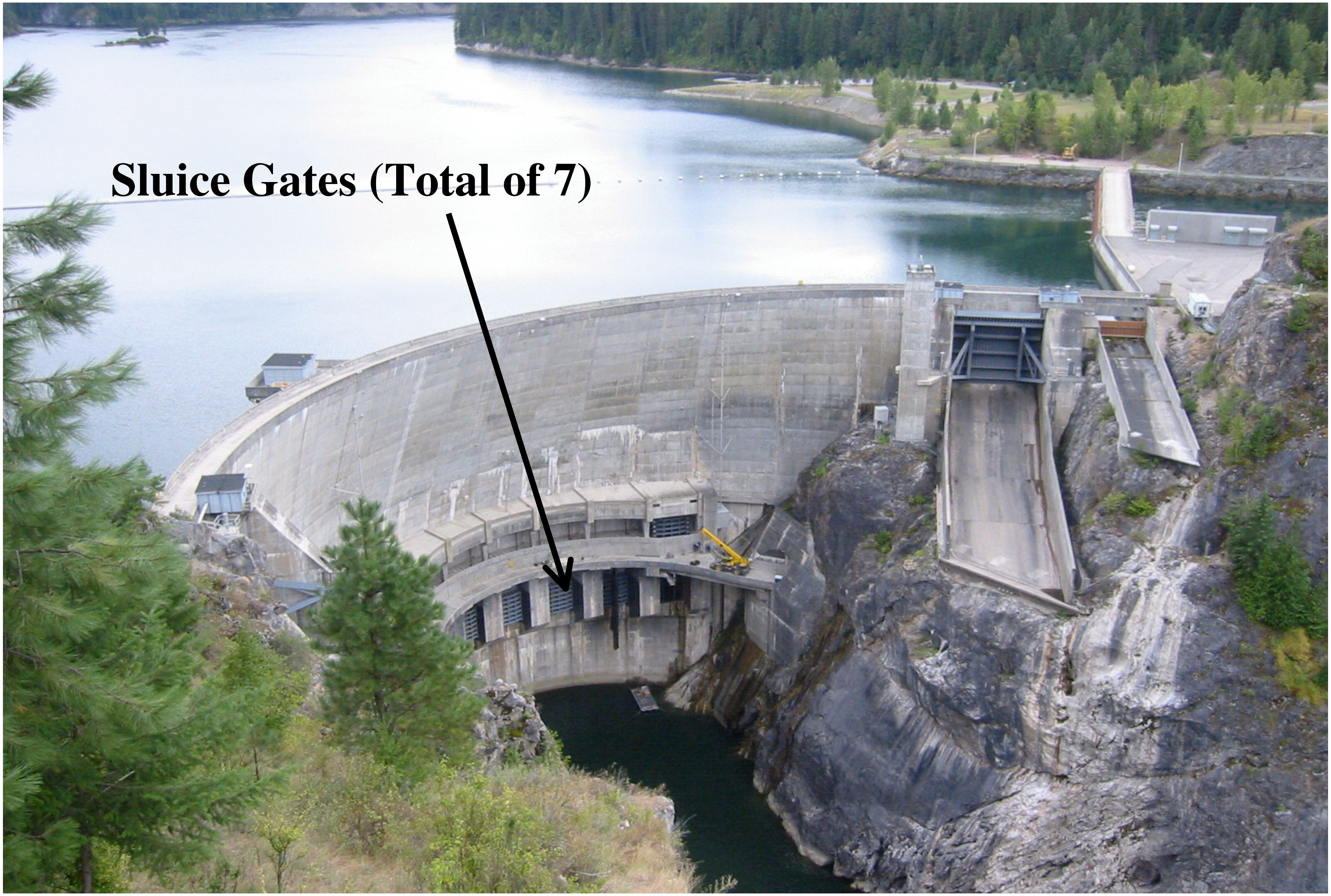
Matrix #3 - Top Six Alternatives from Sorting Matrix #3

No.	Option	Rank w/o Hydraulic Capacity	Rank w/o PMF	Rank w/o TDG Benefit	Rank w/o Constructability	Rank w/o Cost	Rank w/o O&M	Rank w/o Dam Safety	Rank w/o Other Resource Effects	Rank w/o Fish Effects	Rank w/all Criteria
4-9	Penstock/Draft Tube ByPass	2	2	3	1		1	1	1	1	1
3-2	Roughen Sluice Discharge	3	1	1	5		3	2	3	3	2
4-10	New Short Left Abutment Tunnel Next to U51	4	3	4	3		4	3	2	1	3
4-7	New Right Abutment Tunnel w/Submerged Discharge	5	4	6	2		2	4	4	4	4
1-3	Throttle Sluicegates	1	5	2	8		5	5	5	6	5
4-8a	New Left Abutment Tunnel Meeting Diversion Tunnel	8	6	8	7		7	6	6	5	6
4-7A	New Right Abutment Tunnel w/Fixed Cone Valve	9	7	9	4		6	7	7	8	7
4-8	Open Existing Diversion Tunnel and Add Control Struct	11	8	13	6		8	9	8	13	8
4-5B	New Left Abutment Spillway Along Road, Forebay Intake	12	9	7	9		9	11	9	11	9
2-1	Spillway Modifications	14	10	5	15		12	12	10	7	10
3-4	Add Fixed-Cone Valves to Sluices	10	11	16	10		10	13	12	17	11
4-1	Underwater Outlet through Midsection of Dam	6	12	20	12		11	10	11	23	12
4-4A	New Right Abutment Spillway w/Tunnel Outlet	15	13	10	15		13	14	14	9	13
4-4B	New Right Abutment Spillway w/Long Flume	16	14	14	14		15	15	15	10	14
4-5	New Left Abutment Spillway w/Flume along Road	19	15	15	11		14	16	13	14	15
4-4C	New Right Abutment Spillway with Natural Rock Chute	13	16	22	13		18	17	16	11	16
2-2	Skimmer Gate Modifications	7	17	21	24		23	18	19	20	17
2-7	Floating Spill Dissipater	20	18	17	17		16	19	17	15	18
3-7	Floating Barge Deflector	20	18	17	17		16	19	17	15	18
3-5A	Add Branch Outlet to Sluice Liner (submerged discharge)	17	20	23	19		21	8	20	24	20
2-3A	Raise Plunge Floor--Spillway	22	21	11	20		19	21	21	18	21
2-3B	Raise Plunge Floor--Sluiceway	22	21	11	20		19	21	21	18	21
4-4	Bridge-type Spillway Apron	24	23	19	22		22	23	23	21	23
4-4D	New Right Abutment Long Side-Channel Spillway	18	24	24	22		24	24	24	22	24
1-1	Existing Spillway Limited Ops	25	25	25	25		25	25	25	25	25
1-2	Existing Skimmer Gate Limited Ops	25	25	25	25		25	25	25	25	25
1-4	Operate Gates #1 and #7	25	25	25	25		25	25	25	25	25
3-1	Armor Area Downstream of Sluice #1 and #7	25	25	25	25		25	25	25	25	25

Appendix 2: Illustration of Six Total Dissolved Gas Abatement Alternatives

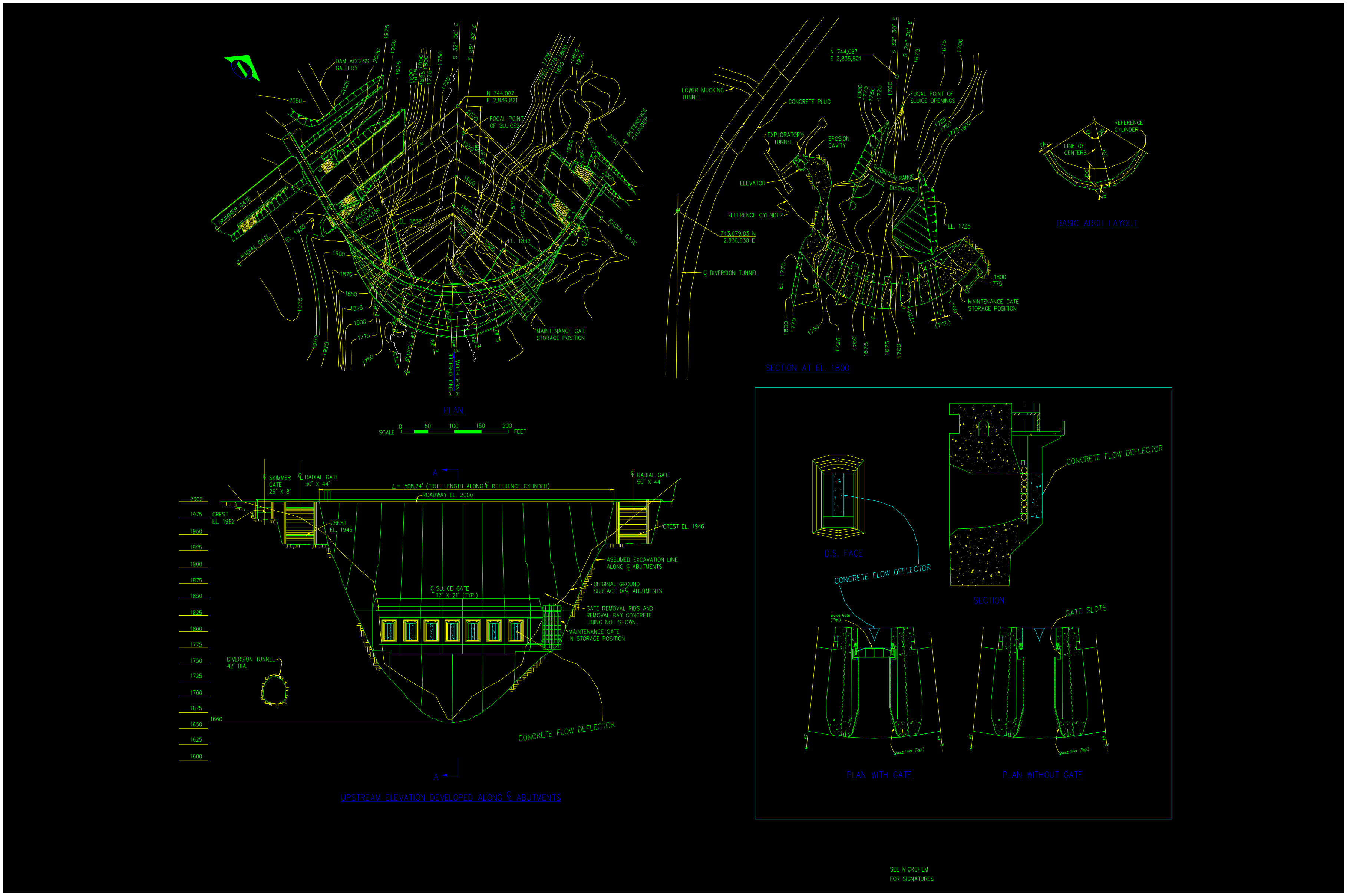
SCL TDG Revised Study Plan(RSP)
Appendix 2: Illustrations of Six Alternatives

Option 1-3. Throttle Sluice Gates



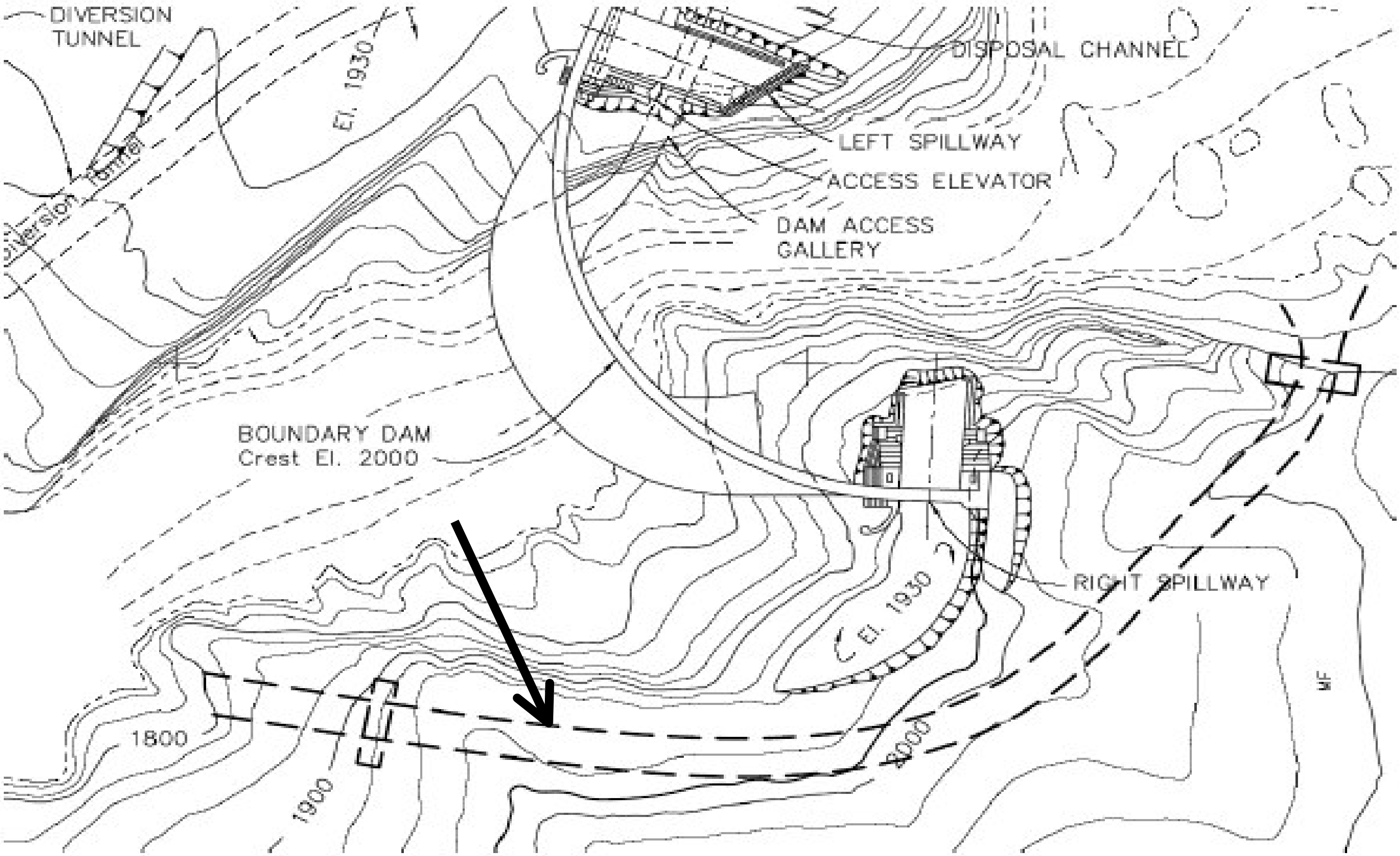
Option 1-3. Throttle Sluice Gates

Option 3-2. Roughen Sluice Gate Discharge

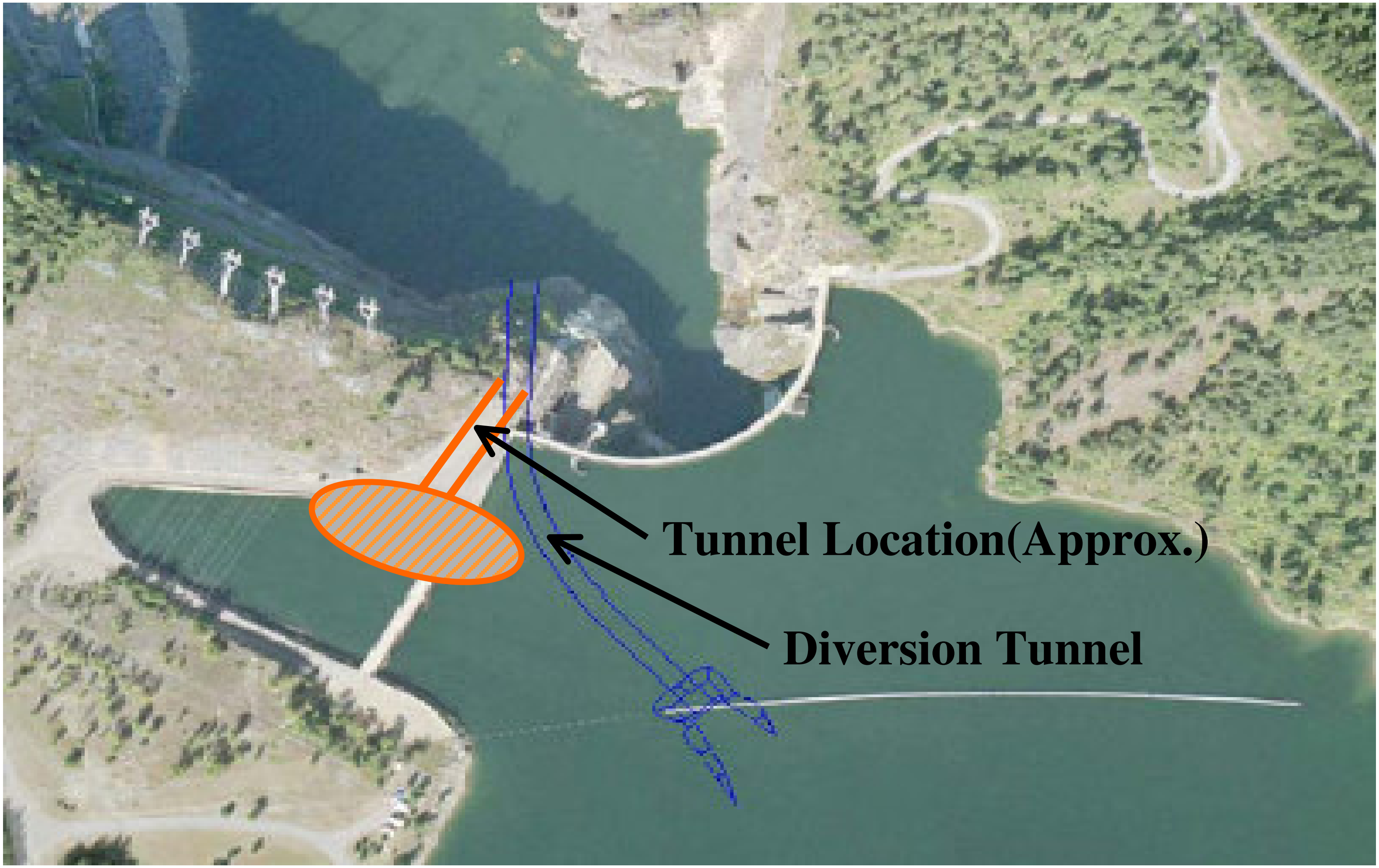


Option 4-7. New Right Abutment Tunnel with Submerged Discharge

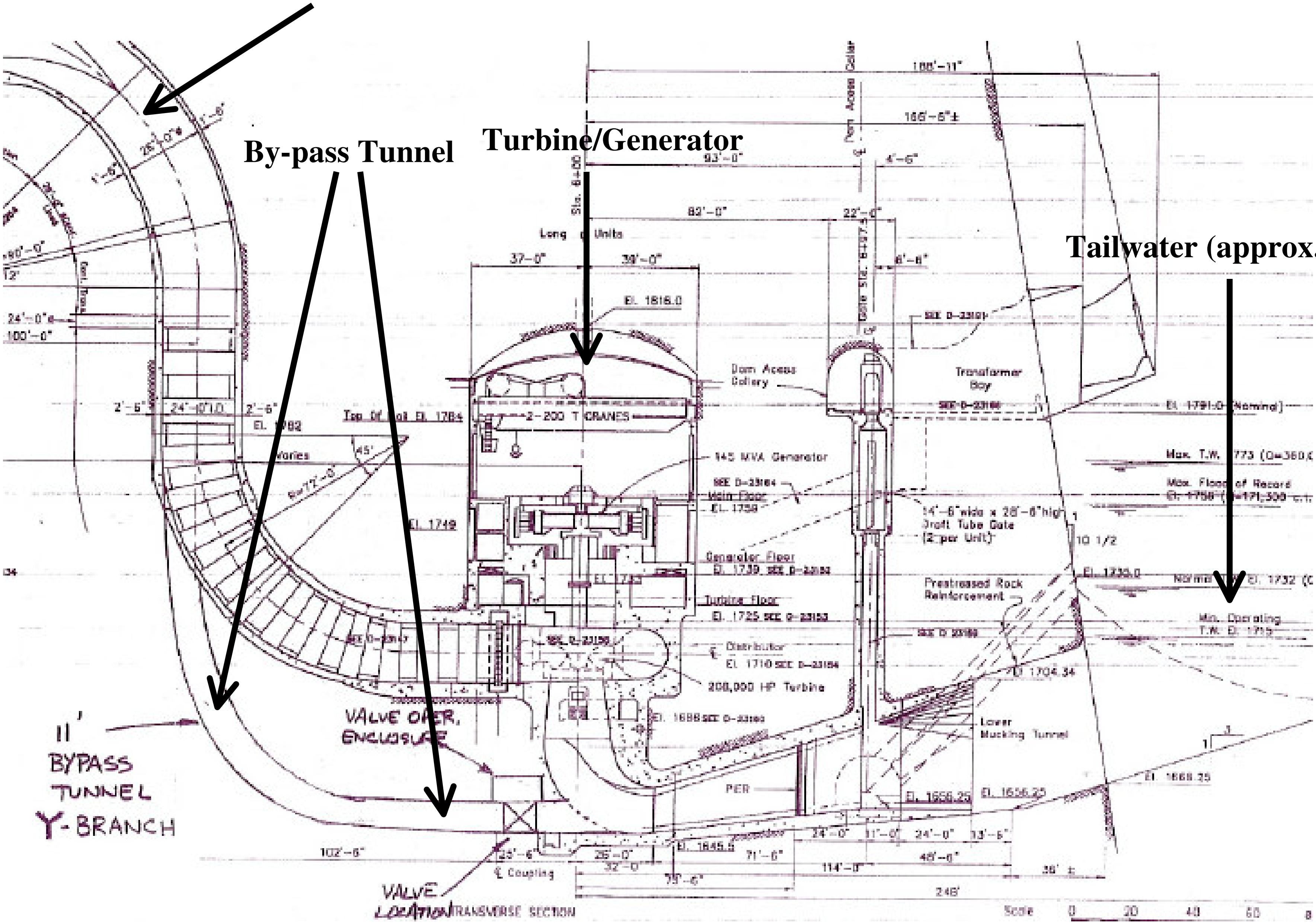
Long curved alternative



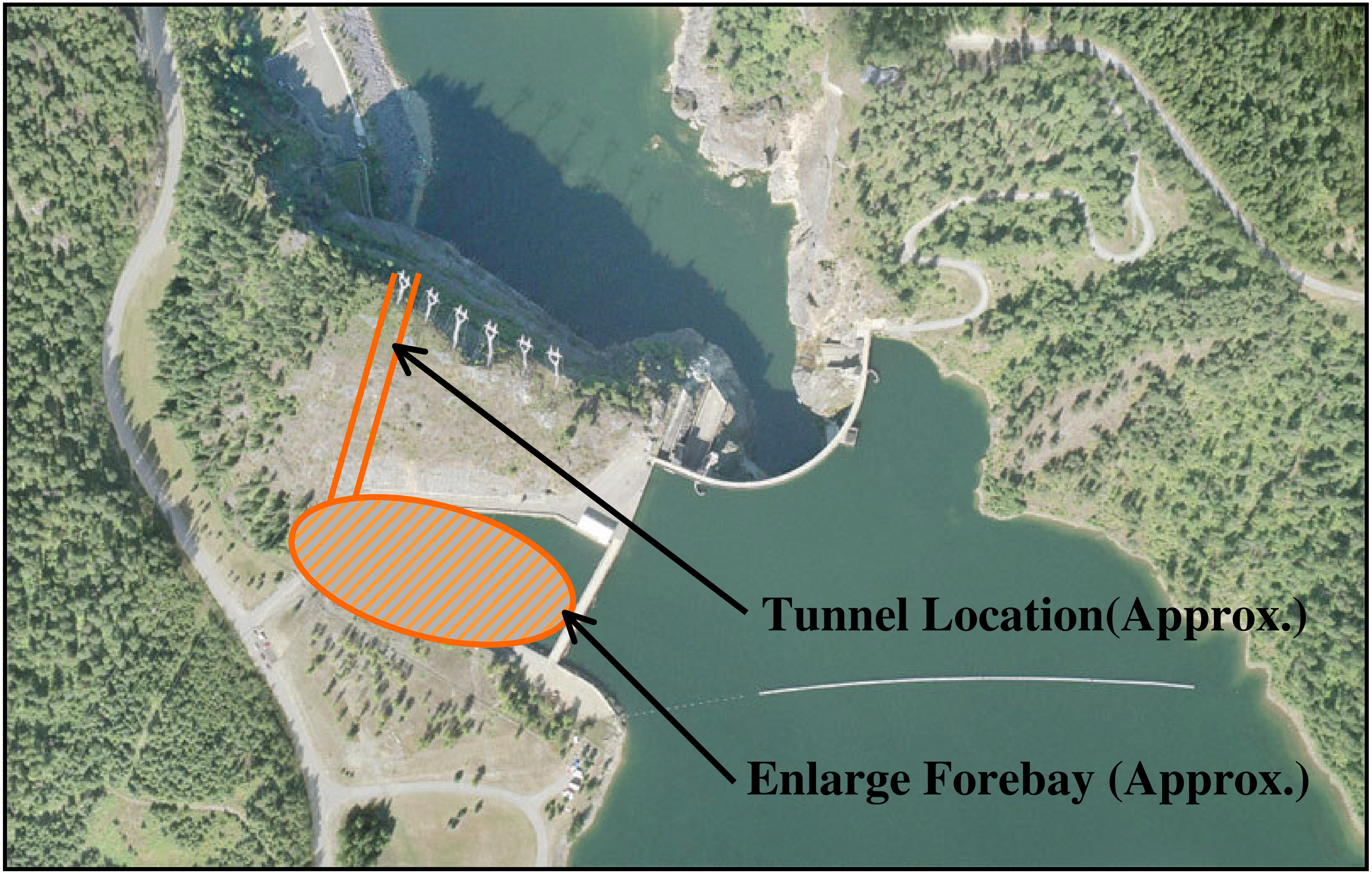
Option 4-8A. New Left Abutment Tunnel Intercepts Diversion Tunnel



Option 4-9. Penstock/Draft Tube By-Pass



Option 4-10. New Left Abutment Tunnel Next to Unit #51 Intake



Appendix 3: Undeveloped Total Dissolved Gas Abatement Alternatives

Appendix 3, Table 1 - Operational Alternatives for Existing Structures

Alt. No.	Name	Expected capacity, cfs	Potential TDG Benefit (1)	Testing Required to Assess Viability	Constructability and Other Assessment Required to Evaluate	Comments
1	Existing Spillway-Limited Spill Operation	18,000	2 - 3	Yes-Confirm gas levels for a range of flows and gate combinations	1. Assess 2002/2003 Spill Test results. 2. Third party review of 2002 data (CBE 2003 report) by Michael Schneider (ACE).	Possibly work with the spillway modifications to boost total spillway flow
2	Existing Skimmer gate-Limited spill operation	1,800	2	Yes-confirm gas level for range of flows	1. Assess during spill test. 2. Evaluate/verify hydraulic capacity.	Perform with testing of main spillway gates
3	Throttling of sluice gates	unknown	3	Yes-confirm gas levels for a range of flows and gate combinations	1. Assess gate vibration when throttling during a spill test. 2. Assess the potential for foundation erosion due to a steeper diving jet when throttling. This is a potential dam safety issue.	Started (1.) in April 2006. (Note: The 1968 Bechtel Leedshill Design Report, Section VI-8 *design criteria for sluice gates* indicates that the gates may be stopped and held in any position of travel. SCL throttled the sluice gates during a 1972 safety inspection.)
4	Operate sluice gates 1 and 7 (outer gates) in lieu of 3-5 (central gates)	36,000 to 72,000	3	Yes-operate the gates during spill and confirm gas levels	1. Test procedure to protect abutment. 2. Evaluate probable need for armoring of abutments where gate discharge hits. This is a dam safety issue. (Note: This option is may be considered a structural option, i.e., armoring of downstream abutments and this option may be moved to a different table.)	These gates historically not used due to abutment erosion.

(1) Potential benefits rated 1 (best-strips gas) to 5 (worst-adds gas). Benefit of 3 is assumed to pass the upstream gas level (no addition of gas or stripping).

Appendix 3, Table 2 - Spillway Structural Modification Alternatives

Alt. No.	Name	Expected capacity, cfs	Potential TDG Benefit (1)	Testing Required to Assess Viability	Constructability and Other Assessment Required to Evaluate	Comments
1	Spillway Modifications: (includes 2004 alternatives) 1a – roughen 1b – deflectors 1c – flared training walls 3a-aim towards shallower area in pool 3b-increase landing area 3c-air entrainment	20,000-60,000	2	Requires prototype modifications of spillways.	1. Hydraulic evaluation of spillway structure needed to predict possible flow rate. 2. Evaluate risk of abutment erosion.	Benefits may be uncertain. All 5 sub-alternatives from April 2004 are really one—modify spillways to spread the flow and reduce the plunge, or to hit the abutments to break fall of water and limit gas uptake. For 3a, add passive air admission towards top of spillway
2	Skimmer gate modification to increase flow capacity (existing is 1,800 cfs)	4,000	2	Use results of testing existing gate. (See Table 1, Alt.#2)	Hydraulic evaluation needed to predict flow rate and shape of flow onto left abutment	4,000 cfs assumes gate sill is cut to double gate height. Very expensive for minor increase in flow.
3A	Raise plunge pool floor, for sluice gate discharge	60,000	4	None possible	Concept development for physical, structural, and hydraulic arrangement	Larger area than for spillway gates, may interfere with spillway flows. Assess interlocking jacks. Potential problems may include erosion, movement, and lateral force.
3B	Raise plunge pool floor, for spillway gate discharge	60,000	4	None possible	Concept development for physical, structural, and hydraulic arrangement	More attractive than sluice gate option (Table 2-3A). Smaller area near dam. (Still need to meet PMF)
6A **Delete**	Modify right abutment spillway to add long flume	52,000	2	None possible	This alternative was **discarded** due to its structural concept being infeasible. The height and length of the flume and problems with sluice gate flows impacting the supports make it unrealistic.	
6B **Delete**	Modify right abutment spillway to add stripping structure	52,000	1-2	None possible	This alternative was **discarded** due to its structural concept being infeasible. The height and length of the downstream structure and problems with sluice gate flows impacting the supports make it unrealistic.	
6C **Delete**	Modify right abutment spillway to shape discharge flows onto the right abutment	2,000 to 5,000	2-3	None possible	This alternative was **discarded.** It is essentially the same as alternative 1c, which is shaping the spillway discharge to hit the abutment.	
7	Floating spill dissipater (Note: Similar to raising plunge pool floor)	60,000?	2-3	None possible	Concept development for physical, structural, and hydraulic arrangement	Added in May 2004. Could be floating pipe sections to limit plunge depth.

(1) Potential benefits rated 1 (best - strips gas) to 5 (worst-adds gas). Benefit of 3 is assumed to pass the upstream gas level (no addition of gas or stripping).

Appendix 3, Table 3 - Sluice Gates Structural Modification Alternatives

Alt. No.	Name	Expected capacity, cfs	Potential TDG Benefit (1)	Testing Required to Assess Viability	Constructability and Other Assessment Required to Evaluate	Comments
1	Armor area downstream of sluice gates 1 <u>or</u> 7	36,000	3?	Field test possible, after abutment erosion assessment.	Concept development required for physical, structural, and hydraulic arrangement	Potential problems with abutment impacts. Will sluice stream even reach abutments?
2	Roughen sluice gate discharge to spread flow and limit plunge	6,000 per gate	3?	May be possible to prototype one gate	Concept development required for physical, structural, and hydraulic arrangement	Assumes throttling of gates is feasible and structurally acceptable.
3 **Delete**	Install "tubing" from gate discharge to lower pool	36,000	3	None possible	This alternative **discarded** due to concerns on dam safety, lack of upstream shutoff, and risk in throttling and structural concerns with the "tube" being impacted by spill from other gates.	
4	Modify sluice gates to add fixed cone or jet-flow valves to gate leaf	3,000 to 6,000 per gate	2	None possible	Concept study needed to determine valve configuration on sluice gate	Possibly 2 or 3 valves added to gate. 72 inch valve diameter assumed. • Decreases the capacity of the sluiceways • Add air / energy dissipater
5 **Delete**	Alter sluice gates to be bonneted slide gates and add downstream tube	36,000	3	None possible	This alternative **discarded** due to infeasibility of downstream "tube" and dam safety risks with the gate modification.	
5A	Add branch outlet from sluice liner to point below sluice gates, submerged discharge at bottom of dam	3,000 cfs per gate	2-3	None possible	Concept study needed.	Added this alternative during May 2004 meeting. Downstream conduit would be attached to dam. Possible use of dam sump gallery.
6 **Delete**	Enclose discharge from 2 sluice gates in an open flume	36,000	2-3	None possible	This alternative **discarded** due to concerns on dam safety, risk in throttling and structural concerns with the flume being impacted by spill from other gates.	
7	Floating Barge deflector to shape sluice gate flow, reduce plunge	60,000?	2	None possible	Concept development required for physical, structural, and hydraulic arrangement	Comparable to filling plunge pool (See Table 2).

(1) Potential benefits rated 1 (best-strips gas) to 5 (worst-adds gas). Benefit of 3 is assumed to pass the upstream gas level (no addition of gas or stripping).

Appendix 3, Table 4 - New Structure Alternatives

Alt. No.	Name	Expected capacity, cfs	Potential TDG Benefit (1)	Testing Required to Assess Viability	Constructability and Other Assessment Required to Evaluate	Comments
1	Underwater outlet through mid-section of dam	2,800 cfs per 6-ft outlet	3	None possible	Concept analysis required, especially for dam safety	Similar and possibly much less attractive than conduit tapping the sluice gate liners (Table 3, Alt. #5A)
3 **Delete**	Siphon discharge around project	1,500 cfs for 8-ft pipe	2?	None possible	This concept **discarded**. A siphon intake is simply an option for any type of surface release from the reservoir. Other intake options have more capacity and reliability at less cost	
4	Bridge-type spillway apron, span across abutments	60,000	2?	None possible	Concept development required for physical, structural, and hydraulic arrangement	Structure may get blown out (destroyed) in major floods
4A	New right abutment spillway with tunnel outlet gate	40,000	3	None possible	Concept development for physical, structural, and hydraulic arrangement.	Capacity estimated, based on approx 30-ft dia tunnel and 50 fps velocity in tunnel.
4B	New right abutment spillway with long flume	30,000	1-2	None possible	Concept development for physical, structural, and hydraulic arrangement.	Surface intake capacity likely limited by approach flow conditions. Open channel system can degas flows effectively
4C	New right abutment spillway with flow over the right abutment.	30,000	1-2	None possible	Concept development for physical, structural, and hydraulic arrangement.	Abutment shaping and armoring likely required
5	New left abutment spillway with long flume along access road	12,000	1	None possible	Concept development for physical, structural, and hydraulic arrangement.	Capacity limited by space along road. Could effectively strip gas on large flat area below powerhouse.
7	New right abutment tunnel with submerged discharge	40,000	3	None possible	Concept development required for physical, structural, and hydraulic arrangement	
7A	New right abutment tunnel with fixed cone valve discharge	4,000 cfs per valve	2	None possible	Concept development required for physical, structural, and hydraulic arrangement	Valve maximum size estimated at 120 inch dia. Max velocity at valve possibly 50 fps.
7B **Delete**	New right abutment tunnel with powerplant	30,000	3	None possible	This alternative **discarded** based on cost. At $3,000 per kW of capacity a 30,000 cfs option (545 MW), this system's powerplant would cost $1.6 billion	
8	Open existing diversion tunnel and add control structure	27,000	3	None possible	Concept development required for physical, structural, and hydraulic arrangement	Capacity based on limit of 20 fps in unlined 42-ft dia. rock tunnel. May be too optimistic. Need to vent valve to prevent cavitation—TDG increase, or could tunnel to the surface and place valve at intake?

(1) Potential benefits rated 1 (best-strips gas) to 5 (worst-adds gas). Benefit of 3 is assumed to pass the upstream gas level (no addition of gas or stripping).

Appendix 3, Table 5 - Lower River Modification Alternatives

Alt. No.	Name	Expected capacity, cfs	Potential TDG Benefit (1)	Testing Required to Assess Viability	Constructability and Other Assessment Required to Evaluate	Comments
1	Add downstream control weir	118,000	3?	None possible	Concept study required. May be infeasible due to foundation and length requirements	Requires fall of about 3 ft (with 1-ft depth) to allow partial degassing. 3 to 5 miles of weir required to attain 1-ft for less of depth over weir (needed to degas).
2A	Add structure to prevent mixing of powerhouse flow and spill gate flow	60,000	3	None possible	Concept study required. May be infeasible due to foundation and length requirements	Only reduces potential powerhouse entrainment
2B	Add structure to prevent mixing of powerhouse flow and spill gate flow, include weir overflow	60,000	2	None possible	Concept study required. May be infeasible due to foundation and length requirements	Requires fall of about 3-ft to allow partial degassing.
3 **Delete**	Add turbulent mixers to surface of downstream river	unknown	2	Mixer could be installed and tested	This alternative **discarded.** It could not treat the river until well below the project, downstream of the water quality monitoring point.	
					Cost and effectiveness of mixers would need evaluation. Small size may make this system unrealistic	Could only install below area where river flow is free of bubbles

(1) Potential benefits rated 1 (best-strips gas) to 5 (worst-adds gas). Benefit of 3 is assumed to pass the upstream gas level (no addition of gas or stripping).

Appendix E. Response to Public Comments

Summary of comments and responses

The Washington State Department of Ecology (Ecology) posted a draft of this report to the web for a 30-day comment public comment period, August 6 through September 5, 2007.

Ecology received comments from Seattle City Light.

Ecology also received comments from the U.S. Army Corps of Engineers, Seattle District. The Corps asked for, and was granted, a time extension to submit their comments.

These comments, as well as Ecology's response to the comments, are included in this appendix.

Comments from Seattle City Light, September 21, 2007

City of Seattle

Gregory J. Nickels, Mayor

Seattle City Light
Jorge Carrasco, Superintendent

September 21, 2007

Mr. Paul J. Pickett, P.E.
Environmental Assessment Program
Washington State Department of Ecology
Olympia, WA 98504-7710

Mr. Jon Jones
Water Quality Program
Washington State Department of Ecology
Spokane, WA 99205

Dear Paul and Jon:

Thank you for the opportunity to review and provide comments on the Washington Department of Ecology's (Ecology) August 6, 2007 document titled *Review Draft, Pend Oreille River, Total Dissolved Gas, Total Maximum Daily Load (TMDL), Water Quality Improvement Report* (review draft TMDL). The purpose of this letter is to provide Seattle City Light's (SCL) initial written comments on the public review draft TMDL. Additional comments may be provided at public meetings and informally with Ecology personnel regarding the review draft TMDL. Specific comments are included as an attachment to this letter (Attachment 1).

General Comments

In summary, the review draft TMDL document is consistent with SCL's understanding to date considering the complexity of this issue within several regulatory frameworks.

1. For Appendix D, please replace SCL's Proposed Study Plan (PSP) dated October 3, 2006, with the attached Study No. 3 titled "Evaluation of Total Dissolved Gas and Potential Abatement Measures" dated February 2007, and approved by the Federal Energy Regulatory Commission (FERC) study plan determination letter dated March 15, 2007.
2. For the (Schneider, M., 2006) draft report review reference, please update with the attached final report review dated June 21, 2006.

700 Fifth Avenue, Suite 3300, P.O. Box 34023, Seattle, WA 98124-4023
Tel: (206) 684-3000, TTY/TDD: (206) 684-3225, Fax: (206) 625-3709

3. For the Abstract and related data analysis sections, please define "seasonal monitoring" timeframes to provide clarity and context for the stated percentages of TDG impairment in the review draft TMDL since the data analyses only apply to spring runoff periods (freshets) that actually generated spill. Generally, the spill data point statistics cover quarter-hours, hours, or days of monitoring during the months of May through early July in 2001, 2002, 2003, and 2004.

SCL appreciates the recognition of several key points within the context of current FERC relicensing and Section 401 of the Clean Water Act (401 certification) processes, including the following:

1. "Therefore the approach taken in this analysis of illustrating TDG generation processes was to assume no entrainment, with the understanding that, as further analysis occurs, the generation processes will be better understood and the models more predictive." (*Boundary Dam TDG generation, Page 33*)
2. "Seattle City Light (SCL) is in the process of FERC relicensing, and conditions for the license obligates SCL to take steps to address the TDG issue in the Pend Oreille River. The study plan (Appendix D) outlines possible approaches to reduce TDG." (*Reasonable assurances, Boundary Dam, Page 94*).
3. "The compliance area below Boundary Dam will begin approximately 4,500 feet below the dam spillways at the current *(USGS)* tailwater monitoring stations." (*Location of compliance areas, Page 95*).

Thank you for the opportunity to comment. Please also find attached our specific comments listed in Attachment 1. SCL looks forward to continuing to actively participate in the future development of this TMDL. Please feel free to contact Barbara Greene (206.615.1091) or Kimberly Pate (206.684.3705).

Sincerely,

Barbara Greene
Program Lead, Boundary Project Relicensing
Seattle City Light

cc: Lynn Best
Laura Wishik
Helen Rueda, EPA

Attachment 1
Seattle City Light Comments:
Review Draft, Pend Oreille River, Total Dissolved Gas, Total Maximum Daily Load, Water Quality Improvement Report - Dated August 6, 2007

SCL requests specific clarifications or changes that affect the review draft TMDL for the Pend Oreille River:

1. Page 7 for the Abstract and related data analysis sections: The monitoring discussion implies that there is TDG impairment or exceedance of the 110 percent standard throughout any given year. SCL suggests clarifying the monitoring period as "seasonal" and define this timeframe such as "the spring run off period (freshet) for each year" citing the months or timeframe.
2. Page 11 states for TDG analysis: "TDG data showed impairment about 52% of the time during the four seasons of monitoring."
   - SCL interprets this statement that TDG was above the 110 percent standard for 52 percent of the total, four seasons timeframe. What does 52 percent represent in terms of timeframe (number of hours, days, etc.), forebay and/or tailwater location, spill events or a combination of spill and non-spill?

2. Page 88 states as the first bullet: "The utility contacts FERC <u>two years</u> prior to the expiration of their current license."
   - SCL's notice of intent (NOI) to apply for a new license was filed with the FERC on May 5, 2006, nearly 5-1/2 years prior to the expiration of our current license (September 2011) in accordance with the FERC Integrated Licensing Process (ILP).

3. Page 88 states as the third bullet: "The utility requests a new FERC license and includes their study plan proposal."
   - A licensee application for a new license and study plan proposal are two (2) separate filings under the FERC-ILP. For example, SCL filed the proposed study plan (PSP) with the FERC in October 2006 as part of the ILP requirements. Under the ILP, study plans are conducted for approximately two (2) years. In spring 2009, SCL plans to file the Preliminary License Proposal (PLP) or draft license application with the FERC for a new license.
4. Page 92: The FERC has issued their study plan determination (March 2007) and approved Study No. 3 as the TDG study plan (Appendix D).
5. Page 103, Appendix A, Glossary - Seattle City Light: Revise the definition to read "The City of Seattle, a municipal corporation of the State of Washington, acting by and through its City Light Department (SCL), owns and operates Boundary Dam."

700 Fifth Avenue, Suite 3300, P.O. Box 34023, Seattle, WA 98124-4023
Tel: (206) 625-3000, TTY/TDD: (206) 684-3225, Fax: (206) 625-3709

Ecology's Response to Comments by Seattle City Light

General Comment 1

Appendix D, Seattle City Light's Proposed Study Plan has been replaced by "Study No. 3, Evaluation of Total Dissolved Gas and Potential Abatement Measures, February 2007."

General Comment 2

The reference to the Schneider, M., 2006 draft report review has been updated to:
Schneider, M., 2006. Report Review Comments on "Boundary 2002 Spill Evaluation" and "TDG Analysis During the 2002 Spill Event". Memorandum For Record, dated 21 June 2006, City of Seattle, Seattle City Light Department (SCL), U.S. Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS.

General Comment 3

Clarifying language has been added.

Attachment 1, Comment 1

Clarifying language has been added.

Attachment 1, First Comment 2

Additional language about the days of impairment has been added, and the section was edited for clarity.

Attachment 1, Second Comment 2

Clarifying language has been added.

Attachment 1, Comment 3

Clarifying language has been added.

Attachment 1, Comment 4

Clarifying language has been added.

Attachment 1, Comment 5

Changes were made as recommended.

Comments from Seattle District U.S. Army Corps of Engineers, September 24, 2007

September 24, 2007

MEMORANDUM FOR: Paul Picket / Jon Jones, WA Dept of Ecology

SUBJECT: Pend Oreille River TMDL Draft, COE review comments

1. The Seattle District Corps of Engineers reviewed the *Pend Oreille River Total Dissolved Gas Total Maximum Daily Load Water Quality Improvement Report Review Draft 8-6-2007*, prepared jointly by Washington Department of Ecology and the United States Environmental Protection Agency in cooperation with the Kalispel Tribe. Comments as submitted below were provided by Kent Easthouse, Seattle District Corps of Engineers and Mike Schneider, U.S. Army Corps of Engineers Engineering Research and Development Center.

<u>COE General Comment:</u> Why is Washington conducting the TDG TMDL independent of Idaho? The Clark-Fork/Pend Oreille River system should have one TDG TMDL because of the unique nature of the system and the closely coupled nature of TDG properties between the two rivers.

2. Page 25 states: *The tailrace monitoring location is on the left bank above the state highway bridge near Newport, and is representative of river conditions with a bias towards spill conditions from Albeni Falls Dam. Therefore, during Albeni Falls spill the Corps tailrace monitor will tend to read the higher TDG levels in the river and overestimate the average TDG in the river. Therefore, use of these data will tend to be implicitly conservative and introduce a margin of safety.*

<u>COE Comment:</u> The tailwater FMS is representative of conditions in spillway releases. The average flow weighted TDG conditions in the Pend Oreille River downstream from Albeni Falls Dam can be closely approximated by applying the forebay TDG levels to powerhouse flows and the tailwater TDG levels to spillway flows.

3. Page 37-38 states: *Many dams in the Columbia River system have been studied for TDG exchange processes. These studies have shown that, under most conditions, TDG concentrations created by spills are independent of upstream conditions. This is because the spilled water and entrained air rapidly reach a new equilibrium under the hydrostatic pressures of the stilling basin. The only exceptions appear to be when spill volumes are very low and the time for gas absorption short. Therefore, it is a fairly accurate generalization to say that each dam's spill "resets" the TDG levels for the water that passes over the spillway and for any entrained powerhouse water.*

For this reason, the primary approach of this TMDL is that each dam is responsible for the TDG generated by its spill, and not for TDG levels upstream. Each dam has the obligation to meet the *load allocation below the dam and downstream to the forebay of the next dam or to the international boundary if possible. If conditions upstream of a dam exceed allocations and prevent meeting allocations downstream, then that dam should manage its spill to at least make TDG conditions in the downstream compliance area no worse than forebay conditions and perhaps at times to improve TDG levels downstream.*

<u>COE Comment:</u> This assumption is not entirely valid for Albeni Falls Dam which spills water *Under* a gate into a shallow stilling basin rather than *Over* a spillway into a deep stilling basin. Total Dissolved Gas studies in 2003 at Albeni Falls Dam showed that TDG concentrations created as a result of spill in the downstream channel were not independent of upstream conditions (Schneider 2007). Schneider (2007) showed that Albeni Falls tailwater TDG concentrations were the result of a combination of many factors, including upstream TDG concentrations. In addition, at very high flow conditions, the Albeni Falls spillway becomes completely inundated and the presence of highly aerated flow conditions causing TDG exchange is not present.

4. Page 41 states: *The following actions are recommended:*
• *TDG allocations should be met at the Idaho state line by implementing actions in Idaho and Montana. This could include implementing the 401 certification at Cabinet Gorge Dam and developing and enacting a gas abatement strategy for Albeni Falls Dam. EPA will provide oversight of interstate compliance.*

<u>COE Comment:</u> Remove recommendation for enacting gas abatement strategy at Albeni Falls Dam. This TMDL did not analyze TDG exchange at Albeni Falls and the complex issue of TDG generated by Cabinet Gorge Dam travelling through Lake Pend Oreille to the forebay at Albeni Falls Dam. TDG exchange at Albeni Falls Dam is more complicated than for dams on the Columbia River, and Schneider (2007) showed that upstream sources of TDG do have an impact on TDG saturations generated by spill, especially at Albeni Falls Dam. Therefore, to recommend enacting a gas abatement strategy at Albeni Falls Dam when no analysis of TDG generation was performed in the TMDL is not valid and should be removed. Recommendations should only be for projects that were studied in this TMDL and not for projects that had no analysis by this TMDL.

Ed Zapel
Ch, Water Management Section
Seattle District, US Army Corps of Engineers

Cc: Schneider, ERDC
Easthouse, CENWS

Ecology's Response to Comments by the Corps of Engineers

Item 1 General Comment

At the time that the project schedule was established, Idaho did not have a TDG TMDL for the Pend Oreille River included in their schedule, so coordination of the systems was not feasible. The Memorandum of Agreement between EPA, Washington, Idaho, and Kalispel Tribe for the Pend Oreille TMDL (April 29, 2005) states:

The case for developing a single TDG TMDL document is less compelling. TDG is governed by a single numeric standard, consistent among the entities' water quality standards. It is typically only generated by spill from dams and there are not likely to be any natural background issues with TDG in this system, so the TDG TMDLs can address the river in discrete segments bounded by dams. It is also logical and consistent with the Columbia and Snake River TDG TMDLs to address downstream segments for TDG first and move upstream, which matches the states' current schedules. Therefore effective coordination of TMDL development for shared waters can still be achieved with separate TMDLs.

Item 2 Comment

Comment noted. Since the downstream monitor likely includes a mixture of spill and powerhouse flow at times, the calculation proposed would tend to underestimate TDG entering Washington. Therefore, the analytical approach used is appropriate for this TMDL.

Item 3 Comment

Ecology appreciates that the Commenter has made this information available. This section has been edited in light of this additional information. However, Albeni Falls Dam is in Idaho, and since this TMDL is for Washington and Kalispel Tribe waters only, a detailed analysis of TDG processes at Albeni Falls Dam is outside the scope of this TMDL.

Item 4 Comment

This section has been edited to recommend additional analysis of TDG at Albeni Falls Dam as a recommendation and a gas abatement strategy only if the analysis finds that one is needed. Ecology recognizes that the Commenter has done much of this analysis, but that Ecology would not conduct any further analysis and is not identifying a party to do more analysis.