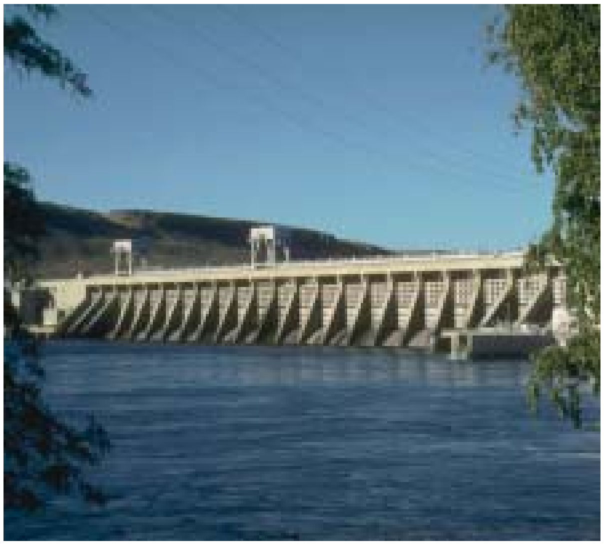
Total Maximum Daily Load (TMDL) for Lower Columbia River Total Dissolved Gas



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Total Maximum Daily Load
for
Lower Columbia River
Total Dissolved Gas

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Acronyms and Abbreviations

Corps	U.S. Army Corps of Engineers
CRITFC	Columbia River Inter-Tribal Fish Commission
DGAS	Dissolved Gas Abatement Study
EPA	U.S. Environmental Protection Agency
FMS	Fixed Monitoring Station
fmsl	feet above mean sea level
kcfs	thousand cubic feet per second
mm Hg	Millimeters of Mercury
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
OAR	Oregon Administrative Rules
TDG	Total Dissolved Gas
TMDL	Total Maximum Daily Load
WAC	Washington Administrative Code
WBID	Waterbody Identification
WRIA	Water Resource Inventory Area
303(d)	Section 303(d) of the federal Clean Water Act
7Q10	Seven-day, ten-year frequency flow
ΔP	Excess gas pressure over barometric pressure

Abstract

This Total Maximum Daily Load (TMDL) addresses total dissolved gas (TDG) in the mainstem Columbia River from its confluence with the Snake River to its mouth at the Pacific Ocean. The states of Oregon and Washington have both listed multiple reaches of the Lower Columbia River on their federal Clean Water Act 303(d) lists, due to TDG levels exceeding state water quality standards. The entire reach is considered impaired for TDG. Oregon and Washington are jointly issuing this TMDL and submitting it to the U.S. Environmental Protection Agency for its approval.

Elevated TDG levels are caused by spill events at four hydroelectric projects on the Lower Columbia River. Water plunging from a spill entrains TDG at high levels. High TDG can cause "gas bubble trauma" in fish, which can cause chronic or acute effects, depending on TDG levels. Spills can be caused by several conditions. "Voluntary" spills are provided to meet juvenile fish passage goals. "Involuntary" spills are caused by lack of powerhouse capacity for river flows. Involuntary spills can result from turbine maintenance or break-down, lack of power load demand, or high river flows. Elevated TDG levels also enter the TMDL area at the upstream boundary from sources outside the TMDL area.

This TMDL sets a TDG loading capacity for the Lower Columbia River in terms of excess pressure above ambient. Allocations are specified for each dam and for the upstream boundary, also expressed in terms of excess pressure. Allocations for the dams must be met at points of compliance within each dam's tailrace at a specified distance below the spillway, corresponding to the end of the aerated zone. The upstream allocation must be met in the pool above McNary dam.

An implementation plan is provided that describes short-term compliance with Endangered Species Act requirements. Long-term compliance is described for both Endangered Species Act and TMDL requirements.

Acknowledgements

The Oregon Department of Environmental Quality and the Washington State Department of Ecology wishes to acknowledge the cooperation of the following agencies in the production of this TMDL.

- The U.S. Army Corps of Engineers (Portland District, Walla Walla District, and Northwest Division) provided extensive technical information for this TMDL. Large tracts of the technical analysis have been quoted or paraphrased from the Corps' Dissolved Gas Abatement Study (DGAS). This TMDL would have been much more difficult without the understanding of total dissolved gas production resulting from the DGAS study.

- The National Marine Fisheries Service provided valuable advice and review. The Biological Opinion issued in December 2000 pursuant to the Endangered Species Act was invaluable in describing the studies that have been conducted to date, and in specifying the effects of total dissolved gas on fish.

- The U.S. Environmental Protection Agency provided financial and technical assistance.

- Tetra Tech and Battelle Northwest Laboratories provided review and technical input.

- The Western Governor's Association played a major role in outreach.

- The Columbia River Inter-Tribal Fish Commission provided invaluable review and coordination. Staff from the Yakama, Nez Perce, Colville, Spokane, and Kalispel Tribes also contributed to the process.

- The Bonneville Power Administration, U.S. Bureau of Reclamation, and Grant County Public Utilities District provided review and input.

Nothing in this TMDL purports to represent the technical or policy positions of any of the above agencies or organizations. Any flaws in this TMDL are entirely the responsibility of the Oregon Department of Environmental Quality and the Washington State Department of Ecology.

Executive Summary

Description of Waterbody, Pollutant of Concern, and Pollutant Sources

This Total Maximum Daily Load (TMDL) addresses total dissolved gas (TDG) in the mainstem Columbia River from its confluence with the Snake River to its mouth at the Pacific Ocean. The states of Oregon and Washington have both listed multiple reaches of the Lower Columbia River on their federal Clean Water Act 303(d) lists due to TDG levels exceeding state water quality standards. The entire reach is considered impaired for TDG. Oregon and Washington are jointly issuing this TMDL and submitting it to the U.S. Environmental Protection Agency for its approval.

Elevated TDG levels are caused by spill events at four hydroelectric projects on the Lower Columbia River. Water spilled over the spillway of a dam entrains air bubbles. When these are carried to depth in 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. Fish in this water may not display signs of difficulty if the 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, forming bubbles in their body tissues. This gives rise to gas bubble trauma, which can be lethal at high levels, or give rise to chronic impairment at lower levels. There is extensive research reported in the literature on the forms of physical damage to fish that represent the symptoms of gas bubble trauma.

Spills can occur at any time for several reasons:

- Fish passage spills (voluntary spills), conducted under the Biological Opinion in compliance with the federal Endangered Species Act.
- Spills required when flow exceeds powerhouse capacity (involuntary spills).

There are three main reasons for involuntary spills:

- The powerhouse cannot pass flood flows.
- The powerhouse is off-line due to lack of power demand.
- The powerhouse is off-line for maintenance or repair.

Dams on the Lower Columbia are run-of-the-river dams with very little storage capacity. Therefore, spills are often forced due to operational decisions at upstream storage reservoirs, such as Washington's Grand Coulee Dam or Dworshak Dam.

This document describes the production of TDG at the four projects in the Lower Columbia River. It presents general production equations representing the production of TDG, and specific equations taking into account each project's particular physical characteristics. Any other sources of TDG in the TMDL area, such as tributaries, are considered negligible compared to the four dams. TDG is also affected by barometric pressure and water temperature, and these influences are addressed in the TMDL.

Description of the Applicable Water Quality Standards and Numeric Target

The water quality standards for both Oregon and Washington have an identical TDG criterion: *110 percent of saturation not to be exceeded at any point of measurement.* This criterion does not apply to flows above the seven-day, ten-year frequency flow (7Q10) flood flow. In addition, special “waiver” limits for TDG have been established as a temporary special condition in Washington rules, to allow higher criteria with specific averaging periods during periods of spill for fish passage. Oregon rules specify a process for establishing waiver limits as variance on an annual basis. Because the waiver limits are either temporary or annually renewed, this TMDL addresses only the 110 percent criterion. However, the implementation plan allows compliance with waiver limits through 2010 as an interim allowance for compliance with the TMDL in the short-term.

Loading Capacity

Loading capacity for TDG has been defined in terms of excess pressure over barometric pressure (ΔP). This parameter was chosen because it can be directly linked to the physical processes by which spills generate high TDG, and it has a simple mathematical relationship to TDG percent saturation. A loading capacity of 75 mm Hg has been assigned to the Columbia River in this TMDL area, based on meeting 110% saturation during critically low barometric pressure conditions.

Pollutant Allocations

Because of the unique nature of TDG, load allocations for dam spills are not directly expressed in terms of mass loading. Like loading capacity, load allocations for each dam will be made in terms of ΔP defined site-specifically for each dam. A load allocation is also specified for the upstream boundary of the TMDL area. The wasteload allocation under this TMDL is zero, because no NPDES-permitted sources produce TDG.

Long-term compliance with load allocations for dam spills will be at the downstream end of the aerated zone below each spillway. Distances are specified for the compliance location at each dam. As a result, the load allocation must be met in the spill from each dam individually at a specified compliance location, with allowance made for degassing in the tailrace below the spillway and above the compliance location.

Compliance with load allocations are tied to structural changes at each dam, and are intended as long-term targets. Short-term compliance will be established under the implementation plan, and will be based on operational management of spills, implementation of the “fast-track” DGAS structural modifications, and compliance with Endangered Species Act requirements and TDG waiver criteria.

Margin of Safety

A margin of safety is supplied implicitly by use of conservative critical conditions for ambient barometric pressure. The common occurrence of wind-induced degassing in the TMDL area also provides a margin of safety. The TDG criterion itself provides a margin of safety due to its stringency as compared to site-specific effects documented by extensive site-specific research on TDG and aquatic life in the Columbia River. Due to extensive data collection in the TMDL area, the margin of safety for data uncertainty is small.

Seasonal Variation

Spills and associated high TDG levels, although most likely to occur in the spring and early summer, can potentially occur at any time. Therefore, TMDL load allocations apply year-round. Seasonal effects have been evaluated in the development of critical conditions, but seasonal variations appear to be small. The TMDL only applies for flows below the 7Q10 flood flows, which have been calculated for each dam.

Monitoring Plan

Long-term compliance with load allocation will be monitored at the compliance location below the aerated zone with special studies in the tailrace of the dam, following structural modifications. Also, continuous monitoring will be used for long-term compliance by determining the statistical relationship between continuous monitors and conditions at the compliance location. Monitoring of implementation and operational controls in the short term will use continuous monitoring at fixed monitoring station sites.

Implementation Plan

The Implementation Plan incorporates actions described and analyzed by the National Marine Fisheries Service in the Biological Opinion and by the U.S. Army Corps of Engineers in its Dissolved Gas Abatement Study. Both short-term (Phase I) and long-term (Phase II) measures are described with specific TDG and spill reduction measures. Phase I is in effect through 2010. Phase II begins in 2011 and continues until 2020. The Implementation Plan has been developed in consultation with the National Marine Fisheries Service, so that TMDL implementation will be coordinated with requirements of the Endangered Species Act.

Reasonable Assurance

Structural work has already been carried out to reduce TDG at the four Lower Columbia River dams. Both the Oregon Department of Environmental Quality and the Washington State

Department of Ecology have regulatory authority over the four federal dam projects. However, both are confident that the collaborative effort with the dam operators toward reducing gas will continue and be enhanced through this TMDL. The track record for Congressional funding for these projects is good, and there is reason to believe that further funding of projects will continue.

Public Participation

Extensive public involvement activities, organized by the inter-agency TMDL Coordination Team, have occurred under this TMDL for over a year. Activities have included websites, focus sheets, coordination meetings, stakeholder meetings, conference presentations, and public workshops. Public hearings were held in March 2002 (see *Summary of Public Involvement* section of this report).

Introduction

State water quality standards establish criteria at levels that ensure the protection of the water's beneficial uses. Water that fails to meet water quality standards triggers a state action in Oregon and Washington. The Oregon Department of Environmental Quality and Washington State Department of Ecology are charged to assess, manage, and protect the beneficial uses of the waters of their respective states.

A number of waterbodies fail to meet water quality standards. Oregon and Washington are charged with returning waterbodies to standards. The requirement under the federal Clean Water Act for achieving this is known as a Total Maximum Daily Load (TMDL).

Oregon and Washington have established criteria for total dissolved gas (TDG), which at high levels has deleterious effects on fish and other aquatic life. This document details a TMDL approach for TDG in the mainstem Columbia River from the mouth of the Snake River to its mouth at the Pacific Ocean (Figure 1). This report will explain what TDG is, why high TDG is a problem, and a strategy for managing it so water quality standards will be met.

Purpose of, and Authority for, TMDL

Compliance with Clean Water Act

The border between the states of Washington and Oregon follows the geographic center of the Columbia River mainstem for most of the river from the Wallula Gap (a few miles below the confluence of the Snake and Columbia rivers) to its mouth. Both states have adopted water quality standards for TDG to protect aquatic life. This entire reach of the river is out of compliance with the TDG water quality standard both for the state of Oregon and the state of Washington. In both states the river is listed on their 1998 lists of waterbodies failing to meet standards pursuant to Section 303(d) of the federal Clean Water Act. As a result of the standards exceedances and subsequent listings, this TMDL is being prepared jointly by Oregon and Washington.

Although Oregon and Washington only have authority over the waters within their boundaries, under federal law each state must meet the standards of the other where the waters are shared, such as in the Lower Columbia River. Therefore, the goal of this TMDL is to provide a single TMDL analysis and implementation plan that both states agree to, which will then be implemented by each state with their unique authorities.

A TMDL determines the quantity (load) of a pollutant that can enter a waterbody and still meet water quality standards. This load is then allocated among the various sources. An implementation component (in Washington, Summary Implementation Strategy or SIS) is included to identify actions that appropriate agencies and stakeholders (in Oregon, Designated Management Agencies or DMAs) will undertake to achieve the allocated loads.

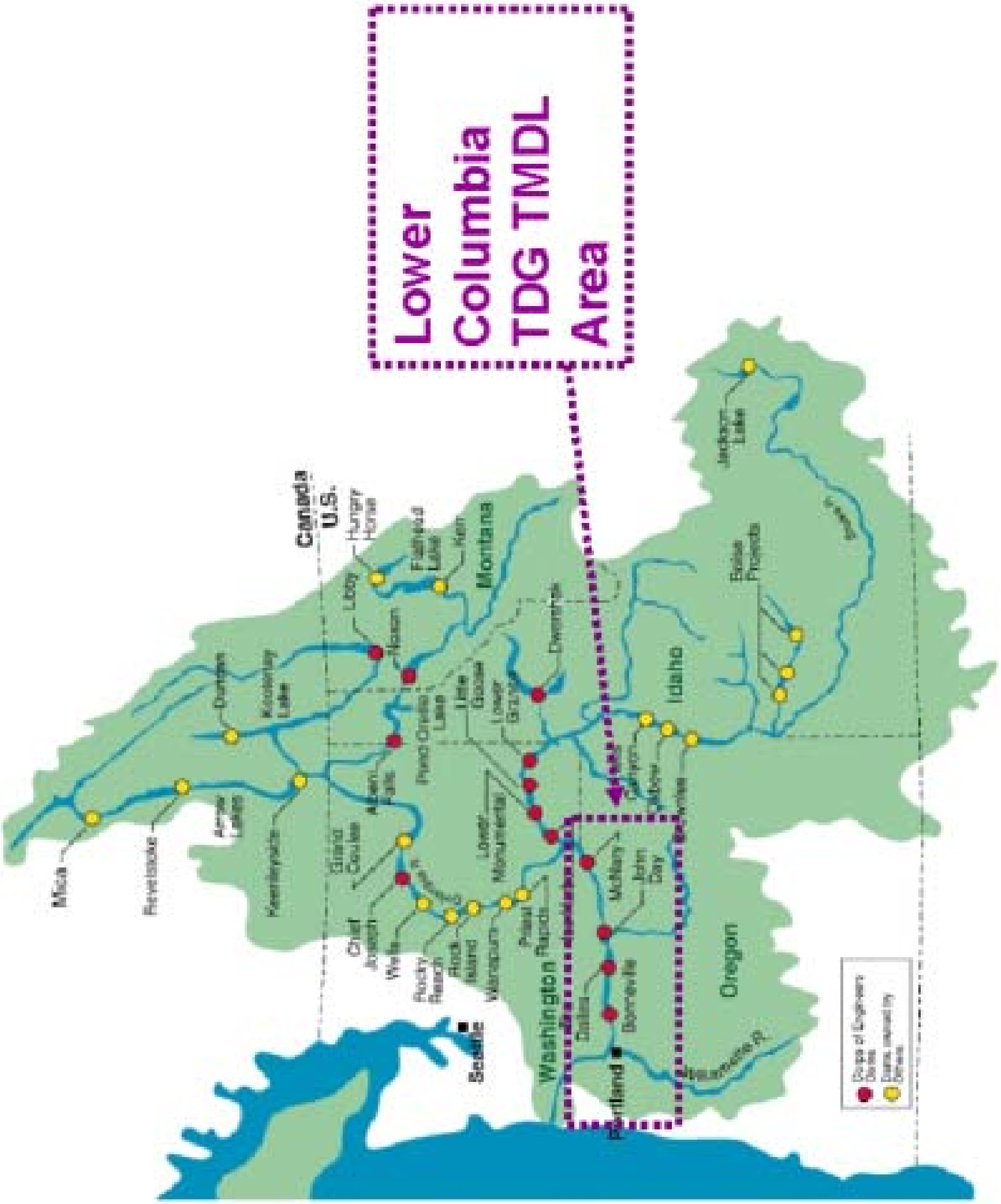

Figure 1: Map of Lower Columbia TMDL Area

The TMDL, as described in this document, must be submitted to the U.S. Environmental Protection Agency (EPA) for their approval. Oregon and Washington each operate under a Memorandum of Agreement with EPA, which guides the TMDL submittal. This document has been organized by Oregon's guidelines, but Table 1 outlines the components of Washington's TMDL submittal and how they match up.

Table 1: Comparison of Oregon's and Washington's TMDL Submittal Format

State of Oregon	State of Washington
Table of Contents	(Optional)
List of Tables	(Optional)
List of Illustrations	(Optional)
Acknowledgement	(Optional)
Executive Summary	(Optional)
Introduction	Introduction
Purpose of, and Authority for, TMDL	Introduction
Geographic Extent	Background
TDG Water Quality Standards	Applicable Criteria
Basin Assessment	Background
Deviation of Ambient Conditions from Water Quality Standards	Water Quality and Resource Impairments
Loading Capacity	Technical Analysis; Loading Capacity
Identification of Sources	Technical Analysis
Load Allocations	Load and Wasteload Allocations
Margin of Safety	Margin of Safety
Seasonal Variations	Seasonal Variation
Implementation Plan	Summary Implementation Strategy
References and Bibliography	References Cited

Coordination with Endangered Species Act

In Oregon and Washington, a TMDL is a planning tool, not a rule of law or other stand-alone enforceable document. It does not take precedence over the federal Endangered Species Act, Indian Treaties, or federal hydropower system enabling legislation. It takes no action that would trigger a review under the National Environmental Policy Act or Washington State Environmental Policy Act. TMDLs may be used to condition exemptions, modifications, variances, permits, licenses, and certifications.

There is much overlap between this TMDL established pursuant to the federal Clean Water Act and anadromous fish passage for salmonids listed as threatened or endangered under the Endangered Species Act, administered by the National Marine Fisheries Service (NMFS). It is therefore important that there is a clear understanding of the requirements of this TMDL relative to measures required by Biological Opinions issued in relation to the threatened and endangered species of the Snake and Columbia rivers.

The 2000 Federal Columbia River Power System (hydrosystem) Biological Opinion requires that the action agencies (U.S. Army Corps of Engineers, Bonneville Power Administration, and the U.S. Bureau of Reclamation) meet specific hydrosystem biological performance standards for both adult and juvenile salmon. The purpose of these standards is to help reverse the downward trend in listed salmon populations and therefore ensure viable salmon resources in the Columbia River Basin. The juvenile hydrosystem goals are one part of a three-tiered approach to assessing performance of implementation of the Reasonable and Prudent Alternative Section items presented in the Biological Opinion. These hydrosystem standards are combined with standards for harvest, habitat, and hatcheries and other life stage indicators to arrive at a population level standard.

The hydrosystem survival performance standards can be met by a combination of controlled spills, fish passage facilities to divert juvenile salmon from passing through the turbines, or juvenile transportation by truck or barge. Due to the current configuration of the hydroelectric projects along the Columbia and Snake rivers, NMFS sees spill as the safest, most effective tool available. However, these performance standards are not being met at the current implementation level of the spill program. Therefore, in the short-term, structural gas abatement solutions may result in higher spills rather than lower TDG levels. But as new, more effective fish passage facilities are completed and evaluated, their contribution to the attainment of hydrosystem performance standards will hopefully allow spill levels for fish passage and associated TDG levels to be reduced, but only as long as the performance standards are met.

Spills for fish passage under the Biological Opinion cause TDG supersaturation above the 110 percent criterion. The state water quality standards are meant to be sufficiently protective so as to prevent damage to beneficial use of the state waters. The effects of elevated dissolved gas on migrating juvenile and adult salmon due to voluntary spill have been monitored each year of spill program implementation. Based on five years of data from the biological monitoring program, the average incidence of gas bubble disease signs has been low, although the state-allowed maximum TDG due to spill was 120 percent in the tailrace and 115 percent in forebays. From 1995 to 1996, only 1.6 percent of all the juveniles sampled, nearly 200,000 fish, showed signs of disease (Schneider, 2001). These results suggest that, in weighing the benefit gained in increased salmon survival by spills for fish passage against the benefit to the beneficial use from strict adherence to the standard, it would be reasonable to find flexibility in application of the standards.

In summary, the provisions of both Acts must be met. Notwithstanding that, it is not the purpose of the Clean Water Act to usurp functions properly undertaken pursuant to the Endangered Species Act. On the contrary, the Endangered Species Act contains provisions that encourage EPA to consult with NMFS prior to approval of a TMDL that affects ESA-listed species to ensure the TMDL is consistent with species recovery goals. The 2000 Biological Opinion issued pursuant to the Endangered Species Act requires attainment of certain fish passage performance standards. One of the means of attaining these is through spilling water over hydroelectric dam spillways. This action, though, results in elevated TDG. Control of TDG is the purpose of this

TMDL. The Clean Water Act does not envisage trade-offs of fish passage for TDG; it requires, rather, attainment of water quality standards. This is one of the significant challenges posed by this TMDL.

This TMDL must be written to reflect ultimate attainment of the TDG water quality standard. Fish passage requirements can be facilitated under an implementation plan, but the clear expectation of the Clean Water Act is that water quality standards will be attained in a limited amount of time. NMFS and EPA have been discussing how to meet biological performance standards under the Endangered Species Act at the same time as meeting the water quality standards of the Clean Water Act. However, the primary purpose of this TMDL must be to comply with the Clean Water Act, although finding a means of compliance with both laws is also a goal.

Geographic Extent

This TMDL applies to the Columbia River mainstem from the confluence of the Snake and Columbia rivers to its mouth at the Pacific Ocean.

The laws of the state of Oregon apply to the river's southern half from its point of entry into Eastern Oregon from the state of Washington. This takes in seven river segments as follows:

- The mouth to Tenasillahe Island. Segment number COLU0
- Tenasillahe Island to Willamette River. Segment number COLU037
- Willamette River to Bonneville Dam. Segment number COLU102.
- Bonneville Dam to The Dalles Dam. Segment number COLU146.
- The Dalles Dam to John Day Dam. Segment number COLU191.6.
- John Day Dam to McNary Dam. Segment number COLU215.6.
- McNary Dam to the Washington border. Segment Number COLU292.

These seven segments fall on the Columbia River mainstem. The hydrologic unit code for the Columbia Basin is 1707. All of these waters have been identified as impaired and have been included on Oregon's 1998 303(d) list.

The laws of the Washington apply to the entire Columbia River from the mouth of the Snake River to the Oregon border in Wallula Gap, and to the northern half of the river from there to the mouth. All of these waters have been included on Washington's 1996 303(d) list, and have been identified as impaired or have been included on Washington's 1998 303(d) list. The segments covered by this TMDL are listed in Table 2, along with the Water Resource Inventory Area (WRIA) and Waterbody Identification (WBID) numbers.

TMDLs are also planned for the Lower Snake River (Clearwater River to confluence with the Columbia River), and for the Mid-Columbia River (Canada border to confluence with Snake River). Those two TMDLs at their downstream end will address compliance with this TMDL at its upstream end.

Table 2: Washington's Lower Columbia River TDG Listed and Impaired Segments

Segment description	WRIA	WBID	1996 303(d) listings	1998 303(d) listings	1998 impaired but unlisted
Bonneville Dam to Mouth	(24 – 28)	WA-CR-1010	1		
Willapa	24	NN57SG		1	
Grays-Elokoman	25	NN57SG		1	
Cowlitz	26	NN57SG			1
Lewis	27	NN57SG		1	
Salmon-Washougal	28	NN57SG		6	
McNary Dam to Bonneville Dam	(28 – 31)	WA-CR-1020	1		
Salmon-Washougal	28	NN57SG		2	
Wind-White Salmon	29	NN57SG			1
Klickitat	30	NN57SG		3	
Rock-Glade	31	NN57SG		3	
Oregon Border to McNary Dam	(31)	WA-CR-1026	1		
Rock-Glade	31	NN57SG		2	
Snake River to Oregon Border	(31 – 32)	WA-CR-1028			
Rock-Glade	31	NN57SG			1
Walla Walla	32	NN57SG			1
Totals			3	19	4

Total Dissolved Gas Water Quality Standards

For waters that are shared by two states, water quality must meet the standards of both states. For this TMDL, the standards of the two states are virtually identical.

State of Oregon Standards

Oregon's Water Quality Standards are contained in Oregon Administrative Rules (OAR) 340, Division 41. The standards relevant to the total dissolved gas (TDG) TMDL [OAR 340-041-0205(2)(n)] are:

(A) *The concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection shall not exceed 110 percent of saturation, except when stream flow exceeds the ten-year, seven-day average flood. However, for Hatchery receiving waters and waters of less than two feet in depth, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection shall not exceed 105 percent of saturation;*

(B) *The Commission may modify the total dissolved gas criteria in the Columbia River for the purpose of allowing increased spill for salmonid migration. The Commission must find that:*

- *(i)* *Failure to act would result in greater harm to salmonid stock survival through in-river migration than would occur by increased spill;*
- *(ii)* *The modified total dissolved gas criteria associated with the increased spill provides a reasonable balance of the risk of impairment due to elevated total dissolved gas to both resident biological communities and other migrating fish and to migrating adult and juvenile salmonids when compared to other options for in-river migration of salmon;*
- *(iii)* *Adequate data will exist to determine compliance with the standards; and*
- *(iv)* *Biological monitoring is occurring to document that the migratory salmonid and resident biological communities are being protected.*

(C) *The Commission will give public notice and notify all known interested parties and will make provision for opportunity to be heard and comment on the evidence presented by others, except that the Director may modify the total dissolved gas criteria for emergencies for a period not exceeding 48 hours;*

(D) *The Commission may, at its discretion, consider alternative modes of migration.*

"Commission" means the Oregon State Environmental Quality Commission.

State of Washington Standards

Washington's Water Quality Standards, Chapter 173-201A Washington Administrative Code (WAC), classify the reaches of the Columbia River covered by this TMDL as Class A. The following standards specifically apply to this TMDL:

WAC 173-201A-030:

Total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection.

WAC 173-201A-060:

(4)(a) The water quality criteria herein established for total dissolved gas shall not apply when the stream flow exceeds the seven-day, ten-year frequency flood.

(b) The total dissolved gas criteria may be adjusted to aid fish passage over hydroelectric dams when consistent with a department approved gas abatement plan. This gas abatement plan must be accompanied by fisheries management and physical and biological monitoring plans. The elevated total dissolved gas levels are intended to allow increased fish passage without causing more harm to fish populations than caused by turbine fish passage. The specific allowances for total dissolved gas exceedances are listed as special conditions for sections of the Snake and Columbia rivers in WAC 173-201A-130 and as shown in the following exemption:

Special fish passage exemption for sections of the Snake and Columbia rivers: When spilling water at dams is necessary to aid fish passage, total dissolved gas must not exceed an average of one hundred fifteen percent as measured at Camas/Washougal below Bonneville dam or as measured in the forebays of the next downstream dams. Total dissolved gas must also not exceed an average of one hundred twenty percent as measured in the tailraces of each dam. These averages are based on the twelve highest hourly readings in any one day of total dissolved gas. In addition, there is a maximum total dissolved gas one hour average of one hundred twenty-five percent, relative to atmospheric pressure, during spillage for fish passage. These special conditions for total dissolved gas in the Snake and Columbia rivers are viewed as temporary and are to be reviewed by the year 2003.

(c) Nothing in these special conditions allows an impact to existing and characteristic uses.

The “ten-year, seven-day average flood” or “seven-day, ten-year frequency flood” are usually termed the “7Q10” flood flows.

The criteria in WAC section 173-201A-060 are sometimes termed the “waiver” TDG limits for fish passage. Oregon establishes “waiver” limits on an annual basis using the procedures outlined above. Since the Oregon waiver limits are established annually, and the Washington waiver limits are to be viewed as temporary, this TMDL cannot use the waiver limits as a compliance endpoint. TMDLs must by law ensure compliance with the existing permanent standards. There are separate processes to revise the water quality standards and establish new criteria. If the TDG standards are ever revised in a way that affects this TMDL, then the TMDL would need to be revisited and modified at that time.

Basin Assessment

Total dissolved gas (TDG) levels can be increased above the water quality criteria by spilling water over spillways of dams on the Columbia River. These are the major sources of elevated TDG in the Columbia mainstem. There are a variety of other ways that TDG may be elevated: passage of water through turbines, fishways, or locks; and natural processes such a low barometric pressure, high water temperatures, or high levels of biological productivity. However, the vast majority of the high TDG levels found in the Columbia River are caused by spills from dams. Man-made sources other than spill are minor, and can be considered negligible. Natural processes may have a significant effect on TDG, and are addressed in setting load allocations.

Spill at dams occurs for several reasons:

1. To enhance downstream fish passage (to meet “Performance Standards” for fish survival under the Endangered Species Act).
2. To bypass water that exceeds the available hydraulic capacity of the powerhouse due to:
    - High river flows.
    - Lack of power market.
    - Maintenance, break-down, or other reasons.

The first type of spill is sometimes called “voluntary spill”, while the second types are termed “involuntary spills”. Figure 2 illustrates the typical configuration of a dam on the Lower Columbia River.

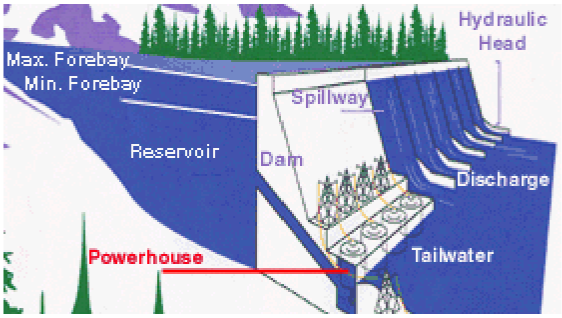

Figure 2: Typical Dam Configuration

Spill for Fish Passage

Spill for purposes of fish passage involves water deliberately released over dam spillways, rather than being discharged through turbines or fish bypass facilities. The intent is to reduce turbine and bypass mortalities. For example, Schoeneman et al. (1961) found that mortality in Chinook juveniles spilled over McNary Dam (Columbia River) and Big Cliff Dam (Santiam River) was less than two percent. Subsequent studies confirmed this estimate, and research is ongoing. The requirement for spring and summer spills to pass juvenile salmon was included in the 1995 and 2000 Biological Opinions for the Columbia River dam operations. To comply with these Biological Opinions, Oregon and Washington have established the waiver TDG limits to allow limited fish passage spill.

In Oregon, the Environmental Quality Commission has granted variances to the TDG standard to enable spill for salmonid juvenile passage for species listed under the federal Endangered Species Act. This has occurred annually since 1994. Variances usually require TDG levels not exceed 120 percent saturation relative to atmospheric pressure in the tailrace of the spilling dam, and 115 percent TDG saturation relative to atmospheric pressure as measured in the forebay of the next dam downstream. Variance periods usually extend from the middle of April through the end of August each year. Additional variances have been granted each year for spill over Bonneville Dam for up to ten days each March to assist with passage of the Spring Creek National Fish Hatchery Tule Chinook release. One variance has also been given for John Day Dam to enable testing of flow deflectors.

Washington’s approach to conform with the Biological Opinion was to adopt a rule revision specifying the TDG criteria for fish passage spill (see above). These waiver limits have generally been identical to Oregon’s annual variances.

Involuntary Spill

Like spills for fish passage, involuntary spill involves water being discharged over dam spillways. The causes and intended consequences, though, are different. As its name suggests, there is no choice involved in "involuntary" spill. At times of very high river flows, the quantity of water exceeds the capacity of a dam to either temporarily store the water upstream of the dam or pass the water through its turbines. In these circumstances, water is released over the spillway, because there is nowhere else for it to go. The Columbia River hydropower system in Washington and Oregon is somewhat unique in that regard. With the exception of Washington’s Grand Coulee Dam, it contains very little storage potential relative to the quantity of spring runoff. At times of rapid runoff, the dams cannot constrain the quantity of water, and it is spilled with attendant high TDG levels. Often dissolved gas levels from involuntary spill exceed those experienced during periods of spill for fish. However, high river flows under these circumstances are often in excess of the 7Q10 high flow, in which case the TDG standard would not apply.

Involuntary spill as a result of lack of power market is a variant of the above. In this scenario, the power marketing authority cannot sell any more power, and even though turbines are available, water is released over the spillway because there is nowhere for electricity generated to go. Running water through the turbines with no load increases wear and tear with attendant higher maintenance costs, and also may reduce fish survival. Lack of power load demand can occur at times of both high and low flows (e.g., in the spring or fall when power demands are low both in California and the Pacific Northwest). Also releases from upstream storage dams during high load times (morning and evening) can result in high flows at downstream dams during low load times (middle of the night), causing an involuntary spill.

Involuntary spill can also occur at low flows when powerhouses are taken off-line for maintenance, breakdown, or other needs. Maintenance is usually scheduled to prevent a spill, by doing maintenance on one or two generating units at a time during low power demand periods. Nonetheless, releases from upstream dams can complicate management of spills during powerhouse maintenance. Also, unscheduled maintenance and repairs sometimes occur, which may require a powerhouse shut-down and involuntary spill.

In general, involuntary spill conditions at the “run of the river” dams may result from reservoir control and power marketing decisions made by the federal project operators having storage capacity upstream. Improved accuracy in water forecasting could help avoid understating or overstating available water supply, which could cause the federal project operators to spill water because they left too little or too much room in the reservoirs. Additionally, a water management plan could also identify uncoordinated releases and manage intra-day fluctuations in river flows. These events often result in isolated involuntary spill events, because reservoir elevation must be maintained within limits at run of the river projects.

Deviation of Ambient Conditions from Water Quality Standards

TDG Generation from Spills

Spills for fish passage typically occur during the spring and summer months. During periods of fish spills, deviations of ambient conditions from the water quality standard are frequent but usually small. This is because spill quantities are managed to meet the waiver levels for fish passage: either variances granted by the state of Oregon or Washington's Special Conditions (described above). For the past six years, Oregon has granted a variance to its water quality standard for TDG to facilitate fish passage. These variances are virtually identical to Washington's Special Conditions, which allow TDG levels to rise to 120 percent of saturation relative to atmospheric pressure in the tailrace of the dam that is spilling, and 115 percent in the forebay of the next dam downstream.

The excursions beyond this level usually have been no more than one or two percent above the variance request, and occur as a result of the imprecision in reproducing exact TDG levels at specific spillway gate set points due to all the sources of TDG variability described. Generally, the fishery management agencies have sought spill quantities in order to remain right at the TDG variance limit at the fixed monitoring station sites. Any small change in conditions that influence TDG, such as change in barometric pressure, water temperature, incoming gas, total river flow or tailwater elevation will cause an exceedance when operated this way. Also, these levels do not meet the 110 percent criterion of either state.

Involuntary spills can occur at any time. Involuntary spills caused by river flows above powerhouse capacity are most likely to occur from late fall to early summer, depending on rainfall or snowmelt in the tributary watersheds. However, high flows could also occur due to releases from upstream dams with significant storage, such as Grand Coulee or the Canadian dams. Involuntary spill due to low power demand is most likely in the spring, although this is also dependent on regional power management by the Bonneville Power Administration. Loss of powerhouse capacity to maintenance or repair is usually scheduled so that no more than one or two turbines are out at any given time, but an emergency powerhouse shutdown and spill could occur at any time as the result of a fire or other disaster.

At times of involuntary spill, exceedances above the standard can rise dramatically, peaking above 130 percent of saturation, and even 140 percent. Absolute TDG pressures at these levels, which usually only occur in shallow waters, can be lethal to fish. Usually fish are protected from fatal pressures in deeper waters by compensation from hydrostatic pressures, which reduces absolute TDG levels.

For all spills, the highest TDG levels, and therefore the area most likely to exceed standards, is directly below the spillway. In this area, the plunging and air entrainment of the spill (aerated zone) generates high levels of TDG, but then quickly degasses while the water remains turbulent and full of bubbles. However, as this water moves from the stilling basin into the tailrace, degassing slows and the TDG levels stabilize.

In the pools, gas exchange rates increase as wind speeds rise, which produces degassing. If conditions are still and TDG concentrations are constant, the percent saturation of TDG can increase if the water temperature increases or barometric pressure drops (Figure 3). Also, primary productivity (periods of algal growth) can increase dissolved oxygen levels, which results in a higher TDG percent saturation. However, because oxygen is metabolized by the aquatic life, the physical effects of supersaturated oxygen are minor compared to nitrogen and can be considered *de minimus.*

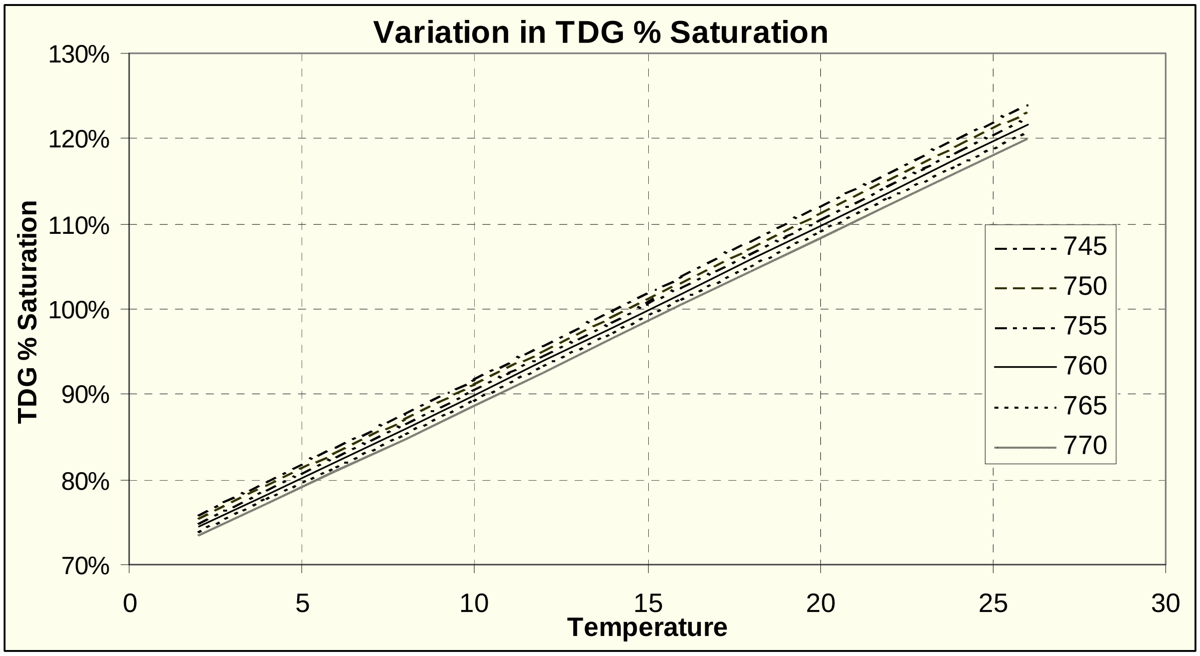

Figure 3: Variation in TDG Percent Saturation with Temperature and Barometric Pressure at Constant Concentration

Due to the hydraulic properties of the spill, a proportion of the powerhouse flow entrains with the spill and is aerated as if it were part of the spill. This amount may be negligible where physical structures separate powerhouse from spillway flows, such as islands at Bonneville Dam. The rest of the powerhouse flow mixes with the spillway flows at varying rates, sometimes quite slowly, as the river moves downstream from the dam. Powerhouse TDG levels are typically identical with forebay TDG levels – very little gas exchange occurs as water passes through the powerhouse. Therefore, if the forebay TDG levels are lower than levels below the spillway, the powerhouse flows that mix slowly and farther downstream will reduce the TDG levels in the spillway waters by dilution.

TDG Impacts on Aquatic Life

Fish and other aquatic life inhabiting water supersaturated with TDG may tend to display signs of difficulty, especially if higher dissolved gas pressure gradients occur. Gas bubbles form only when the TDG pressure is greater than the sum of the compensating pressures. Compensating pressures include water (hydrostatic) and barometric pressure. For organisms, tissue or blood pressure may add to the compensating pressures. Gas bubble development in aquatic organisms is then a result of excessive uncompensated gas pressure. The primary actions which will enhance the likelihood of bubbles forming in the fish are (1) continued exposure to the highly saturated water, (2) rising higher in the water column bringing about a higher pressure gradient (decreased hydrostatic pressure), (3) decreases in barometric pressure, and (4) increasing water temperature.

The damage caused by release of gas bubbles in the affected organism is termed gas bubble trauma or gas bubble disease. There is a wide body of research on this condition. Effects of gas bubble trauma include emphysema, circulatory emboli, tissue necrosis, and hemorrhages in brain, muscle, gonads, and eyes (Weitkamp and Katz 1980). Nebeker et al. (1976) found that death in adults was due to massive blockages of blood flow from gas emboli in the heart, gills, and other capillary beds. Investigators in the 1970s reported many and varied lesions in fish exposed in the 115%-to-120% TDG range in shallow water. At higher gas exposures (e.g., 120% to 130% TDG) death frequently ensued before gas bubble trauma signs appeared (Bouck et al. 1976). External signs of gas bubble trauma (e.g., blisters forming in the mouth and fins of fish exposed to chronic high gas) often disappeared rapidly after death. The signs were largely gone within 24 hours (Countant and Genoway 1968).

Water quality standards for TDG were set at 110 percent, the threshold for chronic effects found in the literature. The severity of gas bubble trauma increases as the absolute TDG level increases, until at higher levels lethality can occur swiftly. However, there are a number of factors that affect a particular organism's response to high TDG levels. Different species respond to changing TDG differently, and the response also varies by life stage. Juvenile salmonids appear to be relatively resilient compared to adults or to non-salmonids.

The duration of exposure to high TDG appears to have an impact on the severity of gas bubble trauma symptoms. Although the standards are not specific on this issue, defining a duration of exposure to be applied to the criteria is appropriate. The waiver limits developed for fish passage provide two levels: a one hour maximum, and the average of the twelve highest hourly readings in any 24-hour period. Based on the 110 percent criteria representing chronic impacts, use of the longer averaging period is appropriate.

Extensive research has been conducted on the effects of TDG on anadromous fish in the Columbia River. It is beyond the scope of this TMDL to review that literature. The Clean Water Act requires compliance with existing standards, although existing research can be used to aid in interpretation of those standards. A review of the standards to look at adoption of different criteria, duration, frequency, and spatial application, if appropriate, would occur through a completely separate process. If new standards were adopted, then the TMDL could be reviewed and possibly revised.

It is possible that TDG became elevated under historical natural conditions in the Columbia River, such as below Celilo Falls. However, elevated TDG probably dissipated quickly as it passed over shallows and rapids. Conditions different from natural conditions exist at the Columbia dams that create high TDG levels. These conditions include the height of the dams, the shape of the spillways, and the presence of the long deep pools below the dams. Allowing a point of compliance below the aerated portion of the tailrace can be considered to reflect gas generation patterns in a natural system.

Monitoring of TDG

Routine monitoring of instream TDG levels occur at fixed monitoring station (FMS) sites above and below each dam. The tailwater FMS sites in some cases may be a mile or two downstream of the dam. The FMS sites have been the primary point of compliance and assessment of TDG levels, especially for compliance with waiver limits during fish passage spills. The locations have been chosen for a variety of reasons, a primary one being the logistics and feasibility of long-term monitoring. However, studies suggest that some of these sites are not collecting data that are representative of river conditions. The FMS sites will continue to be the primary location for determining compliance with waiver limits used for fish passage management. For the purposes of TMDL compliance, TMDL requirements do not need to drive FMS siting issues.

The interagency Water Quality Team manages issues regarding the fish passage program and FMS. The Water Quality Team is jointly chaired by NMFS and EPA. It is charged with providing technical advice and guidance on temperature and total dissolved gas water quality in the context of the NMFS 2000 Biological Opinion relating to the Columbia River Hydropower System. A subgroup of that team has been addressing concerns with the FMS sites, and the appropriateness of the current FMS locations has been the subject of vigorous debate between the resource agencies and U.S. Army Corps of Engineers within the subgroup. The subgroup has concluded that the “representativeness” of FMS data is a very difficult characteristic to define. The TDG measurements at a given location in the river are influenced significantly by environmental factors such as water temperature, biological productivity, barometric pressure, and wind, as well as the spill. The Water Quality Team will continue to study and discuss these issues in order to achieve a mutually satisfactory monitoring end product.

To gain additional knowledge of TDG conditions in the river, the Corps has conducted a number of detailed special studies of TDG levels below the dams (e.g., Schneider and Wilhelms, 1996; Wilhelms and Schneider, 1997a; Wilhelms and Schneider, 1997b; Schneider and Wilhelms, 1999). These studies have shown that TDG levels measured at the FMS sites are usually lower than levels longitudinally upstream towards the spillway, may be lower than levels laterally across the river if powerhouse flows are not fully mixed, and in some conditions may be lower than levels longitudinally downstream.

Loading Capacity

Analysis of TDG generation processes

Introduction

The discussion that follows is taken (sometimes verbatim) from the Dissolved Gas Abatement Study conducted by the U.S. Army Corps of Engineers, and in particular from Appendix G: "Spillway Discharge Production of Total Dissolved Gas Pressure" (USACE, 2001a).

The material in this section provides a general overview of TDG generation processes at the Lower Columbia River dams. Specific details may change over time as structural changes are made to these projects. These processes provide the basis for the determination of loading capacity.

The TDG exchange associated with spillway operation at a dam is a process that couples both the hydrodynamic and mass exchange processes. The hydrodynamics are shaped by the structural characteristics of spillway, stilling basin, and tailrace channel as well as the operating conditions that define the spill pattern, turbine usage, and tailwater stage. The hydrodynamic conditions are influenced to a much smaller extent by the presence of entrained bubbles.

The air entrainment will influence the density of the two-phase flow and impose a vertical momentum component associated with the buoyancy in the entrained air. The entrained air content can result in a bulking of the tailwater elevation and influence the local pressure field. The transfer of atmospheric gasses occurs at the air-water interface, which is composed of the surface area of entrained air at the water surface. The exchange of atmospheric gases is greatly accelerated when entrained air is exposed to elevated pressures because of the higher saturation concentrations. The pressure time history of entrained air will, therefore, be critical in determining the exchange of atmospheric gases during spill.

The volume, bubble size, and flow path of entrained air will be dependent on the hydrodynamic conditions associated with project releases. The bubble size has been found to be a function of the velocity fluctuations and turbulent eddy length. The bubble size can also be influenced by the coalescence of bubbles during high air concentration conditions. The volume of air entrained is a function of the interaction of the spillway jet with the tailwater. The entrained bubble flow path will be dependent upon the development of the spillway jet in the stilling basin and associated secondary circulation patterns. The turbulence characteristics are important to the vertical distribution of bubbles and the determination of entrainment and de-entrainment rates.

Physical Processes

The exchange of TDG is considered to be a first order process where the rate of change of atmospheric gases is directly proportional (linear relationship) to the ambient concentration. The driving force in the transfer process is the difference between the TDG concentration in the water and the saturation concentration with the air. The saturation concentration in bubbly flow will be greater than that generated for non-bubbly flow where the saturation concentration is determined at the air-water interface. The flux of atmospheric gasses across the air-water interface is typically described by Equation 1.

$$J = K_l(C_s - C) \qquad \text{Equation 1}$$

Where:

J = gas flux (mass per surface area per time)
K_l = the composite liquid film coefficient
C_s = the saturation concentration (mass per volume)
C = the ambient concentration in water (mass per volume)

The rate of change of concentration in a well-mixed control volume, $\frac{dC}{dt}$, can be estimated by multiplying the mass flux by the surface area and dividing by the volume over which transfer occurs as shown by Equation 2:

$$\frac{dC}{dt} = K_l \frac{A}{V}(C_s - C) \qquad \text{Equation 2}$$

Where:

A = the surface area associated with the control volume
V = the volume of the waterbody over which transfer occurs

This relationship shows the general dependencies of the mass transfer process. In cases where large volumes of air are entrained, the time rate of change of TDG concentrations can be quite large, as the ratio of surface area to volume becomes large. The entrainment of air will also result in a significant increase in the saturation concentration of atmospheric gases, thereby increasing the driving potential over which mass transfer takes place. Outside of the region of aerated flow during transport through the pools, the contact area is limited to the water surface and the ratio of the surface area to the water volume becomes small, thereby limiting the change in TDG concentration. The turbulent mixing will influence the surface renewal rate and hence the magnitude of the exchange coefficient K_l.

Equation 2 can be integrated, provided the exchange coefficient, area, and volume are held constant over the time of flow. The initial TDG concentration at time=0 is defined as C_i and the final TDG concentration time=t is defined as C_f shown in Equation 3. The resultant concentration C_f exponentially approaches the saturation concentration for conditions where the term $K_t \frac{A}{V}$ is large. The final concentration becomes independent of the initial concentration under these conditions.

$$C_f = C_s(l - e^{-K_l \frac{A}{V}t}) + C_i e^{-K_l \frac{A}{V}t} \qquad \text{Equation 3}$$

Modeling TDG Transfer

The TDG exchange process involves the coupled interaction of project hydrodynamics and mass transfer between the atmosphere and the water column. Mechanistic models of TDG transfer must simulate the two-phase (liquid and gas phases) flow conditions that govern the exchange process. Several mechanistic models have been developed to simulate the TDG exchange in spillway flows.

Orlins and Gulliver (2000) solved the advection-diffusion equation for spillway flows at Wanapum Dam for different spillway deflector designs. Physical model data were used to develop the hydraulic descriptions of the flow conditions throughout the stilling basin and tailrace channel. The model results were also compared to observations of TDG pressure collected during field studies of the existing conditions.

A second model developed by Urban et al. (2000), used the same mass transport relationships together with the hydraulic descriptions associated with plunging jets. This approach does not require the specific hydraulic information to be derived from a physical model, but it can be applied to any hydraulic structure that has plunging jet flow. This model accounted for the TDG exchange occurring across the bubble-water interface and the water surface. This model was calibrated to observations of TDG exchange at The Dalles Lock and Dam (The Dalles) and was developed as part of the U.S. Army Corps of Engineers Dissolved Gas Abatement Study (DGAS). This model successfully simulated the absorption and desorption exchange caused by the highly aerated flow during spillway operations.

As a part of its DGAS study, the Corps decided to use empirically derived equations of TDG exchange, based on the recognition that data were not available to support mechanistic models of the mass exchange process at all the projects in the Columbia/Snake River system. The greatest unknowns associated with the development of a mechanistic model of highly aerated flow conditions in a stilling basin revolve around the entrainment of air and subsequent transport of the bubbles. The surface area responsible for mass transfer will require estimates of the total volume and bubble size distribution of entrained air. In addition, the roughened water surface is thought to contribute to the net exchange of atmospheric gasses. The pressure time history of entrained air would also need to be accounted for to determine the driving potential for TDG mass exchange.

A description of the highly complex and turbulent three-dimensional flow patterns in the stilling basin and adjoining tailrace channel would need to be defined for a wide range of operating conditions. The influence of turbulence on both the mass exchange coefficients and redistribution of buoyant air bubbles would also need to be quantified throughout a large channel reach and for a wide range of operating conditions.

The flow conditions generated by spillway flow deflectors have been found to be sensitive to both the unit spillway discharge and submergence of the flow deflector. The presence of flow deflectors has significantly changed the rate of energy dissipation in the stilling basin and promotes the lateral entrainment of flow. These entrainment flows are often derived from powerhouse releases, which reduce the available volume of water for dilution of spillway releases.

TDG Exchange Formulation

The accumulated knowledge generated through observations of flow conditions during spill at Columbia/Snake River projects and in-scale physical models at the Waterways Experiment Station in Vicksburg, MS, along with mass exchange data collected during site-specific near-field TDG exchange studies and from the fixed monitoring stations, has led to the development of a model for TDG exchange at dams throughout the Columbia/Snake river system for the federal hydropower projects. The general framework is based upon the observation that TDG exchange is an equilibrium process that is associated with highly aerated flow conditions that develop below the spillway. It recognizes that flow passing through the powerhouse is not generally exposed to entrained air under pressure and, therefore, does not experience a significant change in TDG pressure. It also recognizes that powerhouse releases can directly interact with the aerated flow conditions below the spillway and experience similar changes in TDG pressure that are found in spill.

The large volume of air entrained into spillway releases initiates the TDG exchange in spill. This entrained air is exposed to elevated total pressures and the resulting elevated saturation concentrations. The exposure of the bubble to elevated saturation concentrations greatly accelerates the mass exchange between the bubble and water. The amount and trajectory of entrained air is greatly influenced by the structural configuration of the spillway and the energy associated with a given spill.

The presence of spillway flow deflectors directs spill throughout the upper portion of the stilling basin, thereby preventing the plunging of flow and transport of bubbles throughout the depth of the stilling basin. Spillway flow deflectors also greatly change the rate of energy dissipation in the stilling basin, transferring greater energy and entrained air into the receiving tailrace channel.

Generally, spill water experiences a rapid absorption of TDG pressure throughout the stilling basin region where the air content, depth of flow, flow velocity, and turbulence intensity are generally high. As the spillway flows move out into the tailrace channel, the net mass transfer reverses and component gases are stripped from the water column as entrained air rises and is vented back to the atmosphere. The region of rapid mass exchange is limited to the highly aerated flow conditions within 1,000 feet of the spillway.

In general, downstream of the aerated flow conditions, the major changes to the TDG pressures occur primarily through the redistribution of TDG pressures through transport and mixing processes. The in-pool equilibrium process established at the water surface is chiefly responsible for changes to the total TDG loading in the river.

One of the more important observations regarding TDG exchange in spillway flow is the high rate of mass exchange that occurs below a spillway. The resultant TDG pressure generated during a spill is almost entirely determined by physical conditions that develop below the spillway and is effectively independent from the initial TDG content of this water in the forebay. The TDG exchange in spill is not a cumulative process where higher forebay TDG pressures will generate yet higher TDG pressures downstream in spillway flow. The TDG exchange in spill is an equilibrium process where the time history of entrained air below the spillway will determine the resultant TDG pressure exiting the vicinity of the dam.

One consequence of this observation is that spilling water can result in a net reduction in the TDG loading in a system if forebay levels are above a certain value. This was a common occurrence at The Dalles during the high-flow periods during 1997 where the forebay TDG exceeded 130 percent saturation. A second consequence of the rapid rate of TDG exchange in spill flow is that the influence from upstream projects on TDG loading will be passed downstream only through powerhouse releases. If project operations call for spilling a high percentage of the total river flow, the contribution of TDG loading generated from upstream projects will be greatly diminished below this project.

Given the conceptual framework for TDG exchange described above, the average TDG pressures generated from the operation of a dam can be represented by the mass conservation statement using TDG pressure shown in Equation 4:

$$P_{avg} = \frac{(Q_{sp} + Q_e)P_{sp} + (Q_{ph} - Q_e)P_{ph}}{Q_{sp} + Q_{ph}} \qquad \text{Equation 4}$$

Where:

Q_{sp} = Spillway discharge [thousands of cubic feet per second (kcfs)]

Q_{ph} = Powerhouse discharge (kcfs)

Q_e = Entrainment of powerhouse discharge in aerated spill (kcfs)

Q_{se} = $Q_{sp} + Q_e$

= Effective spillway discharge (kcfs)

Q_{tot} = $Q_{sp} + Q_{ph}$

= Total river flow (kcfs)

P_{ph} = TDG pressure releases from the powerhouse [mm Hg]

P_{sp} = TDG pressure associated with spillway flows (mm Hg)

P_{avg} = Average TDG pressure associated with all project flows (mm Hg)

This conservation statement assumes the water temperature of powerhouse and spillway flows are similar, and that the heat exchange during passage through the dam and aerated flow region is minimal. Some projects have other water passage routes besides the powerhouse and spillway, such as fish ladders, lock exchange, juvenile bypass systems, and other miscellaneous sources.

These sources of water have generally been lumped into powerhouse flows and are not accounted for separately.

Equation 4 contains three unknowns: Q_e = powerhouse entrainment discharge, $P_{sp} = TDG$ pressure associated with spillway flows, and $P_{ph} = TDG$ pressure associated with powerhouse releases. The TDG pressure associated with the powerhouse release is generally assumed to be equivalent to the TDG pressure observed in the forebay. Numerous data sets support the conclusion that turbine passage does not change the TDG content in powerhouse releases. All of the near-field TDG exchange studies have deployed TDG instruments in the forebay of a project and directly below the powerhouse in the water recently discharged through the turbines. An example of this type of data is shown in Figure 4 during the 1998 post-deflector John Day Lock and Dam (John Day) TDG exchange study (Schneider and Wilhelms, 1999a).

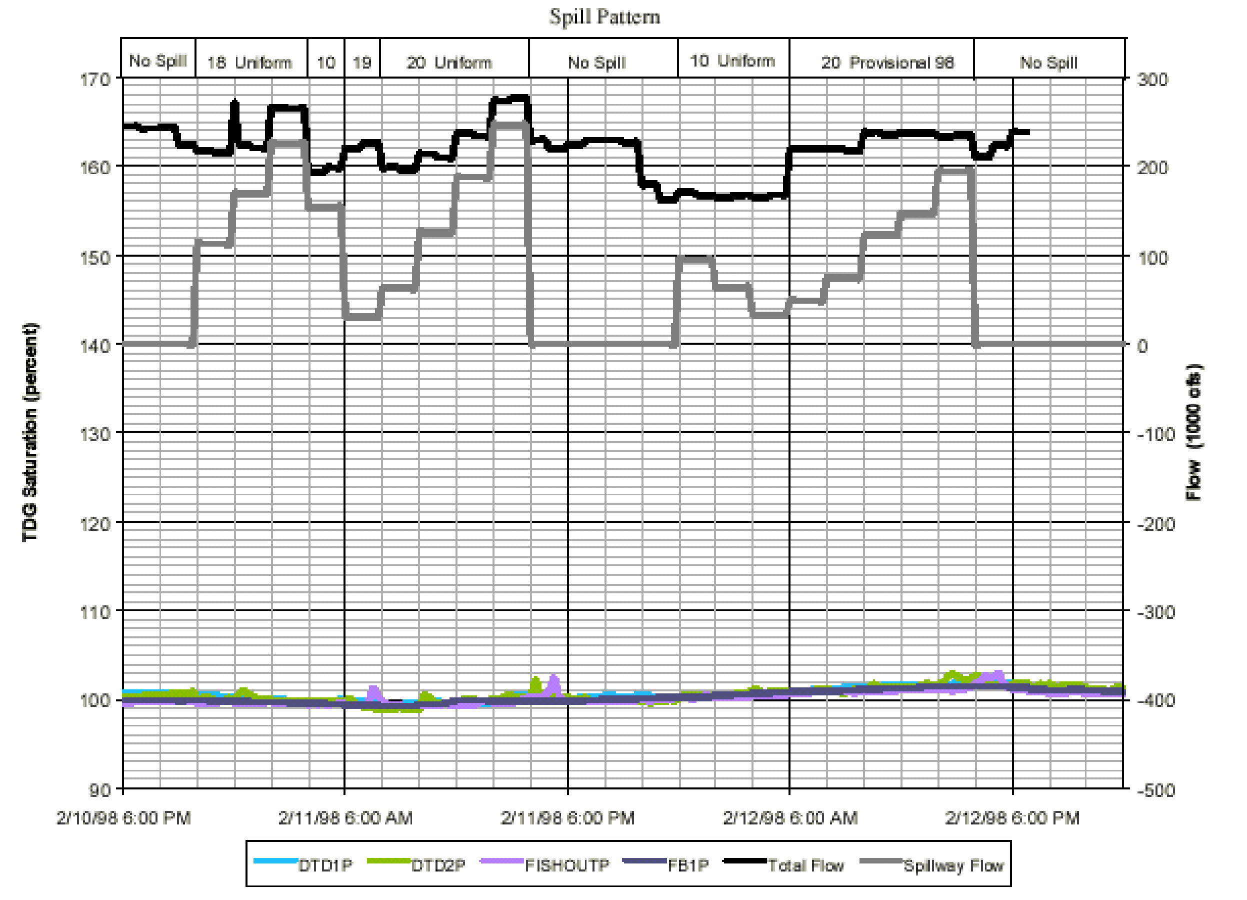

Figure 4: TDS Saturation in the Forebay and Below the Powerhouse Draft Tube Deck of John Day Dam, February 1998

The TDG instruments were deployed in the forebay of John Day (station FB1P) and in the tailwater below powerhouse draft tube deck (station DTD1P and DTD2P), near the fish outfall (FISHOUTP). The TDG pressure was logged on a 15-minute interval at each of these stations throughout the testing period. All four stations recorded the same TDG saturations throughout the testing period, even during operating events calling for spilling nearly the entire river on February 11 and 12. The TDG pressure from the forebay and tailwater fixed monitoring stations should also be similar during periods of no spill, provided that these stations are sampling water with similar water temperatures. In cases where a turbine aspirates air or air is injected into a turbine to smooth out operation, the above assumption will not hold.

Spillway TDG Exchange

The TDG exchange associated with spillway flows has been found to be governed by the geometry of the spillway (standard or modified with flow deflector), unit spillway discharge, and depth of the tailrace channel. The independent variable used in determining the exchange of TDG pressure in spillway releases is the delta TDG pressure (ΔP) defined by the difference between the TDG pressure (P_{tdg}) and the local barometric pressure (P_{atm}) as listed in Equation 5. The selection of TDG pressure as expressed as the excess pressure above atmospheric pressure accounts for the variation in the barometric pressure as a component of the total pressure.

$$\Delta P = P_{tdg} - P_{atm} \qquad \text{Equation 5}$$

Restating the exchange of atmospheric gases in terms of mass concentrations introduces a second variable (water temperature) into the calculation. The added errors in calculating the TDG concentration as a function of temperature and TDG pressure were the main reasons for using pressure as the independent variable. The TDG concentration would also vary seasonally with the change in water temperature.

The TDG pressure is often summarized in terms of the percent saturation or supersaturation. The TDG saturation (S_{tdg}) is determined by normalizing the TDG pressure by the local barometric pressure as expressed as a percentage. The delta pressure has always been found to be a positive value when spillway flows are sampled. The TDG saturation (S_{tdg}) is determined by Equation 6.

$$S_{tdg} = \frac{P_{tdg}}{P_{atm}} * 100 = \frac{(P_{atm} + \Delta P)}{P_{atm}} * 100 \qquad \text{Equation 6}$$

Unit Spillway Discharge

The TDG exchange associated with spillway flows has been found to be a function of unit spillway discharge (q_s) and the tailrace channel depth (D_{tw}). The unit spillway discharge is a surrogate measure for the velocity, momentum, and exposure time of aerated flow associated with spillway discharge. The higher the unit spillway discharge, the greater the TDG exchange during spillway flows. An example of the dependency between the change in TDG pressure and unit spillway discharge is shown in Figure 5 at Ice Harbor Lock and Dam (Ice Harbor).

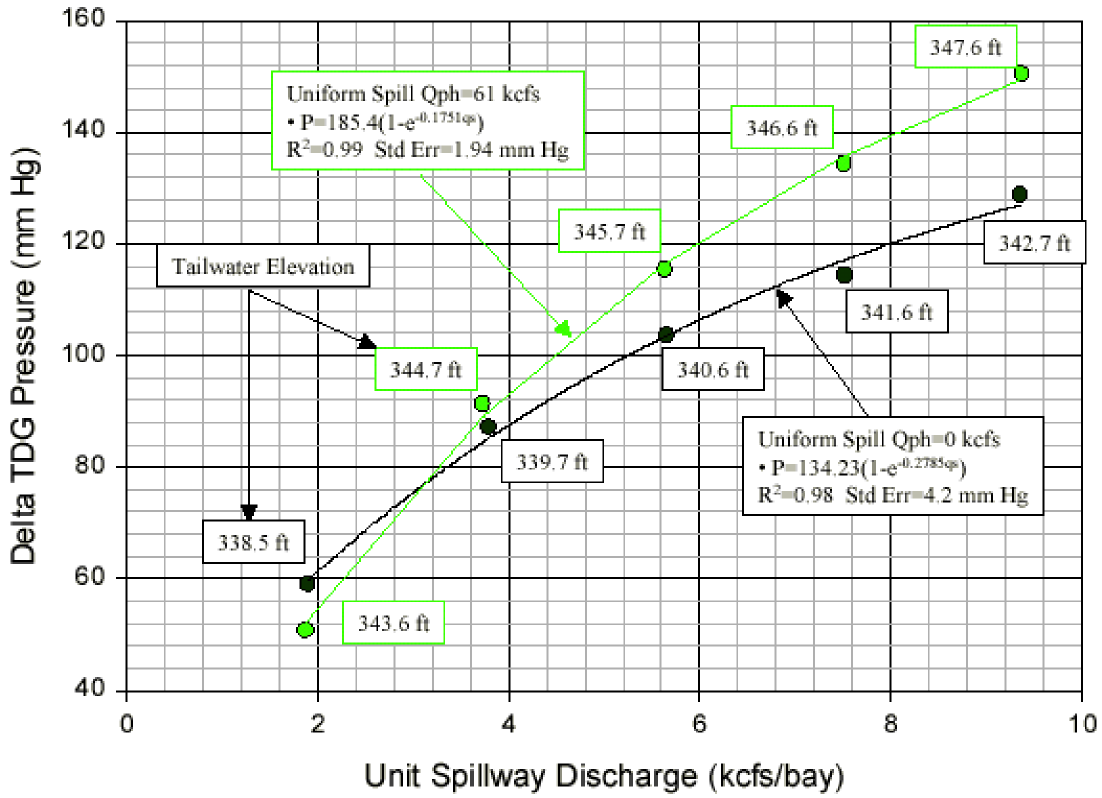

Figure 5: TDG Pressure (Delta P) as a Function of Unit Spillway Discharge and Tailwater Elevation at Ice Harbor Dam, March 1998

This figure shows two sets of tests involving a uniform spill pattern over eight bays with flow deflectors. The two sets of tests were distinguished only by the presence of powerhouse releases. In both cases, the resultant spill TDG pressure was found to be an exponential function of the unit spillway discharge. The determination of a single representative unit discharge becomes problematic in the face of a non-uniform spill pattern. The flow-weighted specific discharge was found to be a better determinant of spillway TDG production in cases where the spill pattern is highly non-uniform. The flow-weighted unit discharge places greater weight on bays with the higher discharges. The following Equation 7 describes the determination of the specific discharge used in the estimation of TDG exchange relationships:

$$q_s = \frac{\sum_{i=1}^{nb} Q_i^2}{\sum_{i=1}^{nb} Q_i} \qquad \text{Equation 7}$$

Where:

q_s = Specific discharge (flow-weighted unit discharge)
Qi = Flow for spill bay i (for nb number of bays)

Depth of Flow

The large amount of energy associated with spillway releases has the capacity to transport entrained air throughout the water column. In many cases, the depth of flow is the limiting property in determining the extent of TDG exchange below a spillway. An example of the influence of the depth of flow on TDG exchange is shown in Figure 4 at Ice Harbor. The only difference between the two sets of data in this figure was the presence of powerhouse flow. The events with powerhouse flow resulted in higher TDG pressure than comparable spill events without powerhouse releases at higher spillway flows. The observed tailwater elevation is also listed in Figure 4 for each test event. The tailwater elevation was about five feet higher during the events corresponding with powerhouse operation.

The depth of flow in the tailrace channel was hypothesized to be more relevant to the exchange of TDG pressure than the depth of flow in the stilling basin because of the influence of the flow deflectors and resultant surface jet, and the high rate of mass exchange observed below the stilling basin. The average depth of flow downstream of the spilling basin was represented as the difference between the tailwater elevation as measured at the powerhouse tailwater gauge and the average tailrace channel elevation within 300 feet of the stilling basin. The tailrace channel reach within 300 feet of the stilling basin was selected because most of the TDG exchange (degassing) occurs in this region. A summary of project features at the time of the Corps DGAS study are listed in Table 3, including stilling basin elevation, deflector elevation, and tailrace channel elevation.

Table 3: Columbia River and Snake River Project Features (April 2001)

Project	Spillway Crest Elev. (ft)	Number Spillways: Deflectors		Deflector Elevation (ft)	Stilling Basin Elev. (ft)	Tailwater Channel Elev. (ft)	Min. Pool (ft)	Normal Tailwater Pool (ft)
		w/	w/out					
Bonneville	24	13	5	14/7[1]	-16	-30	70	20
The Dalles	121	0	23	NA	55	58	155	80
John Day	210	18	2	148	114	125	257	162
McNary	291	18	4	256	228	235	335	267

Source: U.S. Army Corps of Engineers DGAS Study, Appendix G, p. G-8 (USACE, 2001a)
[1] Existing deflectors/New deflectors installed 2001-02

The functional form of the relationship between the change in TDG pressure change and the prominent dependent variables unit spillway discharge and tailrace channel depth of flow, takes the same form as the exponential formulation shown in Equation 3. The delta TDG pressure was found to be a function of the product of the depth of flow and the exponential function of unit spillway discharge as shown in Equation 8.

$$\Delta P = C_1 D_{tw}(1 - e^{-c_2 q_s}) + C_3 \qquad \text{Equation 8}$$

The coefficients C_1, C_2, and C_3 were determined from nonlinear regression analyses. The product of C_1 and the tailwater depth (D_{tw}) represents the effective saturation pressure in Equation 3 while the product of C_2 and the unit spillway discharge (q_s) reflects the combined contribution from the mass exchange coefficient, ratio of surface area to control volume, and time of exposure.

A second formulation used in this study relating the delta TDG pressure and independent variable involves a power series as shown in Equation 9. This equation can also result in a linear dependency between the delta TDG pressure and either tailwater depth or unit spillway discharge. A linear dependency in the tailwater depth occurs when C_2=1 and C_3=0. A linear dependency between TDG pressure and unit spillway discharge occurs when C_2=0 and C_3=1.

$$\Delta P = C_1 D_{tw}^{C_2} q_s^{C_3} + C_4 \qquad \text{Equation 9}$$

Entrainment of Powerhouse Flow

The interaction of powerhouse flows and the highly aerated spillway releases can be considerable at many of the projects. Observations of the flow conditions downstream of projects where the powerhouse is adjacent to the spillway often indicate a strong lateral current directed toward the spillway. The presence of Bradford and Cascade Islands at Bonneville eliminates the potential entrainment of powerhouse flow into aerated spillway releases.

The clearest example of the influence of the entrainment of powerhouse flow on TDG exchange was documented during the near-field TDG exchange study at Little Goose. The study at Little Goose was conducted during February 1998 when the ambient TDG saturation in the Snake River ranged from 101 to 103 percent. The test plan called for adult and juvenile fish passage spill of up to 60 kcfs with the powerhouse discharging either 60 kcfs or not operating. The cross-sectional average TDG pressure in the Snake River below Little Goose was determined from seven separate sampling stations located across the river from the tailwater FMS. The project operations and resultant TDG saturation are summarized in Figure 6 where the observations from the forebay and tailwater fixed monitoring stations are shown as LGS and LGSW, respectively. The cross-sectional average TDG saturation at the tailwater FMS is labeled $T5_{avg}$, and the flow-weighted average TDG saturation assuming no entrainment of powerhouse flow is labeled FWA (flow-weighted average).

The TDG saturation estimated by assuming that powerhouse releases were available to dilute spillway flows during this test (FWA) were significantly less than estimates derived from averaging information from the seven sampling stations at the tailwater fixed monitoring station ($T5_{avg}$). This study demonstrated that nearly all of the powerhouse flows from Little Goose were entrained and acquired TDG pressures similar to those in spillway flows during this study.

The circulation patterns below the dam during the test clearly supported the TDG data indicating high rates of entrainment of powerhouse flows into the stilling basin.

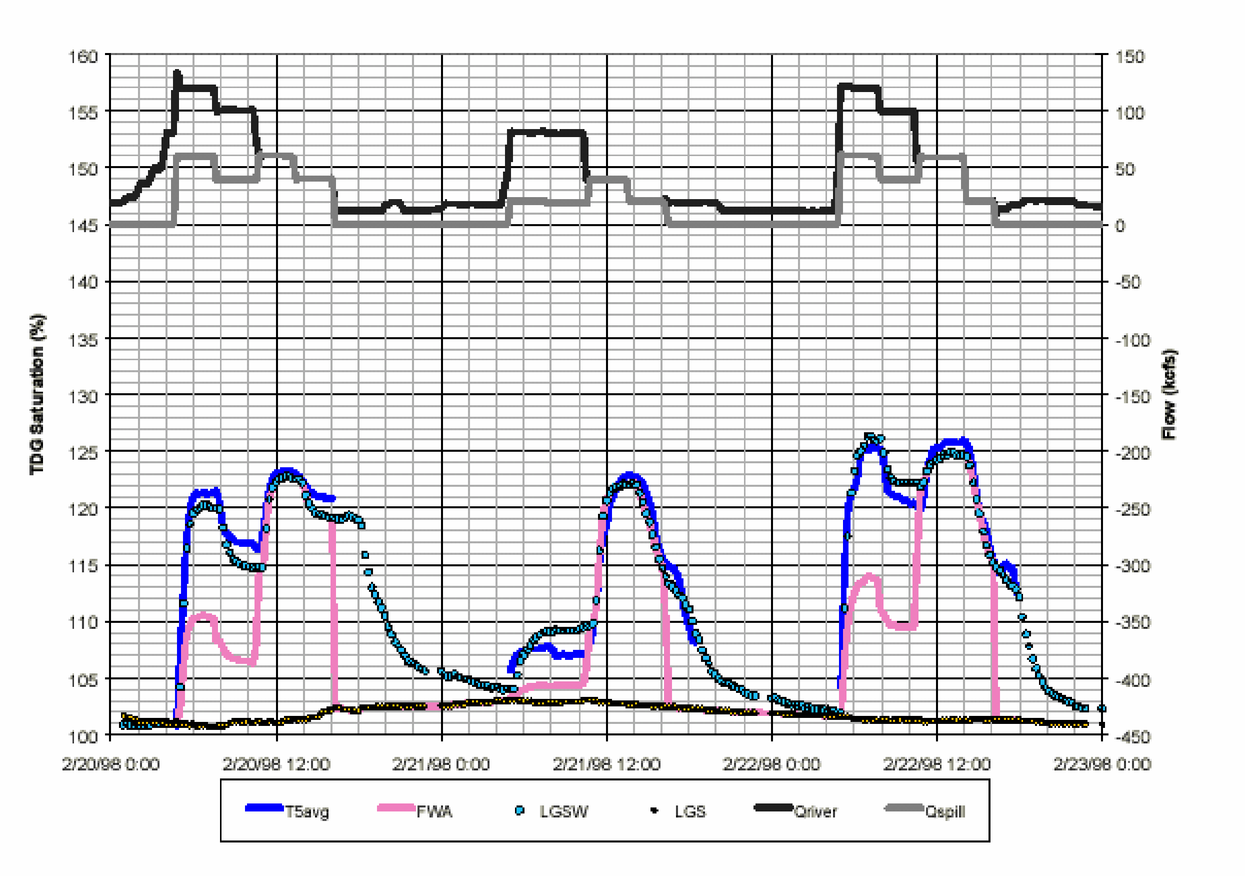

Figure 6: Project Operation and TDG Saturation at Little Goose Dam, February 1998 ($T5_{avg}$ Average TDG Level at Tailwater FMS, LGS- Forebay FMS, LGSW- Tailwater FMS, FWA- Flow Weighted Average Assuming No Entrainment)

The entrainment of powerhouse flow was modeled as a simple linear function of spillway discharge. The relationship shown in Equation 10 was used to estimate the entrainment discharge for each project. The coefficients C_1 and C_2 are project-specific constants. The entrainment of powerhouse flow was assumed to be exposed to the same conditions that spillway releases encounter and, hence, achieve the same TDG pressures.

$$Q_e = C_1 Q_{sp} + C_2 \qquad \text{Equation 10}$$

The loading capacity of the river segments identified for this TMDL are the water quality standard, namely 110 percent of saturation relative to atmospheric pressure.

Analysis of TDG Loading Capacity

Linkage of TDG Loading to the Criteria

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 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 the development of TMDLs.

To determine the TMDL loading capacity, ΔP can be directly related to the TDG water quality criteria, as describe in Equation 6:

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

If S_{tdg} is set at the criterion of 110 percent 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 a loading capacity, the 95th percentile low pressure was determined. This pressure varies from 743 mm Hg at the McNary forebay to 754 mm Hg in the Bonneville tailwater. Therefore, the loading capacity for the Lower Columbia River is set to ΔP of 75 mm Hg.

Identification of Sources

There are four sources of TDG within the geographic scope of this TMDL:

1. McNary Dam
2. John Day Dam
3. The Dalles Dam
4. Bonneville Dam

No other significant sources of elevated TDG exist in the Lower Columbia River, other than increases in TDG caused by natural changes in barometric pressure, temperature, or biological activity. Tributary sources of TDG are negligible.

Water entering the portion of Lower Columbia River covered by this TMDL at times exceeds the TDG standard at the upstream boundary. Future TMDLs for the Mid-Columbia and Lower Snake rivers will address upstream sources and compliance with a load allocation at the upstream boundary of this TMDL. This TMDL addresses those loads of TDG introduced by dams on the Lower Columbia River that fall within both Oregon and Washington below the confluence of the Snake and Columbia rivers.

The discussion of gas generation at each dam provided in this section is based on the U.S. Army Corps of Engineers analysis reported in the DGAS report (USACE, 2001a) and other sources. The information is provided to illustrate processes at the dams with their configuration at the time of the studies described. As structural modifications are made at the dams, the specific gas generation equations will change.

Analysis of Current Conditions

Data Sources

TDG data were available on many of the projects from several sources: the fixed monitoring station (FMS) system; near field (tailrace) and spillway performance tests; and in-pool transport and dispersion tests. Operational data were obtained from each project detailing the individual spillway and turbine discharge on an interval ranging from five minutes to one hour. These sources of data are discussed below. With these data sources, the most appropriate analysis was selected for each project. Individual mathematical relationships were developed on a project-by-project basis.

Data Quality

TDG data collected in the Columbia River has undergone rigorous evaluation for data quality. For the TDG controlled spill studies, Wilhelms, Carroll, and Schneider (1997) reported on a workshop attended by a team of experts who evaluated the quality of data collections and recommended area for improvement. The workshop built on previous data quality evaluations.

The U.S. Army Corps of Engineers and the U.S. Geological Survey collect FMS data jointly following rigorous quality control. Basic data quality procedures are provided in the annual Plan of Action (e.g., USACE, 2001b). Detailed methods and quality assurance data are reported by the U.S. Geological Survey (e.g., Tanner and Johnston, 2001). The Corps annual water quality reports provide detailed data quality analysis (e.g., USACE, 2000). The TDG data quality target for the FMS stations is a precision of no greater than one percent for paired readings.

In general, the data quality assurance/quality control procedures for the source information used in this TMDL meet or exceed the standards applied by the Washington State Department of Ecology and the Oregon Department of Environmental Quality for their own data collection and analysis for TMDL development.

The Fixed Monitoring Station (FMS) Data

The TDG data from the FMSs consisted of remotely monitored TDG pressure, dissolved oxygen, water temperature, and atmospheric pressure from a fixed location in the forebay and tailwater of each project. Data from the FMSs provide a long-term hourly record of TDG throughout the season, capturing detailed temporal and extreme events. However, the FMSs provide only limited spatial resolution of TDG distribution. In some cases, the TDG observed in the tailwater at the FMS location was not representative of average spillway conditions and misrepresented the TDG loading at a dam.

Spillway Performance Tests and Near-Field Studies

Spillway performance tests and near-field tailwater studies were conducted at several projects to define the relationship between spill operation and dissolved gas production more clearly. Water temperature, TDG, and dissolved oxygen were monitored in the immediate tailrace region, just downstream of the project stilling basin. These observations provided a means to relate the local TDG saturation to spill operations directly, and to define gas transfer in different regions of the tailrace area. Manual sampling of TDG pressures in spillway discharges from several bays was conducted downstream of the aerated flow regime at Lower Granite Lock and Dam, Little Goose Lock and Dam, Ice Harbor, and The Dalles (Wilhelms 1995); and John Day, Lower Monumental Lock and Dam, and Bonneville Lock and Dam (Wilhelms, 1996).

In these studies, automated sampling of TDG pressures in spillway discharges during uniform and standard spill patterns was conducted with an array of instruments in the stilling basin and tailwater channel of all the projects in the study area with the exception of Lower Granite. Automated sampling of TDG levels provide the opportunity to assess three-dimensional characteristics of the exchange of TDG immediately downstream of the stilling basin on a sampling interval ranging from five to 15 minutes. The integration of the distribution of flow and TDG pressure can yield estimates of the total mass loading associated with a given event. These tests were of short duration, generally lasting only several days and, therefore, pertain to the limited range of operations scheduled during testing.

In-Pool Transport and Dispersion Studies

During the 1996 spill season, in-pool transport and dispersion investigations were conducted to define the lateral mixing characteristics between hydropower and spillway releases. Water temperature, TDG levels, and dissolved oxygen were measured at several lateral transects located over an entire pool length. These studies focused on the lateral and longitudinal distribution of TDG throughout a pool during a period lasting from a few days to a week. In-pool transport and mixing studies were conducted below Little Goose, Lower Monumental, Ice Harbor, John Day, The Dalles, and Bonneville during the 1996 spill season. In most cases, a lateral transect of TDG instruments was located below the dam to establish the level of TDG entering the pool, with additional transects throughout the pool. These studies provided observations of the TDG saturation in project releases as they moved throughout an impoundment. However, only a limited range of operations was possible during the relatively short duration of these tests.

Operational Data

Operational data were obtained from each project detailing the spillway and powerhouse unit discharge on time intervals ranging from five minutes to one hour. The average hourly total spillway and generation releases, and forebay and tailwater pool elevations were summarized in the DGAS database. The tailwater pool gauge was generally located below the powerhouse of each dam. The tailwater elevation at the powerhouse was found to be within one foot of the water elevation downstream of the stilling basin in most instances.

Data Interpretation

The objective of this analysis was to develop mathematical relationships between observed TDG and operational parameters such as discharge, spill pattern, and tailwater channel depth. These relationships were derived with observations from the FMSs and spillway performance tests. However, before the analysis could be conducted, the monitored data had to be evaluated to determine its reliability for this kind of analysis. For example, the monitored TDG data from the FMSs provide a basis for defining the effects of spillway operation on dissolved gas levels in the river below a dam, but the following limitations should be noted:

- The FMSs sample water near-shore, which may not reflect average TDG levels of the spill. The monitor sites were, in general, located on the spillway side of the river to measure the effects of spillway operation. However, with a non-uniform spill distribution and geometry across the gates of the spillway, the FMS may be more representative of the spillbays closest to the shore. Outside spillbays, without flow deflectors can create elevated TDG levels downstream from these bays compared to adjacent deflectored bays. A spill pattern that dictates higher unit discharges on these outside bays can further elevate the TDG levels downstream of these bays relative to the releases originating from the deflectored interior bays.

- Depending upon the lateral mixing characteristics, the FMS downstream of a project may be measuring spillway releases that have been diluted with hydropower releases. The tailwater

FMSs below The Dalles and Bonneville are located in regions where substantial mixing has occurred between generation and spillway discharges. Under most conditions, the TDG saturation of generation releases is less than the TDG level associated with spillway releases. The TDG at the tailwater FMS will be a function of the discharge and level of TDG from both generation and spillway releases. Obviously, if there is no spill, then the monitored TDG levels will reflect the TDG saturation released by the hydropower facility.

- Passage of generation flows through a power plant does not significantly change the TDG levels associated with this water. However, there can be a significant near-field entrainment of powerhouse flow by spillway releases at some projects, especially if flow deflectors are present. Observed data suggest that, under these conditions, some portion of the powerhouse discharges will be subjected to the same processes that cause absorption of TDG by spillway releases. In these cases, the TDG levels measured immediately downstream of a spillway will be associated with the spillway release plus some component of the powerhouse discharge.

The observations of tailwater TDG pressure need to be paired up with project operations to conduct an evaluation of the data. A set of filters or criteria were established to select correctly-paired data for inclusion in this analysis. The travel time for project releases from the dam to the tailwater FMS was typically less than two hours and steady-state tailwater stage conditions were usually reached within this time period. Thus, the data records were filtered to include data pairs corresponding with constant operations of duration greater than two hours to exclude data corresponding with unsteady flow conditions. This filtering criterion eliminated data associated with changing operations and retained only a single observation for constant operating conditions equal to three hours in duration.

- *Manual and Automated Inspections for Obviously Inaccurate Observations.* An automated search for values above or below expected extremes identified potential erroneous and inaccurate data in the database. These data were inspected and, if appropriate, excised from the database.

- *Comparison of Measurements from Forebay and Tailwater Instruments During Non-Spill Periods.* During the non-spill periods, downstream measurements should approach the forebay concentration when only the hydropower project is releasing water. Inspection of the data was conducted to identify errors when this condition was not met.

- *Comparison of Measurements from Redundant Tailwater TDG Monitors, if Available.* TDG tailwater data was rejected when measurements of two instruments at the same site varied by more than three percent saturation.

McNary Dam

The TDG Exchange

A TDG exchange field investigation was conducted at McNary during February 11-13, 1996, with the study summarized in Wilhelms and Schneider (1997a). The study consisted of sampling

TDG pressures below the spillway during spillway discharges ranging from 50 to 285 kcfs. Two different spill patterns were investigated during this study, standard and uniform.

The study findings indicated that the TDG production was directly related to the unit spillway discharge. The TDG saturation ranged from 108 to 135 percent during the study for unit spillway discharges ranging from two to 17 kcfs/bay. The influence of the operation of spillway bays without flow deflectors was found to increase the TDG exchange for comparable unit spill discharges. The relatively small total river flows and associated range in tailwater elevations resulted in test spill conditions corresponding with tailwater elevations ranging from 265.5 to 269.0 feet above mean sea level (fmsl).

Regression

The TDG production during spillway releases from McNary, as defined by . $P = P_{tw} - P_{bar}$, was found to be a power function of tailwater depth and the specific discharge as shown in Equation 11. The regression equation was based on data collected during the 1997 spill season. The data filtering resulted in 172 observations. The delta TDG pressure ranged from 81.9 mm Hg to a maximum value of 307.6 mm Hg as listed in Table 4. The range in unit spillway discharge ranged from 2.0 kcfs/bay to 21.9 kcfs/bay and the tailwater depth ranged from 30.8 to 40.5 feet.

$$\Delta P = D_{tw}^{0.647} q_s^{0.969} + 82.14 \qquad \text{Equation 11}$$

Where:

ΔP = P_{tw} - P_{bar}
P_{tw} = TDG pressure at the tailwater FMS (mm Hg)
q_s = Flow-weighted unit spillway bay discharge (kcfs/bay)
D_{tw} = Tailrace channel depth (feet) (E_{tw} - E_{ch})
E_{tw} = Elevation of the tailwater (ft)
E_{ch} = Average elevation of the tailrace channel (320 fmsl)
P_{bar} = Barometric pressure at the tailwater FMS (mm Hg)

Table 4: Statistical Summary of Regression Variables for McNary Dam

	Delta Pressure ΔP (mm/Hg)	Unit Spillway Discharge q_s (kcfs/bay)	Tailwater Depth D_{tw} (ft)
Number	173	173	173
Minimum	81.9	2.0	30.8
Maximum	307.6	21.9	40.5
Average	191.6	11.7	35.0
Standard Deviation	53.0	5.4	2.2

Source: U.S. Army Corps of Engineers DGAS Study, Appendix G, p. G-29

The unit spillway discharge was plotted against the observed and calculated tailwater TDG pressure difference in Figure 7.

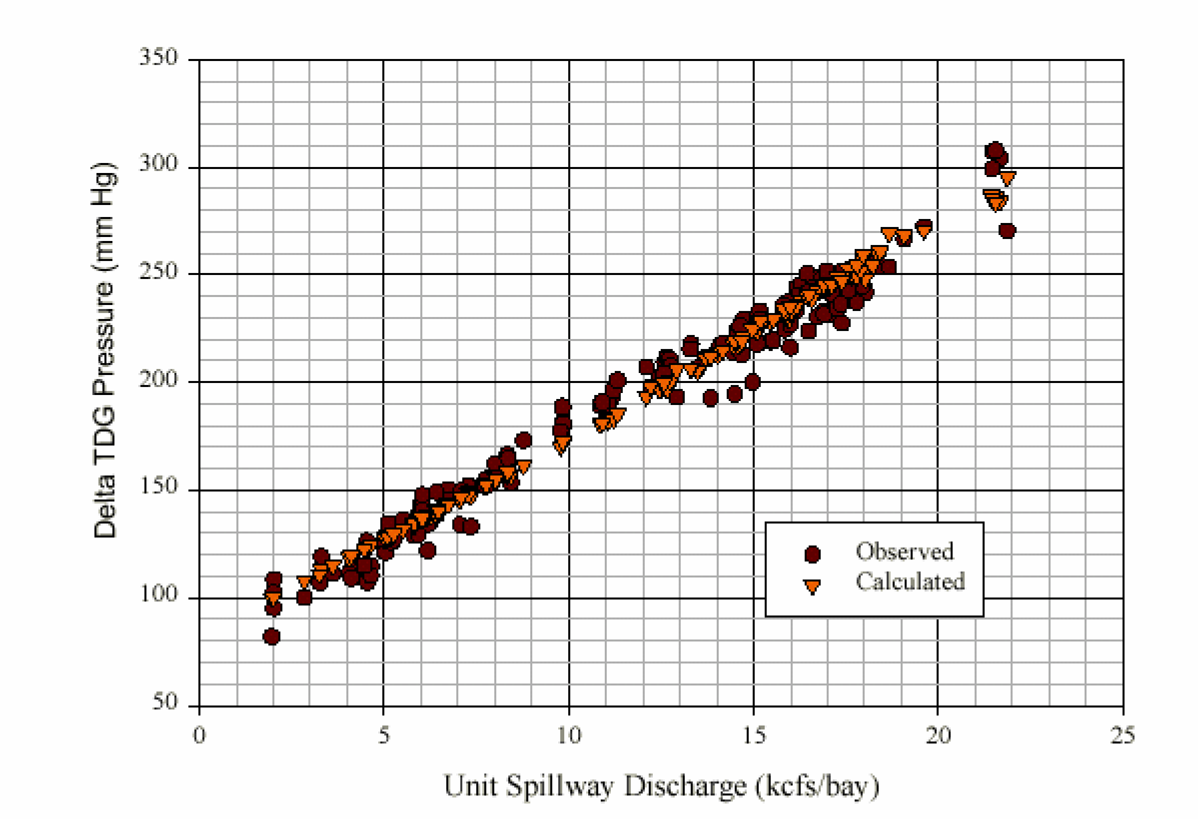

Figure 7: Unit Spillway Discharge versus TDG Pressure Above Barometric Pressure at McNary Dam, 1997

The near linear relationship between the TDG pressure and unit discharge is evident in this figure as the TDG pressure continues to increase as the specific unit discharge becomes large. Much of the variability in the TDG pressure for a constant unit discharge can be accounted for by the variation in the tailrace channel depth. All of the coefficients determined by the nonlinear regression analysis were significant to at least a 99 percent confidence interval as shown in Table 5. This formulation explained much of the variability in the data with an r^2 of 0.97 and a standard error of 9.25 mm Hg.

Table 5: Statistical Summary of Nonlinear Regression at McNary 1997 Spill Season

$$\Delta P = D_{tw}^{c1} q_s^{c2} + c3$$

Number of Observations n=173

$r^2 = 0.97$

Std Error = 9.26 mm Hg

Coefficient	Estimate from Regression	Standard Error	t-statistic	Probability
C_1	0.647	0.0693	12.71	<0.0001
C_2	0.969	0.0762	9.35	<0.0001
C_3	82.14	5.89	14.08	<0.0001

Source: U.S. Army Corps of Engineers DGAS Study, Appendix G, p. G-29

A review of the regression coefficients in Equation 11 reveals that the TDG exchange is relatively insensitive to the variation in the depth of flow below McNary. The response surface for TDG pressure above atmospheric pressure as a function of both unit spillway discharge and tailwater stage is shown in Figure 8.

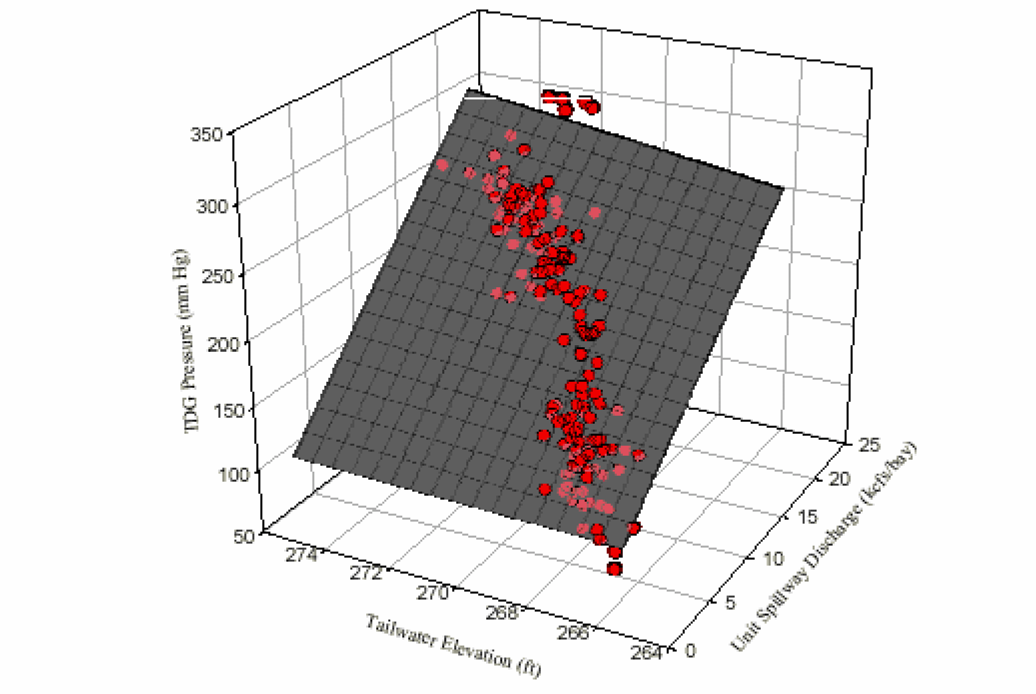

Figure 8: Unit Spillway Discharge, Tailwater Elevation, and TDG Pressure Above Barometric Pressure at McNary Dam, 1997

The response function as defined in Equation 11 was used to create a hindcast of the TDG production observed during the 1997 spill season. The hourly project operation and TDG saturation at the McNary FMSs for June 1998 are shown in Figure 9 along with the estimates of TDG saturation based on Equation 3.

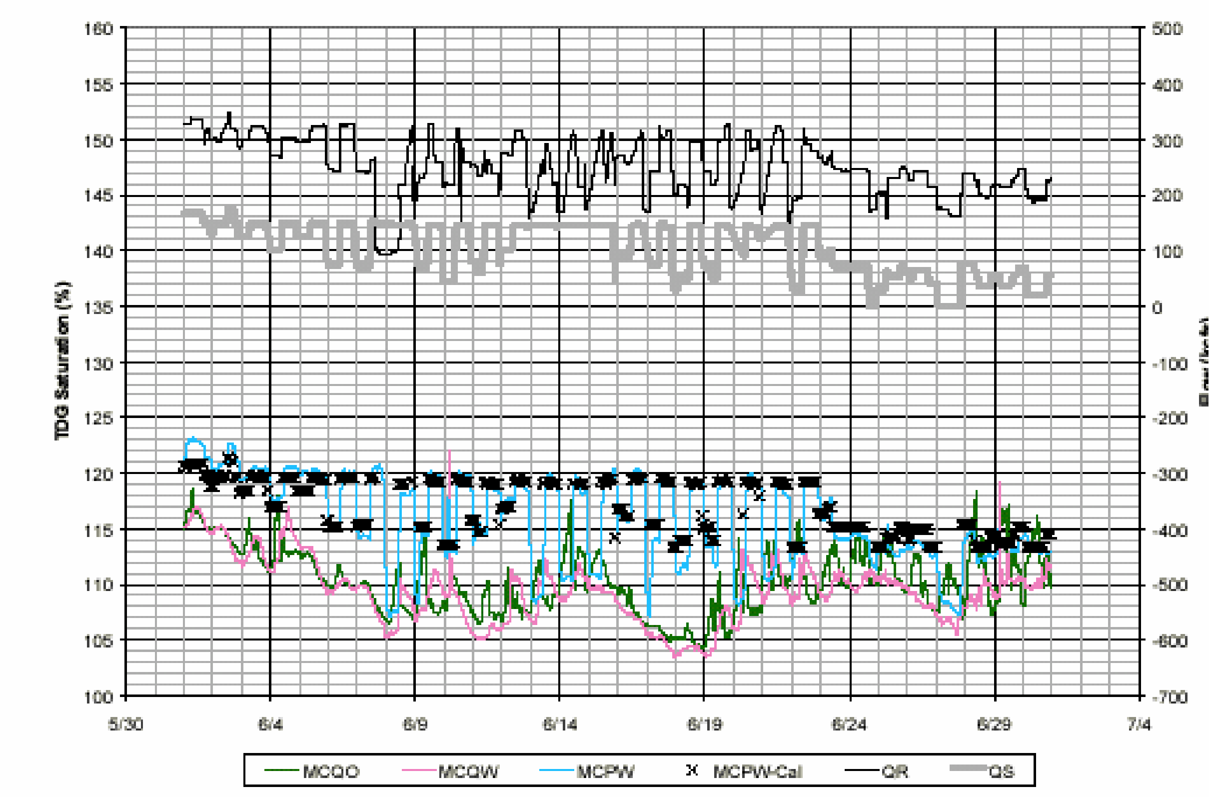

Figure 9: Observed and Estimated TDG Saturation at the Tailwater Fixed Monitoring Station at McNary Dam, June 1998. (MCQO/ MCQW= Observed Forebay TDG, MCPW= Observed Tailwater TDG, MCPW- cal= Calculated Tailwater TDG, QR= Hourly Total River Flow, QS= Hourly Spillway Flow)

In general, the estimated TDG saturation was generally within one percentage point of the observed tailwater TDG saturation. The maximum daily spillway discharge remained constant during much of June with little variation in the production of TDG saturation. The forebay TDG level however, varied. The TDG performance of the spillway bays without flow deflectors was needed to derive the TDG exchange from the exiting spillway. Spillway bays 1, 2, 21, and 22 do not have flow deflectors and are typically operated by raising only the upper leaf of the split leaf vertical gates. This operation results in a jet that plunges into the stilling basin as a fully aerated nap. It should be noted that bay 22 is not typically operated due to absence of a dedicated gate hoist.

The results from the near-field TDG exchange test were used to estimate the TDG exchange characteristics of standard spillway bays. The TDG production resulting from uniform spill flows from bays 3 through 20 (bays with flow deflectors) was subtracted from the TDG response for the standard spill pattern. The difference in the delta TDG pressure generated between these curves was divided by the discharge from the spillway bays 1, 2, and 21 to arrive at the response relation listed in Equation 12. A linear relationship between the unit spillway discharge and delta TDG pressure was estimated for these end bays at McNary. The non-deflectored bays generated TDG saturation about ten percent greater on average than deflectored bays.

$$\Delta P = 11.35_{qs} + 143.1 \qquad \text{Equation 12}$$

Powerhouse Entrainment

Estimates of the entrainment of powerhouse flows into spillway discharge were not available from this study because of the limited amount of powerhouse discharge and the absence of flow distribution information. Since direct determination of the entrainment of powerhouse flows into the highly aerated conditions below McNary were not practical, it was assumed for this study that the entrainment characteristics of McNary were similar to John Day. The entrainment of powerhouse flows was estimated to average 35 kcfs at McNary and to be independent of the total spillway discharge.

John Day Dam

The TDG Exchange

The installation of spillway flow deflectors at John Day was completed during the winter of 1997-98. Deflectors were installed in spillway bays two through 19 at elevation 148 fmsl. The flow deflectors significantly changed the TDG exchange properties of releases from John Day. A detailed near-field study of TDG exchange below John Day was conducted during February 10-12, 1998, as described by Schneider and Wilhelms (1999a). The study consisted of sampling TDG pressures below the stilling basin during spillway discharges ranging from 36 to 246 kcfs. Several different spill patterns were investigated during this study: uniform bays two through 19, uniform bays one through 20, provisional standard spill pattern, and uniform bays ten through 19.

The study findings indicated that the TDG production was directly related to the unit spillway discharge. The TDG saturation was found to be an exponential function of unit spillway discharge with 115 percent saturation associated with a unit spillway discharge of four kcfs/bay and 120 percent saturation generated for a unit spillway discharge of nine kcfs/bay for the uniform spill pattern. The main limitation of this TDG exchange study was the small range in tailwater elevations (158.4 to 161.3 fmsl).

The influence of standard operating conditions on TDG exchange was further investigated through analyzing the TDG exchange indicated by the FMS during the 1998-spill season. These conditions involved the newly adopted spill pattern, a wider range in tailwater elevation, and both fish passage and involuntary spill discharges. The observed TDG data at the John Day tailwater FMS were used to generate a description of TDG exchange. The filtering of these data resulted in a total of 51 observations as summarized in Table 6. The observed delta pressure ranged from 108 mm Hg to 184.0 mm Hg for these 51 events. The unit spillway discharge was found to range from 4.3 to 9.4 kcfs/bay and the tailwater depth was found to range from 33.6 to 42.4 feet.

Table 6: Statistical Summary of Regression Variables

	Delta Pressure ΔP (mm/Hg)	Unit Spillway Discharge q_s (kcfs/bay)	Tailwater Depth D_{tw} (ft)
Number	52	52	52
Minimum	108.0	4.3	33.8
Maximum	184.0	9.4	42.4
Average	152.7	7.1	38.7
Standard Deviation	16.7	1.2	1.9

Source: U.S. Army Corps of Engineers DGAS Study, Appendix G, p. G-31

The functional relationship between TDG production and project operation at John Day was similar to those relationships derived for upper Snake River projects. The delta TDG pressure, as defined by $\Delta P = P_{tw} - P_{bar}$, was found to be proportional to the product of tailwater depth and an exponential function of the specific discharge as shown in Equation 13. Both of the coefficients determined by the nonlinear regression analysis were significant to at least a 99 percent confidence interval as shown in Table 7. This formulation explained much of the variability in the data with an r^2 of 0.84 and a standard error of 6.8 mm Hg.

$$\Delta P = 4.969 D_{tw}(1 - e^{-0.2278 q_s}) \qquad \text{Equation 13}$$

Where:

ΔP = $P_{tw} - P_{bar}$

P_{tw} = TDG pressure at the tailwater FMS (mm Hg)

q_s = Unit spillway bay discharge (kcfs/bay)

D_{tw} = Tailrace channel depth (feet) (Etw-Ech)

E_{tw} = Elevation of the tailwater (fmsl)

E_{ch} = Average elevation of the tailrace channel (125 fmsl)

P_{bar} = Barometric pressure at the tailwater FMS (mm Hg)

Table 7: Statistical Summary of Nonlinear Regression at John Day 1998 Spill Season
(Bays 2 Through 19 With Flow Deflectors)

$$\Delta P_{tw} = C_1 * D_{tw} * (1 - \exp(C_2 * q_s))$$

Number of observations n=51

$r^2 = 0.84$

Std. Error=6.78 mm Hg

Coefficient	Estimate from Regression	Standard Error	t-statistic	Probability
C_1	4.969	0.192	25.908	<0.0001
C_2	-0.2278	0.0221	10.3069	<0.0001

Source: U.S. Army Corps of Engineers DGAS Study, Appendix G, p. G-32

The unit spillway discharge was plotted against the observed and calculated tailwater TDG pressure above the local barometric pressure as shown in Figure 10.

The exponential relationship between the TDG pressure and specific discharge is not as clearly defined at John Day as at other projects with this functional form. Much of the variability in the TDG pressure for a constant unit discharge can be accounted for by the variation in the tailrace channel depth. Equation 13 can be solved directly for the unit specific discharge assuming a delta pressure of 150 mm Hg (120 percent saturation) and a tailwater depth of 35 feet. The resultant unit spillway discharge of about nine kcfs/bay is the solution to this equation. This unit spillway discharge was similar to the spillway capacity determined during the near-field TDG exchange study.

The three-dimensional response surface for Equation 13 is shown in Figure 11 along with the observed data.

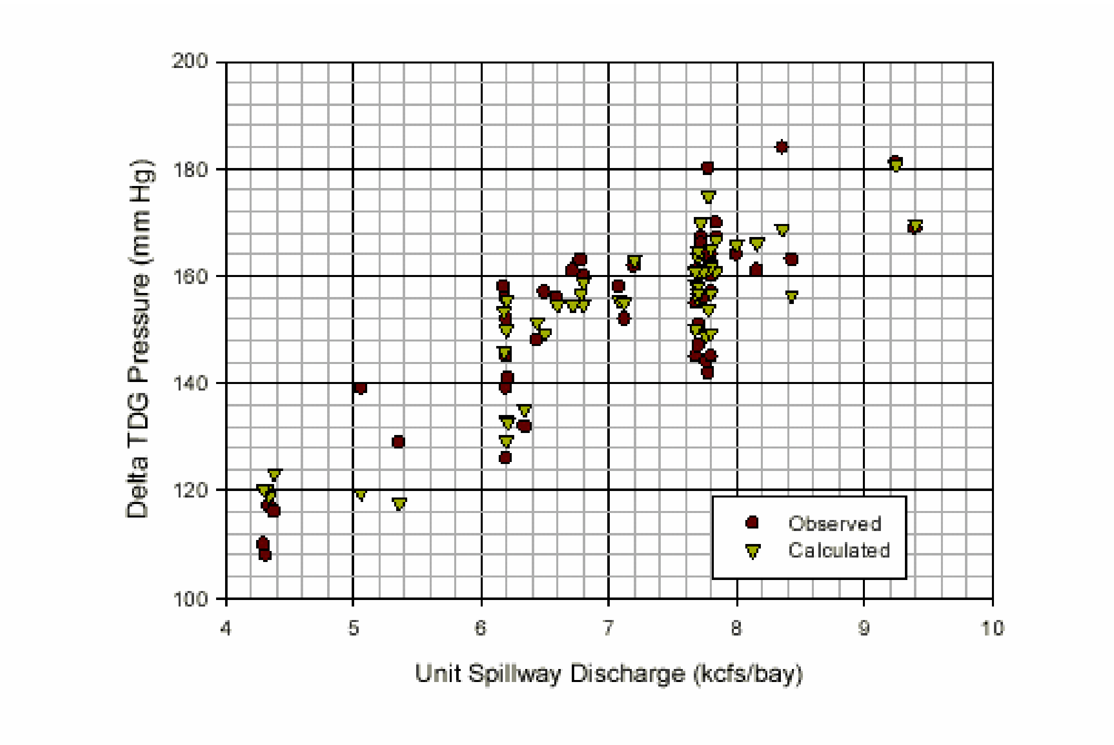

Figure 10: Unit Spillway Discharge versus TDG Pressure Above Barometric Pressure at John Day Dam, 1998

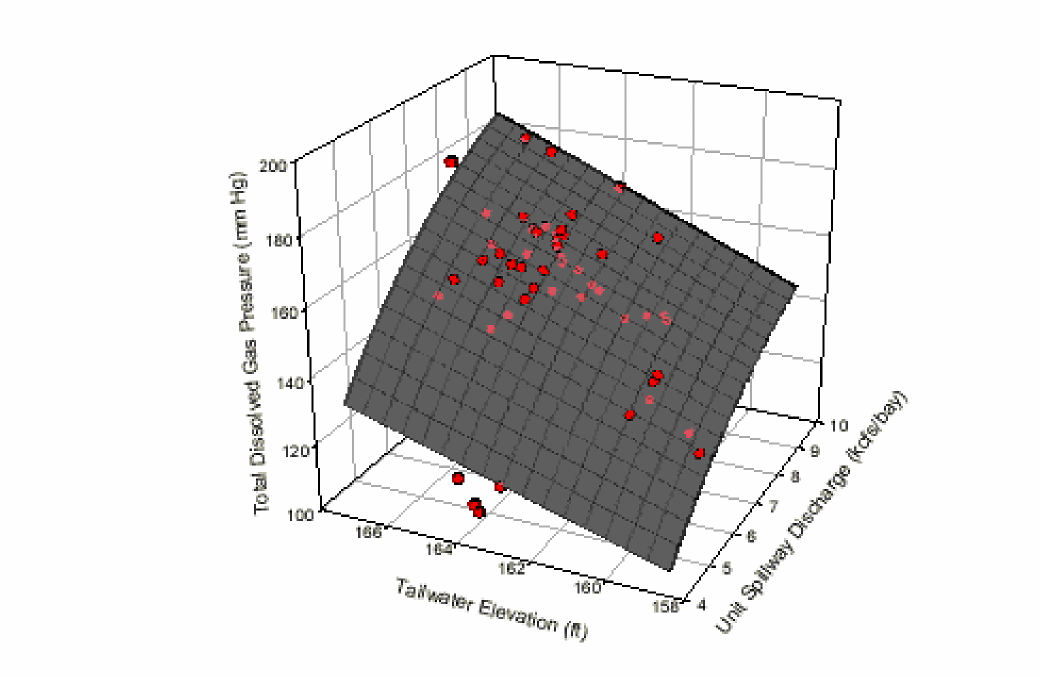

Figure 11: Unit Spillway Discharge, Tailwater Elevation, and TDG Pressure Above Barometric Pressure at John Day Dam, 1998

The TDG pressure increases for a constant unit spillway discharge as the tailrace channel depth increases. The influence of the tailwater depth is significant as evidenced by the slope in the response surface for a constant unit discharge. The upper limit in delta TDG pressure will continue to increase with increasing tailwater elevation. The TDG response during fish passage spill conditions will be different than a comparable spill discharge at a much higher total river flow.

The tailwater TDG saturation as approximated by Equation 13 was used to create a hindcast of the TDG production observed during the 1998 spill season below John Day. The hourly project operation and TDG saturation at the John Day tailwater FMSs (JHAW) for the months of May and June 1998 are shown in Figure 12 along with estimates of the tailwater TDG saturation (JHAW-est).

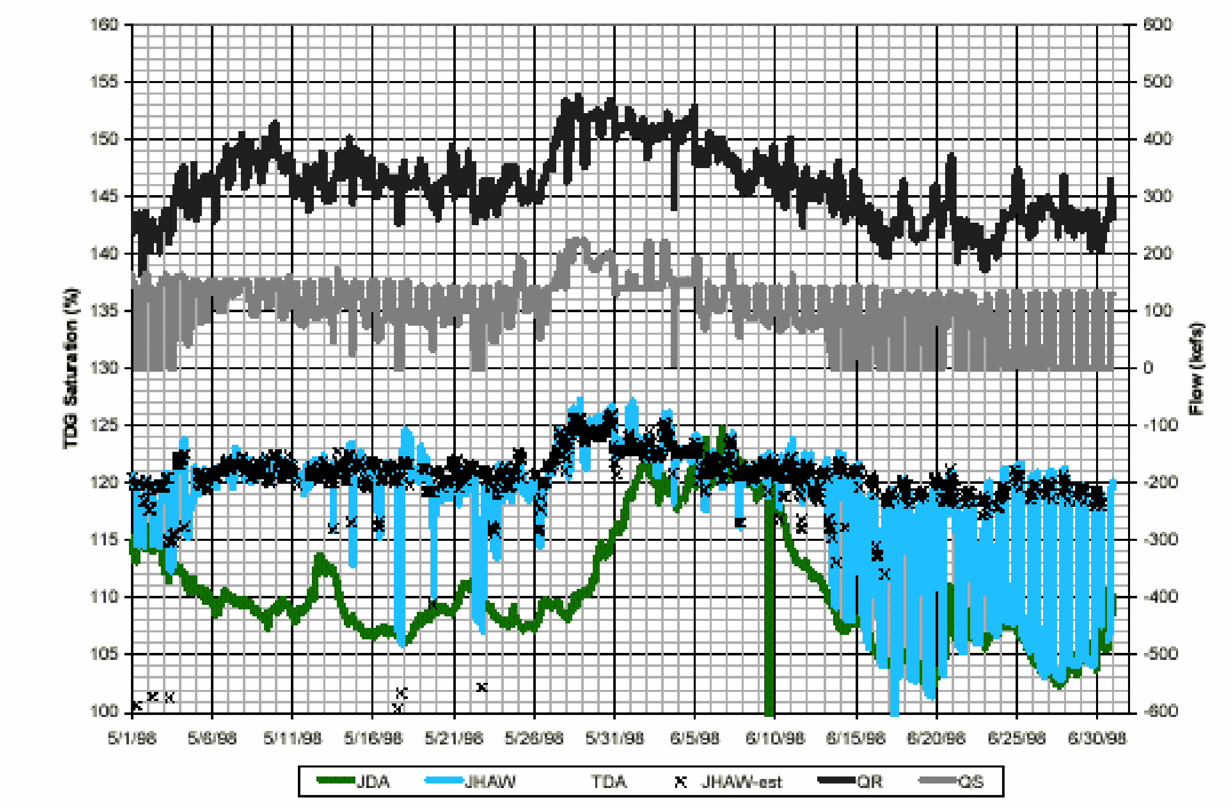

Figure 12: Observed and Estimated TDG Saturation at the Tailwater Fixed Monitoring Station at John Day Dam, May- June 1998. (JDA= Observed Forebay TDG, JHAW= Observed Tailwater TDG, JHAW- est =Calculated Tailwater TDG, QR= Hourly Total River Flow, QS= Hourly Spillway Flow)

In general, the estimated average TDG saturation was generally within seven mm Hg of the observed tailwater TDG pressure. The operating conditions during May 1998 depict both fish passage and involuntary spill conditions. The spill discharges were as high as 230 kcfs for total river flows over 400 kcfs, resulting in tailwater TDG saturation of about 126 percent. The nighttime-only spill operations during the last two weeks of June imply fish passage spill conditions. Note the range in TDG response for the constant nighttime spill operations during this period. The nighttime spill on June 21 corresponded with elevated total river flows and high tailwater conditions resulted in TDG saturation exceeding 121 percent. A comparable spill two days later during much lower total river flow and tailwater stage conditions resulted in TDG saturations of only 119 percent.

Regression

John Day has two spillway bays without flow deflectors. The TDG response of these two bays were estimated using tailwater TDG pressures observed prior to the installation of the 18 flow deflectors during the 1996 and 1997 spill seasons. A total of 1,137 hourly observations were pooled from the 1996 and 1997 spill seasons. The presence of two flow deflectors located in bays 18 and 19 during the 1997 spill season were not thought to influence the TDG response at the tailwater FMS below John Day. The delta pressure for these events ranged from 84 to 324 mm Hg as shown in Table 8. The unit spillway discharge ranged from 1.8 to 15.3 kcfs/bay and the tailwater depth ranged from 35.6 to 46.7 feet during this sample period.

Table 8: Statistical Summary of Regression Variables

	Delta Pressure ΔP (mm Hg)	Unit Spillway Discharge q_s (kcfs/bay)	Tailwater Depth D_{tw} (ft)
Number	1137	1137	1137
Minimum	84.0	1.8	35.6
Maximum	324.0	15.3	48.7
Average	223.0	5.8	41.1
Standard Deviation	64.6	3.0	2.3

Source: U.S. Army Corps of Engineers DGAS Study, Appendix G, p. G-33

The delta pressure of a standard spillway bay at John Day was determined to be a function of the unit spillway discharge. The functional form of this relationship is shown in Equation 14 where a threshold delta pressure of 315.3 mm Hg is approached for large unit spillway discharges as shown in Figure 13.

The maximum TDG saturation generated by this relationship approaches 141 percent for a barometric pressure of 760 mm Hg. All of the coefficients determined by the nonlinear regression analysis were significant to at least a 99 percent confidence interval as shown in Table 9. This formulation explained much of the variability in the data with an r^2 of 0.94 and a standard error of 15.9 mm Hg. The TDG exchange for a known spill pattern using bays with and without flow deflectors can be estimated by using both Equations 13 and 14. The average TDG pressure associated with a spill discharge would be determined by calculating a flow-weighted average of the individual spillway bay responses.

$$\Delta P = 315.29 - 519.09e^{-0.365q_s} \qquad \text{Equation 14}$$

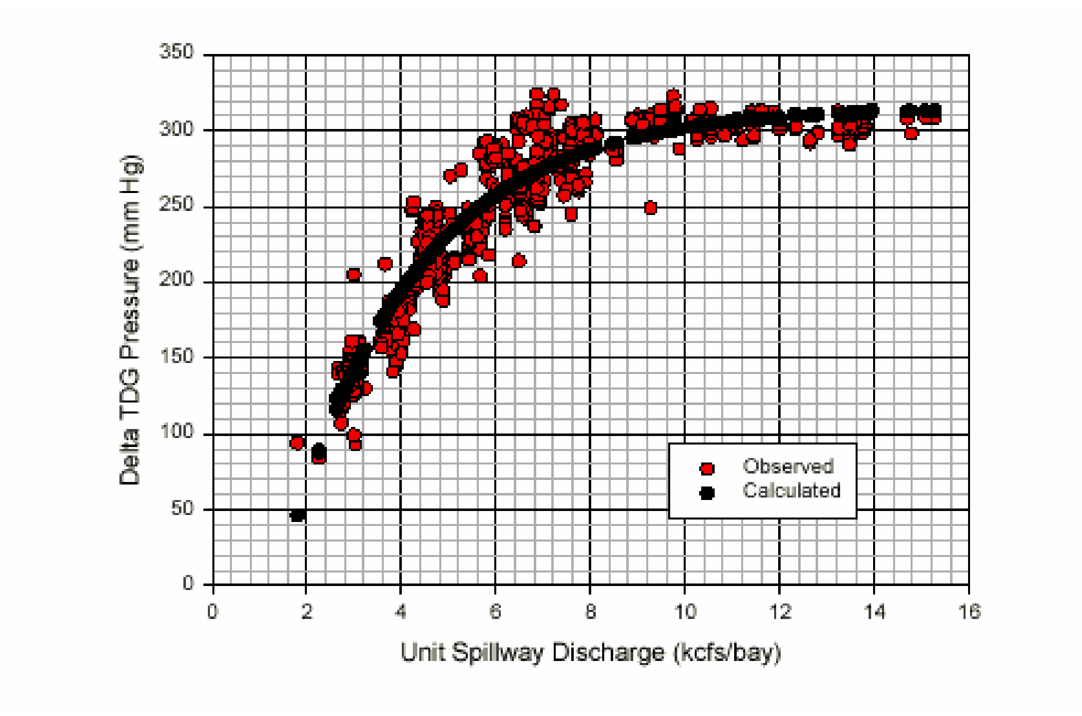

Figure 13: Observed and Calculated Delta TDG pressure at John Day Dam
(Standard Spillway – no Deflector)

Table 9: Statistical Summary of Nonlinear Regression at John Day 1996-1997 Spill Season

$\Delta P_{tw} = C_1 - C_2 * (\exp(C_3 * q_s))$ Number of observations = 1137 $r^2 = 0.94$ Std. Error = 15.95 mm Hg				
Coefficient	Estimate from Regression	Standard Error	t-statistic	Probability
C_1	315.29	1.647	191.48	<0.0001
C_2	-519.09	10.3867	-49.975	<0.0001
C_3	-0.3649	0.0084	-43.38	<0.0001

Source: U.S. Army Corps of Engineers DGAS Study, Appendix G, p. G-34

Powerhouse Entrainment

The entrainment of powerhouse flows into the highly aerated flow conditions below John Day was estimated from data collected during the 1998 spillway TDG exchange study (Schneider and Wilhelms, 1999a). The average TDG pressure of project and spillway releases was used with a simple mass balance statement of project flows to provide estimates of the effective spillway discharge and entrainment of powerhouse flows. The estimates of the entrainment of powerhouse flows were found to range from five to 60 kcfs average and average about 35 kcfs. The powerhouse entrainment discharge was not found to vary as a function of the total spillway discharge.

The Dalles Dam

The TDG Exchange

A TDG exchange field investigation was conducted below The Dalles during August 28-29, 1996, with the study summarized in Schneider and Wilhelms (1996a). The study consisted of sampling TDG pressures below the spillway during spillway discharges ranging from 50 to 200 kcfs. Three different spill patterns were investigated during this study: adult, juvenile, and uniform spill patterns.

The study findings indicated that the TDG production was weakly related to the unit spillway discharge. The TDG saturation ranged from 119 to 124 percent during the study for unit spillway discharges ranging from two to 14 kcfs/bay. The influence of the spill pattern was found to be accounted for by representing the total spillway discharge as defined by unit spillway bay discharge. The main limitation of this TDG exchange study was the small range in tailwater elevation (75.7 to 78.3 fmsl).

Regression

The high river flows and spillway discharges during 1997 generally fell outside of the range of conditions scheduled during the 1996 spillway performance test. The application of the TDG production relationship determined during the 1996 near-field study did not replicate TDG conditions observed below The Dalles during the 1997 spill season.

The observed TDG data at The Dalles from the forebay and tailwater FMS were used to generate an alternative description of TDG exchange. The TDG pressures observed at the forebay FMS were assumed to represent the conditions discharged from the powerhouse. The TDG pressures observed at the tailwater FMS were assumed to reflect the average TDG pressures in the Columbia River. The TDG properties of spillway discharge were estimated by performing a simple mass balance of project releases. The hourly data were filtered to retain only those data having constant project operations for a six-hour duration. This criterion was selected to allow steady-state conditions to develop at the tailwater FMS located three miles downstream of the project. This criterion also allowed the inclusion of a single datum for each extended event.

This data filtering resulted in a total of 87 observations as summarized in Table 10. The estimated delta pressure ranged from 143.3 mm Hg to 203.6 mm Hg for these 87 events. The unit spillway discharge was found to range from 4.3 to 19.0 kcfs/bay and the tailwater depth was found to range from 8.3 to 23.3 feet.

Table 10: Statistical Summary of Regression Variables

	Delta Pressure ΔP (mm Hg)	Unit Spillway Discharge q_s (kcfs/bay)	Tailwater Depth D_{tw} (ft)
Number	87	87	87
Minimum	143.3	4.3	8.3
Maximum	206.6	19.0	23.3
Average	178.4	9.6	14.5
Standard Deviation	14.1	3.6	3.6

Source: U.S. Army Corps of Engineers DGAS Study, Appendix G, p. G-35

The spillway releases from The Dalles, as defined by $\Delta P = P_{tw} - P_{bar}$, was found to be proportional to the product of tailwater depth and the specific discharge as shown in Equation 15. The regression equation was based on data collected during the 1997 spill season. The data filtering resulted in a total of 87 independent observations. The unit spillway discharge was plotted against the estimated and calculated tailwater delta TDG pressure in Figure 14.

The form of the relationship shown in Equation 15 implies the TDG exchange for small spillway discharge will exceed 120 percent as was observed during the 1996 near-field investigation. All of the coefficients determined by the nonlinear regression analysis were significant to at least a 99 percent confidence interval as shown in Table 11. This formulation explained much of the variability in the estimated dependent variable with an r^2 of 0.735 and a standard error of 7.3 mm Hg.

$$\Delta P = D_{tw}^{1.02} q_s^{0.33} + 145.9 \qquad \text{Equation 15}$$

The dual dependency of the delta pressure change on tailwater depth and unit spillway bay discharge is shown in Figure 15.

Table 11: Statistical Summary of Nonlinear Regression at The Dalles 1997 Spill Season

$$\Delta P_{tw} = D_{tw}^{C_1} q_s^{C_2} + C_3$$

Number of observations = 87

$r^2 = 0.735$

Std. Error = 7.34 mm Hg

Coefficient	Estimate from Regression	Standard Error	t-statistic	Probability
C_1	1.02	0.12	2.69	<0.0086
C_2	0.33	0.12	8.72	<0.0001
C_3	145.9	2.21	66.11	<0.0001

Source: U.S. Army Corps of Engineers DGAS Study, Appendix G, p. G-36

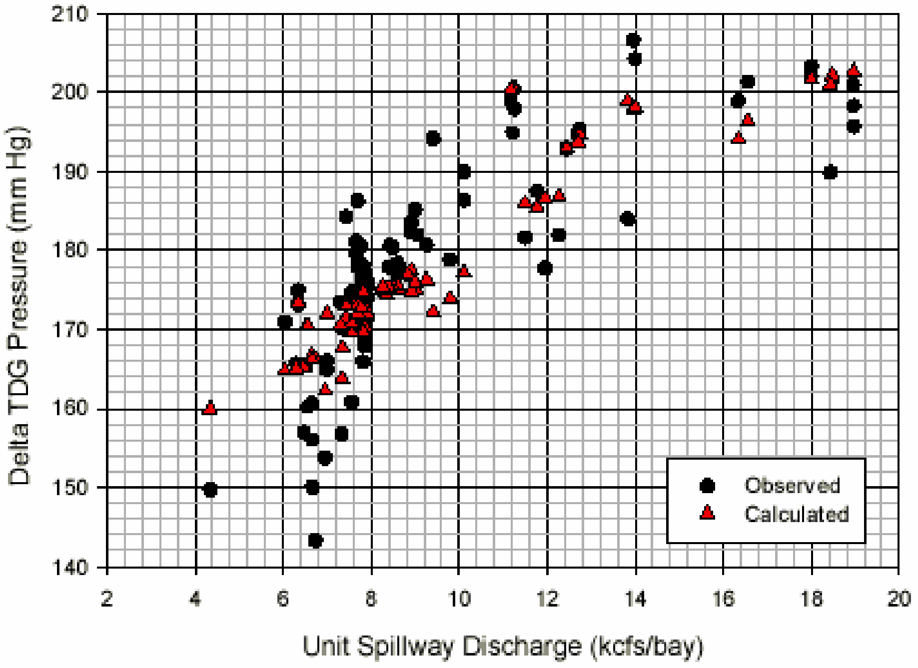

Figure 14. Unit Spillway Discharge versus TDG Pressure Above Barometric Pressure at The Dalles Dam, 1997

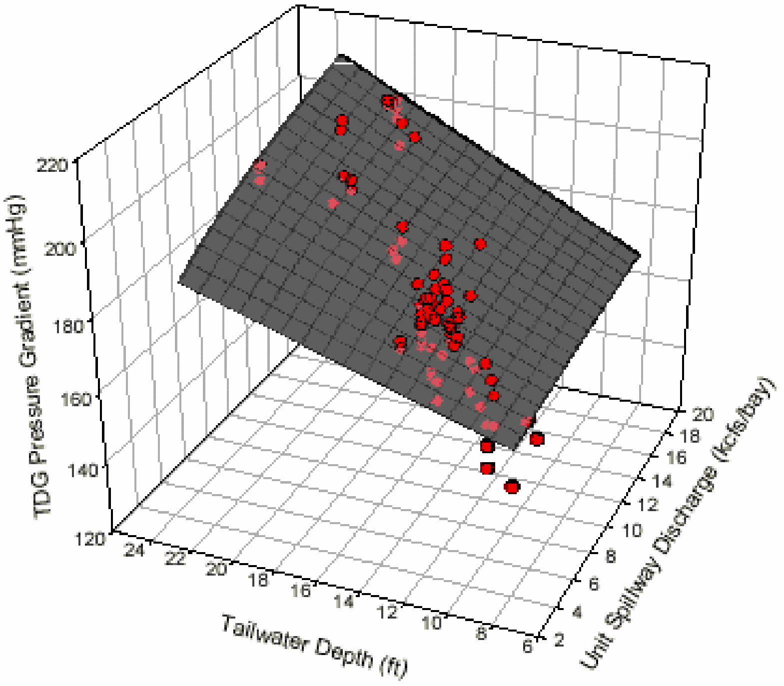

Figure 15: Unit Spillway Discharge, Tailwater Elevation, and TDG Pressure Above Barometric Pressure at The Dalles Dam, 1997

This equation also indicates that the depth of flow accounts for most of the variability in the increase in TDG pressure associated with spillway discharges. The increase in TDG pressure was found to be a linear function of the depth of flow for a constant unit spillway discharge. The tailrace channel depth is a function of the total river flow and the pool elevation of the lower reservoir. This relationship couples the operation of the powerhouse at The Dalles and the storage management in Bonneville pool to the TDG production in spillway releases from The Dalles spillway.

The response function as defined in Equation 15 was used to create a hindcast of the TDG production observed during the 1997 spill season. The hourly project operation and TDG saturation at The Dalles tailwater FMS for June 1997 are shown in Figure 16 along with the estimates of the flow-weighted TDG saturation released from The Dalles based on Equation 15 and observations of TDG pressures in the forebay. In general, the estimated average TDG saturation was generally within seven mm Hg of the observed tailwater TDG pressure.

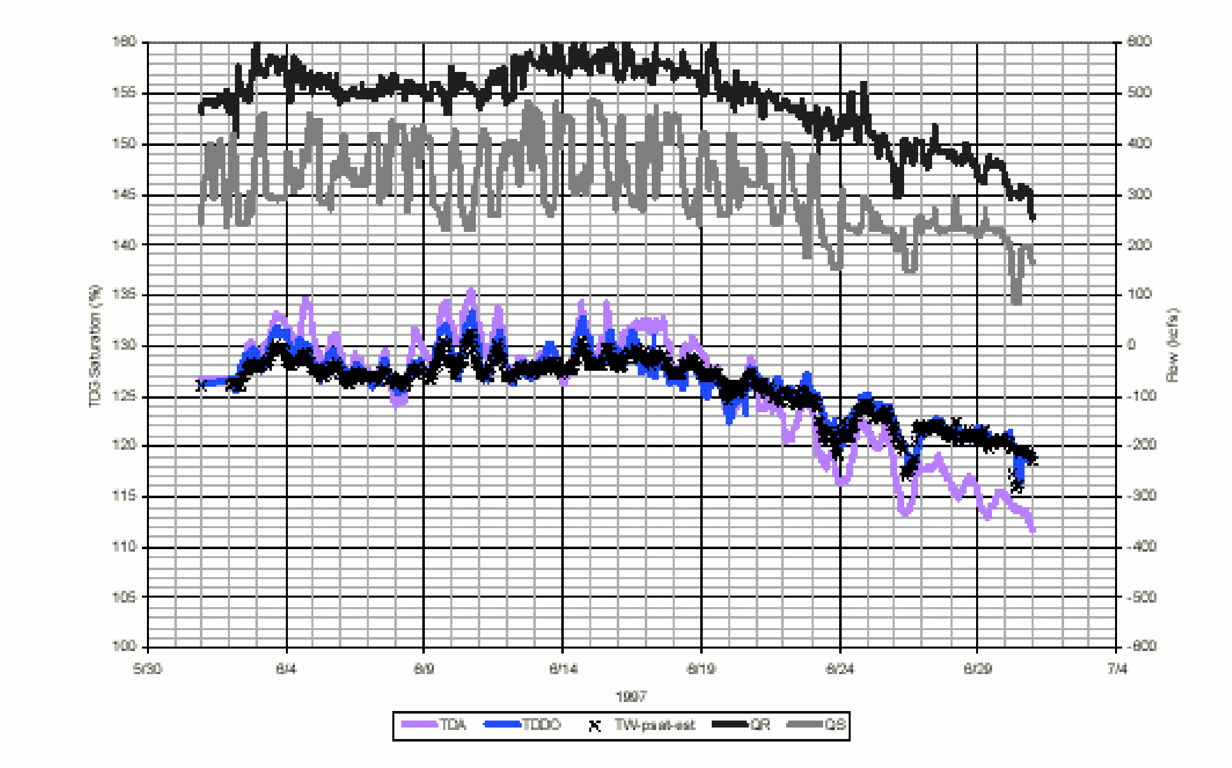

Figure 16: Observed and Estimated TDG Saturation at the Tailwater Fixed Monitoring Station at The Dalles Dam, June 1997. (TDA= Observed Forebay TDG, TDDO= Observed Tailwater TDG, TW-psat-est =Calculated Tailwater TDG, QR= Hourly Total River Flow, QS= Hourly Spillway Flow)

The maximum daily spillway discharge and percent of river spilled varied greatly during June 1997, with spill discharges as high as 480 kcfs. The forebay TDG pressures often were higher than the tailwater TDG pressures, implying a net reduction in TDG conditions in the Columbia River as a result of the operation of The Dalles. The second half of June found the TDG pressures below The Dalles larger than observed at the forebay station, implying a net increase in TDG conditions in the Columbia River as a result of the operation of The Dalles. The conditions during the latter half of June in 1997 reflect conditions more typical of fish passage spill conditions where spill at The Dalles contributes to higher TDG loading in the Columbia River.

Powerhouse Entrainment

The entrainment of powerhouse water into the aerated spilling basin was assumed to be zero at The Dalles. The powerhouse is located a considerable distance from the spillway. The standard spillway design efficiently dissipates energy in the stilling basin, which minimizes the potential to entrain flow laterally. The extent of aerated flow generally does not extend downstream of the shallow shelf below the stilling basin. The TDG exchange was not found to be large near the downstream limits of the shallow tailwater shelf below the spillway (Schneider and Wilhelms, 1996a).

Bonneville Dam

The TDG Exchange

A description of TDG exchange at Bonneville is needed to evaluate dissolved gas abatement alternatives and develop a system model of TDG properties. The following summarizes the findings of two TDG exchange studies conducted below Bonneville and the TDG production relationships that were derived from this body of work.

The first study was conducted during February 1-4, 2000 and involved measuring TDG pressures and velocities below the Bonneville spillway. The objective of this investigation was to describe the TDG exchange processes associated with non-deflectored bays, deflectored bays, and a combination of deflectored and non-deflectored bays as dictated by the standard spill patterns.

The second test was conducted during May 7-June 7 and involved measuring TDG pressures near the exit of the Bonneville spillway channel. The objective of this test was to investigate the role of tailwater elevation changes on the exchange of TDG associated with spillway releases during standard operating conditions.

The TDG pressures and flow distributions were measured near the exit of the Bonneville spillway channel during the first week in February (Schneider, 1999). A total of 11 TDG instruments were deployed across the channel at fixed locations and logged TDG pressure, water temperature, dissolved oxygen, and instrument depth on a 15-minute interval. The velocity field was also measured near this array of instruments using an Acoustic Doppler Current Profiler. The TDG pressures were then integrated with the velocity field to estimate the TDG loading produced during spillway operations.

The test conditions involved spillway flows over non-deflectored bays, deflectored bays, and a combination of both deflectored and non-deflectored bays. A total of five spill levels corresponding with gates setting of one, two, three, four, and five dogs were investigated for four different spill patterns. (“Dogs” are pawls or cams that drop into holes on the sides of leaf gates on Bonneville and McNary dams. The leaf gates are hoisted by cranes, the dogs drop in to keep the gate set at one place. They are spaced approximately a foot apart.) The first day of testing used only non-deflectored bays two, three, 16, and 17 (day one). The spill pattern for the second day of testing involved only deflectored bays eight through 15 with spill flow uniformly distributed (day two). The third day of testing involved a uniform pattern over deflectored bays nine through 15, and non-deflectored bays 16 and 17 (day three). The spill pattern tested on the fourth day involved the standard 1997 spill pattern (day four).

The non-deflectored bays generated the highest TDG saturation for gate setting(s) up through three dogs as shown in Figure 17.

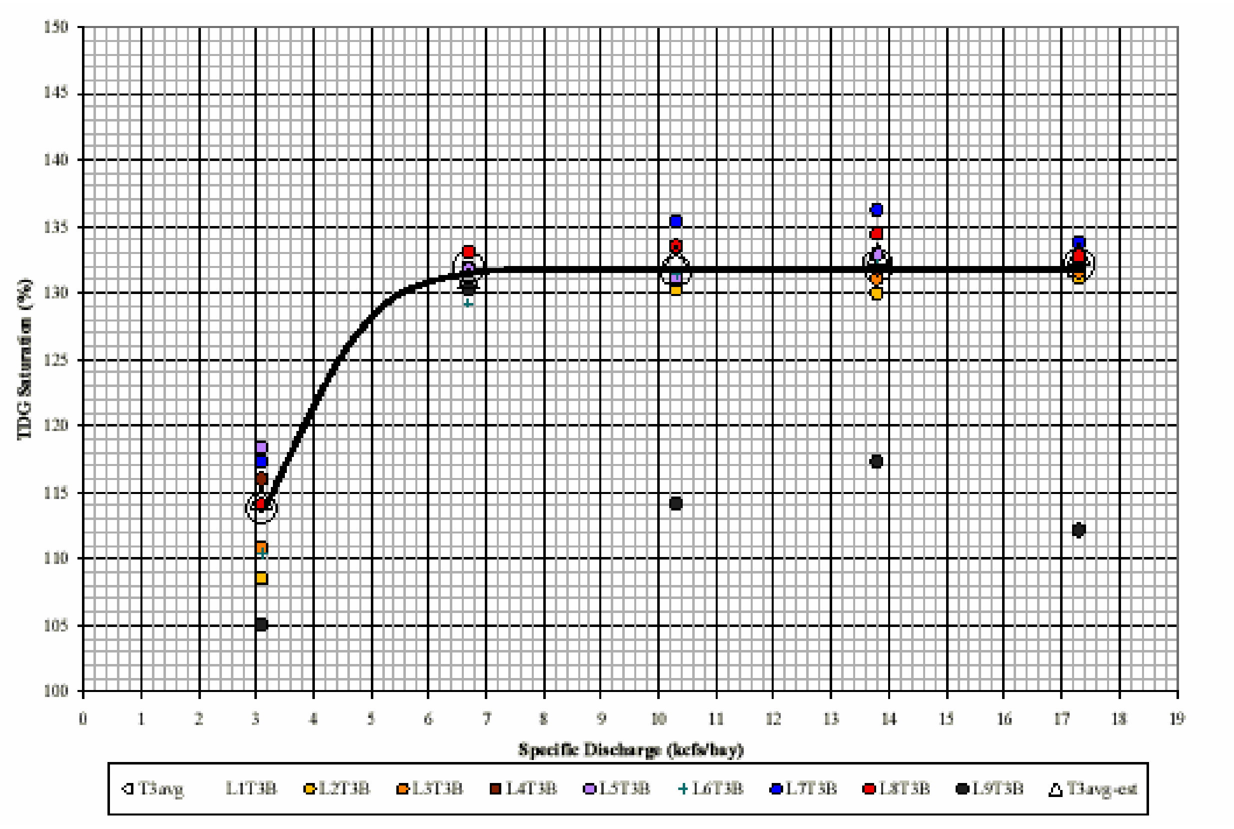

Figure 17: TDG Saturation from Non-deflectored Bays at Exit of the Bonneville Spillway Channel, February 1, 1999

The steady-state TDG saturation at nine sampling stations on transect T3 located at the mouth of the spillway channel are shown in this figure. The stations were labeled L1 through L9 from south to north along this transect. The flow-weighted TDG saturation on this transect is labeled

T3avg. During the two-dog setting, the non-deflectored bays generated an average TDG saturation of 132 percent or about 12 percent greater than the comparable flows during day two. The TDG saturation associated with non deflectored bays remained constant for gate settings of two dogs and higher.

The TDG saturation response to the unit spillway discharge over only deflectored bays was nearly linear for gate settings of one through four dogs. This relationship was nearly identical to similar conditions measured during the initial Bonneville spillway performance test (Wilhelms and Schneider, 1997b). The TDG saturation at two dogs was observed to be about 120 percent on all 11 instruments located across the spillway exit channel. Larger lateral gradients in TDG pressure were observed for higher discharges over the deflectored bays as shown in Figure 18.

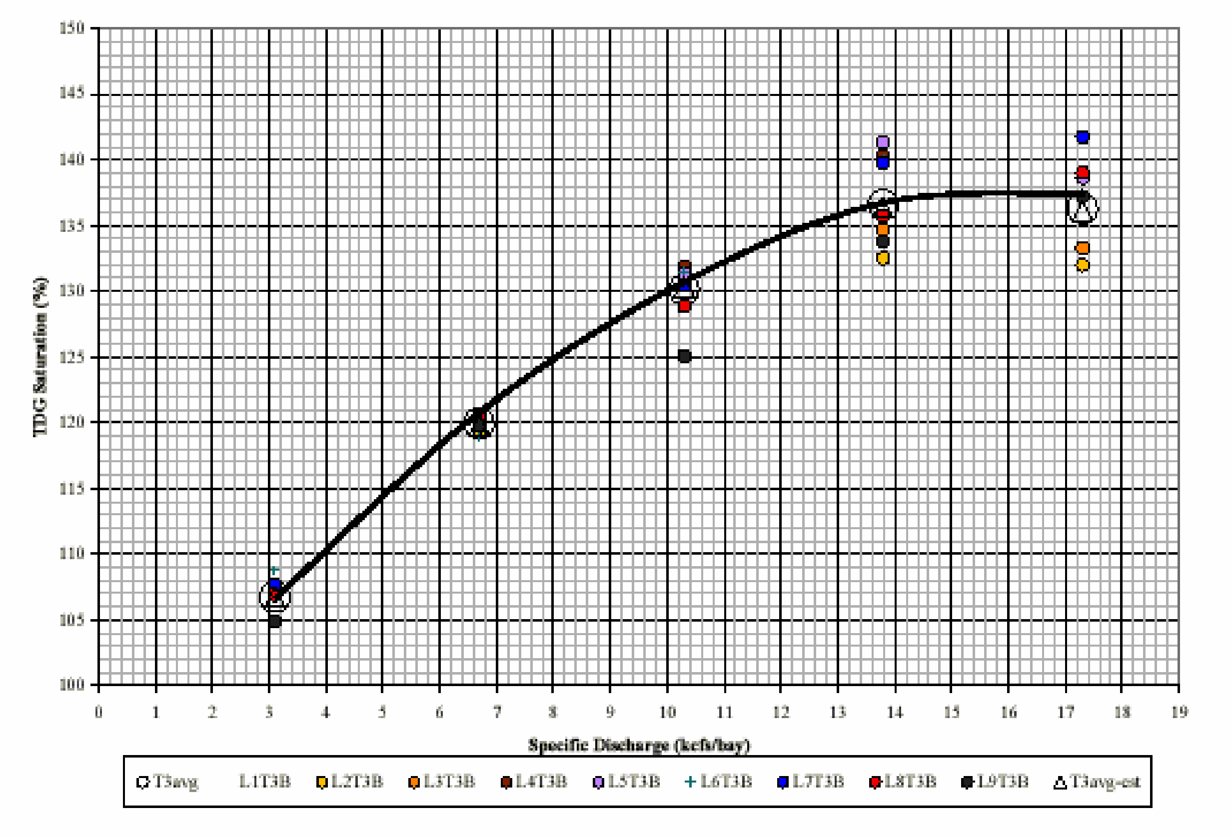

Figure 18: Observed TDG Saturation below Bonneville Spillway during Uniform Flow over Deflected Bays 8-15, February 1-4, 1999

The TDG pressures generated with deflectored spillway releases were observed to be greater than conditions for non-deflectored bays for spillway flows of four dogs and higher.

A flow-weighted specific spillway discharge was determined for the standard spill pattern because of the non-uniform distribution of flow. This representation of unit spillway discharge places more importance on flows from bays with larger discharges. The spill patterns during the five test conditions on day four are shown in Figure 19.

The initial discharge of 50 kcfs on day four had a flow-weighted discharge of over 6 kcfs/bay due to the gap-toothed pattern where a highly non-uniform flow distribution was used. The high percentage of flow over the non-deflectored bays resulted in nearly a constant TDG saturation for the first three test conditions. The slope of the TDG saturation and unit discharge curve approached conditions observed during the uniform patterns on day 3 during spill over both deflectored and non-deflectored bays. The TDG saturation associated with the standard spill pattern was 125 percent and higher for all the test conditions.

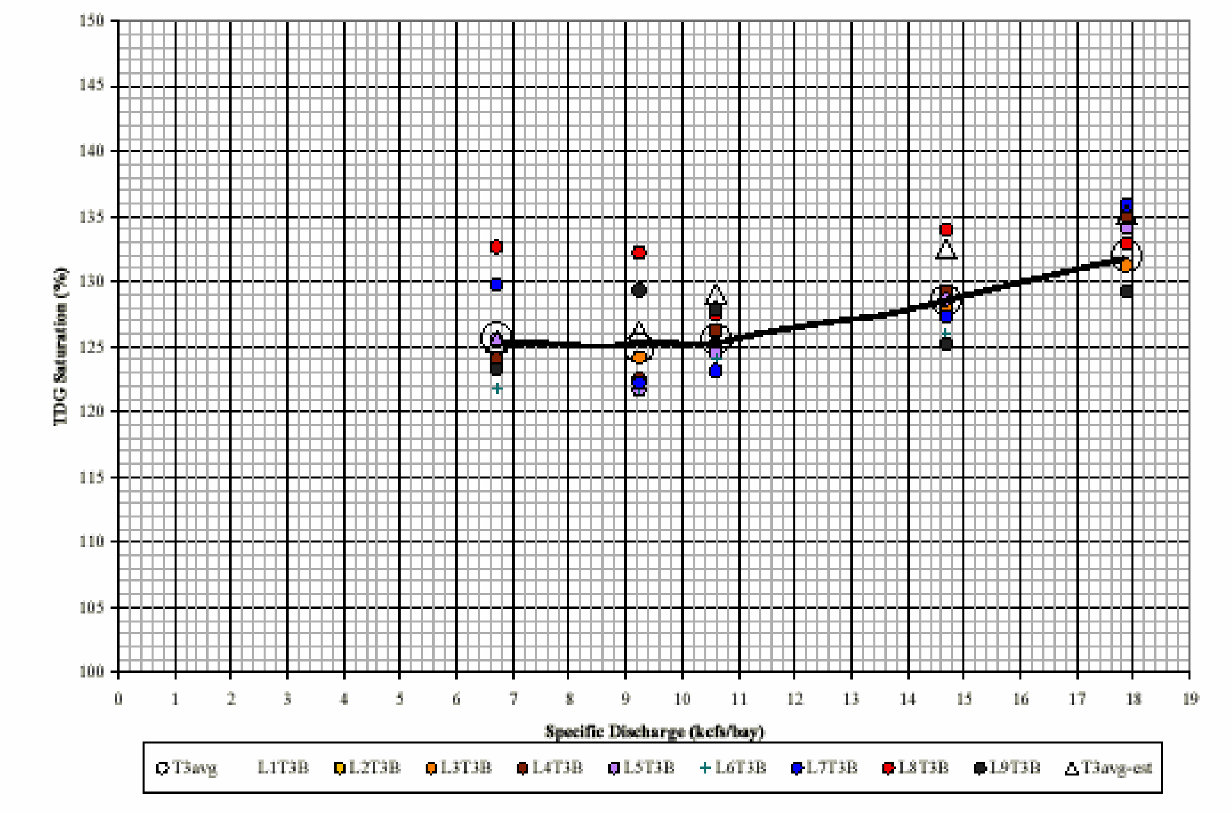

Figure 19: Observed TDG Saturation below Bonneville Spillway During Standard Spill Patterns Over Deflected Bays 4-15 and Non-Deflected Bays 2-3, 16-17, February 1-4, 1999

Regression

Empirical relationships were derived for non-deflectored and deflectored bay spill conditions. These regression equations were then applied to the individual bays used in the mixed bay spill patterns on the third and fourth day of the test to determine if these properties were additive. An exponential equation was fitted to the five flow conditions observed on the first day (non-deflectored bays only). The following equation expresses the increase in TDG pressure over barometric pressure as a function of the unit discharge. Equation 16 is applicable only to non-deflectored bays 1, 2, 3, 16, and 17 at the Bonneville spillway.

$$\Delta P = 255.58 - 1031.58e^{-0.639q_s} \qquad \text{Equation 16}$$

Where:

$.\Delta P$ = $P_{tdg} - P_{bar}$ (mmHg)

q_s = Unit spillway discharge (kcfs/bay)

q_s > 3.0 kcfs/bay

A third order polynomial was fit to the five test conditions associated with the uniform spill over deflectored bays. A third order polynomial was chosen because of the rapid change in slope of the curve at the higher discharges. Equation 17 expresses the increase in TDG pressure over barometric pressure as a function of the unit discharge. This equation only applies to the deflectored bays four through 14 at the Bonneville spillway. This equation is not appropriate for unit discharges less than three kcfs/bay.

$$\Delta P = -0.0567q_s^3 + 0.421q_s^2 + 27.823q_s - 37.067 \qquad \text{Equation 17}$$

Where:

$.\Delta P$ = $P_{tdg} - P_{bar}$ (mmHg)

q_s = Unit spillway discharge (kcfs/bay)

q_s > 3.0 kcfs/bay

Equations 16 and 17 were applied to the individual spillway bay discharges observed during the third and fourth day of testing during the first week in February. The resulting pressures were then multiplied by the ratio of spillway bay discharge to total spillway discharge and summed to determine the flow-weighted pressure change. The barometric pressure was then applied to calculate the TDG saturation. The individual station saturations (L1T3B-L9T3B), cross-sectional average saturation (T3avg), and forecasted aggregate saturation (T3avg-est) are shown in Figure 19 for the standard spill pattern. The forecast of the TDG saturation associated with the standard pattern followed the general trend in the data. The forecasted TDG saturation overestimated the observed average conditions for the higher gate settings. The forecasted value falls within the range of observed values of TDG saturation downstream of the highly aerated flow regime.

The two-equation flow-weighted average formulation was also applied to the operations data gathered during the supplemental TDG test conducted below Bonneville from May 7-June 7. Equations 16 and 17 were applied to the observed spillway bay discharge and average TDG saturation for spillway releases was determined using a flow-weighted approach. The average spillway TDG saturation was plotted with project operations, forebay FMS TDG saturation, tailwater FMS TDG saturation, and auxiliary station TDG saturation as shown in Figure 20.

The average TDG saturation released from Bonneville was estimated using the formulation presented above for the spillway contribution. The TDG loadings associated with powerhouse releases were estimated by the product of powerhouse discharge and forebay FMS TDG saturation. The estimated loading from the spillway was determined by the product of the spillway discharge and estimated spillway TDG saturation. The flow-weighted average TDG saturation released from Bonneville is shown in Figure 20 under the heading of TDG-tw-est. The estimated average TDG saturation closely followed the observed data at the tailwater FMSs during most of the study period. The TDG distribution at the tailwater FMS is often not uniform and, therefore, cannot be used as a rigorous validation of this formulation. However, this comparison does lend additional credence to the formulation cited above.

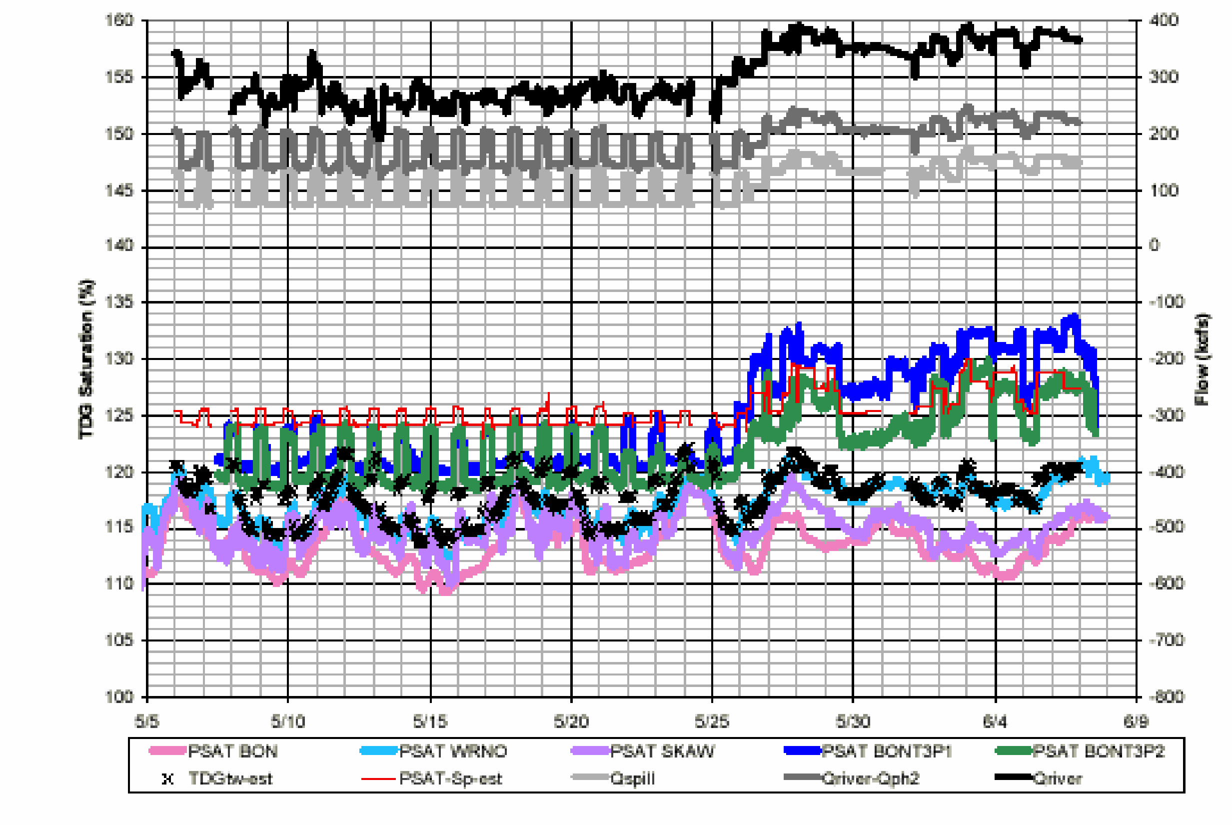

Figure 20: Observed and Estimated TDG Saturation Below Bonneville Spillway During Spill Season, May 5 – June 8, 1999

Powerhouse Entrainment

The entrainment of powerhouse flow was assumed to be zero at Bonneville because of the physical barriers created by Bradford and Cascade Islands. The TDG exchange was not found to extend below the spillway channel during near-field investigations.

Load Allocations

For the purpose of this TMDL, each dam will be provided with a load allocation, 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 state, much like a high-energy release of water might erode a stream bank.
- Dams are essentially very large instream structures that will require modifications to achieve compliance with 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.

Wasteload allocations in this TMDL are zero, because there are no NPDES-permitted point sources that contribute to elevated TDG in the Lower Columbia River.

Table 12 shows the load allocations for each of the four dams on the Lower Columbia River. Because of the unique nature of TDG, load allocations are not directly expressed in terms of mass loading. Like loading capacity, allocations are in terms of ΔP applied site-specifically for each dam.

Table 12: Load Allocations for TDG in Lower Columbia River

Location Name	Load Allocation*
Upstream Boundary	75
McNary Dam spill	75
John Day Dam spill	75
The Dalles Dam spill	75
Bonneville Dam spill	75

* as excess pressure above ambient ΔP), mm Hg

Load allocations for spills are equal to loading capacity. An analysis was conducted to evaluate the possibility of applying background load allocations that represent an increase in TDG percent saturation caused when ambient water temperatures increase as water moves downstream through the pool of the downstream dam. This can occur because, if gas exchange is negligible (such as occurs on windless days), an increase in water temperature will decrease the saturation concentration. As a result, a fixed mass of TDG in the pool will represent a higher TDG percent saturation if water temperature increases.

---

[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 states of Washington and Oregon are to not issue NPDES permits for TDG.

The potential temperature increase in each pool was evaluated. For each dam the time of travel was estimated from the application of EPA's RBM-10 model (USEPA, 2001) for a 10-year period. The 90th percentile travel time (in days) for each month was then used to determine the maximum temperature increase for that travel time. The increase in TDG for highest 90th percentile seasonal temperature increase was then determined. However, it is likely that windy conditions in the TMDL cause sufficient degassing to offset increases in TDG from water temperature increases. Average daily wind speed was evaluated and plotted against temperature increases (shown in Figure 21 for The Dalles). Then the potential degassing effect was evaluated from several of the equations used in TDG modeling as summarized in Appendix B of Cole and Wells (2001). This analysis indicates that the concurrence of increasing temperature with low rates of degassing is relatively rare. Therefore, the effect of water temperature increases on TDG is not included in this TMDL.

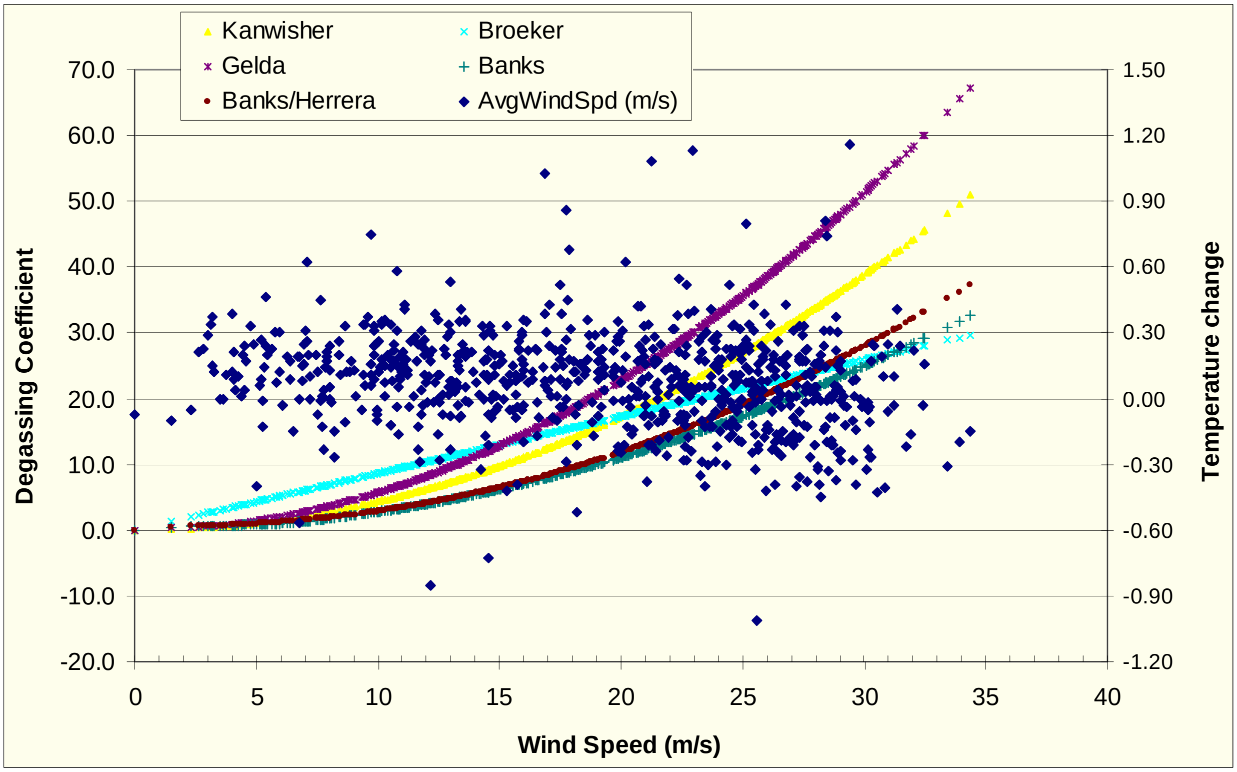

Figure 21. Comparison of Water Temperature Increases to Wind Speed

Given the clear mathematical relationship between spill quantities, the load allocations (ΔP), and TDG percent saturation, compliance with load allocations will be met by specifying operational and structural goals for spills that prevent the load allocation from being exceeded. In general, the long-term goal of meeting water quality standards must be met with structural modifications to the dam projects. In the short-term, operational methods will be used to protect beneficial uses to fullest extent and meet standards whenever possible.

Long-term Compliance with Water Quality Standards

Compliance with Standards for All Spills

Federal and state laws and rules require compliance with state water quality standards, and therefore the ultimate goal of this TMDL is to achieve compliance. However, to meet this goal, this TMDL must address several complicating factors.

In much of the literature a distinction is made between "voluntary" and "involuntary" spill. In terms of compliance with water quality standards, this distinction is misleading. Endangered Species Act requirements for spills must be considered to be just as binding as Clean Water Act requirements. And like many other situations in the environmental field, the solution for a problem impacting one resource may cause problems to another resource. As an example, chlorine may be added to wastewater to provide disinfection to protect public health. But chlorine also can create a problem with toxicity in the effluent for fish and other beneficial species. This conflict does not mean the dischargers get to stop disinfecting, it means that they either need to reduce chlorine toxicity by dechlorination or find other non-chlorine methods of disinfection. The goal here is to balance two valued resources, human health and aquatic life. Similarly, the dams have an obligation to both meet water quality standards and Endangered Species Act requirements. If spills are necessary to protect endangered species, then those spills must also meet standards to protect aquatic life in general. The dam operators also have the option of finding alternative ways to protect species without spills.

The point here is that spills for fish passage are not really "voluntary"; rather they are spills required for reasons other than a lack of powerhouse capacity. If the public interest necessitates that spills be required to protect fisheries or other beneficial uses of the water, then dams must meet water quality standards under spills of any volume up to the 7Q10 flood flows. In addition, spills can occur at any time and at any volume due to lack of power demand or powerhouse maintenance or failure. Therefore, this TMDL will be applicable for all spills below 7Q10 river flood flow conditions, regardless of the cause of the spill. (See Table 14 in *Seasonal Variations* for 7Q10 flows.)

Operational versus Structural Solutions

The Lower Columbia River dams, as currently designed, are incapable of meeting the water quality standards for all spill flow levels. Therefore, compliance with this TMDL will require structural changes. The Dissolved Gas Abatement Study (DGAS) report outlines a variety of alternatives for operational and structural changes, which move in the direction of compliance under all spill levels. However, the effectiveness of these changes can only be estimated, and must be assessed after implementation. Also, implementation of structural solutions is dependent on Congressional appropriations. Therefore long-term compliance with this TMDL will take a significant length of time and must take into account a certain level of inherent uncertainty.

Compliance Locations

The compliance locations for dam spills were chosen from several options, illustrated in Figure 22:

1. By a strict interpretation of state water quality standards without any consideration of applying the mixing zone provisions of the water quality standards, the point of compliance would be at the point of maximum TDG. However this is a location that is difficult to identify and monitor in real time, and does not take into account the rapid degassing in the aerated zone.

2. If mixing zone provisions were applied to the aerated zone, then the point of compliance would be at the end of the aerated zone. This location would be easier to identify for regulatory purposes.

3. The point of compliance could be at the FMS sites, but mixing zone provisions would need to be applied to the entire river, including powerhouse flow. The location of the FMS sites area clearly identified, but are inconsistent with respect to the mixing of spills with powerhouse flows.

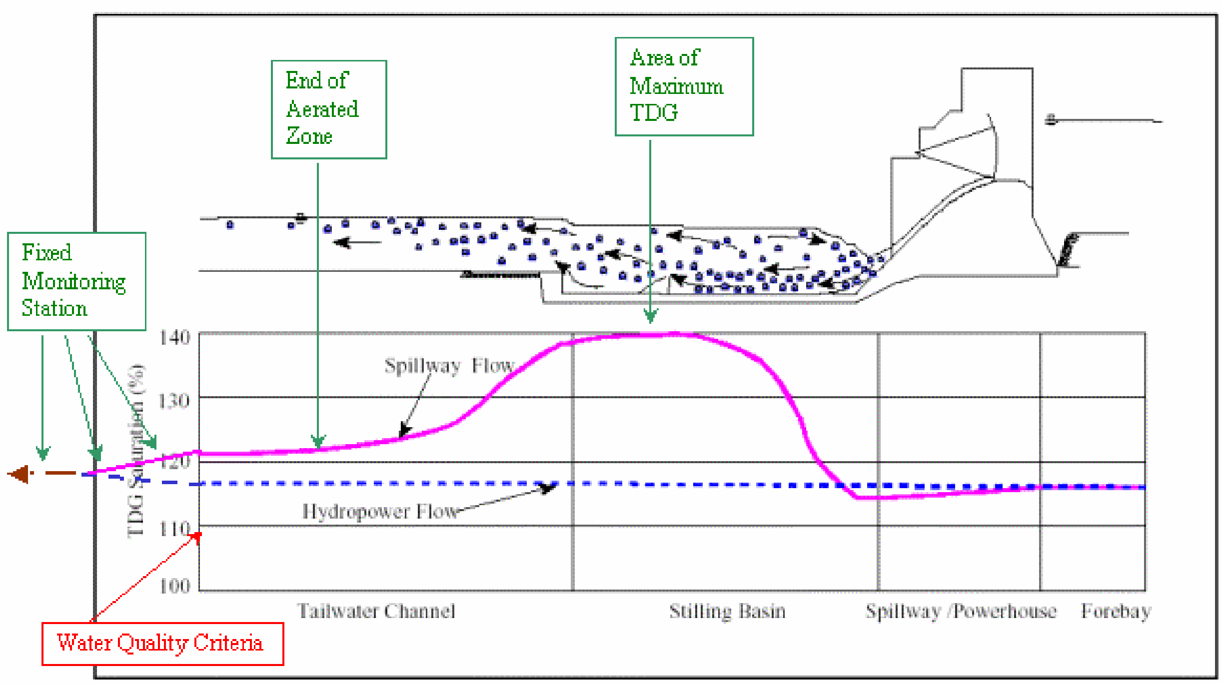

Figure 22: Possible locations of Compliance Locations with Respect to TDG Levels

The point of compliance for load allocations for the dams in this TMDL will be based on application of the mixing zone to the aerated zone immediately below the spillways of the dams. The water quality standards for the states of Washington and Oregon provide an allowance for a mixing zone, and compliance with standards is required at the boundary of the mixing zone.

There are several reasons that use of a mixing zone is appropriate in this situation:

- TDG levels rise immediately below the spillway, but then degas for some distance downstream. The points of compliance were determined from U.S. Army Corps of Engineers 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 very dynamic, TDG levels are difficult to accurately assess.
- Extensive fisheries research has shown that most anadromous 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, little or no resident fish habitat is available in this area. (The zone below the compensation depth is 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 compliance locations for load allocations are shown in Table 13. The load allocation for the upstream boundary applies below the Snake River confluence, and will be addressed in the TMDLs for the Mid Columbia and Lower Snake rivers. The compliance location for each spill load allocation will be at the end of the aeration zone in the tailrace of each dam, at the location specified in the Table 13. The pool above each dam also must comply with the load allocation for the upstream dam, which is equal to the loading capacity.

Monitoring of Compliance

For monitoring of long-term compliance, it will be necessary to monitor at the loading capacity compliance locations in the tailrace. However, it is not expected that these locations will lend themselves to a permanent remote monitoring setup. Compliance will be determined in two ways: (1) periodic synoptic surveys, especially after structural changes have been completed, and (2) continuous monitoring, using a statistical relationship between the continuous monitor and conditions at the compliance location. This allows long-term monitoring to be managed separately from monitoring for short-term operational needs.

For short-term compliance, the FMS stations can continue to be used, or new FMS stations can be established. This will allow operational management that is linked to easily accessible data, based on overall environmental management needs and the realities imposed by structural characteristics. Thus, short-term compliance can remain adaptive and flexible, while long-term compliance remains fixed to firm goals.

Table 13: Compliance Locations for TDG Load Allocations

Project	Location
Upstream Boundary	Below Snake River confluence (to be linked to upstream TDG TMDLs)
McNary Dam spill	1000 feet below end of McNary spillway [1]
John Day Dam spill	1700 feet below end of John Day spillway [2]
The Dalles Dam spill	600 feet below end of The Dalles spillway [3]
Bonneville Dam spill	1700 feet below end of spillway [4]

[1] Wilhelms and Schneider, 1997b
[2] Schneider and Wilhelms, 1999
[3] Schneider and Wilhelms, 1996
[4] Wilhelms and Schneider, 1997a

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- or low-flow critical conditions exist for this TMDL. Spills that generate high gas levels can occur in any season and load allocations are applicable to spills at all flow levels below the 7Q10 flood flow.

Certain parameters that are necessary to develop load allocations were established at levels equivalent to critical conditions. As described above, time of travel, temperature, and barometric pressure were all developed at critical levels. This approach introduces several conservative assumptions that provide a margin of safety to the TMDL.

Criteria versus Site-specific Conditions

Probably few river systems have been as extensively studied for the effects of TDG than the Columbia system. Extensive research has been conducted for over 40 years on TDG and aquatic life. Currently federal, state, and tribal fishery agencies all support a more lenient standard than currently in state regulation. Review of EPA guidance also suggests the 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 monitoring requirements imposed by the Oregon Environmental Quality Commission and Washington State Department of Ecology as a part of the fish passage program over the past seven years, there is a great deal of hourly data of TDG levels, barometric pressure, water temperature, tailwater elevation, forebay elevation, total river flow and spill quantity. Fairly rigorous standardized data quality procedures are provide for these data. These data are available on the Technical Management Team homepage, hosted by the Northwest Division of the U.S. Army Corps of Engineers at: http://www.nwd-wc.usace.army.mil/TMT/welcome.html.

Further, the Corps has undertaken an extensive Dissolved Gas Abatement Study (DGAS) over the past five years. The study included near-field TDG monitoring and the development of a mathematical model to describe the production, dissipation, and behavior of TDG in the Columbia system for the federal projects. The data collection also followed standardized data quality procedures. The production of TDG at the four hydroelectric projects that are the identified sources in this TMDL are, therefore, well understood.

As a result of this monitoring, there are abundant data of good quality for constructing this TMDL. The margin of safety required for data and modeling variability is therefore considered to be small.

Seasonal Variations

Exceedances of the TDG standard occur most commonly during mid-April to the end of August, which is both the fish migration season and the high-flow season in conjunction with spring runoff. One of the determinants of TDG levels is total river flow. When river levels are particularly high, TDG levels rise more rapidly if there is any water spilled over the spillway. During low-flow periods, there is generally not a TDG problem, other than spill for fish passage, as long as all water is passed through the powerhouses.

Occasionally turbine units will be out of service for maintenance, either scheduled, or on an emergency basis. This may require water to be spilled, because there are insufficient turbines available to handle the water in the river. This can occur due to Bonneville Power Administration power purchasing and the sequencing of water releases from upstream storage reservoirs.

Clearly, there is little control over emergency outages. Maintenance is generally scheduled (1) to coincide with low electricity demand periods, and (2) when river flows are such that they will not cause TDG exceedances.

In summary, spills can occur at any time, although they are most likely in the spring and early summer. The TMDL has been written so that the limits apply at any season, since they are based on spill and not on river conditions. The *Margin of Safety* section describes how seasonal critical conditions were applied to the development of load allocations. TMDL limits apply year-round, but they have taken season critical conditions into consideration.

7Q10 Flows

As discussed above, Oregon and Washington’s water quality standards only apply when river flows are below the 7Q10 flood flows. These flows, shown in Table 14, were calculated from flows measured and reported by the U.S. Geological Survey. Methodology followed the guidelines of the U.S. Water Resources Council (1981):

- U.S. Geological Survey flows at The Dalles were used for The Dalles Dam and as a starting point for the other three dams.
- For Bonneville Dam, flows from the major tributaries below The Dalles (Hood, Klickitat, and White Salmon rivers) were added on a day-by-day basis to create a synthetic time series for Bonneville, and then followed the process for fitting the distribution and calculating the 7Q10.
- For John Day Dam, Deschutes River flows were subtracted from The Dalles flows, lagging The Dalles data by two days. The lag was determined by the best fit to a linear regression from a series of different lags using the 90 percent highest flows.
- For Mc Nary Dam, John Day River flows and Umatilla River flows were subtracted from the John Day Dam flow series, lagging the John Day Dam and River flows by three days. The lag was determined as described above.

Annual peak 7-day average flows were calculated (using the October-September Water Year from 1975 through 2000), and then the 10-year return flow was determined by the Log-Pearson Type 3 method. The skew coefficient used in the analysis was calculated from the data; the generalized and weighted skew was not determined or used, but the error introduced by this shortcut was probably small to nil.

Table 14: Lower Columbia River 7Q10 flood flows

Site	Flow (cfs)
Mc Nary Dam	447,000
John Day Dam	454,000
The Dalles Dam	461,000
Bonneville Dam	467,000

Summary Implementation Strategy

Overview

The goal of this total dissolved gas TMDL for the Lower Columbia River is to meet Oregon and Washington's water quality standards for TDG. The goal of water quality standards is to protect beneficial uses of the river. While these include such beneficial uses as hydropower generation, irrigation, drinking water, and water contact recreation, the most sensitive use is anadromous salmonids. These species are particularly vulnerable, as they navigate past the dams both as downstream migrating juveniles and as upstream returning adults.

The four dams on the river pass water by spilling over the spillway, by generating electricity through the turbines, and to a much lesser extent by passing water through special fish facilities such as adult ladders and juvenile fish passageways. TDG is generated by spilling water over the spillway. Absent considerations for fish survival, spills are considered "involuntary" since they occur due to lack of powerhouse capacity. Involuntary spills can be caused by flood flows, lack of electric load for powerhouse generation, or turbines being off-line due to maintenance or repair. However, fish survival needs necessitate spills to improve juvenile fish passage.

Up to a point, the danger to fish from exposure to high TDG is overshadowed by the dangers to fish of going through the turbines. In response, the National Marine Fisheries Service performed a comparison risk analysis that forms the basis for modifications to both Washington and Oregon's water quality standard for TDG.

In December 2000, the National Marine Fisheries Service released a Biological Opinion under the federal Endangered Species Act for 12 listed species in the Columbia River. A significant component of this Biological Opinion is the provision of spilled water at the Lower Columbia River hydropower facilities to facilitate fish passage. In addition, spill for juvenile fish passage is beneficial for non-ESA listed species. Clearly, if spilled water is the cause of elevated TDG levels but is required for fish passage, care needs to be taken not to implement gas abatement measures that may benefit water quality, while damaging the beneficial uses, such as juvenile migration, that the federal Clean Water Act was designed to protect.

This implementation strategy therefore must take into account both requirements: to reduce high TDG generated at the dams by spilling water, and to provide the levels of spill under the Biological Opinion to facilitate fish passage. Additional provision for spill is sometimes necessary for non-listed species.

Gas reduction at the four Lower Columbia River dams has been the subject of intensive research over the past six years. Federal fish agencies, tribes, the U.S. Environmental Protection Agency, Bonneville Power Administration, state fish and wildlife departments, and the U.S. Army Corps of Engineers are organized into work groups to address the TDG problems. The result of this is a much enhanced understanding of the generation and dynamics of TDG production. In addition, implementation actions designed to reduce TDG generation have already been undertaken (e.g., the installation of flow deflectors or “flip lips” at John Day Dam). Further actions are planned, but funding is often dependent on Congressional approval and is linked to basin priorities for the Columbia River.

Implementation Plan Development

The operation of the Columbia River hydropower system is carried out through multiple agencies and governed by several regulatory authorities. The following is a list of these parties:

- The U.S. Army Corps of Engineers operates the dams and provides engineering, contracting and construction authorities (based on funding from Congress) for structural changes at these dams. The Corps provides flood control oversight and responds to the energy, environmental, transportation, and recreational needs of the public. The Corps is required to achieve a balance between these requirements where they conflict.

- The National Marine Fisheries Service and the U.S. Fish and Wildlife Service oversee the protection of endangered species, 12 of which are salmonids found in the Lower Columbia River. Several forums have been established to oversee implementation of the Biological Opinion requirements for these species. These forums include a water quality team which focuses on temperature and TDG management, a technical management team that makes decisions regarding hydropower operations, a system configuration team that makes decisions on structural modifications, and an implementation or policy team to which policy issues that cannot be resolved in the other forums are elevated.

- Tribes have treaty rights to the salmon in the Columbia and are involved on many levels of fish management and environmental protection.

- The Bonneville Power Administration oversees power production and distribution. Revenues help fund fish and environmental mitigation for the impact of the dams.

- Washington and Oregon Departments of Fish & Wildlife work within the forums detailed above, as well as protect and enhance non-listed salmon, resident fish, and wildlife.

- The U.S. Environmental Protection Agency is part of the caucus of federal agencies involved in operation and management of the federal Columbia River hydropower system. Its specific role is to ensure consistency with federal environmental laws and regulations. The agency will ultimately approve this TMDL under Section 303(d) of the federal Clean Water Act.

- Washington State’s Department of Ecology and Oregon’s Department of Environmental Quality will oversee implementation of this TDG TMDL. They will work collaboratively with each other, as well as with the U.S. Army Corps of Engineers, tribal, and other state and federal agencies through existing forums.

- Numerous other agencies are involved in different aspects of river management that can have a bearing on TDG generation. The most prominent include the Northwest Power Planning Council, data gatherers such as the Fish Passage Center and U.S. Geological Survey, upriver activities and interests that affect gas production such as BC Hydro and the U.S. Bureau of Reclamation, as well as Corps storage facilities in Canada and Lake Roosevelt: the U.S./Canada Treaty power sharing and storage agreement, public utility districts on the Mid-Columbia, and the state of Idaho.

Meeting the load allocations in this TMDL will fall into two phases. Phase I will involve improving water quality, while ensuring that salmonid passage is fully protected in accordance with the National Marine Fisheries Service's Biological Opinion. Phase II will involve structural and operational changes to dams to achieve the water quality standard for TDG.

The short-term actions in Phase I will focus on meeting the fish passage performance standards as outlined in the National Marine Fisheries Service 2000 Federal Columbia River Power System Biological Opinion through spills that generate gas no greater than the “waiver” levels of the water quality TDG standards (Oregon variances or Washington temporary special conditions). Water quality standards are measured at existing fixed monitoring stations managed by the U.S. Army of Engineers and U.S. Geological Survey. This phase will also include short-term structural modifications at the dams to achieve TDG reductions during periods of spill, while ensuring that the fish passage requirements of the 2000 Biological Opinion are met. As part of Phase II, a Detailed Implementation Plan or equivalent will be developed (possibly through the Water Quality Plan under the Biological Opinion).

Phase II will evaluate success from the short-term actions. The second phase will also move toward further structural modifications and reductions in fish passage spill if the Biological Opinion specified performance standards are being met and adequate survival is provided for non-listed species.

Biological monitoring has been required by the states of Oregon and Washington in order to assess gas bubble trauma to fish as a result of spill. Based on six years of data, the results show little trauma to migrating juvenile salmon at TDG levels allowed by the states in their modified water quality standards. As a result, thought has been given to permanently modifying the water quality standards or establishing site-specific criteria for TDG for the Columbia River. The purpose of this TMDL, however, is to allocate loads to meet the existing water quality standard.

Changing water quality standards is a separate process and is not one of this TMDL's implementation strategies. However, the authors of this report support the evaluation of the appropriateness of the water quality standards for these four specific sites on the river in terms of TDG impacts to aquatic species. Any revision would proceed through the normal scientific review of the standard to ensure full beneficial use protection.

Implementation Activities

As the operator of the four Lower Columbia River dams, the U.S. Army Corps of Engineers published its Final Draft Technical Report and Appendices of the Phase II Dissolved Gas Abatement Study (DGAS) in April 2001. This study was undertaken as part of the Columbia River Fish Mitigation Program. This study has been the result of an ongoing collaborative effort between many federal and state fisheries agencies, dam operators, tribes, and environmental agencies toward reducing TDG in the river in balance with enhancing spill opportunities for juvenile salmon.

As detailed above, this implementation strategy is to be carried out in two phases.

Short Term – Phase I

This phase is already underway, as a result of actions taken by the Corps, and will continue through 2010. As detailed above, the emphasis in this phase will be taking those actions that will result in reductions of TDG, while ensuring the fish passage requirements of the 2000 Biological Opinion are met. The Biological Opinion envisions spill for fish passage under modified water quality standards of Oregon and Washington, as have been provided for the past six years. Included in this program will be the near-term actions that have been identified in the Biological Opinion. Maintenance of required spill at the modified standards to allow for fish passage will be as measured at the fixed monitoring stations both in the forebay and the tailrace of each dam.

This phase will also address the first stages of reducing gas during spills due to high-flow events, turbine outages, and during lack of demand for electrical power. This is outlined in the Corps report, "Final Draft Dissolved Gas Abatement Report," April 2001.

Table 15 includes specific structural implementation actions (from the National Marine Fisheries Service 2000 Federal Columbia River Power System Biological Opinion) that will be completed during this phase and are directly related to achievement of the water quality standard.

Table 15: Short-term Implementation Activities

2000 Biological Opinion Action Item Description	Completion Date	Action Item #
Ice Harbor Deflectors	Done	134
John Day Deflectors	Done	134
Survival based spill caps at all dams (e.g. 40% at The Dalles).	Done, ongoing	68, 82
Bonneville Endbay Deflectors	2002	134
McNary Endbay Deflectors	2002	134
Lower Monumental Endbay Deflectors	2003	134
Little Goose Endbay Deflectors	2003	134
Chief Joseph Deflectors	2003	136
The Dalles Deflectors	Under Evaluation	134
John Day Endbay Deflectors	Under Evaluation	140
Divider Walls at Appropriate Dams	Under Evaluation	135

Several operational implementation actions are available to minimize involuntary spill that are already in use, or can be evaluated during Phase I and implemented if practical. These include:

- Scheduling routine turbine maintenance and repair during low-power load and river flow periods.
- Preventive maintenance of turbines to prevent breakdown.
- System management of water release from upstream storage reservoirs to minimize involuntary spills at dams in the TMDL area.
- Optimizing power purchasing to allow maximum use of powerhouse capacity and minimization of involuntary spill.

Specific implementation methods for these actions will be provided in a Detailed Implementation Plan, or equivalent.

Table 16 contains additional short-term implementation actions that are indirectly related to achievement of the water quality standard. Implementation of these measures, though, is likely to improve salmonid passage and help achieve the performance standards of the Biological Opinion. Carrying out these actions will enable a decreased reliance on spilling water for fish passage in the near-term period. Voluntary spill levels for fish passage with their associated TDG will be reduced as these actions are implemented, and will result in achieving the survival performance standards contained in the 2000 Biological Opinion.

Table 16: Additional Short-Term Implementation Activities

2000 Biological Opinion Action Item Description	Completion Date	Action Item #
Bonneville Powerhouse 2 Corner Collector	2003 or 2004	66
Bonneville Powerhouse 2 Fish Guidance Efficiency Improvement	2003 - 2004	67
Lower Granite Removable Spillway Weir	2002	80
The Dalles Turbine Intake Blocks	2002 - 2004	69
Lower Monumental Bypass Outfall Relocation	2003 or 2004	76
The Dalles Sluiceway Outfall Relocation	Under Evaluation	70
Bonneville Powerhouse 1 Surface Bypass or Extended Screens	2004 or 2005	61, 62

Long Term – Phase II

This phase will begin in 2011 and proceed through 2020. Actions taken in the previous phase will be reviewed for their efficacy, both in improving TDG levels and for protecting salmonid passage. The Biological Opinion survival goals are being met through fish passage actions other than spilling water. Reductions in gas entrainment through spill will be realized so that the required final goal of meeting the water quality standard for TDG can be met as measured at the end of the aerated zone below each dam.

Table 17 details those long-term actions that will protect fish passage while moving the system toward attainment of the water quality standard for TDG.

Table 17: Fish Passage Actions That Support TDG Water Quality Goals

2000 Biological Opinion Action Item Description	Completion Date	Action Item #
John Day Surface Bypass (may be Removable Spillway Weir)	Under Evaluation	72
Removable Spillway Weirs at Lower Monumental, Little Goose, and Ice Harbor	Under Evaluation	75, 77
McNary Bypass Improvements (outfall, temperature)	Under Evaluation	74, 142
Lower Monumental Extended Screens	Under Evaluation	78
John Day Extended Screens	Under Evaluation	73
Spill Effectiveness Studies	Ongoing	83
Predator Removal and Abatement	Ongoing	100-103
Improved Operation and Maintenance	Ongoing	58,59,63,144, 145,146
Bonneville Powerhouse 1 Minimum Gap Runners	Ongoing	64
Implement Turbine Survival Program Results	Under Evaluation	88, 90, 91, 92

The U.S. Army Corps of Engineers DGAS study identified a number of structural measures designed to abate TDG. Several of these measures should be evaluated for their efficacy in abating gas and ensuring that they provide safe and effective fish passage. If necessary, those measures found to be effective and safe should be identified for funding and implementation.

Reasonable Assurance

In support of this implementation strategy, structural work has already been carried out to reduce high levels of TDG at the four Lower Columbia River dams. Structural work has also been done on Snake River and Mid-Columbia River dams that can reduce high gas concentrations to the lower river. The track record for Congressional funding for these projects is good and there is reason to believe that further funding of projects will continue. Funding for the more expensive structural modifications of the second phase is entirely dependent on Congressional will, national and regional priorities, and budgetary availability of funds. Funding to improve fish passage facilities also has a good track record, and there is reason to believe that this will continue to be funded both through Congress and energy revenues.

Both the Washington State Department of Ecology and the Oregon Department of Environmental Quality are responsible for ensuring that water quality standards are met. Both agencies are confident that the collaborative relationship with the dam operators toward reducing gas will continue and be enhanced through this TMDL. The U.S. Army Corps of Engineers has agreed to continue working through the Endangered Species Act forums established to oversee and to carry out the requirements of the Biological Opinion.

Both state environmental agencies have regulatory authority over the four federal dam projects. Washington's regulatory authority comes through the *Federal Clean Water Act*, the *Revised Code of Washington's Pollution Control Act 98-48* and the *Washington Administrative Code's Water Quality Standards 173-201A*. Oregon's authority comes through the *Federal Clean Water Act*, the *Oregon Revised Statutes' Water Pollution Control 468B*, and the *Oregon Administrative Rules' Water Quality Standards and Beneficial Uses 340-041-0001 to 0975*.

Adaptive Management

The process for reviewing the status of implementation of this TMDL will follow the timing and process for the review of the federal Biological Opinion in 2010. The Washington State Department of Ecology will convene an advisory group comprising representatives of tribes and federal and state agencies to evaluate appropriate points of compliance for this TMDL. Based on these findings, further studies may be needed, and structural and operational gas abatement activities will be redirected or accelerated if needed.

Monitoring Strategy

Short-term compliance and the effectiveness of operational implementation actions will be monitored at existing fixed monitoring station sites. The current fixed monitoring station TDG monitoring system consists of tailrace and forebay monitoring stations at each mainstem lower Snake and Columbia River dam and at key locations in some tributaries. While most of these stations do a credible job of reporting meaningful data, some have been shown to be questionable. This system is now undergoing a thorough review by the National Marine Fishery Service's Water Quality Team. Screening criteria will be developed and used to evaluate all existing monitoring stations. Stations that do not conform to these criteria will be relocated to more appropriate locations. This screening process will include consideration of how well the station represents TDG and water temperature in a given river reach and how sensitive the station is to non-spill factors that affect TDG, such as temperature and aquatic plant respiration.

Monitoring of long-term compliance with load allocations and the effect of structural changes will include an evaluation of previous and future near-field transect studies at the compliance location (the end of the aerated zone below each dam). Load allocation compliance monitoring will occur following major structural changes or immediately following the end of Phase I and

Phase II. Also, statistical relationships may be developed between TDG levels at the continuous monitoring location and the compliance location that allow real-time and long-term trend evaluation of compliance. Prior to the initiation of a load allocation monitoring survey, a quality assurance project plan, or equivalent, must be approved by the Washington State Department of Ecology and the Oregon Department of Environmental Quality. The quality assurance project plan should address the safety and stability of the site to support monitoring equipment and activities when subject to the strong hydraulics below the dams. Due to these factors, it is possible that an alternate site may be needed. If so, some correlation to the load allocation compliance point will be necessary.

Potential Funding Sources

A discussion on funding is warranted, given the expensive nature of some of the suggested structural actions. Known funding sources include power generation revenues through Bonneville Power Administration, as directed by the Northwest Power Planning Council and System Configuration Team and the U.S. Congress. State, tribal, and federal agencies will continue to work with their counterparts in Canada in an attempt to reduce the TDG loading coming across the international border. Canada has shown a great willingness to invest in technologies to help reduce TDG loadings.

Summary of Public Involvement

The states of Washington and Oregon developed and implemented the Public Involvement and Outreach strategy for this TMDL project in partnership with the Columbia/Snake Rivers Mainstem TMDL Coordination Team.

These TMDL team members include the U.S. Environmental Protection Agency, Idaho Department of Environmental Quality, Oregon Department of Environmental Quality, Washington State Department of Ecology, Western Governors Association, Columbia Basin Tribes, and the Columbia River Inter-Tribal Fish Commission.

The public involvement period on this proposed TMDL began February 18, 2002 and ended April 15, 2002.

Public hearings were held:

- March 18, in Kennewick, Washington
- March 19, in Pendleton, Oregon
- March 22, in Portland, Oregon and in Vancouver, Washington

Individual outreach meetings were held with the appropriate watershed advisory groups and with primary stakeholders, which included:

- Spokane Tribe
- Confederated Tribes of the Colvilles
- U.S. Army Corps of Engineers (Portland, Walla Walla, and Seattle Districts, and Pacific Northwest Division)
- Grant, Chelan, and Douglas Public Utility Districts
- U.S. Bureau of Reclamation
- Bonneville Power Administration
- National Marine Fisheries Service

In addition, meetings and presentations were held with the National Marine Fisheries Service Water Quality Team that includes federal and state agencies, public utility agencies, tribes, and Bonneville Power.

The TMDL team held public meetings to receive input and comments from all interested participants. These meetings included public workshops to accept informal comments for each regional phase of the TMDL project, and public hearings for the formal public comment period.

The TMDL team used public outreach tools such as letters, focus sheets, and other printed materials; websites with short narratives and graphics, downloadable documents and relevant links; news releases and special news articles; and field visits.

Public Involvement Actions

- U.S. Environmental Protection Agency website
- Focus sheets
- News releases
- E water news – Washington State University Water Research Center newsletter article
- Monthly coordination team meetings – EPA, Idaho Department of Environmental Quality, Oregon Department of Environmental Quality, Washington State Department of Ecology, Western Governors Association, Columbia Basin Tribes, Columbia River Inter-Tribal Fish Commission (CRITFC)
- Monthly updates and discussions with the NMFS Water Quality Team
- Presentations to the NMFS Implementation Team
- Periodic meetings with Transboundary Gas Group
- Public workshop in Portland, OR – Nov. 28, 2000
- Columbia River Tribal TMDL workshop – Nov. 17 - 18, 2000
- Meeting with U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, and Bonneville Power Administration – Jan. 30, 2001
- Meeting with Grant County Public Utility District – Feb. 2, 2001
- Meeting with Mid-Columbia Public Utility Districts – Feb. 14, 2001
- Meeting with Pulp & Paper Association – Feb. 27, 2001
- Meeting with East Columbia Irrigation District – March 9, 2001
- Meeting with Mid-Columbia Public Utility Districts – March 13, 2001
- Transboundary Gas Group – April 5, 2001
- Western Governors Association joins the Columbia/Snake TMDL Coordination Team – May 2001
- Public meetings in Spokane, WA and Portland, OR – July 23 - 24, 2001
- Presentations to Southwest Washington Watershed Planning Unit – Sept. 10, 13, 26, 2001
- Presentation to Lower Columbia River Fish Recovery Board – Sept. 12, 2001
- Washington Pulp & Paper – Sept. 14, 2001
- Presentations to CRITFC Tribal Water Quality Conference – Sept. 26 - 28, 2001
- Public meetings in Lewiston, Idaho and Pasco, WA – October 29 - 30, 2001
- Meetings with Spokane and Colville Tribes – Nov. 5 - 6, 2001
- Meetings with U.S. Army Corps of Engineers and U.S. Bureau of Reclamation – Nov. 5 & 15, 2001
- Meeting with CRITFC – Nov. 26, 2001
- Meeting with Washington Department of Fish and Wildlife – Dec. 11, 2001
- Meetings with Mid-Columbia Public Utility Districts – Dec. 18 - 20, 2001

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Appendix

Response to Comments from the Public Review Period, February 18 – April 15, 2002

Table of Contents for the Appendix

Introduction

The public review draft of the *Lower Columbia River Total Dissolved Gas TMDL* was released for public comment on February 18, 2002. A comment period of 45 days was established by public notice issued concurrently with the release of the draft TMDL. The notice scheduled four public hearings and a closing date for the receipt of written comments. A copy of the public notice is attached near the end of this appendix.

Public Hearings

Four public hearings were held:

1. Kennewick, WA.
   Washington Department of Ecology Field Office
   1315 W. Fourth Avenue

   Monday, March 18, 2002
   3:30 p.m. Question and Answer Session
   4:00 p.m. Public Hearing

2. Pendleton, OR.
   Tamastslikt Cultural Institute
   72789 Highway 331

   Tuesday, March 19, 2002
   1:30 p.m. Question and Answer Session
   2:00 p.m. Public Hearing

3. Portland, OR.
   Oregon State Office Building
   800 NE Oregon Street

   Friday, March 22, 2002
   8:30 a.m. Question and Answer Session
   9:00 a.m. Public Hearing

4. Vancouver, WA.
   Washington Department of Fish and Wildlife
   2108 Grand Boulevard & Fourth Plain

   Friday, March 22, 2002
   1:00 p.m. Question and Answer Session
   1:30 p.m. Public Hearing

No public testimony was offered at these hearings. Sign-in sheets for these four hearings are attached at the end of this appendix.

Written Comments

Written comments were received from the following:

- Steven Hays, Fish and Wildlife Consultant, Chelan County Public Utility District No. 1
- Alexandra B. Smith, Vice President Environment and Wildlife and Roy B. Fox, Manager Federal Hydro Projects, Department of Energy, Bonneville Power Administration
- Jannine Jennings, Watershed Restoration Unit, Office of Water, United States Environmental Protection Agency, Region X
- Liaqat Khan, ENSR International
- Mark J. Schneider, Water Quality Advisor, United States Department of Commerce, National Marine Fisheries Service
- Deirdre Marlarkey
- Gerald R. Bouck
- Stu McKenzie
- Candice J. Irish, Records Management Consultant, NSRI
- Michele DeHart, Fish Passage Center
- Don Sampson, Executive Director, Columbia Inter-Tribal Fish Commission
- Rick Emmert, United States Army Corps of Engineers[1]
- Mike Schneider, United States Army Corps of Engineers[2]

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[1] Comments received via e-mail on April 9, 2002.

[2] Comments received via e-mail on April 11, 2002.

Response to Comments

The following response to comments is organized under the same headings as are found in the draft TMDL. A general section for comments that are overarching precedes them.

General Comments

Comment: Ecology and Oregon DEQ Draft TMDL is Well Written and Technically Adequate. Chelan PUD wishes to compliment the authors for producing a TMDL document that is clearly written, understandable and technically complete. The TMDL document does well in laying out the regulatory and scientific basis for the load allocations, its explanation of the physical mechanisms producing TDG and the discussion of the dilemma of using spill to improve fish survival while attempting to meet water quality standards.
Response: This TMDL has been greatly strengthened by public input and technical and policy input from many people.

Comment: The Public Participation Process has been Thorough. Chelan PUD appreciates the efforts taken by Ecology, Oregon DEQ, and EPA to assure adequate public participation and participation by the regulated community, including the mid-Columbia PUDs. Chelan PUD has reviewed each of the three draft TMDLs and appreciated the time and opportunity given us to follow the development of this TMDL.
Response: Thank you.

Comment: NEPA/SEPA Analysis Is Appropriate Even If Not Required. The role of this TMDL as an action requiring NEPA/SEPA review is somewhat ambiguous in the document. The document states "in Oregon and Washington, a TMDL is a planning tool, not a rule of law or stand-alone enforceable document" (p. 4). However, in the same paragraph it states that "TMDLs may be used to condition exemptions, modifications, variances, permits, licenses, and certifications." The statements appear to be contradictory. While the TMDL itself may not initiate an action, Ecology and other agencies will certainly use it as justification for regulatory actions and may require that agency decisions regarding permits, certifications, licenses and other regulatory procedures conform to the allocations and implementation plans expressed within this TMDL. Given this level of importance, it would be appropriate to treat this TMDL as a significant rulemaking activity that should be reviewed in conformance with the requirements of the National Environmental Policy Act or Washington State Environmental Policy Act. The implementation plan, particularly for long-term compliance, could have significant environmental effects for both aquatic life and other environmental concerns. For example, major structural changes to the projects, such as raised stilling basins and tailraces, side channels, submerged spill and other major changes to the river bed or project structures, may be the only way that the current water quality standard of 110% TDG can be accomplished for involuntary spill at levels approaching the 7Q10 flows. The October 2001 Preliminary Draft TMDL noted that these measures would cost from $100 million up to over $1 billion, yet would still likely fail to meet the load allocation at 7Q10 flows. The U.S. Corps of Engineers DGAS Program also identified that a number of these potential options would pose risk of injury to fish. Certainly, the raised tailrace option would have impacts to habitat for sturgeon and other non-salmonid fish

in the Columbia River. While a NEPA/SEPA analysis may not technically be required for the TMDL, the delineation of environmental impacts that could result from measures taken to meet the 110% TDG standard would be an appropriate and responsible action for Ecology to undertake as part of the process for establishing the TMDL and implementation plan. Certainly, the environmental and social consequences of meeting the load allocations established in the TMDL should be reviewed prior to using the TMDL to "condition exemptions, modifications, variances, permits, licenses, and certifications".
Response: The state environmental agencies do not take any environmental action or decision by preparing and submitting load allocations to the Environmental Protection Agency for their approval. The "exemptions, modifications, variances, permits, licenses, and certifications" that use the TMDL for input are the actions that could trigger NEPA/SEPA. Therefore no National or Washington State Environmental Procedures Act process is required or appropriate. (Oregon has no process analogous to NEPA or Washington's SEPA.)

Comment: I have not been able to obtain a copy of the draft TMDL.
Response: A copy was sent, along with the URL for the website the same day.

Comment: A TMDL for total dissolved gas should not be adopted until research clarifies whether N_2 or total dissolved gas is a more accurate estimator of safe conditions for fish and aquatic life at low levels of saturation.
Response: A TMDL is required to be written in order to address an exceedance of a current water quality standard. Currently, the standard is specified as total dissolved gas. There is the opportunity to consider a standard change in conjunction with the States' triennial standards review. The Implementation Plan appended to the TMDL provides for a review of the standard in the long-term actions. This would be an appropriate time to consider the efficacy of changing to N_2.

Comment: How does this TMDL promote the system Water Quality benefits associated with pollution trading? This document seems to be headed towards the preparation of a "TMDL TDG report card for individual projects". How will system TDG abatement solutions that involve pollution trading fit into this TMDL formulation?
Response: Most pollution trading projects currently in place deal with the cumulative effects of nutrients in waterbodies such as lakes or rivers. The TDG problem is not a cumulative situation and requires a solution that does not allow TDG exceedances above the criteria at any location on the river outside of the mixing zone. (An assumption here is that the sources of TDG have implemented all technology-based requirements for TDG reduction.) Pollution trading does not directly apply due to the nature of TDG generation during spills. Typical spills supersaturate the water with gas then release the gas during travel through the aeration zone. The level of TDG in a parcel of water after passing through a spillway is independent of the level of TDG in the parcel prior to the spill. Each dam is responsible for the TDG effects during spill events at the dam.

In the Lower Columbia, planning to minimize adverse spills at the four dams will continue within the Corps. In future TDG TMDLs there may be situations where TDG is cumulative or where trading can occur as part of the interim implementation period. For example, trading may be able to occur between spill at one dam and power generation at another. These possibilities will be addressed at the appropriate time.

Comment: How will progress towards meeting TMDL objectives be determined? What metric will be used and over what time frame will this evaluation take place? Need to recognize the substantial effort that has already been implemented by CE at lower Columbia River project.
Response: Progress will be measured in two principal ways. The FMS monitoring network will be used to evaluate real-time data. As long as the FMS is reporting TDG levels above the standards, the TMDL objectives have not been achieved. But long term trends could be evaluated to determine progress towards the objectives. Second, as major structural modifications are implemented, near-field monitoring could be conducted under varying spill conditions to determine the effectiveness of TMDL implementation at the compliance location. It is likely that these studies will be performed after major work or at the end of each implementation phase.

List of Figures

No comments received.

List of Tables

No comments received.

Acronyms and Abbreviations

No comments received.

Abstract

Comment: Page vii, PH 1, line 5 – "The entire reach is considered impaired for TDG" What data are you using to say the TDG exceeds 110 percent of saturation to the mouth of the Columbia River? I know of none at the Columbia River mouth.
Response: The data used for the original listing is as follows:

- COE Data (1993);
- WA DOE 303(d) List;
- NMFS (1995);
- 1993 Dissolved Gas Monitoring for the Columbia and Snake Rivers (US Army Corp of Engineers, 1993);
- Fuhrer et al (USGS, 1995).

The Wauna Mill TDG station, at River Mile 42, was the farthest downstream monitoring station. Modeling using MASS1 only extended to River Mile 21. Results from both modeling and monitoring suggest that high gas levels extend downstream considerably farther. For example, during June 1996, when flows were just below 7Q10 flood levels, TDG averaged 125% at Camas and 118% at Wauna Mill. The average drop in gas levels was 7 percentage points in this 80 mile stretch. If gas continued to drop at the same rate, the river would still have been above

110% until the river plume mixed with ocean water. Thus, it is reasonable to infer that impairment of the TDG standards occurs over the entire reach, as stated.

Comment: Page vii, PH 2, line 1 and 2 – "Elevated TDG levels are caused by spill events at four hydroelectric projects on the Lower Columbia River" This suggests that water from the Mid Columbia and Snake Rivers do not exceed 110 percent of saturation? I suggest a reference to the data that shows the high values or alter the wording in this sentence.
Response: The geographic scope of this TMDL is the Columbia River mainstem from the confluence of the Snake River to the mouth of the Columbia River. In this stretch of river, elevated levels of total dissolved gas occur as a result of spill at the lower four hydroelectric projects. However, elevated levels of dissolved gas do arrive at the boundary of this TMDL from both the mid-Columbia River and the lower Snake River. Upstream effects are included in the TMDL as an allocation at the upstream boundary. The sources of upstream TDG will be addressed in separate TMDLs. Wording to clarify this has been added.

Comment: Page vii, PH 2, line 2 – "Water plunging from a spill entrains *air that results in* TDG …" I do not think the spill entrains TDG.
Response: The suggested amendment has been incorporated.

Comment: Page vii – Abstract "Load allocations are also expressed in terms of excess pressure as referenced to the local barometric pressure, with allocations for each dam,"
Response: The suggested amendment has been incorporated.

Comment: Page vii – Abstract "Other allocations must be met in the forebays of the dams." This statement is listed in the abstract but I don't think it is well developed in the following document. If the intent of the TMDL is to comply with the federal WQ standard for TDG of 110% at "any point of measure" then why specify that allocations must be met in the forebays of the dams. It may be more appropriate to recognize that the TDG maximums during the spill season in the Lower Columbia River are most often located within spill waters of main-stem dams and because of this fact should be considered as the limiting point of compliance.
Response: This sentence has been changed to read, "The upstream allocation must be met in the pool above McNary dam." In Phase 2 of implementation, the standard of 110% total dissolved gas must be met below the aerated zone at each dam and in the pools and forebays. In the short term, the higher gas level "waiver standards" in the forebays of each dam have been established in response to needs of Endangered Species Act protected fish. Structural and operational modifications create the ability to create greater masses of gassed water when spilling for juvenile salmon migration. This often causes forebay waiver standards to be exceeded prior to standards at the fixed monitoring stations in the tailraces.

Comment: Page vii, Paragraph 2, Line 3 "gas bubble trauma" in fish which ……
delete: which causes chronic or acutely lethal effects insert: which generally results in chronic gas bubble lesions or may lead to acute mortality
Response: This line has been edited to change "cause" to "can cause". Very high gas levels can be more or less instantly lethal. We agree that gas bubbles can also impair fish health and behavior at lower levels which may lead to death.

Acknowledgements

No comments received.

Executive Summary

Comment: Page ix, PH 1, line 5 – "The entire reach is considered impaired for TDG." Same as the first comment.
Response: The data used for the total dissolved gas 303(d) listings are cited above. Analysis of the data supports this statement.

Comment: Page ix, PH 2, line 1 and 2 – "Elevated TG (sic) levels are caused by spill events at four hydroelectric projects on the Lower Columbia River." This suggests that spills on the Snake River dams and Mid Columbia River dams are not contributing. Is this what you are meaning to say?
Response: See the response above. For the geographic extent of this TMDL the events leading to elevated levels of total dissolved gas are spills at the lower four hydroelectric projects. Elevated total dissolved gas levels arrive at the McNary forebay from the Snake and mid-Columbia Rivers. Upstream effects are included in the TMDL as an allocation at the upstream boundary. The sources of upstream TDG will be addressed in separate TMDLs. The language has been edited to clarify this.

Comment: Page x. Description of the Applicable Water Quality Standards and Numeric Target, "However, the implementation plan allows compliance with waiver limits as an interim allowance for compliance with the TMDL in the short-term." This sentence should specify the time period, such as ten years.
Response: The time period has been specified in the Implementation Plan. However, we have also amended the language in the Executive Summary.

Comment: Page x. A general objectives regarding the proposed point of compliance should be presented.
Response: The general objectives have been included in the main report, and the Executive Summary also mentions the compliance location.

Comment: Page x. Loading Capacity. A scientific description of why 75 mm was selected as a loading capacity should be described.
Response: An abbreviated description of this has been included, as appropriate for the Executive Summary.

Comment: Page x. Pollutant Allocations. Long-term compliance with load allocations for dam spills will be at the downstream end of the aerated zone below each spillway. There will have to be representativeness issues addressed and cross-sectional characterization done at each downstream site. How much of a factor will fish passage considerations in the aerated zone play in the determination of water quality standards compliance?

Response: The long-term compliance location will have to be the most accurately representative place or places below the aerated zone of each dam. Safety of monitoring, hydraulics, representativeness of spill water, and cross sectional characteristics will be taken into consideration. These issues can be addressed specifically in a TMDL effectiveness monitoring plan. Fish passage considerations in the aerated zones will not be taken into account. Fish passage considerations will be taken into account by evaluating TDG levels at the existing fixed monitoring sites in comparison to levels at the long-term compliance locations below the aerated zones, based on alternative fish passage successes.

Comment: Page x, Paragraph 51, Line 2 downstream end of the aerated zone below each spillway delete: each insert italics: downstream end of the aerated zone below *the* spillway *at spill levels equivalent to flows in excess of powerhouse hydraulic capacity at the 7Q10 flow level.*
Response: Highest regulated flows, such as flows close to 7Q10 flows, would move the compliance location far downriver. During non-7Q10 spills the area between the dam and the compliance location might be excessively large, and there might be the potential for turbine water to influence the gas measurements. Also, no data exists that defines the location of end of the aeration zone at 7Q10 flood flows. By the logic employed in the TMDL, the compliance location might move up and down stream with the end of the aeration zone, but this would be very difficult to use in a regulatory setting. The compliance locations in the TMDL are based on existing data from controlled spill studies, and that is the best data we have to work with. The compliance locations will take into account the cross-section, representativeness of gas-producing spill flows, and distance downstream from the dams. Also, since the implementation plan provides many years before the compliance locations come into effect, this allows time to evaluate alternative approaches and collect the data needed to apply them.

Comment: Page x – "Short-term compliance will be established under the implementation plan and will be based on operational management of spill." The ongoing fast-track DGAS program involved additional spillway flow deflectors as a means of reducing the TDG exchange associated with spillway discharges.
Response: This comment has been incorporated.

Comment: What is the rationale for not requiring the specific dams, as identified in the Draft Report, to have NPDES permits? As discussed later in the TMDL, there are only four points of total dissolved gas of concern in the Lower Columbia- Bonneville Dam, The Dalles Dam, John Day Dam, and McNary Dam. Since these are the known sources of total dissolved gas (TDG) why does the TMDL or the water quality agencies not require a NPDES-permit? If a NPDES permit is not required for exceedences of total dissolved gas at the dams, then we do not understand why a temporary TDG waiver for total dissolved gas is required from the Corps to implement the yearly fish spill program. The final Report should explain this inconsistency.
Response: 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 States of Washington and Oregon are to not issue NPDES permits for TDG. Language has been added to this effect.

Comment: page xi -- It looks like year-round TMDL load allocation is year round. We anticipate that current year round monitoring at Warrendale, Bonneville and McNary is adequate.
Response: We agree.

Comment: Page xi, PH 1, line 4 and 5 – "Due to extensive data collection in the TMDL area, the margin of safety for data variability is small." This suggests those large amounts of data mean that variability is small. I would suggest that the variability could still be large, but the uncertainty may be small.
Response: Amended wording has been inserted to clarify this.

Comment: Page xi – "The margin of safety is supplied implicitly by use of conservative critical conditions." Is this the appropriate use of the term critical conditions? Would the usage of compliance threshold conditions be more appropriate in this connotation. The following citation was taken from *Water Quality Standards for Surface Waters of the State of Washington.*
"Critical condition" is when the physical, chemical, and biological characteristics of the receiving water environment interact with the effluent to produce the greatest potential adverse impact on aquatic biota and existing or characteristic water uses. For steady-state discharges to riverine systems the critical condition may be assumed to be equal to the 7Q10 flow event unless determined otherwise by the department.
Response: "Conservative assumptions" is a better term, and has been included here. Nonetheless, the definition of critical conditions still apply since temperature, wind, barometric pressure, spill volumes, and total river flow are characteristics that can interact to produce greater impacts. The key term in the citation is "unless determined otherwise by the department". In this situation we have determined otherwise.

Comment: Page xi. Margin of Safety. Is the margin of safety supplied by the TDG criterion too conservative?
Response: This is not an issue to be addressed in a TMDL. However, in the long-term phase of the Implementation Plan we have indicated that this could be an issue that could be addressed. Also, the apparent stringency of the standards is identified as a source of a Margin of Safety in the Report.

Comment: Page xi. Monitoring Plan. If monitoring of implementation and operational controls in the short term will be accomplished using the fixed monitoring sites, why can't the fixed monitoring sites be used in the long-term instead of using the downstream end of the aerated zone?
Response: The fixed monitoring sites have been established for a variety of reasons, not the least of which is accessibility. Some of them have not been sited in order to monitor a representative site in the river. We believe the edge of the aerated zone provides the most consistent and reliable site at which to measure representative total dissolved gas after it has had a chance to attenuate.

Comment: Page xi – Monitoring Plan - Does this section imply that continuous monitoring will not be needed for the evaluation of long term compliance load allocations?

Response: No, continuous monitoring will still be useful, especially when good relationships can be established between continuous monitoring data and TDG levels at the compliance locations. The language has been edited to reflect this.

Comment: Page xi, Executive Summary – The first sentence under Implementation Plan should read: "…analyzed by the National Marine Fisheries Service in the Biological Opinion and the U.S. Army Corps…"
Response: The sentence has been amended to incorporate this.

Comment: Page xi. Reasonable Assurance. I believe that the statement: "The track record for Congressional funding for these projects is good, and there is reason to believe that further funding of projects will continue." is too general. For instance, funding for Chief Joseph TDG work in FY 02 was not successfully obtained.
Response: The failure of one project to be funded does not negate the generally good funding for work to attenuate total dissolved gas levels. Flow deflectors at Ice Harbor and at John Day, along with other projects have all been successfully funded.

Comment: The monitoring plan is divided into short-term and long-term compliance and the relationship of and timeline for these periods should be described here as well as in the implementation plan.
Response: This wording has been inserted.

Comment: The TMDL discusses the ability of funding for structural projects required to reduce total dissolved gas production from the dams. While there has been past funding available for these types of projects, future funding is less certain. In 2002, the Columbia River Fish Mitigation Program (CRFMP), is not being funded by Congress to the level necessary to meet all of the reasonable and prudent requirements outlined in the 2000 Biological Opinion. Due to budgetary constraints, the Corps and NMFS are prioritizing projects to reduce dissolved gas levels below the current temporary waiver levels lower than 1) projects that address direct survival for ESA-listed species as well as 2) projects that will attempt to identify future management decisions to promote the best operations in the Columbia for fish passage. Further, there is a possibility that BPA may, in the future, assume full responsibility for funding the CRFMP, and whether or not funding for CWA structural measures for total dissolved gas will be prioritized is uncertain.

While CRITFC has strongly recommended that CRFMP projects which address meeting long-term CWA standards for total dissolved gas and temperature be given priority over other CRFMP projects, the federal hydro operating agencies, including the Corps, have largely disregarded these recommendations. CRITFC has also requested that EPA and the state water quality agencies use their authorities to assure that priority be given to these actions, but the water quality agencies have not consistently responded to these requests. It is vital that the final Report clearly outline to the federal agencies that funding of structural measures to meet CWA standards be given priority status, and that the mechanism to force compliance with these actions is definitive.
Response: No Executive Branch action can force a legislative body to appropriate money. We have indicated to the action agencies that we expect that they will vigorously pursue funding, and are looking at ways to give weight to this message so that the likelihood of funding is improved. However, there is no "mechanism to force compliance" available.

Introduction

Comment: The Draft Report identifies that high levels of total dissolved gas have deleterious effects on fish and other aquatic life. This statement should be quantified and qualified. Significant exposure to high levels of total dissolved gas can impact fish *if they cannot achieve depth compensation*.
Response: Certainly elevated total dissolved gas levels have a deleterious effect on fish if they cannot achieve depth compensation. However, even if depth is available, it is not clear that fish take advantage of it. This is only the introductory statement of the TMDL. Greater detail of the effects of elevated total dissolved gas on fish is contained in the body of the document.

Purpose of, and Authority for, TMDL

Compliance with Clean Water Act

Comment: While these TMDLs have been presented in a single document, the Washington Department of Ecology should issue the TMDLs for waters of Washington State and the Oregon Department of Environmental Quality (ODEQ) should issue the TMDLs for waters of the State of Oregon. This should be indicated in the letter accompanying submittal to EPA.
Response: We will ensure that this is done.

Comment: Page 3. Compliance with Clean Water Act. There should be a discussion about the purpose for regulating the TDG standard is for the protection of aquatic life.
Response: This point was covered on page 15 of the draft. A reference to aquatic life has been included here in the final TMDL.

Comment: Page 3, PH 1, line 3 – "confluence of the Snake [and Columbia] **R**iver [s]) to its mouth." My preference of wording.
Response: Wording is difficult here. The clumsiness in the draft was to recognize that we are talking about the length of the Columbia River mainstem from the inflow of the Snake River to the mouth (of the Columbia River). The difficulty with alternative wording is that it can convey the impression that the mouth refers to that of the Snake River.

Comment: Page 3, PH 1, line 3 and 4 – "This entire reach of the river is out of compliance…" Same as first comment.
Response: Same as response to similar comments above.

Coordination with Endangered Species Act

Comment: The Draft Report raises serious conflicts between meeting the provisions of the Clean Water Act (CWA), meeting the requirements of the Endangered Species Act and meeting legal obligations to the treaty tribes, which are not described, nor are means to resolve the conflicts offered.

Response: The draft TMDL takes great care to explain the potential conflicts between the provisions of the Clean Water Act and the Endangered Species Act. The National Marine Fisheries Service and the U.S. Fish and Wildlife Service were intimately involved in designing the Implementation component of the TMDL expressly to avoid these conflicts. The fact that there is an entire section dedicated to the Endangered Species Act in a TMDL required under the Clean Water Act. Means to resolve potential conflicts are offered in the implementation plan through the phased approach.

Comment: We have concerns that the Draft Report fails to reconcile meeting the needs of tribal treaty obligations, ESA requirements and full protection of the beneficial use, i.e., anadromous fish passage, under the Clean Water Act. It is critical that this is fully addressed in the Final Report.
Response: The draft TMDL expressly seeks to reconcile actions under both acts. This issue is well covered the final report.

Comment: Fish passage and the survival and productivity of salmon and other anadromous fish populations must not suffer by taking measures to control total dissolved gas. These conflicts should be identified and fully described in the main portion of the Final Report. How the TMDL meets treaty obligations, the CWA and the ESA must be identified and fully described in the Final Report.
Response: The water quality agencies are well aware of the potential conflicts between protecting water quality and impeding fish passage. That is why we have gone to great lengths in the TMDL to describe the potential conflicts and to construct an implementation plan in a phased way so that these potential conflicts can be avoided. Protection of fish through total dissolved gas levels at standards and survival targets as defined in the 2000 Biological Opinion is the appropriate outcome of this exercise.

Comment: It is not enough that the TMDL be written to reflect achievement of biological performance standards for the NMFS' 2000 Biological Opinion. As noted by CRITFC (CRITFC 2000), these standards are inadequate to recovery salmon populations to healthy, harvestable levels described in the *Spirit of the Salmon.* For example, as opposed to the Opinion juvenile survival standard of 95% per dam, the *Spirit of the Salmon* recommends a short term fish passage efficiency standard of 80% and a long-term fish passage efficiency standard of 90%. These higher standards, combined with increased, normative flow regimes recommended by the tribes, will require more spill volumes over longer periods at the Lower Columbia Dams. Therefore, the final TMDL must be written to reflect actions that will meet these higher productivity levels by identifying and accomplishing higher standards of protecting the beneficial use. It would be very helpful to identify these short term and long- term compliance goals in the main body of the Final TMDL Report and not solely in the implementation plan.
Response: We are unable to address the perceived deficiencies of a federally constructed biological opinion in the TMDL under the Clean Water Act. There is no action in the implementation plan that is inconsistent with the 2000 biological opinion. Great care was taken o work closely with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service to craft an implementation plan that achieved the requirements of the Clean Water Act while not detracting from the provisions of the 2000 biological opinion or the Endangered Species Act. Implementation provisions being incorporated into the body of the TMDL is neither appropriate nor legal. A TMDL is a quantitative evaluation of loading capacity and an

allocation of loads. Implementation is completely separate from that. The former is an action requiring federal EPA approval; the latter is purely a State action.

Comment: It is our understanding that the implementation plan is not a legally defensible document but the TMDL is. Staff is concerned with potential legal ramifications that the TMDL poses as currently written. Language needs to be added to the main body of the TMDL to address the potential conflicts between the needs of the CWA and the needs of the 2000 Biological Opinion to meet the requirements under ESA.
Response: We are unable to alleviate your potential legal concerns with the TMDL. Language already appears in the body of the TMDL addressing the potential conflicts between the Clean Water Act and the Endangered Species Act, and great care has been taken throughout to avoid these potential conflicts.

Comment: On Page 4 of the Draft Report the TMDL is referred to as a, "[p]lanning tool, not a rule of law or other stand-alone enforceable document." Further the Draft Report states that it does not take precedence over the federal Endangered Species Act, Indian Treaties, or federal hydropower system enabling legislation. The action of reducing spill to meet the TMDL is in direct conflict with the 2000 Biological Opinion spill program, the CRITFC tribes' spill program described in the *Spirit of the Salmon* restoration plan and the Northwest Power Planning Council's 1994 *Strategy for Salmon* restoration plan. These spill programs have been identified as critical components of salmon recovery. The implementation plan outlines how the TMDL is to be achieved, and attempts to reduce the conflict between current ESA operations and the need to meet CWA in the short term.
Response: The State water quality agencies have fully supported the spill program for fish passage over the last eight years. There is nothing in this TMDL that detracts from that support. The major focus of the short-term phase of the implementation plan is on involuntary spill. We have, however, indicated that decreased reliance on fish passage spill will also be a feature of the short-term, but only in conformance with achievement of the survival standards detailed in the 2000 biological opinion.

Comment: As previously stated, the relationship between meeting CWA, ESA and tribal treaty responsibilities and protection of the beneficial use needs to be clearly defined in this section.
Response: On page five we make it clear that the provisions of both the Clean Water Act and the Endangered Species Act must be met.

Comment: Page 5. Coordination with Endangered Species Act. "In summary, the provisions of both Acts must be met." As part of this discussion about meeting both the Clean Water Act and Endangered Species Act, there should be a discussion of how each of the state water quality agencies has made regulatory decisions to selectively favor anadromous fish over resident fish in order to avoid the anadromous fish from becoming threatened or endangered. It should be shown how long-term gassing of the river to save salmon and exposing resident fish to long-term levels of TDG balances "the protection of aquatic life."
Response: Both states have relied on the National Marine Fisheries Service analysis of impacts versus benefits of spill to resident and anadromous fish to modify respective dissolved gas standards. These modifications have been temporary: yearly for Oregon and to be reviewed in 2003 for Washington. The temporary nature of these modifications reflects the need to better

understand the impacts to resident fish which are in the river the entire year. The temporarily elevated gas levels are designed to protect priority species—anadromous fish which are not in the river the entire spill season but are passing through as migrants. Before more permanent standards can be adopted for the Columbia River, studies will have to show minimal impacts on the ability of resident and non-salmonid migratory species to survive in a river with higher gas levels. Language to this effect has been added to the TMDL.

Comment: "Therefore, in the short-term, structural gas abatement solutions may result in higher spills rather than lower TDG levels." The structural measures designed to reduce the TDG exchange in spill have resulted in higher volumes of voluntary spill (increased spill capacities at TDG waiver limits) and increased loading of TDG in the Columbia River.
Response: Agree. The structural and operational improvements allow for more water to be spilled before the gas cap is reached. This increases the mass of gassed water but only up to the gas standard. On the other hand, structural and operational improvements at the dams can, up to a point that varies for each dam, keep gas levels lower during spills that occur for lack of power demand or ability to transmit, lack of hydraulic capacity, or other reasons.

Comment: "But as new, more effective fish passage facilities are completed and evaluated, their contribution to the attainment of hydrosystem performance standards will hopefully allow spill levels for fish passage and associated TDG levels to be reduced, but only as long as the performance standards are met." This statement seems to suggest that spill maybe a long term alternative required to meet fish guidance performance standards that supercedes the requirements set out in the CWA and is at odds with the statement "This TMDL must be written to reflect ultimate attainment of the TDG water quality standard."
Response: This statement is an acknowledgement that some form of spill may continue to occur in order to meet fish passage requirements of the Bi-Op. The TMDL has to be written with the goal to achieve water quality standards. There is no conflict with CWA requirements so long as the water quality standards are met or there continues to be reasonable progress toward meeting the water quality standard. The TMDL will have to be implemented to best protect the beneficial uses, including endangered salmon. Coordination with anadromous fish concerns is vital toward achieving the ultimate goal of the Clean Water Act which is to have fishable and swimmable waters. If further study shows that resident populations of aquatic organisms are being protected at the higher gas levels that are temporarily approved for juvenile fish passage, higher gas levels may be appropriate for at least portions of this river. This would have to be written into the water quality standards which is outside the scope of the TMDL.

Comment: "The results suggest that, in weighing the benefits gained in increased salmon survival…". The finding regarding the benefits of spill on guidance of juvenile and adult fish at Lower Columbia projects has been mixed. Efforts to substantiate the benefits of spill on guidance of salmonids will play a substantial role in spill management planning.
Response: We agree. Although spill plays the major role in bypassing turbines, entrainment into spillways varies at each dam. Many other factors also play a role in fish survival through each dam.

Comment: Other than sluiceway/surface bypass development, no other fish passage technologies are apparent for the short or long-term. Even these technologies require attendant spill to move salmon to the systems and to provide good tailrace egress conditions for juveniles to avoid predators. Permitting increased levels of total dissolved gas in the Columbia River in order to implement spill at the Corps dams will better protect the salmon beneficial use than forcing them through turbines and screened bypass systems (Strong 1998; CRITFC 2000a; CRITFC 2000b). Juvenile salmon mortality through turbines has been estimated between 4% and 19% (Whitney et al. 1997; Gilbreath et al. 1993). Adult salmon mortality through turbines has been estimated from 22% -51% (Wagner and Ingram 1973; Buchanan and Moring 1986; Liscom and Sturehrenberg 1985). Recent radio-telemetry studies for steelhead kelts have indicated that no kelts survived downstream passage during non-spill periods (Evans, 2002 personal comm.). Juvenile and adult salmon that are subjected to screen system passage are exposed to and held at temperatures that are significantly warmer than that found in the ambient river (Hoffarth 2000). Temperatures in bypass systems have been found to exceed water quality standards for much of the summer salmon migration (WDFW and ODFW 2000). Further, recent studies indicate that juvenile salmon that must pass through screen bypass systems have a significantly lower smolt-to-adult return rate than juvenile salmon that pass primarily through spill (Bouwes et al. 2002).

Spill will always be required at mainstem dams for fish passage, although sluiceways and surface bypass development may increase fish passage efficiency, therefore reducing some spill levels. Whether or not these levels will meet CWA standards remains uncertain. What is certain is that involuntary spills will continue, and gas abatement structures that are fish passage friendly must be expedited to reduce dissolve gas generated from dams.

The Draft Report discusses TDG monitoring from 1995 – 1996. There has been considerable in-river monitoring since then which should be incorporated in the Final Report. This includes dam monitoring by the Fish Passage Center (FPC 1997-2001), and monitoring contained in scientific reviews by the NWPPC's Independent Scientific Advisory Board's evaluation of gas abatement (ISAB 98-8 *Review of the U.S. Army Corps of Engineers Dissolved Gas Abatement Program).* These reviews found that dissolved gas levels of 120% TGP were conservative and not harmful to salmon in the river. Further, analysis of three years of research from in-river juvenile salmon sampling in the Columbia River indicates that very low incidences of GBT were found in juvenile salmon that were exposed to dissolved gas levels up to 125% saturation (Backman et al. 2000). Specifically, Backman et al. (2001) found no statistically significant relation between total dissolved gas and gas bubble trauma for chinook salmon. Most gas bubble trauma symptoms were minor (>5% fin occlusion) with severe bubbles (>26% fin occlusion) being observed only when total dissolved gas exceeded 126%. Chinook salmon were rarely observed with gas bubble trauma, despite sampling large numbers when total dissolved gas exceeded 130% saturation (Backman et al. 2001). Based upon this information, CRITFC continues to support a 125% total dissolved gas standard in the Lower Columbia River for the short-term to be modified as gas abatement structures are added to dams. The state water quality agencies should immediately pursue a review of the existing 110% TGP standard and the 115%-120% temporary waiver as they relate to protecting fish passage and the beneficial use under the CWA.

Response: The provision to review the water quality standard for total dissolved gas is already contained in the long-term phase of implementation. The water quality agencies are currently fully committed with reviews of other water quality standards. We always welcome suggestions for standards that are in need of review. Inevitably, the number of standards suggested exceeds our resources at any given time. We also encourage other parties to undertake a full scientific review and submit it to us. The Environmental Protection Agency can provide the process and methodology for such a standards review.

Comment: The final Report should find a means of compliance with the CWA, the ESA and treaty obligations.
Response: This is already fully covered in this section and in the implementation plan.

Geographic Extent

Comment: Page 7, PH 3, line 2 – "All of these waters have been identified as impaired and have been included on Oregon's 1998 303(d) list." The fact that a site within each of the reaches has been identified with concentrations greater than 110 percent of saturation does not mean that the entire river within the seven reaches is exceeding the standard. Suggest you try some different wording.
Response: Data shows that plumes of supersaturated water persist for many miles downstream of a project. Elevated levels of total dissolved gas generated at a project show up as elevated levels in the forebay of the next downstream dam. For the geographic extent of this TMDL the river is impaired along its length. Impairment of the reach(es) below Bonneville Dam has been discussed in an earlier response.

Total Dissolved Gas Water Quality Standards

Comment: The Water Quality Standard and TMDL Should be Based on the Greatest Net Ecological Benefit to Support Aquatic Life. The current TDG water quality criterion of 110% is based largely on laboratory studies where fish were held in shallow water and exposed to elevated levels of TDG in relation to the atmospheric pressure. Most aquatic life in the Columbia River does not typically inhabit the upper 3 feet of the river's depth. The water quality standard and the TMDL should be established to provide the greatest net ecological benefit to support the designated uses. Because TDG is a dynamic, natural process, the goal of the TMDL should be as established for thermal TMDLs, a total maximum daily load that "will assure protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife" (40 CFR 130.7(c)(2)). The use of spill to improve survival of migratory anadromous salmonids, especially for ESA listed species, should be given equal weight to meeting water quality criteria that are set with a conservative margin of safety, as is the 110% TDG criterion. The salmonids, resident fish species, benthic organisms, and other aquatic life forms in the Columbia River all spend most of their time at water depths where TDG saturation levels are less than 100% relative to the ambient hydrostatic pressure, even though the TDG pressure exceeds 110% relative to the atmospheric pressure at the water's surface. As stated in the Draft TMDL (page 69), biological monitoring to assess gas bubble trauma to fish has shown little trauma to migrating juvenile salmon at TDG levels of 120% (modified water quality standards). This TMDL should provide equal consideration to developing the data to support a permanent, site-specific criteria for TDG

for the Columbia River that supports the designated uses to achieve the greatest net ecological benefit.
Response: Total maximum daily loads present recommended allocations that are implemented through other mechanisms. They are not a rule making activity. Setting new rules for adjusted water quality standards to take into account site-specific needs on the Columbia are beyond the scope of this TMDL. Data needs toward a site-specific gas standard on the Columbia will happen outside the scope of this TMDL. The provision to review the water quality standard for total dissolved gas is already contained in the long-term phase of implementation.

Comment: The state water quality agencies must commit to an effort to review the adequacy of the existing total dissolved gas standard for the mainstem Columbia River with respect to protecting the beneficial use, and this effort should parallel implementation plan efforts.
Response: This has been provided for in the long-term phase of implementation. However, a change in water quality standards is a different exercise than a TMDL.

State of Oregon Standards

No comments received.

State of Washington Standards

Comment: Page 10. State of Washington Standards. “TMDLs must by law ensure compliance with the existing permanent standards. There are separate processes to revise the water quality standards and establish new criteria. If the TDG standards are ever revised in a way that affects this TMDL, then the TMDL would need to be revised and modified at that time.” Over the past six years there has been a tremendous amount of data and information showing the Gas Bubble Disease in anadromous fish is not a serious issue above 110%. Is there a public policy issue that needs to be resolved by the states and the National Marine Fishery Service’s Biological Opinion determination that 120% is needed to pass fish over the dams and the standard of 110%? Since ESA actions to avoid anadromous fish from becoming threatened or endangered use TDG standards exceedances as fundamental components of a recovery plan, the state standard should be revisited before developing a TMDL?
Response: This is not a public policy issue. National Marine Fisheries Service, U.S. Fish & Wildlife Service and the state fisheries agencies are in agreement that before a permanent standard can be adopted, an analysis of existing literature, some lab studies (such as sensitivity of lampreys), and habitat inventories need to be undertaken to assess the potential impacts to resident species. However, federal rules and court decisions have been clear that TMDLs must proceed in a timely fashion based on existing rules. The phased approach used in the implementation plan allows time for changes in the rules to occur.

Comment: Page 10 - what is the technical definition of tailrace? None of Portland's instruments are in the tailrace or in the area immediately below the bubble zone as mentioned later in the TMDL as the site of compliance.
Response: The “definition” of tailrace for the purposes of the short-term compliance locations was created for the existing fixed monitoring station system under the ESA forums. These

stations may or may not be measuring pure spill water due to turbine mixing and variations in the spill pattern and flow. Monitoring in the tailrace for long-term TMDL compliance will most likely focus on intensive synoptic near-field studies. Any changes in "tailrace" monitoring stations in the long-term will be defined using a combination of criteria and information. These will include hydraulics, lateral and longitudinal variability of TDG at varying flows, and identification of aerated zones. Existing tailrace FMS stations might be adequate for long-term compliance monitoring if good relationships can be determined between those sites and near-field gas levels at the compliance locations.

Comment: "If the TDG standards are ever revised in a way that affects this TMDL, then the TMDL would need to be revisited and modified at that time." The pollutant TDG is ill suited for being handled in a TMDL planning progress. The loading capacity as defined in this document as a pressure difference is clearly not a mass loading. The outlined approach does not distinguish between a single spill bay releasing 3 kcfs and generating a TDG saturation of 114% and 20 bays uniformly discharging 60 kcfs at 114%. The conditions resulting in exceedance of TDG standards will be dependent only on the operations at a specific dam and independent of dam operations upstream.
Response: The existing standard is a measurement of a single point and does not usually directly reflect mass loading. The effect of this TMDL is that standards are to be measured to show operational gas inputs at each dam independent of upstream conditions. However, flow levels from upstream operations often directly affect amount of water that is spilled and therefore gas measurements are tied indirectly to upstream dam operations.

Basin Assessment

No comments received.

Spill for Fish Passage

Comment: The bottom line for the treaty tribes is protection of the beneficial use, i.e. salmon and other anadromous fish passage through the Federal Columbia River Hydrosystem. Based on numerous biological studies, many of which the Draft Report fails to discuss, we have serious concerns that the existing standard of 110% TGP and the existing variances of 120% TGP in the dam tailraces and 115% TGP in the downstream dam forebays limits protection of the beneficial use. The federal government should do everything possible to meet their obligations under the CWA, but not at the expense of the beneficial use that the CWA is supposed to be protecting.
Response: Anadromous fish passage is one of a number of beneficial uses to be protected on the Columbia River. The criterion of 110 percent of saturation is designed to protect salmonid and resident fish species. A standard change is a different exercise. We have provided for this in the implementation component of the TMDL in the long-term.

Comment: The study finding from recent studies should be referenced in this section (The Dalles Dam for instance).

Response: This section is not intended to provide an exhaustive or up-to-date literature review. The references illustrate the purposes of fish spill. However, language has been added to mention that studies and research are ongoing.

Comment: Page 12, first paragraph under Spill for Fish Passage – Omit "…or fish bypass facilities" in the first sentence. Bypasses discharge a tiny amount of water compared to spill and water is discharged through turbines for power generation purposes, not for fish passage.
Response: The purpose of this section is to differentiate water spilled over the spillway rather than its passage via other routes. While the quantity of water flowing through the fish bypass system is small, it has historically been differentiated from spillway water for fish passage purposes.

Involuntary Spill

Comment: Water management plans are structured to minimize the occurrence of flood flows in the Lower Columbia River. The amount of storage in the basin is limited with river flows frequently exceeding the powerhouse capacity of Lower Columbia River dams. The need to safely discharge flood flow events through a spillway is a fundamental feature of dams and required to maintain designated beneficial uses of the Columbia River.
Response: This, of course, is true but doesn't contradict the requirement for structures in the river to meet the federal Clean Water Act. The challenge is to find ways for the Corps to meet water quality standards for all types of spills up the seven-day in ten-year flood flow, through planning and implementing projects such as gas abatement structures or increased powerhouse capacity.

Deviation of Ambient Conditions from Water Quality Standards

TDG Generation from Spills

Comment: Page 15 – "The excursions beyond this level usually have been no more than one or two percent above the variance request and occur as a result of the imprecision in setting spillway gates." The spill gate settings are automated for the most part and actuation of gate opening are highly repeatable. The excursions above the TDG variance are due to the variability in the TDG exchange process, measurement, and barometric pressure.
Response: It would be more correct to say that excursions are due to the imprecision in reproducing exact TDG levels at specific spillway gate set points due to all the sources of TDG variability described. This passage has been revised.

Comment: Page 16 - "In the pools, gas exchange rates are small to negligible except under high wind conditions …. If conditions are still and TDG concentrations are constant, the percent saturation of TDG can increase if the water temperature increases…" The likelihood of temperature increases resulting in TDG pressure maximums removed from the tailwater channel region are overstated in this document during the spill season. The reduction in TDG pressures

during transport through a pool by air/water interface exchange and mixing between spill and powerhouse flow will result in declining TDG pressures for nearly all situations
Response: To evaluate this and similar comments, temperature increases were compared to wind speeds (The Dalles pool was chosen for this analysis). The analysis indicates that in this reach of the Columbia River, under most conditions the degassing produced by wind offsets the increase in TDG from a water temperature increase. The frequency of low wind speed periods concurrent with water temperature increases is very small at this location. Therefore the allocations for temperature increases have been removed from this TMDL, and the entire allocation for each reach will be placed on the spills and the upstream boundary. It's important to note that future TDG TMDLs may include an allocation for the downstream water temperature increase, depending the results of the analysis for that area.

Comment: "The rest of the powerhouse flow mixes slowly with the spillway flows.". This generalization does not apply to the conditions below The Dalles Dam or to the open channel flow conditions below Bonneville Dam.
Response: This has been edited to avoid over-generalization.

TDG Impacts on Aquatic Life

Comment: Page 17. TDG Impacts on Aquatic Life. "A review of the standards to look at adoption of different criteria, duration, frequency and spatial application, if appropriate, would occur through a completely different process." Same Comment as #9 (Is the margin of safety supplied by the TDG criterion too conservative?).
Response: See earlier responses on this subject. The discussion of Margin of Safety identifies the stringency of the standards as a source of MOS.

Comment: The information provided about total dissolved gas and different levels of total dissolved gas impacts are all derived from laboratory work, which does not adequately represent natural systems. Laboratory studies are very conservative because fish cannot achieve depth compensations. Only data acquired from river studies, as noted above, should be incorporated into the final Report.

It is not clear to us what the water quality agencies' criterion were for developing the two levels of compliance- one hour maximum and the average highest 12 hours? With the current amount of data it seems prudent to determine if these limits are still appropriate. The chronic and acute levels outlined in the waivers should also be further reviewed to determine if the levels are adequate or overly conservative. Restraints from the existing 110% TGP and 115%-120% temporary TGP standards are the major constraints to meeting juvenile passage goals to protect the beneficial use. These levels need to be reviewed as a key component of any short or long-term implementation plan. A review of the acute and chronic levels to determine if more flexibility is available is critical. This could lead to more spill to increase passage of a larger percentage of juveniles and adults.
Response: A review is already provided in the long-term phase of the implementation plan. The criteria for determining the temporal criteria for the total dissolved gas variances are based on applications we receive from the federal agencies.

Monitoring of TDG

Comment: Page 18. All of this page is very qualitative in nature. I suggest you need some quantification of variability; e.g. variability associated with each FMS.
Response: This section of the TMDL – Deviation of Ambient Conditions from Water Quality Standards – is a qualitative description of the problem. The subsection on Monitoring of TDG has been included to describe the monitoring that has been conducted to date. Quantitative analyses of monitoring are included in the Loading Capacity section of the TMDL.

Comment: Page 18. Monitoring of TDG. A recommendation is needed. The use of the existing fixed monitoring sites, with a long history of data collection at each of those sites is appropriate.
Response: This section describes the current situation. Recommendations are provided in a later section (Monitoring of Compliance under Load Allocations, and Monitoring Strategy in the Implementation Plan). We agree that the FMS sites are appropriate in the short term, but their usefulness for long-term TMDL compliance needs further assessment. Long-term monitoring using near-field synoptic surveys also is appropriate.

Comment: Page 18. Monitoring of TDG. “The subgroup has concluded that the “representativeness” of FMS data is a very difficult characteristic to define.” This statement misrepresents the finding of the WQT subgroup. The subgroup has found inconsistencies in the siting of FMS throughout the basin that result in an uneven spill management policy as constrained by the TDG waiver criteria. What is needed is a clear definition of the purpose of the FMS. The CE should be active in promoting a monitoring program that provides reliable and unambiguous measures of the impacts of dam operations on TDG characteristics in the Columbia River.
Response: Since the FMSs were developed through the ESA forums and outside the development of this TMDL, this document proposes to use FMS for short-term fish spill compliance. Further, this TMDL proposes developing less ambiguous monitoring sites and conducting focused near-field studies for the longer term. This monitoring will be used to measure gas being produced at each dam, unmixed with turbine water and far enough from the plunge-pool to not measure in the highly transitory aerated zones.

Loading Capacity

Analysis of TDG generation processes

Comment: Text on page 21 refers to Orlins and Gulliver (2000 and Urban et al (2000), but there is no citation for these in the References.
Response: The full citation for these is:

Orlins, J.J. and J.S. Gulliver, 2000 "Dissolved Gas Supersaturation Downstream of (sic) a Spillway, Part II: Computational Model," Journal of Hydraulic Research, 38 (2), 151-159.

Urban, A.L., D. Johnson, and J.S. Gulliver, 2000 "Preliminary Model for Predicting Dissolved Gas Supersaturation at USACE Spillways on the Snake and Columbia Rivers," Draft Technical Report. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

These have been included in the Reference section of the TMDL.

Comment: Page 23, PH 1, lines 2 to 4 – "The resultant TDG pressure generated during a spill is determined by physical conditions that develop below the spillway and is independent from the initial TDG content of this water in the forebay." Is this true when there in entrainment of powerhouse flow? While I agree that the major identified factors are below the spillway, I would think that there could be some minor influences that have yet to be quantified. Suggest saying these are the major controlling processes.
Response: This has been edited to be more reflect the uncertain knowledge of these processes.

Comment: Page 26, Figure 5 – The equations in the figure were too faint to read.
Response: Since this figure came from the Corps DGAS report, we are unable to improve it. The equations are not specifically important to the TMDL, and we refer you to the DGAS study for that information.

Comment: Page 28, PH 4, line 10 – "LGSW *respectively*, the…"
Response: The recommended wording has been inserted.

Comment: Page 29, Equation 10 – Define Qe and Qsp.
Response: These definitions were provided at equation 4.

Comment: Page 29, Ph 3 – Suggest placing on page 30.
Response: The pagination worked better in the draft this way.

Analysis of TDG Loading Capacity

Comment: Page 30. It would be good to include a discussion here about the variability in the FMS data. For example, 1 percent would be 7.5 mm. Page 34 suggests it could be more equal to 3 % or 22.5 mm.
Response: A sentence has been added about the FMS TDG data quality target (in the Data Quality subsection of the Analysis of Current Conditions section). Page 34 refers to filtering used in the spill performance analysis. This should be clear from the context.

Comment: Page 30, First sentence. TDG gas transfer between air and water is driven by differential pressures - atmospheric and hydrostatic pressures, not solely by "gas pressures". Or, do I misunderstand what is being said?
Response: The differential gas pressures are produced by bubbles under atmospheric pressure being subjected to hydrostatic water pressures. But it is the gas pressure gradient that generates increased pressure. This is more detail than is appropriate for the context of this sentence, so the passage will be left as is.

Identification of Sources

Comment: Page 31, PH 1, line 1 – "There are four *major* sources of…" Minor sources could include photosynthesis, tributaries, and temperature effects.
Response: The minor sources listed above are mentioned in the Report text. Temperature effects were originally included in the load allocations, but further analysis indicates that temperature effects are usually offset by degassing by the wind in the Lower Columbia River. Sources of total dissolved gas in the tributaries are sufficiently *de minimus* as to be discounted relative to the contribution of the hydroelectric projects. Photosynthesis may raise dissolved oxygen levels, but because oxygen is metabolized by the aquatic life its physical effects are minor compared to nitrogen, and therefore can also be considered *de minimus.*

Analysis of Current Conditions

Comment: Page 31 and 32, Data Quality section – This section addressed only quantity of data, not quality. I think you can do better.
Response: Reference is made in this section to multiple sources of data quality information, which for succinctness was not repeated in the Report. We could do better, but prefer to allow the reader to reference the original reports which speak for themselves.

Comment: Page 32, PH 3 – Overall a good paragraph. Line 3 – "Data from the FMSs provided a continuous *hourly* record …"
Response: "Long-term" hourly has been included instead of "continuous".

Comment: The Draft Report discussed the potential impact of non-deflector bays on the outside of spill patterns. However, CRITFC's review of the issue indicates that only John Day Dam possesses non-deflector bays in spillbays 1 and 20. After regional discussions, fish managers and hydroperators reached agreement to avoid using these spillbays, unless they are needed for involuntary spill at levels over the 7Q10.
Response: The discussion of non-deflectored bays is included to provide a thorough analysis of the effects of spill management on TDG levels. The implementation plan addresses any agreements made regarding the use or modification of these bays.

McNary Dam

Comment: General comment on McNary – There is no mention of how you used the temperatures in the forebay, that are often too high and would have caused incorrect TDG values in the summer.
Response: A discussion of temperature effects on total dissolved gas saturation is included in the discussion on load allocations.

Comment: Page 35, Equation 11 – Could you provide an R square for this equation?
Response: The correlation coefficient for this equation is provided in Table 5.

Comment: Page 38, PH 3, line 3 and Figure 9 – Line three says June 1998 data are shown and figure 9 says May 1997 data are shown?
Response: This error was also in the DGAS report. The caption was in error and has been changed.

Comment: Page 38, PH 2, line 1 and 2 – "In general, the estimated TDG saturation was [generally] within one percentage point of the observed tailwater TDG saturation." This is not a very quantitative comparison. It would also be nice to see a statistical comparison between the observed and estimated TDG saturation, such as 5, 10 25, 50, 75, 90, and 95 percentiles; a graph of this information could also be used.
Response: This statement comes directly from the DGAS report and is provided for background. Although we agree that the suggested analysis would be desirable, we did not include it because we do not have the original data, and the analysis would not add sufficient value to this report to justify the effort.

Comment: There is a correction to grammar required under "Powerhouse entrainment." "Determination" in the third line takes a singular.
Response: This error has been corrected.

John Day Dam

Comment: Page 40, PH 1, line 1 – Why are there only 51 observations? Does this suggest that this relationship has less significance or is less well understood? Does it mean that there are many or most conditions that are not covered by the equation?
Response: This statement comes directly from the DGAS report and is provided for background. Although the questions about the relationship and equation are good, the TMDL does not depend on that equation.

Comment: Page 43, PH 1, Line 4 and 5 – "The TDG response during *voluntary* fish passage spill conditions will be different than a comparable spill discharge at a much higher *involuntary* total river flow."
Response: We have tried to move away from the concept of voluntary versus involuntary flow, and characterized spill as 'fish passage' or 'involuntary.' Accordingly, we have inserted the word 'involuntary,' but not 'voluntary.'

Comment: Page 43, figure 12 – Page 39 says that equation 13 is derived from 1998 spill season data. Figure 12 is a comparison of May-June 1998 data. Was the same data used for calibration and checking its performance? If so, say so. If this is the case, I suggest you find another time period to determine the performance of the equation.
Also, there are some very low x values in the figure 12; what do they mean and why are they so low. Again a quantitative comparison would help and provide a basis for how accurate this TMDL is.
Response: This statement comes directly from the DGAS report and is provided for background. Although the questions about "calibration and verification" of the equation are good, the TMDL does not depend on that equation.

Comment: Page 43, PH 3, line 1 – “In general, the estimated average TDG saturation was [generally] …” What is being averaged?
Response: This statement comes directly from the DGAS report and is provided for background. It appears they were comparing the averages of observed and estimated. Nonetheless, the TMDL does not depend on this information.

Comment: Page 44, Equation 14 – Coefficients C1 and C2 are listed as 315.29 and 519.09. How do you justify 5 significant figures? I suggest rounding to 315 and 519 which is to the nearest mm which is probably much better than your equation. I suggest you review the other coefficients and also consider rounding them as well.
Response: This statement comes directly from the DGAS report and is provided for background. You are probably right about the significant figures, but since this is directly from the report and the TMDL does not depend on this information, the text will not be changed.

Comment: Page 45, Table 9 – I suggest rounding the Std. Error from 15.95 to 16 mm Hg.
Response: See response above about significant figures.

Comment: Page 46, PH 1 – What was the powerhouse entrainment discharges a function of?
Response: As described elsewhere in the text, the powerhouse entrainment is caused by an eddy that occurs because of the spill being deflected horizontally, and appears to be a function of the amount of physical separation (such as occurs at Bonneville and the Dalles), and angle of the deflection, the spill volumes, and tailwater elevation.

The Dalles Dam

Comment: Page 46 and 49 – It appears that 1997 data were used to calibrate equation 15 and observe its performance. Suggest you find data not used for the calibration to determine how well it performs and to provide a statistical comparison, using 5, 10, 25, 50, 75, 90 and 95 percentiles.
Response: See response above for a similar comment regarding McNary.

Bonneville Dam

Comment: Page 51, 52, 53 Figures 17, 18, 19 – Can not read the information at the bottom of the figure identifying the different symbols.
Response: These figures were copied exactly from the DGAS report, but were reduced in size to fit this report’s format. We apologize for the difficulty in reading this –our revisions have improved the readability.

Comment: Pages 53 and 54, Equation 16 and 17 – What are the R squares of these equations?
Response: This statement comes directly from the DGAS report and is provided for background. The r-squares were not provided.

Comment: Page 54, PH 3, Line 3 – “Equations 1 and 2 …” Do you mean equations 16 and 17?
Response: Yes – this came over from an error in the DGAS report, and has been corrected.

Comment: Page 55, Figure 20 – It was hard to follow the text on page 54 and figure 20. For example, is the average spillway TDG saturation on page 54 the “PSAT-Sp est” in figure 20? Very hard to read the captions at the bottom of figure 20.
Response: It appears that this question refers to Figure 19. (The text had a typo – Figure 19 was identified as Figure 18 in one location.) The revised text explains: “The flow-weighted average TDG saturation released from Bonneville is shown in Figure 19 under the heading of TDG-tw-est.” The text and figure are confusing, but since this came from DGAS, we can’t improve much on it. Our revisions have improved the figures’ readability.

Load Allocations

Comment: The Load Allocation Should Not Be Reduced For Background Increases In TDG With Temperature Changes. The water quality standard is for 110% TDG and the discharge from a hydroelectric project should be allocated that full level of gas entrainment. Increases in TDG background levels due to changes in temperature, either seasonal or daily, occur regardless of whether dams are adding TDG through spill. This also occurs naturally in large rivers and lakes without hydroelectric projects. Dissolved air in water is not a classic “pollutant” and should not be subjected to load allocations as if it were an unnatural component of the water body. As with water temperature and thermal loads, TDG is a dynamic process where the water either absorbs or releases gas to the atmosphere in relation to equilibrium processes that are affected by ambient temperature and pressure. Spill from hydroelectric processes and the deeper water of reservoirs are human-caused changes to the river system that can overload the equilibrium process, causing TDG levels to remain higher than equilibrium at the surface of the water body for extended periods of time and over extended distances. However, a high TDG pressure at the surface is at equilibrium for water that is only a few feet deep. TDG levels in the Columbia River regularly exceed 100%, relative to surface barometric pressure, even at time of year when the hydroelectric projects are not spilling. This background level has never been shown to cause injury to aquatic life and therefore should not be used to reduce load allocations for hydroelectric projects. The compliance TDG level should be set at the 110%, 120% waiver, or future revised TDG criterion at the end of the mixing zone (end of aerated zone at 7Q10 spillway flow).
Response: We have reviewed the allocation to water temperature increases, and concluded that we will remove them and provide the entire allocation to the dams and upstream boundary. However, the reason for change is not the reasons cited above. Analysis determined that wind-induced degassing was strong enough to offset increases in TDG under a high frequency of situations.

Regarding the arguments above, all processes that can affect TDG must be taken into consideration. TDG is a natural component, as are many other pollutants. They become pollutants when human activities produce levels that have adverse effects. The high TDG produced below dams is a function both of the dam spill and the pool it flows into. A dam spilling into a natural rapids might see rapid degassing back to ambient. Conversely, a natural waterfall spilling and generating gas might pose a problem if high TDG levels were maintained by a reservoir below the falls. Therefore both factors must be taken into account. However, in the Columbia and Snake Rivers there are no natural waterfalls or natural pools. Therefore, we are focusing on the spill as the causing the TDG increase, rather on the pools for prolonging high TDG levels.

The point about the natural variability of TDG is well taken, and must certainly be taken into account in TMDL implementation, monitoring, and compliance.

Comment: Page 57 – The designation of load allocations as a site specific TDG pressure difference is not well founded. The factor of safety is not a realistic correction and is not supported by historic data. The factor of safety described in this document does not take into consideration the dilution of powerhouse and spillway flows nor the off-gassing (air-water exchange at the water surface interface) during transport. This adjustment adds unnecessary complications to the proposed TDG TMDL in the lower Columbia River.
Response: The use of ΔP for load allocations is reasonable, considering the nature of the TDG generation process. It is not clear what "factor of safety" or "adjustment" is being referred to. Dilution by powerhouse flows cannot be taken into account quantitatively because they generally occur far downstream from the dam and cannot be predicted. However, compliance with the TMDL includes any dilution that reduces maximum TDG levels between the dam and the compliance location. The final TMDL also takes into account off-gassing produced by wind in the downstream pool.

Comment: page 57 A listing of the formulas and calculations that were used to determine delta P would be helpful In the Load Allocations Table. Its not clear how the figures were arrived at even though earlier in the document the regression equations are presented. A step-by-step carry through of the calculations would clarify the delta Ps. To me this is a big deal. The whole document is about determining these delta Ps, then suddenly they appear in a table with no equations showing the exact values of the variables that were used to derive them. How do we know the calculations are correct?
Response: The equations for determining the loading capacity are already included. The figures in Table 12 have been revised, and the allocations are now very simple, so the concerns here should be moot.

Comment: Page 57. Loading Allocations. "Because of the unique nature of TDG, load allocations are not directly expressed in terms of mass loading." Load allocations is a fundamental part of the TMDL process. If allocations cannot be directly expressed, this comment suggest, therefore, that TDG, as a parameter, may not be a pollutant; and it suggest that TMDL process may not be the appropriate vehicle to address concerns.
Response: There are many parameters that do not lend themselves to the rigid use of "loading" in mass per time, such as temperature, turbidity, and bacteria. Nonetheless, these are legally pollutants and must be addressed by standards and TMDLs where necessary. The Clean Water Act takes into account the use of TMDLs to address pollutants using "other appropriate measures".

Comment: Since there is such a small factor of safety why are the load allocations not set to capacity? Considering the changing levels of spill throughout the season it would be better to allow for flexibility in the load allocations such that the individual projects are held accountable to levels determined at the monitoring point instead of an allocation. The allocation could reduce and impact

the ability of the spill program to meet the fish passage goals set out in the various regional recovery plans. Further, it is unclear as to when this load allocation goes into effect, since there are both short and long-term compliance plans. The current variance process is used to dictate what level of spill a project is allowed. However, the current levels of spill outlined in the 2000 Opinion could be altered under this loading allocation arrangement since this would be based on a set volume of spill that is expected to produce a specific load of TDG at a point of compliance. This appears inconsistent with the short-term implementation plan outlined in the Draft Report's implementation section.
Response: The Clean Water Act requires that TMDLs allocate loads to sources. The load allocations will equal loading capacity for each dam and the upstream boundary. This has been made clearer in the final TMDL. The load allocations go into effect upon approval of the TMDL by the US Environmental Protection Agency. However, full compliance with the load allocations will occur in conformance with the implementation plan. We acknowledge that there will be a period of time required for full compliance with the load allocations. The load allocations are based on a change in pressure, not on a spill quantity. There is full consistency between the load allocations and the measures contained in the implementation plan.

Comment: "Below Bonneville Dam, degassing processes are expected to exceed increases in TDG percent saturation from temperature increases." This statement is not supported by the data. This open river reach experiences significant heat increases during the spring and summer months resulting in large diurnal temperature related fluctuations in TDG pressures. These conditions contribute to the difficulty in managing spillway releases at Bonneville Dam.
Response: Analysis of wind patterns and temperature increases indicates that temperature increases are frequently offset by wind-induced de-gassing in the Lower Columbia River. Also, since the reach below Bonneville is not impounded, more consideration can be given to natural process. Compliance and monitoring will have to take into account the variability of TDG and the travel time between the dams and monitoring stations.

Long-term Compliance with Water Quality Standards

Comment: Page 58. Long term Compliance with Water Quality Standards. "The point here is that spills for fish passage are not really "voluntary"; rather they are spills required for reason other than a lack of powerhouse capacity." Dams are multipurpose water resource projects that have mandates to provide a wide range of benefits to the general public including the production of power. One challenge of Dam operators is to balance competing project purposes. The preservation of fish and wildlife is one purpose that has been promoted through scheduling spillway releases to aid fish guidance. Involuntary or forces spill also can be thought of as aiding fish guidance past main-stem dams in some cases.
Response: This is understood. The Columbia River dam system must be used to satisfy a multiplicity of interests and uses. Maintenance and improvement of water quality is one of many issues. The water quality agencies will continue to work with fisheries agencies, tribes, dam operators, power distributors, and others to move forward with water quality improvements and balanced use of the river.

Comment: Page 58. Compliance with Standards for All Spills. "Endangered Species Act requirements for spills must be considered to be just as binding as, say disinfection requirements for wastewater. ….Similarly, the dams have an obligation to both meet water quality standards

and ESA requirements." The analogy is not appropriate because chlorine is used to kill bacteria while promoting public health for humans, while spill is to promote survival of anadromous fish, which in turn, could also have a chronic effect on resident fish. The relative value of bacteria versus humans is more solidly accepted than the relative value of anadromous versus resident fish.
Response: This section has been reworded to avoid confusion. The balance is not between humans and bacteria, but between human health and aquatic life. The value of both are recognized, with one perhaps carrying more weight, such as endangered salmon carrying more weight than impaired but not threatened sucker populations.

Comment: This section should be eliminated or rewritten. The paragraphs referring to compliance with standards for all spills is inconsistent with previous sections that declare that the TMDL does not take precedence over ESA, or Indian Treaty rights. Proposing the fish spill program must be applicable for this TMDL appears to mean that the TMDL takes precedence over ESA and tribal treaty rights. This inconsistency should be addressed in the Final Report. CRITFC agrees that the specified hydroprojects need to comply with the Clean Water Act but not at the expense of the very same beneficial use that the TMDL is trying to protect.

Further, public interest is not what necessitates the fish spill program. Passage protection of ESA-listed and non-listed anadromous fish migrants is what necessitates the spill program.
Response: This section is pertinent, and should remain. Previous sections have stated that the Clean Water Act does not take precedence over the Endangered Species Act. However, neither does the Endangered Species Act take precedence over the Clean Water Act. Both Acts need to be met simultaneously. The Departments respectfully disagree that protecting fish is for other than meeting the public interest.

Comment: In the first sentence under "Point of Compliance," "chose" should be "chosen."
Response: This error has been corrected.

Comment: Page 59 and 61 -- Are the points of compliance the FMSs and are these locations providing representative TDG measurements relative to the DGAS study results?
Response: The long-term TMDL compliance locations are independent of the FMS locations. However, some of the FMS sites may be measuring TDG levels equivalent to the compliance locations, while some may not. More information and analysis is needed before conclusions can be drawn about whether the FMS data are representative of conditions at the compliance locations.

Comment: Page 59 Point of Compliance   "If mixing zone provisions were applied to the aerated zone, then the point of compliance would be at the end of the aerated zone.", The application of the mixing zone provision applies to the region where receiving water dilute the effluent discharge. This would apply to the region downstream of aerated flow where spill flows encounter powerhouse releases. The figurative end of the pipe would correspond with the bubble free territory immediately downstream of the aerated flow. The mixing zone in this instance does not apply to the two-phase flow air/water interaction but to the spillway/powerhouse flow interaction. The stated definition of a mixing zone as spelled out by the State of Washington is as follows: "Mixing zone" means that portion of a water body

adjacent to an effluent outfall where mixing results in the dilution of the effluent with the receiving water. Water quality criteria may be exceeded in a mixing zone as conditioned and provided for in WAC 173-201A-100.
Response: We must respectfully disagree with your interpretation. The state regulations that govern mixing zones are being applied to provide some flexibility in the compliance with standards. The figurative end of the pipe is the foot of the spillway where the spill leaves the dam and reenters the free-flowing river. In this TMDL we are designating an “aerated zone” in which the standards do not apply based on our authority provided by the mixing zone language. We are not applying the “mixing zone” to the mixing of powerhouse and spillway flows, except to the extent that this may occur within the aerated zone.

This zone must be limited in geographic scope. For Washington, the greatest mixing zone area is one quarter of a waterbody at most, unless an exception can be granted. The conditions for an exception include: “AKART [all known available and reasonable treatment] appropriate to the discharge is being fully applied”; “all siting, technological, and managerial options which would result in full or significantly closer compliance that are economically achievable are being utilized”; and “the mixing zone would not have a reasonable potential to cause a loss of sensitive or important habitat, substantially interfere with the existing or characteristic uses of the water body, result in damage to the ecosystem, or adversely affect public health as determined by the department”. We have determined that hydraulic characteristics of the aerated zone justify the use of the mixing zone provision in this area. However, because of the lack of full implementation of gas abatement alternatives and possible impacts on habitat and the ecosystem, a mixing zone that extends for miles downstream is not justified.

Comment: “Because the area below the spillway is very dynamic, TDG levels are difficult to accurately assess.” The spatial variation of TDG pressure in the area just downstream of highly aerated flow can be quite large due to non-uniform spill patterns, depth variation, dilution with powerhouse flow, and pressure time history of entrained bubbles. This document does not describe how TDG observations in this area will be used to determine compliance with TMDL criteria.
Response: Research done in support of the DGAS study and subsequent deflector studies has been reasonably successful in mapping TDG patterns in the area below the aerated zone. Future monitoring would build on that experience. The specific description of how monitoring would assess TMDL compliance will be included in monitoring plans developed at the appropriate time in the future.

Comment: “Extensive fisheries research has shown that anadromous fish are able to pass through this area below the spillway quickly without ill effects.” Flow recirculation underneath the spill jet can retain water and fish for a consideration period of time. Physical injury is a concern for fish passing through the stilling basin and adjoining tailwater channel.
Response: This comment has been incorporated into the document to read, “Extensive fisheries research has shown that most anadromous fish are able to pass through this area below the spillway without ill effects.” The possibility that flow recirculation retains and harms fish will need some more study. If the TMDL is fully implemented, and evidence is produced that the aerated “mixing” zone being applied results in “a reasonable potential to cause a loss of sensitive or important habitat, substantially interfere with the existing or characteristic uses of the water

body", or "result in damage to the ecosystem", the size of the zone could be reduced or the zone eliminated.

Comment: "Because of the turbulent flow associated with the spill, no resident fish habitat is available in this area." The data does not universally support this statement. Areas of slack water and recirculating flow has been identified as habitat for resident fish.
Response: This has been reworded to say "Because of the turbulent flow associated with the spill above the compensation depth, little or no resident fish habitat is available in this area. (The zone below the compensation depth is in compliance with standards.)" Also, see previous comment.

Comment: How does the mixing zone definition apply to the highly aerated flow regime associated with major spillway releases from a dam?
Response: The mixing zone definition provides the flexibility to designate an area were rapid physical and chemical transformations of short duration can occur in an area small enough or inaccessible enough to not impact the aquatic resource. This definition is being applied to the zone of aeration below each dam's spillway. The size of the mixing zone is being set at a specific distance downstream of the dam, based on the near-field studies conducted at the site. The fixed distance is being applied for regulatory simplicity and because of the lack of data to create more complex distance criteria. For spillway releases close to but below the 7Q10 flood flow, compliance with the TMDL is still required at the compliance locations. Compliance in real time would be determined from a fixed monitor, and evaluated by an analysis of the relationship of the fixed monitor to TDG levels at the compliance location. The effectiveness of structural changes to meet the TMDL would be determined by near-field synoptic studies over varying spill levels in the area of the zone of compliance.

Comment: "The forebay of each dam must comply with the sum of the load allocation for the upstream dam and the background load allocation for temperature in the upstream pool, which is equal to the loading capacity." See the response in paragraph 1.
Response: The TMDL has been modified, so this language no longer applies and the sentence has been edited.

Monitoring of Compliance

Comment: The Point of Compliance Should Be Better Defined. The Draft TMDL expresses the point of compliance with the load allocations alternatively as the end of the aeration zone in the tailrace and at a specific distance below the end of the spillway for each dam. It is unclear at what spill volume the specific distance (end of aerated zone) was determined. The distance below the spillway that the aerated zone will extend varies with changes to spill volumes, the locations of gates that are in operation and possibly with changes in tailwater depth, a function of total flow. Many of the short- and long-term measures described for implementation to reduce TDG loading are also going to change the location of the end of the aeration zone. If the point of compliance were to change from the fixed distance to some point further upstream, following installation of removable spillway weirs or other measures that reduce the total volume of water that is loaded with TDG, the new measurement location may not demonstrate the full benefit of

the structural modification to the TDG level in the river. Since the ultimate requirement is to meet the load allocation at the 7Q10 spill level, the end of the aeration zone at the current spill operations needed to pass that flow volume should be the point of compliance. This can be converted to a fixed distance and thus any modifications that reduce the volume of water being loaded with TDG will be able to demonstrate improvement due to dilution within this fixed mixing zone.
Response: This comment makes some good points. However, the TMDL specifies the compliance location as a single fixed distance for regulatory clarity and simplicity and because of the lack of data to create more complex distance criteria. Simply

Comment: Page 61-Monitoring of Compliance. How will the TDG data within 1700 ft of the spillway be used to determine compliance?
Response: The TMDL anticipates that near-field synoptic surveys will assess TDG levels across the channel and above and below the compliance location under varying spill conditions to evaluate the compliance of structural changes with the TMDL. This data could also be used to determine the relationship of TDG at the compliance location to a real-time fixed monitor, to evaluate compliance from dam operations.

Comment: Page 61, paragraph 1, lines 4-5 Specify that the end of the aeration zone is for spills at the 7Q10 flow level and check the distances in Table 13.
Response: See response above for Executive Summary. Data are not available to determine the size of the aeration zone at 7Q10 levels. A compliance location at a set distance based on observed data has been chosen as the most reasonable approach.

Margin of Safety

No comments received.

Critical Conditions

Comment: Critical Conditions. See the response in paragraph 7.
Response: See earlier response to the comment above.

Criteria versus Site-specific Conditions

No comments received.

Data Quality

Comment: Page 63 and 64, Data Quality – There is no data quality statement here. This is data quantity. Suggest you rewrite and address data quality.
Response: The amount of data available does relate to the margin of safety. However, the comment is accurate in noting that the quality of the data is not mentioned. This section has been revised.

Seasonal Variations

No comments received.

7Q10 Flows

Comment: Seasonal Variations. What years of data were used in the 7Q10 evaluation? What is the scientific rational for selecting a 7Q10 event to identify exempt conditions? Add a 95 percent confidence interval to Table 14 to help quantify the uncertainty in the design discharge for DGAS abatement measures for short and long-term alternative.
Response: The years of data used to determine a 7Q10 high flow event for the Columbia and Snake, Water Years 1975 through 2000, were selected using best professional judgment. The rationale was that the last of the dams on the Columbia were built in Canada by 1974, before the Clean Water Act was created (1975). These dams reconfigured the hydrology of the river to such an extent that 7Q10 had to be calculated with all the dams in place. The water quality standards often use 7Q10 flows to identify natural droughts or floods that are beyond human control. Since the point of the Clean Water Act and Water Quality laws is to control human activities, extreme natural conditions become exempt from the law. Since the 7Q10 flow is a regulatory value, a 95 percent confidence interval would be confusing. The uncertainty in DGAS abatement measures should be assessed separately.

Comment: Page 66, Table 14 -- Suggest you reduce the flow values to 4 significant figures, which is all the data will support, at best. Also, there is no mention of which water years were used to make this calculation. With climatic change, these calculations may need to be repeated in 10 or so years.
Response: Table 14 has been changed to include 3 significant figures, and the years used for the calculation are now described. Reassessment of the 7Q10 in the future would be reasonable.

Summary Implementation Strategy

Overview

Comment: The timetable for compliance seems vague and open-ended. It doesn’t identify a time when compliance will be achieved. The TMDL should identify a point in time when it would be reasonable to expect compliance. Without a timetable, it is possible that efforts to achieve the standard could continue indefinitely.
Response: Identifying a specific point for standards compliance is difficult with this TMDL. One of the major difficulties is that compliance could be specified within a relatively short period, were there not fish passage requirements to be protected. Further, many of the structural measures identified can be numerically and physically modeled, but until they are implemented ‘on-the-ground,’ actual total dissolved gas improvements are speculative.

As a result of both of these factors, the compliance timetable has been left deliberately flexible. However, there is a clear expectation that compliance will be achieved within the long-term timeframe – *i.e.* by 2020.

Comment: The Draft Report discusses the beneficial uses of the river outlined by the Oregon and Washington's water quality standard, but none of these uses, except the anadromous fish identified in the Draft Report are impacted by total dissolved gas. Therefore, what constitutes the best operations for the needs of the anadromous and other resident and aquatic species should take precedence when considering the strategy to meet the total dissolved gas TMDL.
Response: Limiting total dissolved gas is designed specifically to address the needs of anadromous and resident fish.

Implementation Plan Development

Comment: Pages 69 and 71, Implementation Plan Development – On these pages references are made to a "Detailed Implementation Plan." What is meant by a "Detailed Implementation Plan" and how is this different from the title of the document section, i.e., "Summary Implementation Strategy?"
Response: The confusion of terminology here is an artifact of the language contained in each of the States of Washington's and Oregon's consent decrees on the TMDL program. For the State of Washington, a TMDL is required to contain an implementation strategy. The State then has a year in which to provide a detailed implementation plan. The State of Oregon is required to provide an implementation plan with the TMDL. The Implementation Plan provided with this TMDL is more detailed than that usually supplied by the State of Washington as a Summary Implementation Strategy. It is, in content, more akin to the plan required of the State of Oregon. The terminology is required so that each State can demonstrate that it has complied with the provisions of its consent decree.

Comment: Page 69, Implementation Plan Development, second paragraph – The first sentence should be changed to read, "The short-term actions in Phase I will focus on meeting the fish passage performance standards as outlined in the National Marine Fisheries Service 2000 Federal Columbia River Power System Biological Opinion through spills…"
Response: This amended wording ahs been included.

Comment: Page 69, Implementation Plan Development, third paragraph – In the second sentence replace "fish survival rates" with "performance standards."
Response: This amended wording has been included.

Comment: Page 69, Implementation Plan Development, fifth paragraph – Second sentence should be modified to read, "However, the states of Oregon and Washington support the evaluation…"
Response: The Clean Water Act provides a mechanism under which water quality standards may be reviewed. This is known as a triennial standards review. Any revision of the total dissolved gas standard could take place under this review. However, this will be, in part, dependent on resource availability and the other standards requiring review. Any evaluation of

the total dissolved gas standard will require a full scientific review, and a demonstration that an alternative criterion will be fully protective of designated beneficial uses.

Comment: Page 69. Implementation Plan Development. “As a result, thought has been given to permanently modifying the water quality standards or establishing site-specific criteria for TDG for the Columbia River. The purpose of this TMDL, however, is to allocate loads to meet the existing water quality standards.” Same Comment as #9.
Response: See earlier responses.

Comment: CRITFC strongly supports the Draft Report’s statement that a review of the standard should take place before the end of the short-term compliance phase. Current data indicates that for the anadromous fish, resident fishes and other aquatic life, the 110% TGP standard is overly conservative. A thorough scientific review and any additional research to verify past findings should be conducted to determine the standard. This review would need to determine if the current level is adequately protecting the beneficial uses. A process to determine if a new level TDG or permanent waiver change for the Columbia Basin would be a better balance for the requirement of the beneficial uses needs to be undertaken. It is critical that CRITFC and its member tribes, as resource co-managers, should be full participants in this review and the short and long-term implementation plans.
Response: The review of the standard, resources permitting, will occur in the long-term phase of implementation. Such data and studies as would be needed to support a review of the standard will be collected in the short-term. The process for changing standards is a public one. The Tribes will be involved in it.

Comment: The Final Report should also include 1) completion of monitoring and other scientific literature relative to the short-term standard, 2) provision for implementing a review of the existing standard in parallel with development of short-term and long-term implementation plans and, 3) inclusion of tribes as co-managers of the resource in development of these actions.
Response: Amendments to the water quality standard are a different exercise and will be fully developed in the appropriate forum. The Tribes are co-managers of the fishery resource, and we always welcome input on managing water quality improvements.

Comment: The TMDL discusses the spill program objective which is to generate spill “no greater” than the wavier levels. To what level does “no greater” mean? Currently there is much debate about how close total dissolved gas levels can be to the waiver levels before spill needs to be reduced. Due to the great benefits of spill and the lack of data that would indicate levels of total dissolved gas at 115%-120 % are harmful to anadromous species, it would seem that some flexibility could be used when managing the spill program at the fixed monitoring sites. There is no discussion of this in the Draft Report. The Final Report should address this important issue.
Response: “No greater than,” means “shall not exceed as measured at the fixed monitoring stations.” This TMDL has been written to meet the water quality standard as required by the Clean Water Act.

Implementation Activities

Comment: On page 17 (sic) the third paragraph should read "Table 16 contains short-term implementation actions that are not directly related…"
Response: This has been amended.

Comment: The measures that are identified as Phase II, or long-term structural changes to the dams are confusing in terms of their relationship to meeting the water quality standard. Most of the measures listed improve fish passage at the dams, and thereby may, at some time in the future, allow for a reduction in "voluntary" spill to meet fish passage/survival goals at individual dams. And while this may relate to attaining compliance for fish mitigation spill, it is unclear how these measures would ever reduce TDG production at flows up to the 7Q10 levels as specified in the standard. When flows in excess of hydraulic capacity occur, that are above Biological Opinion spill levels and up to but below the 7Q10, these fish mitigation measure will have no effect on TDGS production. Long-term alternatives should be identified that bring the projects into compliance outside the relationship to voluntary or fish mitigation spill. If such measures have not yet been identified, the TMDL should require an effort to develop and implement them. It is at these high flows where the greatest excursions from the standard are likely to occur and concomitantly, when the greatest risk from high TDGS levels to fish health occurs.
Response: Many of the implementation measures identified relate specifically to fish passage. We wanted to ensure that attainment of the water quality standard was achieved concurrently with adequate fish passage. We believe that the structural measures identified will improve total dissolved gas levels both for fish passage and for flows up to the 7Q10 level.

Comment: Both Ecology and ODEQ will continue to work with the Corps of Engineers and others in the lower Columbia River to ensure implementation of this TMDL. A strong presence by both agencies can help to provide additional pressure for the federal action agencies to recognize the provisions of the Clean Water Act and comply with state water quality standards.
Response: Both agencies intend to remain engaged with this issue throughout implementation.

Comment: Page 70, Short-Term – Phase I, Third paragraph – The statement should read "Table 15 includes specific structural implementation actions (from the National Marine Fisheries Services (sic) 2000 Federal Columbia River Power System Biological Opinion) that will be completed during this phase and are directly related to achievement of the water quality standard."
Response: Amended wording has been included.

Comment: Implementation Strategy. The water quality benefits associated with Activities identified in Table 16 are uncertain.
Response: The language in the paragraph prior to Table 16 has been changed to read, "Table 16 contains additional short-term implementation actions that are indirectly related to achievement of the water quality standard. Implementation of these measures though, is likely to improve salmon passage and help achieve performance standards of the biological opinion."

Comment: The wording that describes the Long Term Phase II section should be clarified in the Final Report. Reductions in spill would only occur if tribal fish passage goals are being met through surface bypass methods. All structural changes to abate dissolved gas should be implemented and the standard should be reviewed before reductions in the spill program are implemented. It is unacceptable to CRITFC to use turbine or screened bypass operations as a means to reduce fish passage spill.
Response: The actions detailed in the Implementation Plan will be pursued adaptively. We want to ensure that water quality standards are attained, and that the survival standards established by the National Marine Fisheries Service are met.

Comment: Page 72, Long Term – Phase II, paragraph below Table 17 – Delete "do not impede fish passage" in the second sentence and replace with "provide safe and effective fish passage." In the third sentence add "and safe" between the words "effective" and "should."
Response: These amendments have been included.

Reasonable Assurance

Comment: The TMDL Does Not Provide Reasonable Assurance that the Load Allocations Will Be Achieved. The TMDL addresses water quality standards for TDG that are probably impossible to meet at hydroelectric projects. While the 110% criterion has been in existence for over 20 years, failure of hydroelectric projects to meet with this water quality criterion during spill events has been largely ignored by Ecology when setting conditions for licenses and certifications. This lack of action was not due to ignorance of the issue or malfeasance, but rather a recognition that technology did not exist to meet the standard when water is spilled from open discharge spillways. The hydroelectric industry has responded in many ways, even without a TMDL, with practical implementation of measures to reduce involuntary spill and limit TDG levels through structural modifications. These measures include expansion of storage capacity upstream from run-of-river dams, expansion of powerhouse hydraulic capacities, implementation of regional monitoring networks for TDG and shifting of energy load and involuntary spill operations (immediate replacement energy spill) to prevent excessive TDG levels in segments of the Columbia and Snake rivers during high flow periods. The U.S. Army Corps of Engineers DGAS program has been extensive, involving millions of dollars and a thorough look at structural modifications to spillway designs typical of the Columbia River hydroelectric projects. Chelan PUD is unaware of any practical and feasible structural modifications identified in the DGAS program that would meet the concurrent requirements of safety to fish and limiting TDG to 110% at the 7Q10 spill level. In this TMDL document, the unit spillway regressions clearly show that the proposed load allocations can't be met even at very low spill levels. The October, 2001 preliminary draft contained additional information not included in the final draft TMDL. That information (Table 10) demonstrated that even flow deflectors and other structural modifications can't meet the load allocations, even when spillway discharge is less than 25% of the 7Q10 flow. In the October 2001 Preliminary Draft TMDL (Tables 13 – 16), a number of extreme structural modifications (discussed above) are listed that theoretically could meet the 110% standard, but that would still potentially fail to meet the load allocation after allowance for natural background increases in TDG due to temperature changes. Also, these more extreme structural measures were observed in model studies by a panel of scientists and evaluated

regarding their potential for causing fish injury. Some of these options were judged likely to have serious potential to injure fish. Any measures taken to meet involuntary spill TDG load allocations must also be safe for passing fish because most involuntary spill occurs during the juvenile salmonid migration period. Similarly, any structural modifications to meet TDG standards for voluntary spill for fish passage must also not limit the ability to meet TDG standards at the higher flows that occur during involuntary spill. Current information indicates that the proposed load allocations cannot be met for the full range of spillway flows, thus the reasonable assurances section of the TMDL should include greater discussion of the need to review the 110% TDG criterion as part of the actions required under this TMDL.
Response: The TMDL currently addresses the concerns raised here as fully as possible. The level of assurance provided is reasonable, given the context of the expenses involved, the uncertainty of outcome, and the goal of steady progress. Many other kinds of TMDLs that involve nonpoint sources, for example watershed temperature TMDLs, involve long-term compliance with uncertain outcomes. (Uncertain here means the extent of improvement is unknown, even though improvement is certain.) The regressions provided in DGAS are based on empirical analysis of existing structures. Because of the hydraulic and physical complexity of spill flows and gas exchange processes, it is impossible to predict with any accuracy the effects of proposed abatement measures. Therefore, the approach taken in the TMDL is the most reasonable, requiring steady progress, but recognizing the uncertainty of the specific level of improvement.

The TMDL process only allows us to focus on meeting existing standards. A separate process is available to evaluate the standards, and is discussed in the Report and in previous comments. In evaluating implementation options, we have three choices: we might be certain that a source cannot meet standards other than be removal of the source, we may be certain that a source can meet standards by using certain cost-effective methods, or we know of a variety of methods but be uncertain of their effectiveness until they are implemented. I believe the last choice is an accurate assessment of this situation. The second choice is not operative. I don’t believe the non-federal dams want the first choice to be operative, in light of the requirements of FERC license 401 certification.

Comment: Page 72. Reasonable Assurance. “The track record for congressional funding for these projects is good and there is reason to believe that further funding of projects will continue.” Same comment as contained in #6. The past Congressional funding to address TDG has been for ESA reasons; it is not appropriate to expect that the same level of Congressional fiscal support will be awarded to CWA issues.
Response: The perspective is appreciated; however we differ. We expect that over the long-term, congress will equally support the Clean Water Act and the Endangered Species Act.

Comment: Increases of spill and spill efficiency are critical to promote restoration and enhancement of anadromous fish populations in the Columbia Basin that are the foundation of the tribal treaties. The Lower Columbia TMDL should promote protection of the beneficial use by assuring safe dam passage thorough appropriate dissolved gas standards, while requiring the Corps and other federal agencies to prioritize structural measures to reduce the creation of total dissolved gas from federal dams in the Lower Columbia River. We strongly recommend that the state water quality agencies join the tribes in requiring the Corps and other federal agencies to

give top priority to funding of both gas abatement and temperature structures at the Lower Columbia dams.
Response: The function of a TMDL is to return waters to water quality standards. To try and change fish passage past dams is not within the ambit of this TMDL. This should be addressed within a biological opinion under the Endangered Species Act. Indeed, the 2000 biological opinion sets survival standards. This TMDL is consistent with those survival standards. We welcome Tribal support in securing funding for water quality improvements on the Columbia River.

Adaptive Management

No comment received.

Monitoring Strategy

Comment: A clear distinction should be made within the document, between short-term compliance and monitoring versus long-term compliance. Without a clear separation, the document seems to be contradictory regarding such things as the location for measuring compliance, the spill volume that may be allowed based on the measures and others.
Response: Long-term compliance will be established at the edge of the zone of aeration. This will be the point of compliance for this TMDL. However, given the long time series of data obtained from the existing Corps' fixed monitoring stations, and their historic use in relation to fish passage spill, they will continue to be used in the short-term.

Comment: Page 73, Monitoring Strategy, First paragraph – Replace "effective" with effectiveness." Fourth sentence, delete "Endangered Species Act."
Response: The amendments have been included. However, to ensure that readers understand the context for the Water Quality Team, the following words have been inserted just before – "National Marine Fisheries Service's."

Comment: Page 73, PH 5, line 9 – "the station represents TDG *and water temperature* in a"
Response: This has been inserted.

Comment: page 73 The document seems unsettled about the location of FMS for compliance. It seems to say that the WQT can determine the location of the FMS at sites other than the end of the bubble zone based on "screening criteria" related to "how well the station represents TDG in a given river reach and how sensitive the station is to non-spill factors that affect TDG". But no where in the standard are there such criteria other than " at any point of measurement". Then on page 61 there is presented a table showing exact distances downstream from each dam where FMS should be located. I don't think the point of compliance should be turned over to the WQT, instead it should be emphasized that the WQT can make recommendations to the states for approval.
Response: The FMS sites are established by the WQT for the ESA spills program. With the TMDL we are attempting to not interfere with the current process of placing FMS sites. The compliance locations will be evaluated by other means, most likely by synoptic near-field

studies. Nowhere are we requiring FMS sites to be placed at the compliance location. However, in the long run statistical relationships may be established between the compliance locations and FMS sites to allow real-time evaluation. Some FMS sites may already be representative of TDG at compliance locations, while it may be possible to move other sites to representative locations. The TMDL encourages those links, but does not require changes to FMS locations.

Comment: Page 74, Monitoring Strategy, First paragraph – The sentence "The quality assurance project plan should address the safety and stability due to strong…" Safety and stability of what?
Response: This has been amended to show that the plan should address the safety and stability of the site to support monitoring equipment.

Potential Funding Sources

No comment received.

Summary of Public Involvement

No comment received.

Public Involvement Actions

No comment received.

References and Bibliography

No comment received.

Notice of Public Hearing & Comment Period

Lower Columbia Draft TMDL for Total Dissolved Gas & Draft Implementation Plan

The Oregon Department of Environmental Quality (DEQ) and the Washington Department of Ecology are proposing limits to total dissolved gas to protect water quality on the Lower Columbia River.

Notice issued: February 18, 2002

Hearing date(s):

Monday, March 18, 2002
Washington Dept. of Ecology Field Office
1315 W. 4th Ave. (off Olympia St.)
Kennewick, WA

3:30 p.m. Question and Answer Session
4:00 p.m. Public Hearing

Tuesday, March 19, 2002
Tamastslikt Cultural Institute
72789 Highway 331
Pendleton, OR

1:30 p.m. Question and Answer Session
2:00 p.m. Public Hearing

Friday, March 22, 2002
Oregon State Office Bldg.
800 NE Oregon St.
Portland, OR

8:30 a.m. Question and Answer Session
9:00 a.m. Public Hearing

Friday, March 22, 2002
Washington Dept. of Fish & Wildlife
2108 Grand Blvd & 4th Plain
Vancouver, WA

1:00 p.m. Question and Answer Session
1:30 p.m. Public Hearing

Written comments due:
Written comments on the proposed Total Maximum Daily Load and/or the Implementation Plan must be received by 5 p.m. April 5, 2002.

Where can I send comments and get more information?
DEQ and Ecology accept comments by mail, fax and email. Send comments to:

Russell Harding
Oregon DEQ
811 SW 6th Avenue
Portland, OR 97204
E-mail: harding.russell@deq.state.or.us
Phone: (503) 229-5284
Fax: (503) 229-5408

Paul Pickett
Washington Dept. of Ecology
PO Box 47600
Olympia, WA 98504-7600
E-mail: Ppic461@ecy.wa.gov
Phone: (360) 407- 6882

(If there is a delay between servers, e-mails may not be received before the deadline.)

What is proposed?
DEQ and Ecology propose to submit the Lower Columbia River Total Dissolved Gas TMDL and Implementation Plan to the U.S. Environmental Protection Agency (EPA) for approval as a total maximum daily load (TMDL). EPA approval would remove water quality limited streams covered by the TMDL from DEQ's and Ecology's "303d" lists of impaired waterbodies.

The Lower Columbia River Total Dissolved Gas TMDL is based on the Clean Water Act, the Dissolved Gas Abatement Study conducted by the U.S. Army Corps of Engineers and the National Marine Fisheries Service's 2000 Biological Opinion for the Federal Columbia River Power System. This public hearing addresses only the TMDL and Implementation Plan that are being submitted to EPA.
The purpose of this notice is to invite you to make oral comments on this proposed TMDL at a hearing. You also may comment in writing.

Who is affected?
Users of the Columbia River. People interested in water quality and fisheries, and people interested in DEQ's and Ecology's implementation of Section 303(d) of the federal Clean Water Act.

State of Oregon
Department of
Environmental
Quality

811 SW 6th Avenue
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(800) 452-4011
Fax: (503) 229-5408
Contact:
Russell Harding
www.deq.state.or.us

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Washington State Department of Ecology
PO Box 47600
Olympia, WA 98504
Phone: (360) 407-6882
Fax: (360) 407-
Contact:
Paul Pickett
www.ecy.wa.gov

Why is this action necessary?

Section 303(d) of the federal Clean Water Act requires development of TMDLs for waterbodies included on states' "303(d)" list.

Where can I review the documents?

The TMDL/Implementation Plan is available for examination and copying at DEQ's Headquarters Office at Oregon DEQ, Water Quality Division, 811 SW 6th Avenue, Portland, OR 97204.

Documents are also available on DEQ's web site at:

http://www.deq.state.or.us.

Click on "water quality" then on "water quality program public notices".

The TMDL/Implementation Plan is available for examination and copying at Ecology's Headquarters Office at 300 Desmond Drive SE, Lacey, WA 98503.

Documents are also available at:

http://www.epa.gov/r10earth/columbiamainstemtmdl.htm

While not required, scheduling an appointment will ensure documents are readily accessible during your visit.

To schedule an appointment in Portland contact Russell Harding at (503) 229-5284.

For an appointment in Lacey, contact Paul Pickett at (360) 407-6882.

To request copies of the TMDL and Implementation Plan call Russell Harding or Paul Pickett at the above phone numbers.

Questions on the proposed TMDL and Implementation Plan should be addressed to Russell Harding or Paul Pickett at the above phone number.

Additional document locations

Copies of the TMDL/Implementation Plan are also available at:

DEQ - Pendleton Office
700 SE Emigrant, Suite 330
Pendleton, OR 97801

DEQ - The Dalles Office
400 East Scenic Drive, #307
The Dalles, OR 97058

DEQ - Northwest Region Office
2020 SW 4th Ave., #400
Portland, OR 97201

DEQ - North Coast Branch Office
65 N. Highway 101, Suite G
Warrenton, OR 97146

DEQ - Hermiston Office
256 E. Hurlburt, Suite 105
Hermiston, OR 97838

What happens next?

DEQ and Ecology will review and consider all comments received during the public comment period. Following this review, the TMDL and Implementation Plan may be sent to U.S. EPA for approval as a TMDL or may be modified prior to submission. You will be notified of DEQ's and Ecology's final decision if you present either oral or written comments during the comment period. If you do not comment but wish to receive notification of DEQ's and Ecology's final decision, please call or write DEQ or Ecology at the above phone numbers/addresses.

Accommodation of disabilities

DEQ and Ecology are committed to accommodating people with disabilities. Please notify DEQ or Ecology of any special physical or language accommodations you may need as far in advance of the hearing date as possible. To make these arrangements, contact Russell Harding at (503) 229-5284 or Paul Pickett at (360) 407-6882. People with hearing impairments can call DEQ's TTY at 503-229-6993 or Ecology's TTD or at Ecology's TDD number (360) 407-6006.

Accessibility information

This publication is available in alternate format (e.g., large print, Braille) upon request. Please contact DEQ Public Affairs at 503-229-5317 or toll free within Oregon 1-800-452-4011 to request an alternate format. People with a hearing impairment can receive help by calling DEQ's TTY at 503-229-6993.

Sign-in Sheet – Public Hearing on March 18, in Kennewick, Washington

WASHINGTON DEPARTMENT OF ECOLOGY
Public Meeting Sign In Sheet

Lower Columbia TDG TMDL
Meeting Topic

3-18-02 Kennewick, WA
Date

NAME: **ORGANIZATION:**	**ADDRESS—Street/P.O. Mailing AND E-mail** Note: We hope to provide information to you via e-mail, when possible.	**Prefer to receive information via**
Jim Irish	1653 E. Heritage Loop LA Center, WA 98629 JtIrish@BPA.gov	☒E-mail ☒U.S. Mail
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Steve Hays	Chelan PUD	☐E-mail ☐U.S. Mail
		☐E-mail ☐U.S. Mail

Sign-in Sheet – Public Hearing on March 19, in Pendleton, Oregon

ATTENDEE SIGN-IN SHEET

NAME ADDRESS/PHONE REPRESENTING

1. Frank Nicholson, 55 moore, Walla Walla Wa city cw2
2. Rick George (541)276-3449 rgeorge@ctuir.com
3. CARL MERKLE (541) 276-3449 [illegible] carlmerkle@ctuir
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Sign-in Sheet – Public Hearing on March 22, in Portland, Oregon

ATTENDEE SIGN-IN SHEET

	NAME	ADDRESS/PHONE	REPRESENTING
1.	Cliff Sears	P.O. Box 878 Ephrata WA. 98823 (509) 754-6612.	Grant PUD
2.	Waikele Hampton	PO Box 1231 Wenatchee WA 98801 509-663-8121	Chelan PUD
3.	Mike Herold		WA ST ECO.
4.	Mark Schneider	National Marine Fisheries Service 525 - NE Oregon	NMFS
5.	Richelle Harding	301 SE 83rd DRA	Mid-Co PUDs
6.	ROSY MAZAIKA	BLM 333 SW 1ST PDX	BLM
7.	Gary Fredricks	NMFS 525 NE OREGON 5032316855	NMFS
8.	Mike O'Bryant	4932 NE Tillamook PDX 97213	Col. Bas. Bull
9.	Helen Rueda	811 SW 6th PHd	EPA
10.	MARY LOU SOSCIA	EPA 811 S.W. 6th	
11.	John Piccininni	BPA-F+W Div·KEWR P.O. Box 3621, PDX 97208	BPA-
12.	Tom Lorz	CRITFC	CRITFC
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Sign-in Sheet – Public Hearing on March 22, in Vancouver, Washington

WASHINGTON DEPARTMENT OF ECOLOGY
Public Meeting Sign In Sheet

Lower Columbia TDG TMDL Vancouver fo
Meeting Topic

March 22, 2002
Date

NAME: **ORGANIZATION:**	**ADDRESS—Street/P.O. Mailing AND E-mail** Note: We hope to provide information to you via e-mail, when possible.	**Prefer to receive information via**
Richelle Harding D. Rohr & Assoc.	301 SE 83rd ~~hardin~~ Portland, OR 97216 richelledra@ Yahoo.com	☒E-mail ☐U.S. Mail
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