DEPARTMENT OF
ECOLOGY
State of Washington

State of Oregon
Department of
Environmental
Quality

Adaptive Management Team Total Dissolved Gas in the Columbia and Snake Rivers

Evaluation of the 115 Percent Total Dissolved Gas Forebay Requirement

Washington State Department of Ecology and
State of Oregon Department of Environmental Quality

Final

January 2009
Publication no. 09-10-002

Publication and Contact Information

This report is available on the Department of Ecology's website at
http://www.ecy.wa.gov/biblio/0910002.html

For more information contact:

Water Quality Program
P.O. Box 47600
Olympia, WA 98504-7600

E-mail: akah461@ecy.wa.gov
Phone: (360) 407-6404

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

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

If you need this publication in an alternate format, call the Water Quality Program at (360) 407-6404. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call 877-833-6341.

Adaptive Management Team
Total Dissolved Gas in the Columbia and Snake Rivers

Evaluation of the 115 Percent Total Dissolved Gas Forebay Requirement

Washington State Department of Ecology and
State of Oregon Department of Environmental Quality

Final

Table of Contents

List of Figures

List of Tables

Executive Summary

The Oregon Department of Environmental Quality (ODEQ) and the Washington Department of Ecology (Ecology) are making a decision on the need for the 115% forebay total dissolved gas (TDG) requirement to regulate spill during fish passage spill on the Columbia River and Lower Snake River dams. Oregon and Washington both have 110% TDG criteria that are modified for fish passage in the Columbia and Snake Rivers. The requirements for the Columbia and Snake Rivers include a 115% TDG requirement in the forebays and 120% in the tailraces.

This document provides technical decision-making information on forebay total dissolved gas issues, an overview of the regulatory history and requirements as described in the Columbia River and Lower Snake River Total Dissolved Gas Total Maximum Daily Loads, and summarizes and evaluates the technical information presented at the total dissolved gas Adaptive Management Team (AMT) meetings.

Policy and management issues such as setting fish passage spill volumes, fish transport options, and bypass routes are not addressed in this paper. This paper addresses only the 115% forebay TDG requirement. This paper focuses primarily on the Lower Snake River and Lower Columbia River dams, but includes a discussion on the dams from Priest Rapids to Chief Joseph.

All referenced documents are available on the AMT website at http://www.ecy.wa.gov/programs/wq/tmdl/ColumbiaRvr/ColumbiaTDG.html. The document tracking number is included in this document for reference.

Ecology and ODEQ received many comments on the analyses submitted at the AMT meetings. Ecology and ODEQ read each comment and frequently requested additional information from either the entity that did the analysis or the commenter. Because the purpose of this document is to provide a digestible synthesis of the information, a discussion of the comments received during the AMT meeting on each presentation is not included. Ecology and ODEQ understand the issues in the comment letters received regarding each AMT presentation, and the comments helped inform the agencies' decisions. The comments and the responses received on each AMT presentation are all available on the AMT website.

A draft of this document (website tracking #803) was presented to the Adaptive Management Team on September 4, 2008 for a 30-day AMT comment period. ODEQ and Ecology made the appropriate changes to the document based on the comments they received. Ecology and ODEQ responded to each comment from the 30-day AMT comment period. The response to comments summary document (#902) is available on the AMT website. Ecology and ODEQ used the information submitted and all of the comments received to develop the agencies' decisions.

If the 115% requirement was removed, the amount of fish passage spill could be increased, especially at Lower Monumental Dam on the Lower Snake River. The total amount of additional water that could be spilled in the near-term is estimated to be between 1-2%. Due to the expected increased power use in the region, reductions in overgeneration spill are likely. If overgeneration spill is reduced, the 115% forebay requirement limits voluntary spill more frequently. If both the Biological Opinion (BiOp) spill requirements and overgeneration spill volumes change significantly over time, removal of the 115% forebay requirement has the possibility of affecting spill even more significantly (up to a theoretical maximum of 60% more spill in some years).

There is no way to know the exact impacts on fish survival due to the increase in spill. ODEQ and Ecology used four methods provided by resource management agencies to estimate fish survival due to increased spill. Each method has a high level of uncertainty and controversy. With an increased spill of 1-2%, each analysis found that there is likely a small, positive effect on Chinook survival percentage (greater than zero but less than 1%). Some analyses found the potential for much greater survival (4-9%) at the higher spill estimates. One analysis found there might also be small negative effects on Snake River steelhead.

Likewise, there is no way to know the exact impacts on aquatic life from increases in TDG due to the increase in spill. With increases in spill of 1-2%, TDG would likely increase by about 0.3% in the forebays and 0.1% in the tailraces. In some forebays in some situations, TDG could increase by as much as 4% (the maximum TDG is estimated at 120% at Ice Harbor Dam forebay on the Lower Snake River). Results from the gas bubble trauma (GBT) monitoring program predict a small increase (less than 1%) in overall GBT in salmon if the 115% requirement was eliminated. (At 116-120% TDG in the forebays, about 1.4% of fish exhibit signs of GBT; in Oregon's TDG waiver, fish passage spill is terminated if 15% of the fish exhibit signs of GBT.) Two literature reviews argue that any negative effect would be negligible ("negligible" is defined as so unimportant as to be safely disregarded). The third literature review identifies that with depth compensation, aquatic life at one meter or deeper would not be affected if TDG increased to 120%. However, the same review identifies a potential impact that, while probably small, is not negligible for species at depths between the surface and one meter.

Ecology decided not to change its 115% TDG forebay water quality criterion for the Columbia and Snake Rivers. Ecology determined that there would be a potential for a small benefit to salmon related to fish spill if the 115% forebay criterion was eliminated, but there would also be the potential for a small increase in harm from increased gas bubble trauma. The weight of all the evidence from available scientific studies clearly points to detrimental effects on aquatic life near the surface when TDG approaches 120%. Based on the information in this document, Ecology does not believe the overall benefits of additional spill versus additional risk of gas bubble trauma are clear and are sufficient for a rule revision.

ODEQ decided to remove the forebay monitoring requirement. ODEQ finds that removal of the forebay monitoring requirement will not cause excessive harm to the beneficial use - aquatic species in the Columbia River - during fish passage spill. On June 22, 2007, the Environmental Quality Commission acting under the authority of OAR 340-041-0104(3) modified the total dissolved gas standard for the main stem Columbia River during specified periods in 2008 and 2009. Paragraph 3(vi) of the Environmental Quality Commission's Order gives the ODEQ authority to approve changes to the location and use of forebay monitors.

ODEQ and Ecology reached different conclusions regarding the 115% forebay requirement. ODEQ and Ecology do not disagree on the fundamental technical findings in this report. There are important differences in the TDG requirements in the two states; ODEQ issues a waiver with 115% forebay requirements while Ecology's forebay requirements are part of the water quality standards. Changing water quality standards is more difficult than changing a waiver. Further, ODEQ has a 105% shallow water TDG criterion while Ecology does not. Ecology's 115% requirements apply to dams on the Lower Columbia, Middle Columbia, and Lower Snake Rivers while ODEQ's requirement applies only to the Lower Columbia River.

Background

Oregon TDG requirements for the Columbia River

The state of Oregon total dissolved gas (TDG) water quality standard, found in OAR 340-041-0031 (2), states:

> Except when stream flow exceeds the ten-year, seven-day average flood, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection may not exceed 110% of saturation. However, in hatchery-receiving waters and other waters of less than two feet in depth, the concentration of total dissolved gas relative to atmospheric pressure at the point of sample collection may not exceed 105% of saturation.

The Oregon Department of Environmental Quality (ODEQ), with approval from the Environmental Quality Commission (EQC), issues "waivers" to the U.S. Army Corps of Engineers (USACE) to allow for TDG levels above the state standard of 110%. According to OAR 340-041-0104 (3) the EQC may modify the total dissolved gas standard in the Columbia River for the purpose of allowing increased spill for salmonid migration. The commission must find that:

a. Failure to act would result in greater harm to salmonid stock survival through in-river migration than would occur by increased spill.

b. 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.

c. Adequate data will exist to determine compliance with the standards.

d. Biological monitoring is occurring to document that the migratory salmonid and resident biological communities are being protected.

e. 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.

f. The commission may, at its discretion, consider alternative modes of migration.

Oregon first issued a TDG waiver in 1994. The current TDG waiver is available on ODEQ's website: http://www.deq.state.or.us/WQ/TMDLs/columbia.htm.

The TDG waiver allows for total dissolved gas levels of:

- 120% of saturation in the tailrace.
- 115% of saturation in the forebay.
- TDG may not exceed 125% of saturation for more than two hours in every 24 hours in the forebay and tailrace.

ODEQ measures the TDG average as the highest 12 hours in one calendar day. Biological monitoring is required during voluntary spill to determine the incidence of GBT to juvenile salmonids.

Washington TDG requirements for the Columbia and Snake Rivers

The Washington Department of Ecology (Ecology) last modified the TDG requirements in the water quality standards in 2003. The standards, found in WAC 173-201A 200(1)(f), state that the TDG criteria may be adjusted to aid fish passage over hydroelectric dams when consistent with a department-approved gas abatement plan. This plan must be accompanied by fisheries management and physical and biological monitoring plans. The elevated TDG levels are intended to allow increased fish passage without causing more harm to fish populations than caused by turbine fish passage. The following special fish passage exemptions for the Snake and Columbia Rivers apply when spilling water at dams is necessary to aid fish passage:

- TDG must not exceed an average of 115% as measured in the forebays of the next downstream dams and must not exceed an average of 120% as measured in the tailraces of each dam (these averages are measured as an average of the twelve highest consecutive hourly readings in any one day, relative to atmospheric pressure).
- A maximum TDG one hour average of 125% must not be exceeded during spillage for fish passage.

When reviewing the appropriateness of revising a water quality standard, Ecology must carefully consider whether the criteria will adequately protect the designated uses for that water. Designated uses are those water uses (e.g., fishing, boating, aquatic life, water supply) that are specified in the water quality standards for protection in a water body. All designated uses and even the most sensitive use must be fully protected. Sometimes the most sensitive use is not an Endangered Species Act (ESA) listed threatened or endangered species. If Ecology adopts criteria that are less stringent for pollutants, such as TDG, than those published by EPA, Ecology must justify the less restrictive criteria.

Under section 303(c) of the Act, EPA is required to review and to approve or disapprove state-adopted water quality standards. This review involves a determination of whether:

- The state adopted criteria that protect the designated water uses.
- The state followed its legal procedures revising or adopting standards.

EPA reviews any changes Ecology makes to its water quality standards to ensure that the standards meet the requirements of the Clean Water Act. EPA would disapprove the water quality standards and may promulgate federal standards under section 303(c)(4) of the Clean Water Act if state-adopted standards are not consistent with the factors listed above.

Overview of TDG Production

TDG levels can be increased above the water quality criteria by spilling water over spillways of dams on the Columbia River. There is a variety of other ways that TDG may be elevated: passage of water through turbines, fishways, or locks, and natural processes such as 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.

Natural processes may have a significant effect on TDG. TDG exchange rates increase as wind speeds rise, which produces degassing. If conditions are still and TDG levels are constant, the percent saturation of TDG can increase if the water temperature increases or barometric pressure drops. 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 its physical effects are minor compared to nitrogen.

TDG levels above the water quality standard can cause gas bubble trauma (GBT) in fish. GBT is caused by the formation of gas bubbles in the cardiovascular system of aquatic species. These bubbles block the flow of blood and respiratory gas exchange. GBT can cause chronic or acutely lethal effects, depending on TDG levels. Fish are protected from fatal pressures in deeper waters by compensation from hydrostatic pressures, which reduces absolute TDG approximately 10% for every one meter below the surface.

Spill at dams occurs for several reasons:

- "Involuntary spill" 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.
- "Voluntary spill" to enhance downstream fish passage (to meet "Performance Standards" for fish survival under the Endangered Species Act).

Involuntary spill occurs during periods 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 and Snake River hydropower dams contain 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 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.

Spills for fish passage typically occur during the spring and summer months, April 1 to August 31. During periods of fish passage 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 current TDG levels for fish passage: 115% in the forebay and 120% in the tailrace.

The highest TDG levels, and therefore the area most likely to exceed standards, are 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.

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. TDG exchange in spillway flow is the high rate of mass exchange that occurs below a spillway. The large volume of air entrained into spillway releases initiates the TDG exchange in spill. 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.

TMDL Overview

A total maximum daily load (TMDL), as identified in the federal Clean Water Act, determines the quantity (load) of a pollutant that can enter a water body and the water body still meet water quality standards. The TDG TMDLs for the Columbia River and Lower Snake River are available for review at:

Oregon: http://www.deq.state.or.us/wq/TMDLs/columbia.htm#tdg
Washington: Lower Columbia TDG TMDL: http://www.ecy.wa.gov/biblio/0203004.html
Mid Columbia TDG TMDL: http://www.ecy.wa.gov/biblio/0403002.html
Snake River TDG TMDL: http://www.ecy.wa.gov/biblio/0303020.html

The TMDLs address TDG in the mainstem Columbia and Snake Rivers. The states of Oregon and Washington listed multiple reaches of the Columbia and Snake rivers on their federal Clean Water Act 303(d) impaired waters lists due to TDG levels exceeding the states' water quality standards.

The TDG TMDL for the Lower Snake River addresses the 110%, 115% forebay, and 120% tailrace criteria. The Columbia River TDG TMDLs address only the ultimate attainment of the 110% criteria, because the 115% and 120% limits were temporary and annually renewed. The Columbia River TDG TMDLs implementation plans allow compliance with the 115% and 120% limits as an interim allowance for compliance with the TMDL in the short-term. The expectation of the Clean Water Act is that the 110% water quality criteria will be attained in a limited amount of time.

Biological Opinion for the Federal Columbia River Power System

As required by the Endangered Species Act, the Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) requires that the action agencies (U.S. Army Corps of Engineers, Bonneville Power Administration, and the U.S. Bureau of Reclamation) meet specific hydropower system 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 current 2008 Endangered Species Act Section 7(a)(2) Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation, dated May 5, 2008, states that the voluntary spill program is not to exceed established TDG levels by the state water quality agencies (Table 1). The Biological Opinion does not recommend or identify a numeric TDG threshold for state water quality agencies to include in their TDG standard or waiver for voluntary spill purposes, but rather relies on ODEQ and Ecology to make that determination.

Table 1. 2008 Biological Opinion Reasonable and Prudent Alternative Action Description for Total Dissolved Gas.*

RPA No.	Action Description	Implementation Plans, Annual Progress Reporting and Comprehensive RPA Evaluations
Hydropower Strategy 3—Implement Spill and Juvenile Transportation Improvements at Columbia River and Snake River Dams		
29	**Spill Operations to Improve Juvenile Passage** The Corps and BPA will provide spill to improve juvenile fish passage while avoiding high TDG supersaturation levels or adult fallback problems. Specific spill levels will be provided for juvenile fish passage at each project, not to exceed established TDG levels (either 110 percent TDG standard, or as modified by state water quality waivers, currently up to 115 percent TDG in the dam forebay and up to 120 percent TDG in the project tailwater, or if spill to these levels would compromise the likelihood of meeting performance standards (see RPA Table, RM&E Strategy 2). The dates and levels for spill may be modified through the implementation planning process and adaptive management decisions. The initial levels and dates for spill operations are identified in Table 2 [in the BiOp]. Future Water Management Plans will contain the annual work plans for these operations and spill programs, and will be coordinated through the TMT. The Corps and BPA will continue to evaluate and optimize spill passage survival to meet both the hydro system performance standards and the requirements of the Clean Water Act (CWA).	***Implementation Plans*** • The initial spill operation for juveniles is described in the proposed RPA. The spill operation will be updated annually and reported in the FPP. ***Annual Progress Report*** • Spill operations are reported annually. ***2013 and 2016 Comprehensive RPA Evaluation Reports*** • This information is the same as will be reported for each mainstem dam in hydro actions 14-21.

*Reasonable and Prudent Alternative Table, pg 32 of 98, https://pcts.nmfs.noaa.gov/pls/pcts-pub/pcts_upload.summary_list_BiOp?p_id=27149

The provisions of both the Clean Water Act and the Endangered Species Act (ESA) must be met. Notwithstanding that, it is not the purpose of the Clean Water Act to assume functions properly undertaken based on the Endangered Species Act. On the contrary, the Endangered Species Act contains provisions that encourage EPA to consult with National Marine Fisheries Service (NMFS) prior to approval of a TMDL that affects ESA-listed species. This ensures that the TMDL is consistent with species recovery goals. The BiOp issued under the Endangered Species Act requires attainment of certain fish passage performance standards. One way of meeting these is through spilling water over hydroelectric dam spillways (fish passage spill). This action results in elevated TDG. Control of TDG is the purpose of the Columbia and Snake Rivers TMDLs. The Clean Water Act does not suggest trade-offs of fish passage for TDG. Rather, it requires attainment of water quality standards. This is one of the significant challenges posed by the TDG TMDLs.

TMDL Implementation

Meeting the load allocations in the TDG TMDLs fall into two phases. Phase I short-term actions involve improving water quality while ensuring that salmonid passage is fully protected in accordance with the BiOp. Phase II long-term actions will involve structural and operational changes to dams to achieve the water quality standard for TDG.

The short-term actions in Phase I focus on meeting the fish passage performance standards as outlined in the BiOp through spill levels that generate gas no greater than the "waiver" levels of the water quality TDG standards. Water quality standards are measured at existing fixed monitoring stations managed by the U.S. Army Corps 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 BiOp are met.

Short-term compliance and the effectiveness of operational implementation actions are monitored at existing fixed monitoring station sites. The current TDG fixed monitoring station system consists of tailrace and forebay monitoring stations at each mainstem lower Snake and Columbia River dam. While most of these stations do a credible job of reporting meaningful data, some stations may be affected by environmental variables.

The Phase II long-term actions will be determined after evaluating the success of the short-term actions. The second phase will also move toward further structural modifications and reductions in fish passage spill after the BiOp-specified performance standards are met and adequate survival is provided for non-listed species. Actions taken in the previous phase will be reviewed for their effectiveness, both in improving TDG levels and for protecting salmonid passage. The BiOp survival goals may be met through fish passage actions other than spilling water. The final goal is meeting the Oregon and Washington water quality standard for TDG as measured at the end of the aerated zone below each dam. As part of Phase II, a detailed implementation plan or equivalent will be developed by the designated action agencies.

Long-term compliance with load allocations for dam spills will be at the downstream end of the aerated zone below each spillway in the tailrace. The TDG TMDLs specify distances for the compliance location at each dam. As a result, the load allocation must be met at each dam

individually at a specified compliance location, with allowance made for degassing in the tailrace below the spillway.

Need for Adaptive Management

ODEQ was directed to evaluate the need for the 115% forebay TDG monitoring requirement during fish passage spill by the Oregon Environmental Quality Commission (EQC) on June 21, 2007. At this EQC meeting, the 2007 TDG waiver was approved with the condition that the Adaptive Management Team (AMT) evaluates the need for the 115% TDG forebay limit during fish passage spill as stated:

> 3(vi) The Department may approve changes in the location of forebay and tailrace monitors, use of forebay monitors, and may approve changes to the method for calculating total dissolved gas. Before approving any changes, the Department must consult with the Adaptive Management Team or the Federal Columbia River Power System (FCRPS) Water Quality Team or both. The Department is directed to begin this process for consultation immediately and to evaluate and, if appropriate, approve such changes as soon as possible.

Additionally, the TDG waiver outlined the adaptive management process, as per the TDG TMDLs:

> The process for reviewing the implementation status of the 2002 Lower Columbia River Total Dissolved Gas TMDL will begin no later than January 1, 2011. The Washington State Department of Ecology will convene an advisory group comprising representatives of Oregon Department of Environmental Quality, 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. After 2010, the location of total dissolved gas monitors will be consistent with the adaptive management implementation strategy for the 2002 Lower Columbia River Total Dissolved Gas TMDL, may no longer require forebay monitors, and may require only tailrace monitors as TMDL implementation transitions from short-term to long-term strategies.

On June 27, 2007, Ecology received a letter from Save Our Wild Salmon (SOWS) regarding total dissolved gas and the Adaptive Management Team. SOWS stated itsr concern regarding the use of forebay monitors, specifically "monitoring for the forebays at the dams on the river are not working to protect water quality and salmon as they should." SOWS requested that Ecology convene the Adaptive Management Team as soon as possible.

The geographic scope of the AMT is the mainstem Columbia River as specified by the 2002 and 2004 TDG TMDLs (Bonneville, The Dalles, John Day, McNary, Priest Rapids, Wanapum, Rock Island, Rocky Reach, Wells, and Chief Joseph dams), and the lower Snake River in Washington as specified by the 2003 TDG TMDL (Ice Harbor, Lower Monumental Little Goose, and Lower Granite dams), Figure 1.

Figure 1. The Columbia River Basin. This paper addresses the eight Lower Columbia River and Snake River dams: Lower Granite (LGR), Little Goose (LGS), Lower Monumental (LMN), Ice Harbor (IHR), McNary (MCN), John Day (JDA), The Dalles (TDA), and is Bonneville (BON).

The AMT is a technical group. Policy and management issues, such as setting fish passage spill volumes, fish transport options, and bypass routes are not addressed at the AMT meeting. These topics are discussed at the FCRPS Implementation Team, Technical Management Team or other forums, with representation from Oregon and Washington departments of fish and wildlife.

The Adaptive Management Team

The AMT consisted of 11 member organizations, including the states of Oregon and Washington represented by their respective water quality agencies. The AMT membership was limited to 11 member organizations to expedite technical review and decision making while still allowing for input from the multiple viewpoints.

The role of the AMT members was to share and provide technical information to the group and advise Washington and Oregon on TDG. The role of Washington and Oregon was to make decisions using the technical input and follow state and federal laws and regulations. The Washington Department of Fish and Wildlife (WDFW) and Oregon Department of Fish and Wildlife (ODFW) advised Ecology and ODEQ on the adaptive management process.

The AMT held meetings about monthly from November 2007 through September 2008. At the meetings, different facets and impacts of the 115% forebay requirement were discussed. Complete meeting summaries, agendas, presentations, and papers are all available on the AMT website: http://www.ecy.wa.gov/programs/wq/tmdl/ColumbiaRvr/ColumbiaTDG.html.

AMT members:

- State of Washington (Ecology co-chair)
- State of Oregon (ODEQ co-chair)
- NOAA Fisheries
- U.S. Army Corps of Engineers (USACE)
- Save our Wild Salmon
- Confederated Tribes of the Colville Reservation
- Columbia River Inter Tribal Fish Commission
- Grant County Public Utility District (PUD)
- U. S. Environmental Protection Agency (EPA)
- NW River Partners
- U.S. Fish and Wildlife Service (USFWS)

All AMT meetings were open to the public. Regular attendees, in addition to the 11 AMT members, included Bonneville Power Administration (BPA), D. Rohr and Associates, Fish Passage Center (FPC), and Douglas PUD.

Issue for the Adaptive Management Team

The technical issue evaluated by the AMT and described in this document is the need for the 115% forebay TDG requirement during fish passage spill.

A determination that there is no longer a need for the 115% forebay TDG requirement during fish passage spill would result in removing the requirement from the states' water quality standards and waiver, and managing fish passage spill to the tailrace TDG limit of 120%. Currently, fish passage spill is managed to both the forebay and tailrace TDG limits, and would continue to be managed to these limits if the 115% forebay TDG limit is determined to be necessary.

Forebay Gauge History

Currently, there is no research being conducted to assess the representativeness of the forebay monitors as they relate to fish passage spill. However, several past studies evaluated the application and use of the forebay monitors as they relate to fish passage spill.

USACE operates the forebay gauges to accurately represent the TDG levels in the dominant aquatic habitat of each dam. USACE performed 28 TDG exchange research studies on forebay and tailwater gages on the Lower Columbia and Snake Rivers over an 11-year period, 1996 to 2007. The results of these studies reflect that the high TDG levels are generated from the spillway, and forebay TDG levels are carried through the powerhouse so that TDG levels can be different at different points in the tailrace. The TDG gauges are calibrated every three weeks to a primary and secondary standard, and the USGS and USACE perform data quality reviews daily. The TDG data exceeds the 95% data completeness standard. For more information on USACE's

TDG monitoring program history, please see "History of the Total Dissolved Gas Monitoring System" (#812) on the AMT website.

In 2000, National Marine Fisheries Service (NMFS) asked the USACE to address concerns regarding forebay monitor representativeness by including language in its Biological Opinion Reasonable and Prudent Alternatives (RPA) 132 to complete a systematic review and evaluation of the TDG fixed monitoring stations in the forebays. The study was conducted during the 2003 and 2004 fish passage spill season at McNary Dam and the four Lower Snake River projects: Ice Harbor Dam, Lower Monumental Dam, Little Goose Dam, and Lower Granite Dam.

Each of the study project forebay stations experienced "thermally-induced TDG pressure spikes during the test periods." The study resulted in two recommendations. The first was to permanently relocate each forebay gauge to an area just upstream of the project in a location not affected by down-welling surface waters, such as the navigation lock guide wall. Additionally, the study recommended each instrument be positioned at a depth of 12-15 meters to avoid thermal responses in the TDG pressure readings. The findings and full report are available on-line:

> BiOp Measure 132 Final Report, December, 2004: "Total Dissolved Gas Forebay Fixed Monitoring Station Review and Evaluation for Lower Snake River Projects and McNary Dam, 2003-2004,"
> http://www.nwd-wc.usace.army.mil/tmt/wq/studies/rpa132_20041230.pdf

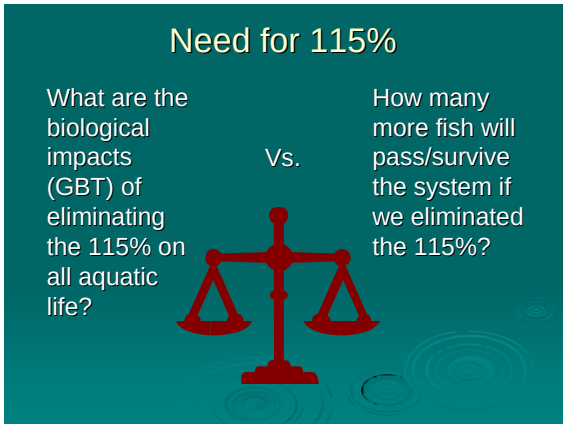
In 2001, the USGS identified representativeness issues with the Camas-Washougal forebay gauge. Specifically, the USGS found that daily variations of TDG were "probably due to the production of oxygen by aquatic plants and to water-temperature variations on warm, sunny days" (Water-Resources Investigations Report 01-4273, page 11 and Figure 13 on page 12, http://or.water.usgs.gov/pubs_dir/WRIR01-4273/index.html). This USGS report led to a 2004 follow-up isotope study of TDG at Camas-Washougal. These data were never published, but the data indicated that the increased afternoon dissolved oxygen at Camas-Washougal forebay gauge was due to photosynthesis rather than Bonneville Dam spill (email communication with Dwight Tanner, USGS, June 24, 2008).

On September 29, 2006, the Fish Passage Center (FPC) sent a memo to the Fish Passage Advisory Committee regarding Spring Spill 2006 (FPC document 136-06.pdf). In that memo, FPC evaluated the "efficacy of forebay monitoring" and discussed the question of "did the USACE's relocation in 2004 and 2005 lead to more accurate monitoring?" in the forebay. The FPC memo concluded that the forebay monitors "do not represent the measurements of TDG in mixed waters as was originally intended." Although the forebay monitors were relocated and lowered deeper into the water column in 2004 and 2005, questions regarding their representativeness of fish passage spill still exist.

Information the AMT Considered

In evaluating the need for the 115% TDG forebay limit during fish passage spill season, the AMT considered how removal of the 115% TDG forebay limit would affect fish and other

aquatic life. ODEQ and Ecology framed the technical evaluation by asking the AMT the following two questions:



Question 1: What are the biological impacts (gas bubble trauma) of eliminating the 115% TDG forebay limit on all aquatic life?

Question 2: How many more fish will survive the system if we eliminated the 115% limit?

Removing the 115% forebay TDG limit has the potential to increase spill volumes at the Columbia and Snake River dams. Increased spill volumes may result from managing fish passage spill only to the 120% tailrace TDG limit. Additional spill has the potential to increase fish passage and survival past each dam. However, increasing fish passage spill may also increase the TDG levels that may increase the incidence of gas bubble trauma and potentially affect aquatic species.

The AMT presented the following data and analytical results to the states to evaluate the need for the 115% TDG forebay limit:

- FPC analysis of spill volume.
- USACE analysis (SYSTDG) of spill volumes.
- BPA analysis (HYDSIM) of spill volumes.
- FPC Analysis of Juvenile Hydro-system Survivals Smolt to Adult Returns (SARs).
- Comparative Survival Study (CSS).
- Comprehensive Passage Model (COMPASS).
- Adult Passage and Survival.
- Smolt Monitoring Program Results on Gas Bubble Trauma Incidence.
- NOAA Fisheries Resident Fish Literature Review.
- Ecology Literature Review.
- Parametrix Literature Review.

All presentations and reports were open for comment. Comments were shared with presenters giving them a chance to respond. All presentations, comments, and responses are available on the TDG AMT website:

http://www.ecy.wa.gov/programs/wq/tmdl/ColumbiaRvr/ColumbiaTDG.html

ODEQ and Ecology used all the information presented at the AMT to form the technical basis of their decision.

Spill Volume Considerations

Setting or limiting fish passage spill volumes are considered a management issue for discussion at the Federal Columbia River Power System (FCRPS) forum or other forums. Spill management will not be set or negotiated at the AMT, but will be discussed in the context of TDG and impacts to aquatic species.

Fish passage spill volumes are determined by several factors:

- Spill operations (as defined by the BiOp.)
- Spill caps (as defined by TDG water quality limits in the forebay and tailrace set by state water quality agencies.)
- Involuntary spill (when the river flow exceeds the hydraulic capacity of the dam.)
- Minimum generation (the amount of flow necessary to generate the minimum amount of electricity to keep the regional electrical grid stable, and the remainder is used for fish passage.)
- Overgeneration spill (spill that must occur when the amount of flow in the river system would otherwise produce more energy, if passed through turbines, than there are accessible energy markets available.)
- Other fish passage spill determinations may exist, such as physical limitations due to erosion in tailrace basins or navigational concerns.

Spill Volume Analysis: With and Without the 115 Percent TDG Limit

The Fish Passage Center (FPC), USACE, and Bonneville Power Administration (BPA) each conducted an analysis of how much more fish passage spill volume would be possible if the 115% was eliminated. The amount of spill varies greatly depending on the fish passage spill volume factors being implemented (described previously) and how much water is in the river. The amount of water in the river varies by year, season, and day. The variations in volume are caused by amount of snow pack, rainfall, water withdrawal, and upstream dam operations.

The three entities analyzed the potential changes in spill volume using different approaches and assumptions. The differences observed among the analyses were due to the flow years used, the assumptions of spill operations, treatment of excess generation spill, and other limitations on spill. The FPC analysis considered past years' empirical data for flow, spill, and TDG and projected what spill would have occurred if the 115% forebay requirement was removed in four different spill scenarios. The USACE and BPA analysis assumed that the 2008 Biological Opinion spill levels were implemented. Their analyses used one spill scenario. The BPA analysis included overgeneration spill and conducted simulations for the 70-year flow record.

One must be careful when directly comparing the spill volumes from the different analyses, given the differences in assumptions for each analysis. Table 2 summarizes the assumptions made for spill program amounts implemented in each of the analyses.

Table 2. Spill Volume Analysis Summary

Author	Report Title	Years Analyzed	Simulation	Data Set
FPC	*Volume Changes with Use of Tailrace Monitors.* (#303), see page 2	**Low - Moderate water years**: 2003, 2005, 2007 **High water year**: 2006	**Base Scenario:** The year's actual spill volume, which accounts for excess generation spill. **Scenario B**: The spill that would have occurred during that year if all projects spilled to the 120% cap on days when spill was restricted by the 115% downstream forebay, but not the 120% tailrace. **Scenario C**: The spill that would have occurred in that year if all projects spilled to the 120% cap. This scenario was limited by planned operations. **Scenario D**: The spill that would have occurred in that year if all projects spilled to the 120% cap, but this spill analysis was not limited by planned operations.	FPC used a statistical analysis of the empirical data set for each year and modeled the estimated changes in spill volumes. The analysis does not include overgeneration or other involuntary spill.
USACE	*Report on the SYSTDG Modeling for AMT: With and without 115 percent TDG standard.* (#710), see page 10.	**Low water year**: 2007 **Moderate water year:** 2002 **High water year**: 1999	Hourly average of spill volume and spill cap with and without the 115% TDG forebay limit for each project and each year.	The ACOE SYSTDG hourly time-step model was used to model the flow assumptions from each year using the 2008 FCRPS BiOp spill operations, including overgeneration and other involuntary spill.
BPA	*HYDSIM Use in Analysis of Removing 115 percent TDG Forebay Gauge Requirements BPA Report to the Adaptive Management Team.* (#710), see page 10, and (#605)	70 years, averaged (1929 - 1999)	70-year average spill with and without the 115% TDG forebay limit for each project.	The BPA HYDSIM monthly time-step model used the SYSTDG hourly calculated spill caps, which were averaged into monthly spill caps for input into HYDSIM using the 2008 FCRPS BiOp spill operations and involuntary spill. HYDSIM modeled 70 years of historical runoff data, including overgeneration spill, to generate monthly average flows and spill volumes at each dam.

FPC Analysis

The FPC's analysis, *Spill Volume Changes with Use of Tailrace Monitors* (#303), is available on the AMT website. BPA and USACE provided comments on the FPC analysis, and FPC responded to the comments. These documents are available on the AMT website.

The FPC analyzed the low to moderate water years of 2003, 2005, and 2007 and the high water year of 2006; see Figures 2 through 5. The FPC ran scenarios with differences in planned operations ranging from the base case (what was actually implemented in that year) to what would occur if there was no spill management except for the 120% TDG requirement (meaning projects were not managed to a specific spill program but spilled the full volume of water to the 120 % TDG). They defined the scenarios as:

Scenario B: Spill that would have occurred if all projects spilled to the 120% cap on days when spill was restricted by the 115% downstream forebay (but not the 120% tailrace).

Scenario C: Spill that would have occurred in that year if all projects spilled to the 120% cap (limited by planned operations).

Scenario D: Spill that would have occurred in that year if all projects spilled to the 120% cap (not limited by planned operations).

The planned operations were different among years, dependent on the spill program implemented. For example, the 2003 spill program followed the 2000 BiOp and the 2005 spring spill followed the 2000 BiOp, whereas the 2005 summer spill followed the court-ordered spill. Years 2006 and 2007 followed the court order.

Depending on the year and the scenario used, removing the 115% forebay requirement would allow an additional 0.5 to 58.1 million acre feet of spill on the lower Columbia and Snake Rivers; see Table 3.

Table 3. FPC Statistical Analysis Additional Spill Volumes (Million Acre Feet) Under the Three Scenarios, Compared to the Base Case Volume (involuntary spill removed).

Water Year	Scenario B: FB Restricted	Scenario C: 120% Limited	Scenario D: 120%
2003	2.27	13.01	41.57
2005	0.52	11.06	43.06
2006	2.8	9.56	52.53
2007	1.45	5.98	58.07

According to the FPC analysis, if the 115% forebay requirement was removed then all the dams would experience an increase in fish passage spill. However, Little Goose and Lower Monument dams on the Snake River would experience the greatest increase in fish passage spill.

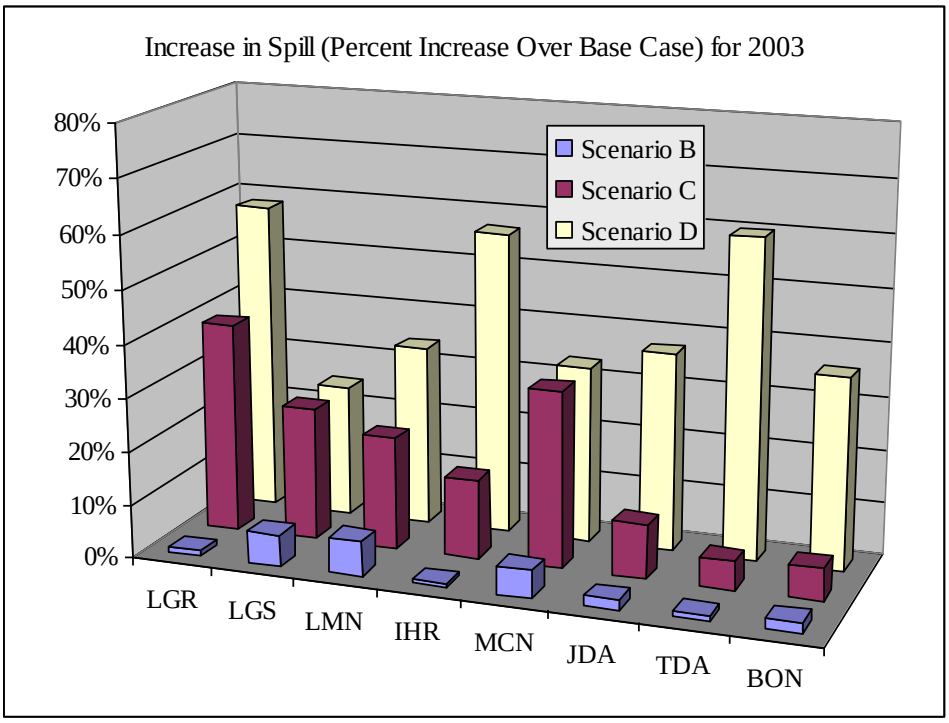


Figure 2. FPC Statistical Analysis of Increased Spill in 2003 (percent increase over base case). Lower Granite (LGR), Little Goose (LGS), Lower Monumental (LMN), Ice Harbor (IHR), McNary (MCN), John Day (JDA), The Dalles (TDA), and Bonneville (BON). The increase in spill (percent increase over base case) is calculated as:

$$\frac{Spill\ Volume\ (KAF)\ of\ Scenario\ B,\ C, or\ D - Spill\ Volume\ (KAF) of\ Base\ Case}{Spill\ Volumbe\ (KAF) of\ Base\ Case}$$

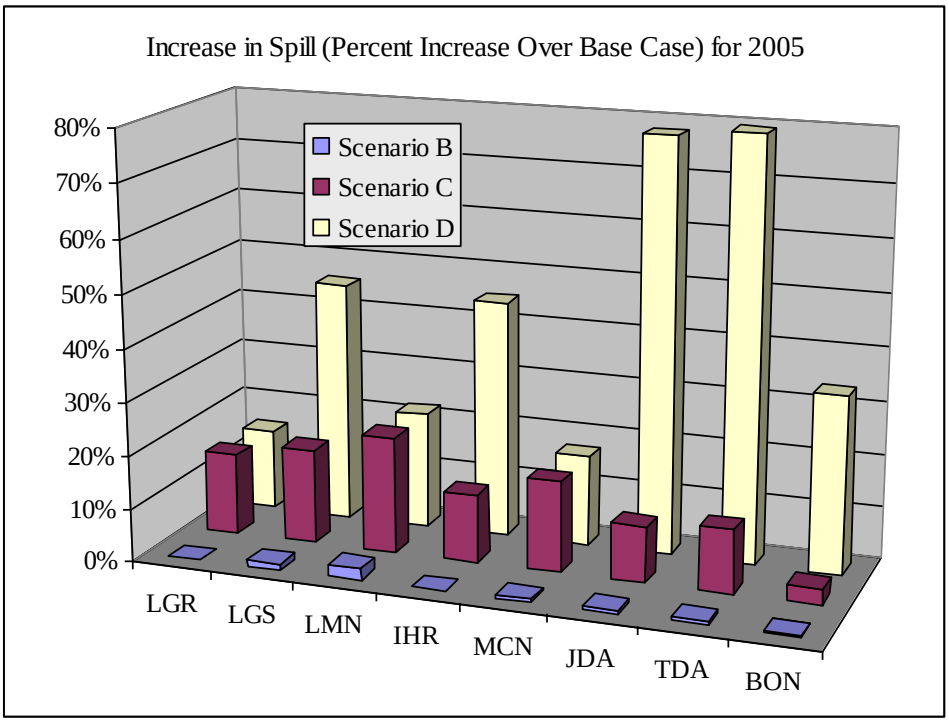


Figure 3. FPC Statistical Analysis of Increased Spill in 2005

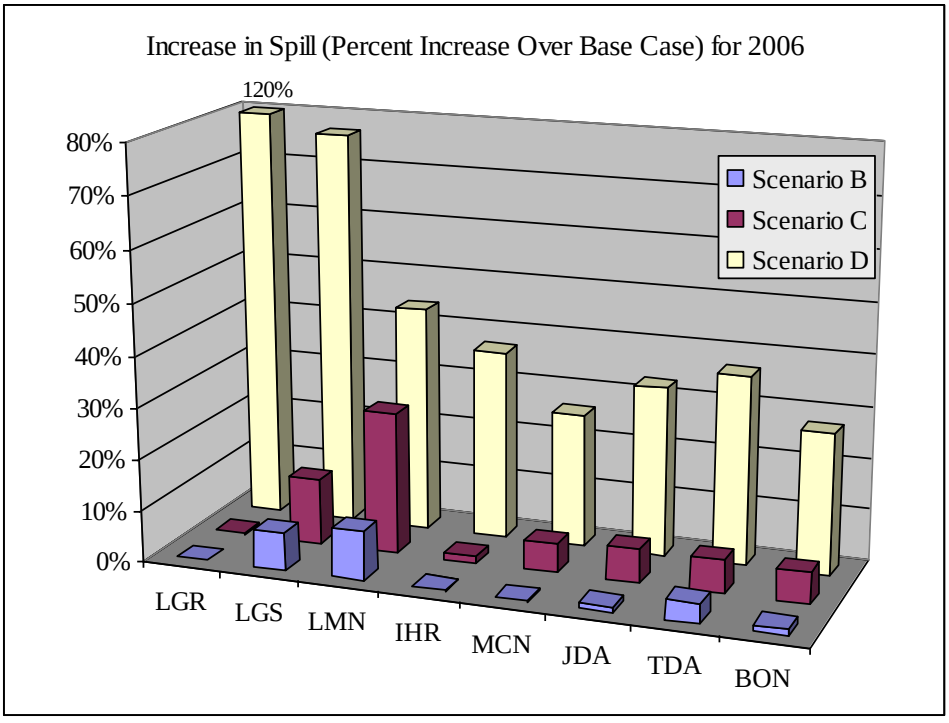


Figure 4. FPC Statistical Analysis of Increased Spill in 2006

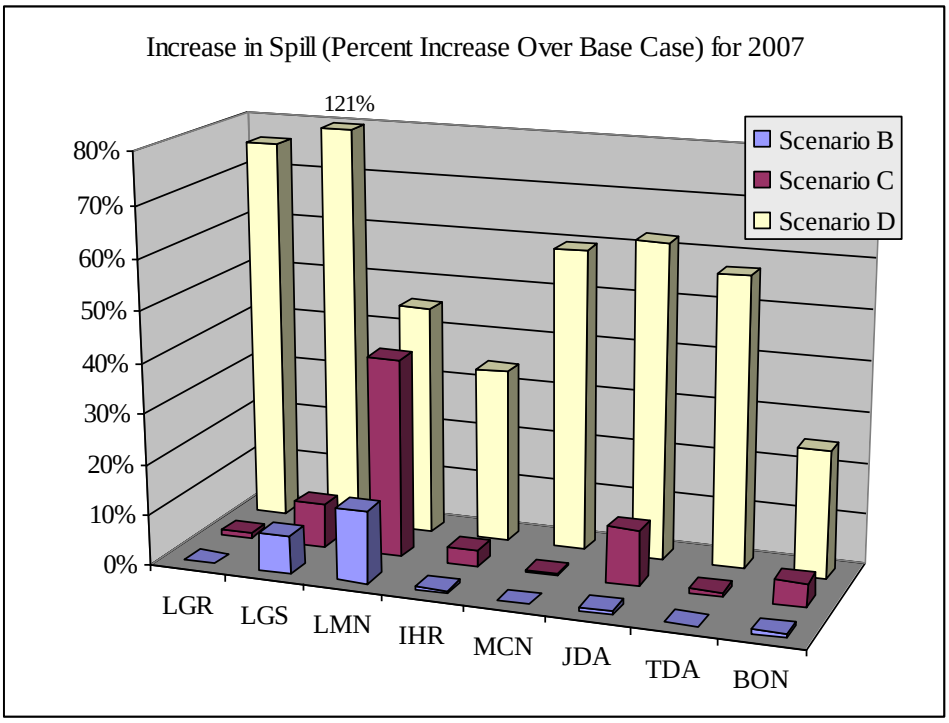


Figure 5. FPC Statistical Analysis of Increased Spill in 2007

USACE Analysis (SYSTDG)

The USACE's analysis, *Report on the SYSTDG Modeling for AMT: With and without 115 percent TDG standard* (#710), is available on the AMT website. Comments on this document are available on the AMT website.

The USACE analyzed the high water year of 1999, the moderate water year of 2002, and the low water year of 2007. The analysis used assumptions from 1999, 2002, and 2007 operations, and spill operations from the October 31, 2007 Columbia and Snake River FCRPS BiOp. See the report for details.

In the USACE analysis, multiple factors controlled spill on the Lower Columbia and Snake Rivers:

- BiOp spill operations (76% of the time).
- The 120/115% spill caps (12% of the time).
- Involuntary spill (8% of the time).
- Minimum generation (4% of the time).

According to the analysis:

- For the 1999 high water year, eliminating the 115% TDG requirement would result in an additional 5.9 Million Acre Feet (MAF) spill (a 4.0% increase).

- For the 2002 medium water year, eliminating the 115% TDG requirement would result in an additional 2.3 MAF spill (a 1.8% increase).
- For the 2007 low water year, eliminating the 115% TDG requirement would result in an additional 2.5 MAF spill (a 2.2% increase).

Most of the additional spill would come from Lower Monumental and Bonneville dams. In high water years, some would also come from John Day, The Dalles, and Little Goose dams. See Figure 6 (and Tables 11-13 of the USACE analysis, document 710) for details.

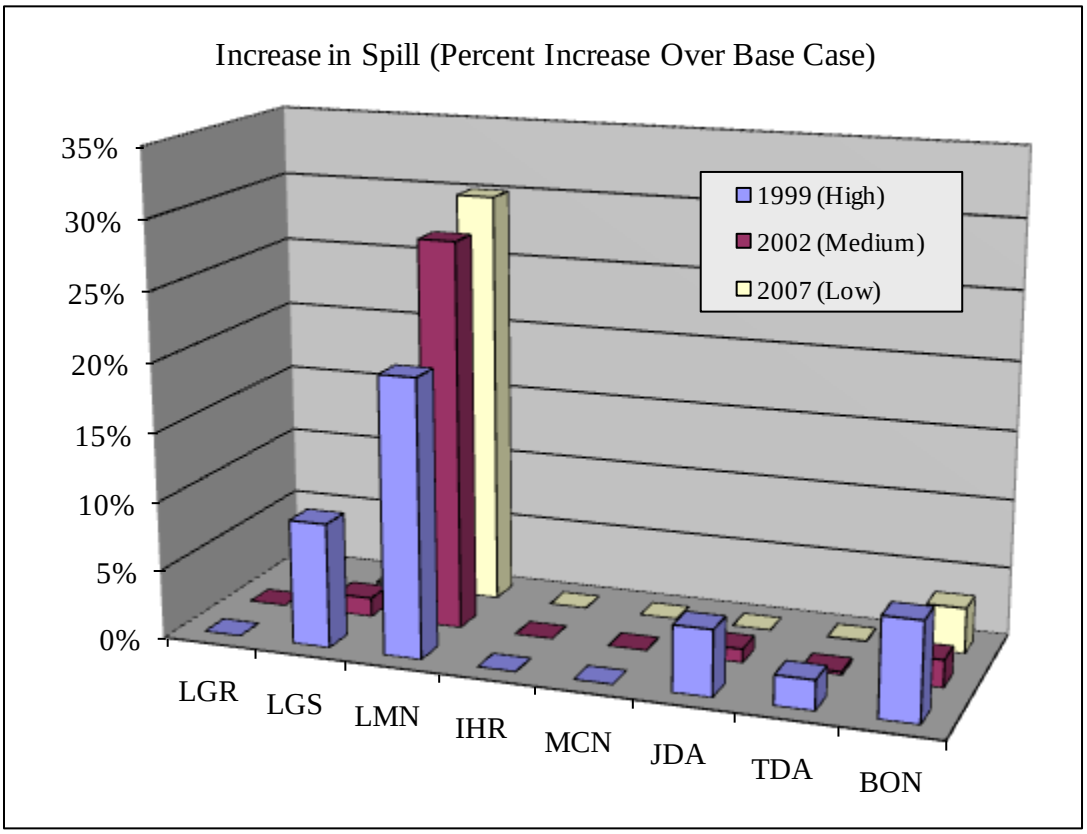


Figure 6. USACE SYSTDG Model Results of Analysis of Spill Volumes. SYSTDG analyzed how much spill would occur under the base case of the 115%/120% requirement and determined how much more spill would occur under a 120%-only scenario. The increase in spill (percent increase over base case) is calculated as:

$$\frac{\textbf{\textit{Spill Volume (KAF) of 120\% only Scenario}} - \textbf{\textit{Spill Volume (KAF) of 115 \& 120 Base Case}}}{\textbf{\textit{Spill Volume (KAF) of 115 \& 120 Base Case}}}$$

BPA Analysis (HYDSIM)

The BPA analysis, *HYDSIM Use in Analysis of Removing 115 percent TDG Forebay Gauge Requirements BPA Report to the Adaptive Management Team – May 2008* (#605) is available on the AMT website. No comments were received on this analysis.

The BPA analysis used spill caps provided by the USACE analysis. The spill caps were applied to 70 years of historical runoff data to generate monthly average flow and spill volumes at each dam. Overgeneration spill that occurred in excess of the planned spill program (the 2008 Biological Opinion) is included in the BPA base case.

According to BPA's analysis, eliminating the 115% requirement would result in more spill at Lower Monumental (13% increase), Bonneville (2.9% increase), and, to a much lesser extent, Little Goose (1.1%) and The Dalles (0.5% increase) dams. The increase in spill at these dams, and the resulting loss of power generation, means the other dams could generate more power and would have less overgeneration spill. Thus, eliminating the 115% requirement would result in slightly less spill at Lower Granite, Ice Harbor, McNary, and John Day by 0.1-0.2%. See Figure 7 for details.

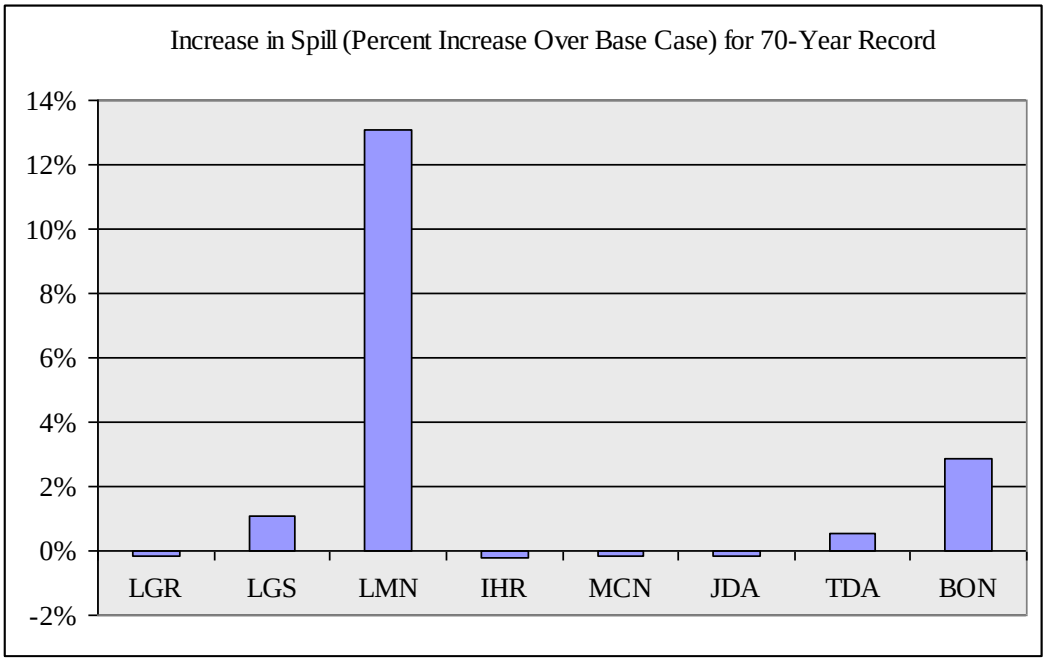


Figure 7. BPA HYDSIM Model Calculations of Spill Changes The increase in spill (percent increase over base case) is calculated as:

$$\frac{\textbf{Spill Volume (KAF) of 120\% only Scenario} - \textbf{Spill Volume (KAF) of 115 \& 120 Base Case}}{\textbf{Spill Volume (KAF) of 115 \& 120 Base Case}}$$

Synthesis of FPC, USACE, and BPA Analyses of Spill Volumes

The three analyses reached similar conclusions on where the elimination of the 115% requirement would have the most significant difference.

Table 4. Dams Most Affected by Removal of the 115% Requirement

Analysis	Dams most affected by eliminating 115% requirement
FPC Analysis	Little Goose and Lower Monumental
BPA HYDSIM	Lower Monumental and Bonneville
USACE SYSTDG	Lower Monumental and Bonneville

The three analyses reached variable conclusions on the total amount of additional spill that would occur if the 115% requirement was eliminated.

Table 5. Increase in Spill. The increase in spill (percent increase over base case) is calculated as:

$$\frac{\textbf{Spill Volume (KAF) of 120\% only Scenario} - \textbf{Spill Volume (KAF) of 115 \& 120 } \textit{Base Case}}{\textbf{Spill Volume (KAF) of 115 \& 120 } \textit{Base Case}}$$

Analysis	Increase in spill (percent increase over base case; per year; an average for all eight Lower Columbia and Snake River dams combined)
FPC Analysis	1% - 60% depending on the year and scenario
BPA HYDSIM	1.8% - 4.0% depending on the year
USACE SYSTDG	1.3% average over 70 water years

One must be careful when directly comparing the spill volumes analyses. While the three analyses presented are addressing the same topic, the assumptions made in each analysis vary. The differences between the FPC, USACE, and BPA analyses were the assumptions each analysis made on inclusion of 2008 BiOp spill operations, the treatment and inclusion of overgeneration spill, the years analyzed, and other limitations on spill programs. Since each analysis treated these important factors differently, the changes in spill volumes with and without the 115% TDG forebay limit range in value.

Fish Survival Impacts

The FPC, U.S. Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA), and the Columbia River Inter-Tribal Fish Commission (CRITFC) each conducted an analysis on how anadromous fish passage and survival would be impacted if the 115% TDG limit was removed. The FPC provided an analysis of the importance of spill in juvenile hydro-system survivals and Smolt to Adult Returns (SARs), using empirical data and a multiple regression analysis. USFWS presented modeling results from the Comparative Survival Study (CSS) on juvenile salmonid survival. NOAA presented results from its Comprehensive Passage (COMPASS) model. Adult passage and survival impacts were summarized by CRITFC. These analyses addressed the eight Lower Columbia and Lower Snake River dams. Table 6 summarizes the assumptions made for each of the analyses.

Table 6. Fish Passage and Survival Impacts Analysis Summary

Author	Report Title	Years Analyzed	Simulation	Data Set
FPC	*Importance of spill in Juvenile Hydro-system survivals and SARs* (#306)	1998 - 2005	Statistical analysis for smolt reach survival analyses for yearling spring / summer Chinook, steelhead and fall Chinook; Relation between juvenile survival and adult return rates with and without the 115% TDG forebay limit.	Empirical data set for each year and species used in the analysis.
USFWS presen-tation	*Comparative Survival Study (CSS) Chapter 2* (#402a)	1998 - 2006	Statistical analysis for yearling Chinook and steelhead migrants' survival.	Empirical and modeled data set for each species analyzed for two reaches: Lower Granite to McNary and McNary to Bonneville. The analysis used weekly released cohort PIT-tagged fish, with median estimated fish travel time and survival rates. The analysis included temperature, turbidity, flow, water travel time, average percent spill, and seasonality for each year and reach modeled.
NOAA	*Explanation of COMPASS Analysis of TDG Alternatives* (#609)	70 years, averaged (1929 - 1999)	Statistical analysis of survival and Lower Granite to Lower Granite smolt-to-adult-return for Snake River spring / summer Chinook and steelhead, Upper Columbia spring Chinook and steelhead, and Mid	Empirical and modeled data set were used for this daily time step model. The HYDSIM monthly modeled mean 70 year average water record was translated into a daily time step for average flow and spill model input. The model includes transport, FCRPS

Author	Report Title	Years Analyzed	Simulation	Data Set
			Columbia steelhead with and without the 115% TDG forebay limit.	survival but not post Bonneville effects for the period starting April to end of June.
CRITFC	*Review of Adult Passage through Different Dam Passage Routes* (#709)	2008 ACOE Steelhead Kelt fish passage	Statistical analysis of four downstream adult passage routes: screen bypass system, spill, turbines, and surface bypass.	Empirical data set for the years analyzed and literature.

FPC Analysis of Juvenile Hydro-system Survivals and SARs

The FPC's analysis, *Importance of spill in Juvenile Hydro-system survivals and SARs* (#306), is available on the AMT website. BPA provided comments on the FPC analysis, and FPC responded to the comments. These documents are available on the AMT website.

The FPC presented statistical analysis for smolt reach survival analyses for yearling spring / summer Chinook, steelhead and fall Chinook, and a relation between juvenile survival and adult return rates for data collected between 1998 and 2005. The study showed a relationship between increased spill and increased reach survival for juvenile migrants. The analyses accounted for the effect of ocean conditions on adult survival and showed a relationship between juvenile reach survival and adult returns.

According to the FPC analysis, the increased benefit of spill occurs when average spill proportions increase above 40% for spring / summer Chinook and steelhead; see Figures 8 and 9. This is likely due to increased numbers of fish passing via spill as spill proportions increase.

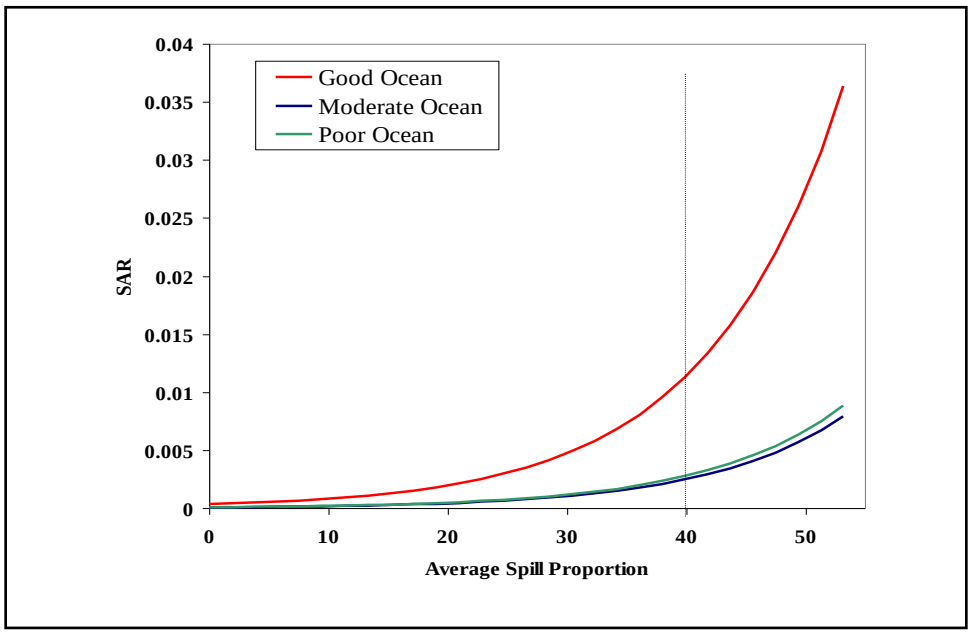


Figure 8. FPC Statistical Analysis Predicted response to increasing spill volumes of Smolt to Adult Returns (SARs) for spring/summer Chinook salmon under good, moderate and poor ocean productivity levels.

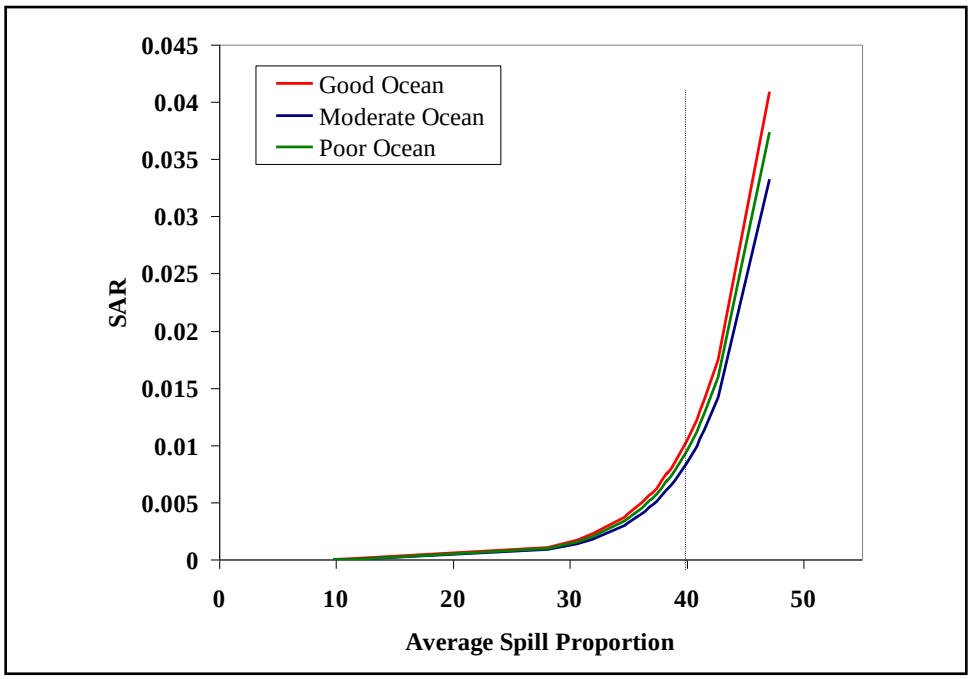


Figure 9. FPC Statistical Analysis Predicted response to increasing spill volumes of Smolt to Adult Returns (SARs) for steelhead under good, moderate and poor ocean productivity levels.

The FPC analysis identified a positive relationship between juvenile reach survival and average spill; see Figure 10.

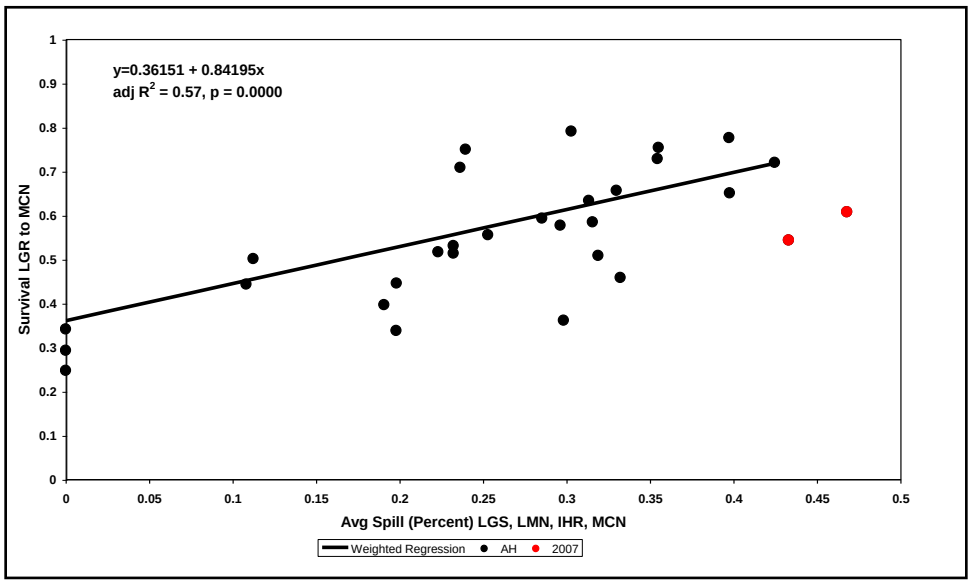


Figure 10. FPC Statistical Analysis x-y Plot of Sub-Yearling Chinook Survival from Lower Granite (LGR) to McNary (MCN) dams versus Average Spill Percent for Little Goose (LGS), Lower Monumental (LMN), Ice Harbor (IHR) and McNary (MCN) dams.

A similar approach showed that an increase in water travel time had a negative relationship with reach survival demonstrating that as water travel time decreases (i.e., flows increase) survival increases; see Figure 11.

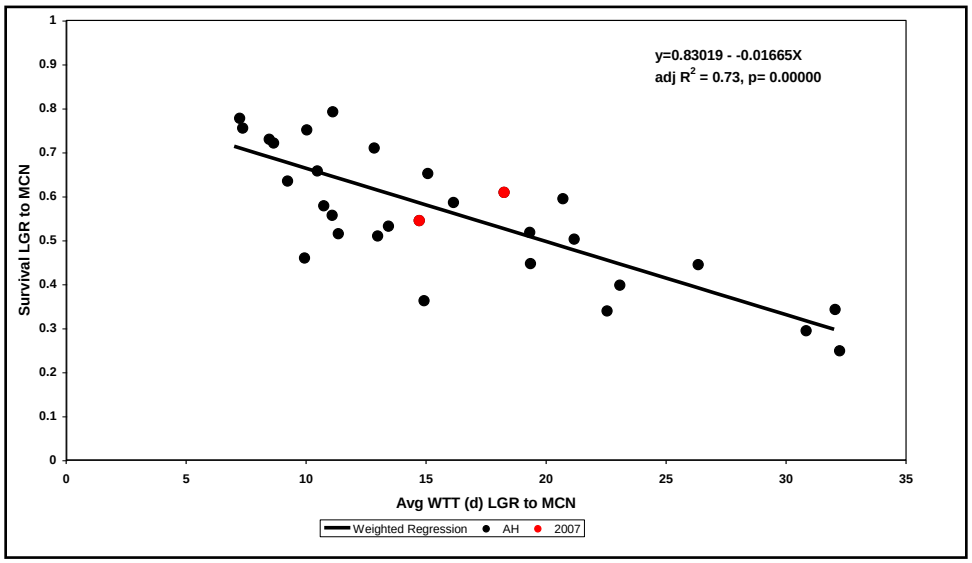


Figure 11. FPC Statistical Analysis x-y Plot of Hatchery Sub-Yearling Chinook Survival versus Water Travel Time (WTT) from Lower Granite (LGR) to McNary (MCN) dams.

CSS Study Presented by USFWS

The *Comparative Survival Study (CSS) Chapter 2* (#402a), presented by USFWS, is available on the AMT website along with comments on the analysis. BPA and Northwest River Partners provided comments on the CSS. Most of the comments received at the AMT were developed during the 2007 regional CSS review. USFWS and FPC responded to the comments received during the AMT process. These comments are available on the AMT website. The CSS is a joint project of FPC, USFWS, Idaho Department of Fish and Game, ODFW, WDFW, and CRITFC.

The CSS used the 1998 to 2006 data set to show that juvenile travel times, instantaneous mortality rates, and survival rates through the hydro system are strongly influenced by managed river conditions including flow, water travel time, and spill levels.

USFWS provided the expected juvenile survival under the different spill volume scenarios presented by the FPC analysis. The spill amounts for each year were further divided by date to match the different steelhead and chinook cohorts. The CSS determined that survival was based on when during the year the salmon migrated (Julian date is used in the formulas), the spill proportion, and either the flow (steelhead) or water transit time (Chinook). FTT is fish transit time and Z is instantaneous mortality.

For wild Chinook, survival from Lower Granite to McNary is:

$$Survival = e^{-Z \times FTT}$$

$$FTT = e^{9.175098 - 0.009814 \times Spill - 0.097455 \times Date + 0.030975 \times WTT + 0.000342 \times Date^2}$$

$$Z = -3.893879 - 0.214382 \times WTT + 0.00394 \times Date + 0.00204 \times Date \times WTT$$

Hatchery Chinook survival uses the same basic formula but different numeric constants.

For steelhead, survival from Lower Granit to McNary is:

$$Survival = e^{-Z \times FTT}$$

$$FTT = e^{2.143886 - 0.0053 \times Date - 0.00513 \times Spill + 0.093911 \times WTT}$$

$$Z = -0.17176 + 0.001806 \times Date - 0.00071 \times Spill + \frac{3.683971}{Flow}$$

The CSS analysis predicted that the absolute increase in juvenile yearling Chinook survival from Lower Granite Dam to McNary Dam would range from 0% to 4%, and 1% to 9% for steelhead; see Table 7. The McNary to Bonneville Dam absolute increase in juvenile yearling Chinook survival would range from 0% to 5%.

Table 7. Absolute Increase in Survival. No planned spill occurred at Lower Granite, Little Goose, and Lower Monument during the spring of 2005.The increase in survival uses the FPC spill volume analysis and is calculated as:

$$Percent\ Survival\ in\ FPC\ Scenario\ B, C, or\ D - Percent\ Survival\ in\ FPC\ Base\ Case$$

Year	Scenario B	Scenario C	Scenario D
Lower Granite to McNary – Steelhead			
2003	0%	3%	8%
2005	0%	2%	5%
2006	1%	2%	6%
2007	2%	4%	17%
Average	**1%**	**3%**	**9%**
Lower Granite to McNary – Wild Yearling Chinook			
2003	0%	1%	3%
2005	0%	1%	3%
2006	0%	1%	2%
2007	1%	2%	7%
Average	**0%**	**1%**	**4%**
Lower Granite to McNary – Hatchery Yearling Chinook			
2003	0%	1%	3%
2005	0%	1%	3%
2006	0%	1%	3%
2007	1%	2%	7%
Average	**0%**	**1%**	**4%**
McNary to Bonneville – Hatchery and Wild Yearling Chinook			
2003	0%	1%	5%
2005	0%	2%	7%
2006	0%	1%	2%
2007	0%	1%	4%
Average	**0%**	**1%**	**5%**

NOAA COMPASS Study

The NOAA analysis, *Explanation of COMPASS Analysis of TDG Alternatives* (#609), is available on the AMT website. ODFW provided comments on COMPASS, and BPA and NOAA responded to those comments. The Independent Scientific Advisory Board's review of COMPASS was also received. These documents are available on the AMT website.

The NOAA analysis incorporated results from three modeling efforts. USACE's SYSTDG model provided spill cap volumes. The SYSTDG model is run on an hourly time step and assumed 2008 FCRPS BiOp operations. The hourly time step spill caps were converted to a monthly average in order to be incorporated into BPA's HYDSIM model. The HYDSIM model incorporated overgeneration conditions and the 2008 electrical load capacity to a model simulation of over 70 years of monthly historical runoff averages. The HYDSIM model-derived

monthly average flow and spill volumes were then converted to daily input for NOAA's COMPASS model. COMPASS calculated daily flows for the period of April to end of June and incorporated fish transport. The COMPASS model ran using the 2008 FCRPS BiOp operations. See the report for details.

COMPASS estimated the downstream passage survival of juvenile salmonids. Survival values were rounded up to one decimal space for relative difference, and to three decimal spaces for absolute difference, which resulted in several calculations of a zero survival difference between the current TDG management scenario and eliminating the 115% TDG forebay limit. However, NOAA states that if model results were carried out to the maximum precision then there would be a small positive difference between alternatives. Differences in survival presented at the AMT can be found in Tables 8 and 9.

Table 8. NOAA COMPASS Model Increase in Steelhead Reach Survivals. The increase in survival uses the USACE's SYSTDG spill volume analysis and is calculated as:

Percent Survival in* 120% *Only Scenario* − *Percent Survival in* 115 & 120 *Base Case

Years	Scenario	Snake River	Columbia River
70-Year Average	120%-Only	66.0%	67.1%
	115/120%	65.9%	67.0%
	Survival Increase	**0.1%**	**0.1%**
Low Flows	120%-Only	49.8%	56.2%
	115/120%	49.7%	56.2%
	Survival Increase	0.1%	0.0%
Mid-Range Flows	120%-Only	70.3%	69.9%
	115/120%	70.2%	69.9%
	Survival Increase	0.1%	0.0%
High Flows	120%-Only	81.0%	76.3%
	115/120%	81.0%	76.2%
	Survival Increase	0.0%	0.1%

Table 9. NOAA COMPASS Model Increase in Spring Chinook Reach Survivals. The survival increase uses the USACE's SYSTDG spill volume analysis and is calculated as:

Percent Survival in* 120% *Only Scenario* − *Percent Survival in* 115 & 120 *Base Case

Years	Scenario	Snake River	Columbia River
70-Year Average	120%-Only	85.5%	71.3%
	115/120%	85.3%	71.3%
	Survival Increase	**0.2%**	**0.0%**
Low Flows	120%-Only	81.8%	68.8%
	115/120%	81.7%	68.8%
	Survival Increase	0.1%	0.0%
Mid-Range Flows	120%-Only	86.7%	71.7%
	115/120%	86.5%	71.7%
	Survival Increase	0.2%	0.0%
High Flows	120%-Only	88.0%	73.4%
	115/120%	87.9%	73.4%
	Survival Increase	0.1%	0.0%

The COMPASS analysis concluded that "elimination of the forebay monitors, with resulting increasing spill rates, would provide a small, but positive effect on survival and adult returns of listed stocks", except for Snake River Steelhead. COMPASS model results showed a drop in estimated survival and SAR for Snake River Steelhead, Table 10. The NOAA analysis states that negative effects estimated for Snake River Steelhead could be reduced through "management actions, such as limiting spill, to increase collection for transportation at Lower Granite Dam." Transport is considered a management option by the states and is not considered in this technical evaluation.

Table 10. Summary of NOAA COMPASS Model Results for Smolt to Adult Returns (SARs).

Species	Measurement	115% and 120%	120% Only	Survival Increase (Relative[1])	Survival Increase (Absolute[2])
Snake River Spring / Summer Chinook	Whole population Lower Granite-Lower Granite SAR	0.915%	0.922%	0.8%	0.007%
Snake River Steelhead	Whole population Lower Granite-Lower Granite SAR	1.803%	1.783%	-1.1%	-0.02%
Upper Columbia River Chinook	Whole population Lower Granite-Lower Granite SAR (surrogate for Rocky Reach Dam to Rocky Reach Dam SAR)	0.768%	0.768%	0.0%	0.0%
Upper Columbia River Steelhead	Whole population Lower Granite-Lower Granite SAR (surrogate for Rocky Reach Dam to Rocky Reach Dam SAR)	0.716%	0.716%	0.0%	0.0%
Mid-Columbia River Steelhead	In-river survival	52.4-90.3%	52.5-90.3%	0.0% - 0.2%	0.0-0.1%

CRITFC Adult Passage Analysis

The CRITFC analysis, *Review of Adult Passage through Different Dam Passage Routes* (#709), is available on the AMT website. USACE and BPA provided comments on the CRITFC analysis. Their comments are available on the AMT website. No response to comments was received from CRITFC.

[1] Since SARs are such low numbers, the relative change in the survival appears much larger than the absolute change provided in the table. Relative change is defined as:

$$\frac{SAR\ percentage\ in\ the\ 120\%\ only\ Scenario - SAR\ percentage\ in\ the\ 115\ \&\ 120\%\ scenario}{SAR\ percentage\ in\ the\ 115\ \&\ 120\%\ scenario}$$

[2] The absolute survival increase uses the USACE's SYSTDG spill volume analysis and is calculated as:

$$Percent\ Survival\ in\ 120\%\ Only\ Scenario\ - Percent\ Survival\ in\ 115\ \&\ 120\ Base\ Case$$

Adult survival is important because of their imminent likelihood to spawn. The CRITFC study states that "the downstream route of adult passage is an important factor that contributes to survival and ultimate escapement to spawning areas and spawning success, reproductive fitness and genetic integrity." The study evaluates four downstream passage routes available to adults. They include the screen bypass system, spill, turbines, and surface bypass.

CRITFC evaluated each of the four adult downstream passage routes. The CRITFC analysis states that the screen bypass system exposes juvenile and adult salmon to increased water temperatures. These fish are held at temperatures that are significantly warmer than that found in the ambient river. Spill has been associated with increased fish passage efficiency, Table 11, and has been demonstrated to reduce travel and passage times. Turbine passage has an increased mortality because of the blade to fish size ratio. The CRITFC study identified surface bypass structures as an "emerging, promising adult downstream passage route" that reduces adult passage delays. The CRITFC review "indicates that spill and surface bypass and probably a combination of both provide the safest downstream passage route for adult migrants, whether they are fallbacks or steelhead kelts heading seaward." Fallbacks occur when adult salmon heading upriver go back downstream through or over a dam.

Table 11. Steelhead kelt fish passage efficiencies through Lower Columbia dams with and without spill (data from Corps 2008).

Dam	Percent Spill	Percent Fish Passage Efficiency
Bonneville	37%	84%
Bonneville	0%	68%
The Dalles	30%	99%

Synthesis of FPC, USFWS, NOAA and CRITFC Analyses

It is difficult to assess the precise impacts on fish passage and survival that would result from removing the 115% TDG limit forebay requirement. The analyses and data presented were based on both empirical and simulated data. The assumptions contained in the simulation analyses often ranged widely among studies.

The FPC analysis noted that increased spill would result in increased juvenile reach and adult survival, and that smolt survival had a strong relation to reach survival and spill.

The CSS report found that higher levels of spill during smolt migration years 1998 – 2006 were associated with:

- Reductions in fish travel time (faster migration rates) for both yearling Chinook and steelhead.
- Reductions in instantaneous mortality rates of steelhead.
- Increased survival rates for both yearling Chinook and steelhead.

The COMPASS model analysis found that most species experienced a small, positive effect on in-river survival (<1%) if the 115% TDG limit was removed due to increased spill. However,

the COMPASS model estimated a decreased survival and SARs for Snake River steelhead. NOAA stated that this decreased estimate result was likely due to reduced collection for transport.

The CSS analyses predicted that the absolute increase in juvenile yearling Chinook survival from Lower Granite Dam to McNary Dam would range from 0% to 4%, dependent on the spill scenario chosen, and would range from 1% to 9% for steelhead. This contrasts with the 0.2% for yearling Chinook, and 0.1% for Steelhead, estimated by COMPASS. The CSS analyses also predicted an increase survival of 0% to 5% for yearling Chinook in the Lower Columbia in contrast to no increase simulated by COMPASS. These results illustrate that the benefits to juvenile and adult salmonid survival are mostly a function of the analysis' assumptions.

The CRITFC study review of four adult passage routes indicated that spill and surface bypass, and probably a combination of both, provide the safest downstream passage route for adult migrants when also evaluating turbine and screen bypass systems. CRITFC states that this route combination is an important factor in adult passage that contributes to survival and escapement to spawning areas and spawning success.

Gas Bubble Trauma Impacts

The USACE analyzed how much TDG would increase if the 115% requirement was removed. Four AMT studies provide gas bubble trauma (GBT) summary information on the possible impacts of eliminating the 115% requirement. The three TDG literature reviews presented to the AMT synthesized hundreds of previous field and laboratory studies. Each review had a slightly different focus. The FPC's report on the Smolt Monitoring Program examined GBT in salmon in the Columbia and Snake Rivers. This report is highlighted separately due to its high relevance to the 115% requirement.

USACE SYSTDG TDG Simulations

The USACE's analysis, *Report on the SYSTDG Modeling for AMT: With and without 115 percent TDG standard* (#710), analyzed the expected change in TDG in the forebays. The USACE analyzed the high water year of 1999, the moderate water year of 2002, and the low water year of 2007. In each case, the high 12-hour average TDG level is reported.

The simulations summarized the TDG levels for each water year, for each project, with and without the 115% TDG standard over the entire spill season (water year), from April through August.

Table 12 and Figure 12 summarize the TDG change in the forebays between the two scenarios, with and without the 115% forebay TDG limit. The values highlighted in gray show an increase in the high 12 hour average TDG levels if the 115% limit was removed.

Table 12. ACOE SYSTDG Modeled Seasonal Average Absolute TDG in the Forebays with and without the 115% Limit. The difference in TDG is calculated as:

$$TDG\ under\ the\ 120\%\ only\ scenario - TDG\ under\ the\ 115\ \&\ 120\ base\ case\ scenario$$

Forebay High 12 Hour Average % TDG Levels

Water Years: Low = 2007; Medium = 2002; High = 1999

		Seasonal **Average** of the High 12 Hour Average TDG		
Year	**Project**	**With 115%**	**Without 115%**	**Difference**
2007	LWG forebay	101.9	101.9	0.0
2002	LWG forebay	101.7	101.7	0.0
1999	LWG forebay	106.1	106.1	0.0
2007	LGS forebay	106.8	106.8	0.0
2002	LGS forebay	106.1	106.1	0.0
1999	LGS forebay	109.2	109.2	0.0
2007	LMN forebay	109.8	109.8	0.0
2002	LMN forebay	110.7	110.7	0.0
1999	LMN forebay	113.3	113.7	0.5
2007	IHR forebay	110.8	111.7	0.9
2002	IHR forebay	110.8	111.3	0.5
1999	IHR forebay	112.2	115.2	3.0
2007	MCN forebay	109.5	109.5	0.0
2002	MCN forebay	109.0	109.0	0.0
1999	MCN forebay	109.4	109.4	0.0
2007	JDA forebay	107.6	107.6	0.0
2002	JDA forebay	106.9	106.9	0.0
1999	JDA forebay	108.1	108.1	0.0
2007	TDA forebay	109.8	109.8	0.0
2002	TDA forebay	108.8	108.8	0.0
1999	TDA forebay	110.4	110.6	0.2
2007	BON forebay	111.2	111.2	0.0
2002	BON forebay	110.1	110.1	0.0
1999	BON forebay	112.2	112.4	0.2
2007	Camas Forebay	113.3	113.8	0.5
2002	Camas Forebay	113.0	113.0	0.0
1999	Camas Forebay	113.9	115.2	1.3

Average % TDG Difference :	**0.3**

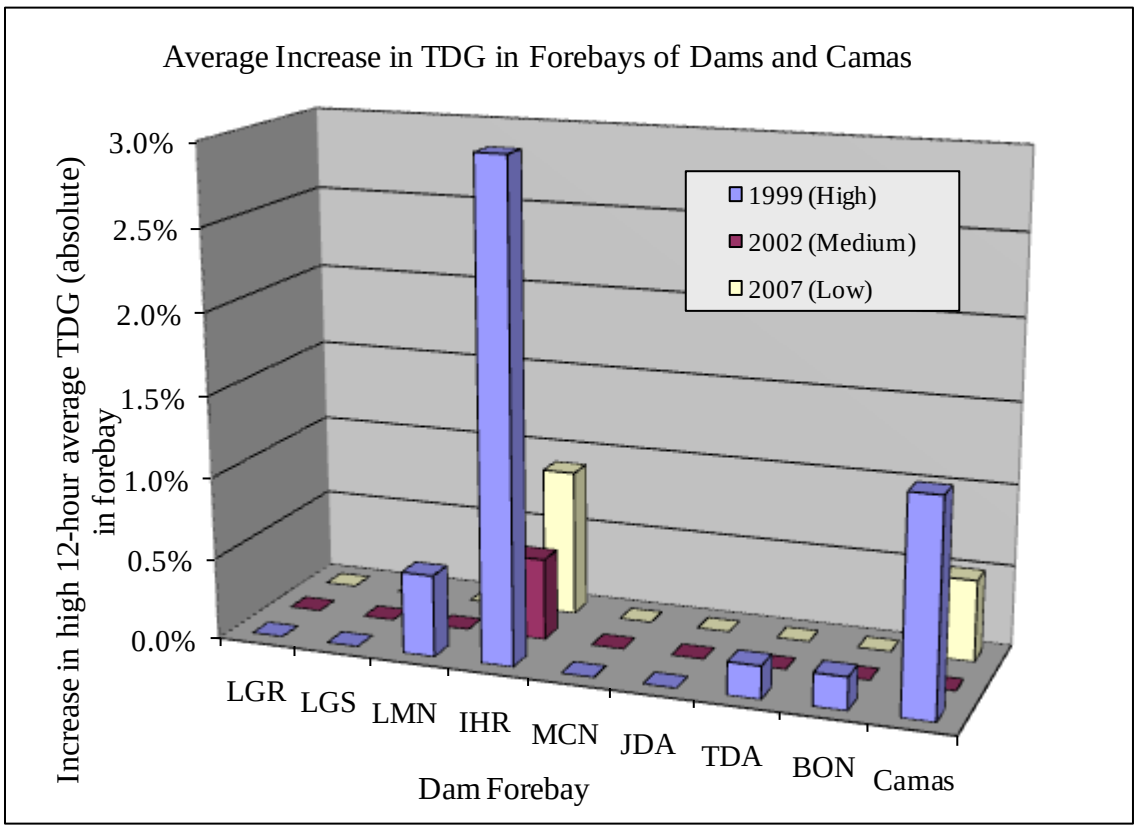


Figure 12. ACOE SYSTDG Modeled Seasonal Average Absolute Increase in Percent TDG in the Forebays without the 115% Forebay Requirement.
The difference in TDG is calculated as:

$$\boldsymbol{TDG\ under\ the\ 120\%\ only\ scenario - TDG\ under\ the\ 115\ \&\ 120}\ \textit{base case scenario}$$

Table 13 and Figure 13 summarize the TDG change in the tailraces between the two scenarios, with and without the 115% forebay TDG limit. The values highlighted in gray show an increase and the black highlighted values show a decrease in the high 12 hour average TDG levels if the 115% limit was removed.

Table 13. ACOE SYSTDG Modeled Seasonal Average Absolute TDG in the Tailraces with and without the 115% Limit. The difference in TDG is calculated as:

$$\boldsymbol{TDG\ under\ the\ 120\%\ only\ scenario - TDG\ under\ the\ 115\ \&\ 120\ base\ case\ scenario}$$

Tailrace High 12 Hour Average % TDG Levels

Water Years: Low = 2007; Medium = 2002; High = 1999

		Seasonal **Average** of the High 12 Hour Average TDG		
Year	**Project**	**With 115%**	**Without 115%**	**Difference**
2007	LWG Tailrace	108.5	108.5	0.0
2002	LWG Tailrace	108.8	108.8	0.0
1999	LWG Tailrace	112.2	112.2	0.0
2007	LGS Tailrace	113.8	113.8	0.0
2002	LGS Tailrace	114.6	114.6	0.0
1999	LGS Tailrace	116.0	116.2	0.1
2007	LMN Tailrace	113.2	114.1	0.9
2002	LMN Tailrace	113.1	113.1	0.0
1999	LMN Tailrace	114.4	115.2	0.8
2007	IHR Tailrace	113.4	113.4	0.0
2002	IHR Tailrace	113.9	113.9	0.0
1999	IHR Tailrace	115.1	115.1	0.0
2007	MCN Tailrace	114.7	114.7	0.0
2002	MCN Tailrace	116.0	116.0	0.0
1999	MCN Tailrace	116.5	116.5	0.0
2007	JDA Tailrace	117.5	117.5	0.0
2002	JDA Tailrace	118.2	118.2	0.0
1999	JDA Tailrace	118.9	119.2	0.3
2007	TDA Tailrace	115.1	115.1	0.0
2002	TDA Tailrace	115.0	115.0	0.0
1999	TDA Tailrace	115.7	115.2	**-0.5**
2007	BON Tailrace	117.1	117.6	0.5
2002	BON Tailrace	117.7	117.7	0.0
1999	BON Tailrace	119.6	120.8	1.2

Average % TDG Difference :	**0.1**

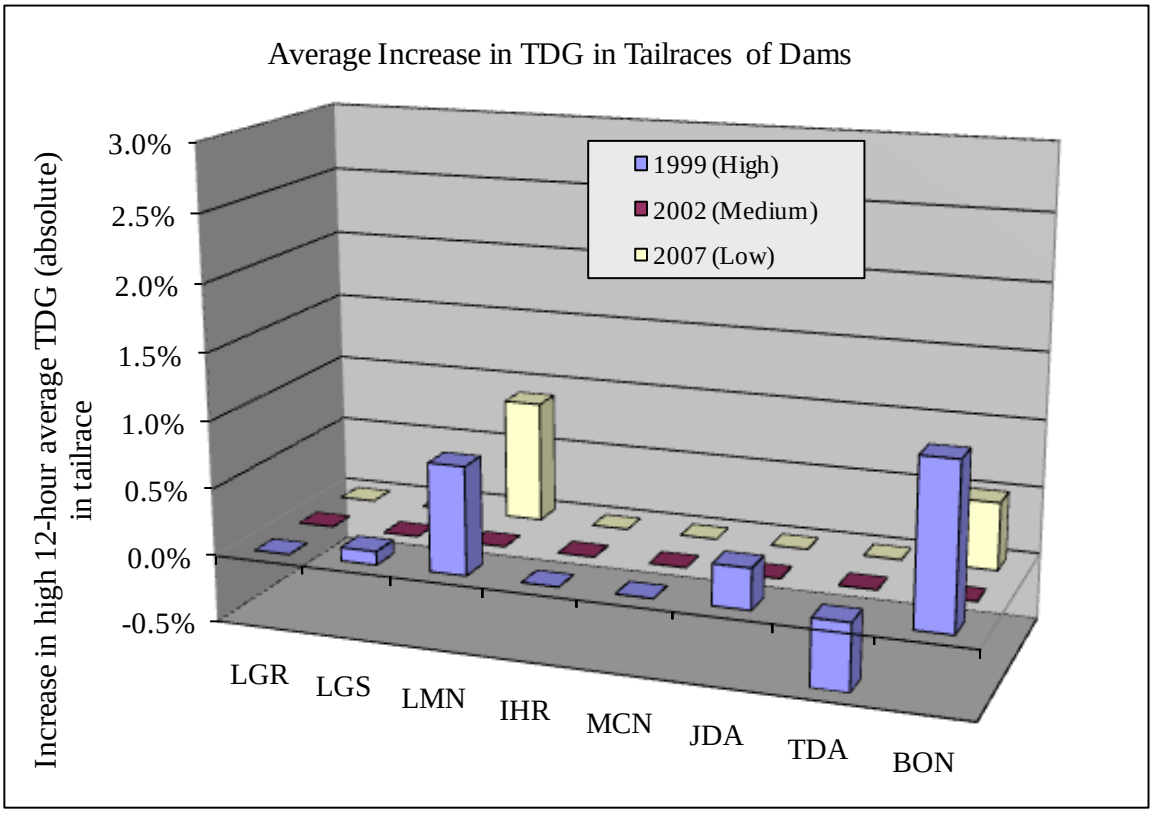


Figure 13. ACOE SYSTDG Modeled Seasonal Average Absolute Increase in Percent TDG in the Tailraces without the 115% Forebay Requirement. The difference in TDG is calculated as:

$$\textit{TDG under the } \mathbf{120}\% \textit{ only scenario} - \textit{TDG under the } \mathbf{115}\ \&\ 120 \textit{ base case scenario}$$

It is expected that TDG in the forebay would not go above 120% because the tailraces are limited to 120% during fish passage spill. The USACE analysis shows that eliminating the 115% requirement would increase TDG by an average of 0.3% in the forebays and 0.1% in the tailraces. The maximum single day increase in forebay TDG values was predicted at Ice Harbor (downstream of Lower Monumental dam), a difference of 4.1% TDG in 2007. The analysis also found situations where TDG appeared to decrease when the 115% requirement was eliminated, but these are believed to be modeling artifacts.

Ecology Literature Review

The Department of Ecology completed a literature review to assess the appropriate water quality criteria for TDG. The review, *Evaluation of Total Dissolved Gas Criteria (TDG) Biological Effects Research* (#713) is available on the AMT website. No comments were received by the AMT regarding the Ecology literature review.

The review showed that, near the surface (less than one meter), increasing the TDG from 115% would have a detrimental effect on aquatic life. However, with depth compensation, aquatic life at one meter or deeper would not be affected if TDG is increased to 120%.

Impacts on aquatic life (in the top one meter):

A number of papers summarized in the literature review studied the impact of TDG on aquatic life near the surface. While some studies did not find any effects at 120% TDG, the weight of all the evidence clearly points to detrimental effects on aquatic life near the surface when TDG approaches 120%. There were fewer effects on aquatic life at 115% TDG. The detrimental effects ranged from behavior changes to high levels of mortality after a few days. A summary of the findings presented in Table 14 are as follows (see Table 14 for details):

At 110% TDG or less, reported symptoms in shallow water included:

- Sub-lethal impacts.
- Mortality in insects and larval striped bass.
- No symptoms present.

At 115% TDG, reported symptoms in shallow water included:

- Sub-lethal impacts (tadpoles floating).
- Mortality in fish such as 20% in 8 days and 56% in 35 days.
- No symptoms present.

As TDG increases to 120%, reported symptoms in shallow water included:

- Sub-lethal impacts (frogs, sturgeon larvae).
- Increased mortality in fish such as 20% in one day, 50% in 3 or 4 days, 20% in 6 days, 42% in 9 days, 10% in 11 days, 32% in 12 days, 50% in 22 days, and 20% in 23 days.
- Some mortality in other aquatic life (daphnia).
- No symptoms present.

It is important to note that high mortalities are not found in the Columbia and Snake Rivers when TDG reaches these levels, presumably due to depth compensation. It is also important to include a significant margin of safety since high mortality is a very undesirable outcome.

Table 14. Summary of TDG Impacts in Shallow Water from Ecology Literature Review.

Author	Species	Percent TDG	Depth	Impact
Anticliffe et al (2003)	Juvenile rainbow trout	118%	0.1-0.25 m	3% had bubbles.
Anticliffe et al (2002)	Juvenile rainbow trout	116%	0.25 m	42% mortality after 9 days.
Bently et al (1981)	Pike minnow	117.2%	0.25 m	32% mortality after 12 days (also observed behavior changes).
Bouck et al (1976)	Various (salmonids and bass)	120%	1 m	No mortality after 12 days for bass. 50% mortality in 4 days for adult salmon.
Clay et al (1976)	Adult menhaden	110%	Very shallow (assumed)	Erratic swimming and death in 24 hours
Colt et al (1985)	Juvenile catfish	115%	Shallow (assumed)	56% mortality in 35 days

Author	Species	Percent TDG	Depth	Impact
Colt et al (1984a, 1984b, and 1987)	Bullfrogs and African clawed frog	116.5%	Shallow (assumed)	All frogs had bubbles in cardiovascular system and other impacts
		120%	Shallow (assumed)	Behavior changes
		114%	Shallow (assumed)	Tadpoles float to surface.
Cornacchia et al (1984)	Larval striped bass	106%	0.1 m	23% increase in mortality after 3 days.
Counihan et al (1998)	White sturgeon larvae	118%	0.25 m	No mortalities, but did have behavior changes.
Dawley et al (1975)	Juvenile rainbow trout, Coho, whitefish, and steelhead	120%	Shallow	50% mortality in 2.5-6 days depending on the species. (At 2.5 meters there were fewer deaths even with higher TDG.)
Dawley et al (1975)	Juvenile Chinook	116%	0.25 m	10% mortality in 11 days.
Dawley et al (1976)	Juvenile Chinook and steelhead	120%	0.25 m	50% mortality in 22 days (Chinook). 50% mortality in 30 hours (steelhead).
Gale et al (2004)	Adult Chinook	114 and 118%	0.5m	Some symptoms, including death. No effect on other some symptoms.
McInerny (1990)	Largemouth bass, bluegill and white bass	115-120%	up to 5-11 m	18-28% gas bubble signs depending on species.
Mesa et al (2000)	Juvenile Chinook and steelhead	113%-120%	0.27 m	60% fin bubble in 22 days and 20% mortality in 1.7-5 days at 120%. No mortalities in 22 days at 113%.
Mesa et al (1995)	Juvenile Chinook	120%	0.28 m	50% mortality in 60 hours. No mortalities in 22 days at 112%, but numerous other symptoms.
Mesa et al (1996)	Juvenile Chinook	120%	0.28 m	43% mortality in 75 hours. At 110%, numerous other symptoms.
Nebeker et al (1976)	Various insects	120%	0.25 m	Daphnia: 50% mortality in 93 hours (compared to 10% mortality in 170 hours at 110%). Crayfish: No deaths for 30 days. Larval Stoneflies: No deaths.

Author	Species	Percent TDG	Depth	Impact
Nebeker et al (1980)	Juvenile cutthroat trout	113-120%	0.6 m	Cutthroat trout: At 113%, 20% mortality in 185 hours and at 120%, 20% mortality was 20 hours (juveniles). At 118%, 20% mortality in 142 hours and at 121%, 20% mortality was 34 hours (adults).
	Juvenile speckled dace	119%	0.25 m	Speckled dace: At 119%, 20% mortality was 550 hours.
Nebeker et al (1976)	Adult sockeye	110-120%	0.7 m	At 110%, no signs. At 115%, first mortality in 21 days. At 120%, first mortality in 3 days.
Nebecker et al (1978)	Steelhead	126.7%	0.08 m	Eggs and embryos showed no signs of trauma for 20 days.
Newcolm (1974)	Juvenile steelhead	110%	0.23 m	46% had gas bubble signs. Blood chemistry changes at 105%.
Parametrix (2002)	Resident fish and macro-invertebrates	105-109% with spikes to 115%	0.5 and 3 m	Little signs of GBD.
Parametrix (2003)	Macro-invertebrates and resident fish	113-118%	3 m or less	Mayflies: 9% had GBD at 118%. Bristle worms: 0.05% had GBD at 113% at 3 m deep. Resident fish in 3 m or less showed signs of GBD.
Richter et al (2006)	Resident fish	120%	Unknown	No gas bubbles found in 20 species.
Schisler (1999)	Juvenile rainbow trout	105%	Shallow	Affected symptoms of whirling disease.
Weitcamp (1977)	Juvenile Chinook	120-128%	Up to 4 m	When fish had access to deeper water, no mortalities within 20 days.
Weitcamp et al (2003a)	Resident fish	<120%	<2 m	Only one fish found with gas bubbles.

Depth Distribution:

A number of papers summarized in the literature review studied the depth compensation of fish in the Columbia and Snake Rivers (see Table 15). While it is important to consider mean and average depth, the number of fish in the top one meter is particularly critical. Fish depth distribution varies between day and night. The mean depth was always deeper than one meter, and usually deeper than two meters. The amount of time spent at depths shallower than one meter was usually (but not always) less than the amount of time where significant detrimental effects were found.

Table 15. Summary of Depth Distribution from Ecology Literature Review.

Author	Species	Fish Observation	Depth
Abernathy et al (1997)	Juvenile Chinook and rainbow trout	Some observed	<1 m
		70% of fish	<3 m
Beeman et al (1997)	Juvenile steelhead	All fish	1.1-4.3 m
Beeman et al (2003)	Resident fish	Suckers (all)	0.3-16 m
		Some observed (all species)	<1 m
		Median (all species)	>= 2 m
Beeman et al (2006)	Juvenile steelhead	Mean	2-2.3 m
	Juvenile chinook	Mean	1.5-3.2
Dawley (1986)	Juvenile Chinook	8-22%	<3 m
Dawley et al (1975)	Juvenile Chinook	46%	<1.8 m
	Juvenile steelhead	29%	<1.8 m
Johnson et al (2007)	Adult chinook	4-12%	Shallow enough to be potentially affected by TDG
Johnson et al (2005)	Adult Chinook	1.3 hours (maximum time)	<1 m
		19 hours (maximum time)	<2 m
		Mean	>2 m
		3-9% of the time	<1m
Johnson et al (2005)	Adult steelhead	10% (Lower Monumental reservoir) 23% (Bonneville tailrace) 1.3% (McNary tailrace) 2.3% (Dalles reservoir)	<1 m
Johnson et al (2008)	Adult Chinook	28% (Dalles) 10% (Bonneville pool)	<2 m
		4.1 hours (maximum time)	<1 m
	Adult steelhead	14% (Lower Monumental reservoir) 2.9% (Dalles reservoir) 21% (Bonneville tailrace) 0.5% (Ice Harbor tailrace)	<1 m
		Some fish spent several days	<1 m
Parametrix (1999) [studied the Clark Fork River]	Brown trout	14%	<1 m
		Mean	3 m
Parametrix (1999) [studied the Clark Fork River]	Brown trout	20%	<1 m
	Rainbow trout	53%	<1 m
	Cutthroat trout	40%	<1 m
	Bull trout	Median	1.5-2 m
	Pikeminnow	1%	<1 m

Author	Species	Fish Observation	Depth
Parametrix (2000) [studied the Clark Fork River]	Brown trout	Median	1.7-5.5 m
	Bull trout	Range	0.9-3.8 m
	Cutthroat trout	Average	1.6 m
		Median hours depth	0.3-2.5 m
	Rainbow	Range	0.3-5.9 m
Smith (1974)	Juvenile Chinook and steelhead	28-46% (Lower Monumental reservoir)	<2m
Weitcamp et al (2003b) [studied Clark Fork River and Lake Pend Oreille]	Resident fish	Half the time (all species)	<2 m
		Median (rainbow trout)	1.3 m

The Ecology literature review also found that:

- Fish cannot quickly avoid high TDG, but some species seem to have some ability to avoid it.
- Fish can be negatively affected by TDG without showing evidence of gas bubbles.
- Susceptibility to gas bubble harm increases with activity, stress, and disease.
- Salmon usually migrate close to the shore where the TDG levels are usually less than in the thalweg (Johnson et al, 2007 and Schrank et al, 1998).
- Depth distribution of aquatic organisms and shallow water exposure is not well-known. There are recent studies on salmonids in the Columbia River, but there is little information on free-floating and surface dwelling organisms such as larvae of fish, crustaceans, and mollusks.

NOAA Fisheries Resident Fish Literature Review

Dr. Mark Schneider conducted a literature review of resident fish for NOAA Fisheries. The review, *Washington and Oregon State – Adaptive Management Team Resident Fish Literature Review* (#708) is available on the AMT website. USACE provided comments on Dr. Schneider's literature review, and Dr. Schneider provided a response to these comments. These documents are available on the AMT website.

This review concluded that there were negligible adverse effects from 120% TDG on resident fish and aquatic invertebrates. Further, with a 10% depth compensation for each meter below the surface, a TDG level of 120% at the surface would mean all aquatic life below one meter would have a depth compensated TDG equivalent to 110%. The report noted that the Columbia River has extensive amounts of deep water habitat available to aquatic life. It also concluded that salmon, resident fish, and invertebrates are similarly affected by TDG supersaturation.

In order to conclude from the report that removing the 115% requirement would be acceptable, two assumptions need to be made:

- "Negligible" adverse effects are acceptable (or are mitigated by the benefits).

- The availability of deep water in the Columbia and Snake Rivers will provide adequate protection even though not all aquatic life lives in that deep water.

Parametrix Literature Review

Dr. Don Weitkamp, Parametrix, conducted a literature review of TDG literature since 1980 on behalf of Avista Utilities, Tacoma Power, and Chelan, Douglas, and Grant County PUDs. The *Total Dissolved Gas Supersaturation Biological Effects, Review of Literature 1980-2007 (#704)* is available on the AMT website. Douglas County PUD commented on Dr. Weitkamp's literature review. The comments are available on the AMT website.

The literature review found:

- TDG supersaturation results in little or no GBT at levels up to 120% of saturation when compensating depths (two meters or more) are available.
- Fish have the capacity to rapidly recover from GBT when they reach compensating depths or TDG supersaturation is decreased.
- Most instances of GBT have reported low incidence and severity; however, there have been a few cases of substantial mortalities reported. The reported mortalities and severe cases of GBT are generally attributed to either TDG supersaturation in situations where available depths are shallow (about one meter or less) or the TDG levels are exceptionally high (greater than 130%).
- Field investigations have not demonstrated population effects resulting from TDG supersaturation.
- Generally the biological effects of TDG supersaturation appear to be influenced by the depth distribution of the fish or invertebrates resulting from their natural behavior, and there is limited evidence suggesting active avoidance of high TDG levels.

Similar to the NOAA Fisheries review, in order to conclude from the Parametrix report that removing the 115% requirement would therefore be acceptable, two assumptions need to be made:

- Negligible adverse effects are acceptable (or are mitigated by the benefits).
- The availability of deep water in the Columbia River will provide adequate protection even though not all aquatic life lives in that deep water.

GBT Monitoring Program

FPC summarized data from its Smolt Monitoring Program for GBT monitoring in salmon in the Columbia and Snake Rivers from 1995 to 2007. This information is available on the AMT website (#607), along with comments on the analysis.

FPC identified relatively low occurrences of fin GBT. The highest was 7%, which occurred when TDG exceeded 130% in the tailwater. The threshold for spill curtailment is a GBT

incidence of 15% in the sampled population. However, during certain situations, such as the end of an abnormally slow steelhead migration in 2007, as high as 39% of the fish at Little Goose dam had signs of GBT. It is important to note that signs of GBT do not directly translate to mortality.

For salmon experiencing TDG of 116-120% in the tailwater of the upstream dam, GBT was found in 1.0% of the fish (compared to 0.6% of the fish when TDG was 111-115%). See Figure 14 for details.

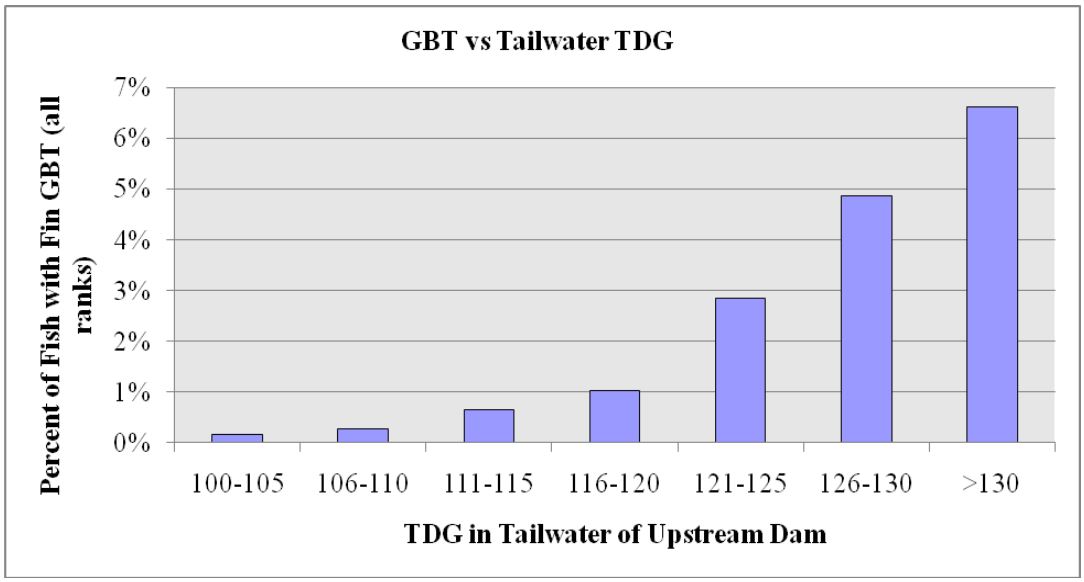


Figure 14. Total GBT at Varying TDG Levels in the Tailrace.

For salmon experiencing TDG of 116-120% in the forebay of the dam, GBT was found in 1.4% of the fish (compared to 0.4% of the fish when TDG was 111-115%). This is a 1% increase in GBT. The increase in GBT is calculated as:

$$Percent\ of\ Fish\ with\ GBT\ at\ 116\ to\ 120\%\ TDG - Percent\ of\ Fish\ with\ GBT\ at\ 111\ to\ 115\%\ TDG$$

See Figure 15 for details.

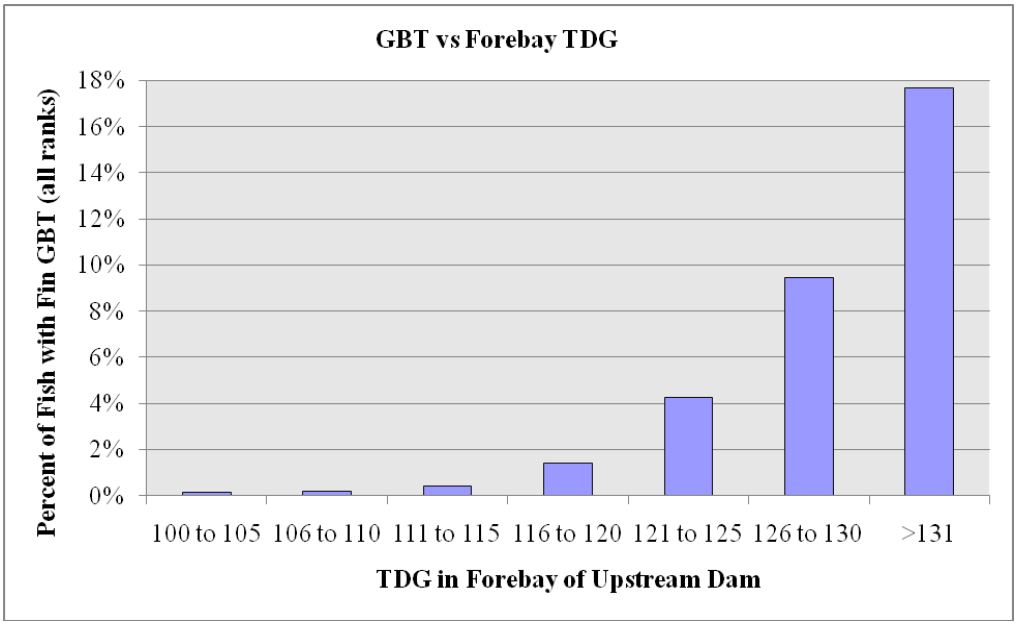


Figure 15. Total GBT at Varying TDG Levels in the Forebay.

Synthesis of Ecology, NOAA Fisheries, and Parametrix Literature Reviews and GBT Monitoring Program

It is expected that TDG in the forebay would not go above 120% because the tailraces are limited to 120%. The USACE analysis showed that eliminating the 115% requirement would increase TDG an average of 0.3% in the forebays and 0.1% in the tailraces. The Ecology, NOAA, and Parametrix literature reviews agree that a one meter or more depth compensation would protect aquatic species if TDG levels were at or below 120%. The three literature reviews and the GBT monitoring program results identify a minor increase in the incidence of GBT if the 115% requirement is removed. The NOAA Fisheries and Parametrix literature reviews both argue that any negative effect would be negligible. Results from the GBT monitoring program predict a 1% increase in GBT signs even if TDG increases from 111-115% to 116-120%. The Ecology literature review identifies an impact to aquatic species near the surface (less than one meter deep) that should not be considered negligible. The Ecology review found that there is a detrimental effect on aquatic life at less than one meter depths, and that some aquatic life may be residing near the surface for long enough to suffer the detrimental effects of GBT.

Chronic, long-term effects of exposure to high TDG are difficult to fully study. Some studies have been done on various aspects of chronic exposures, but few studies have been completed on high TDG exposures greater than one month.

Dams on the Middle Columbia River

There are six dams on the middle Columbia that are regulated by the 115% forebay requirement. Chief Joseph Dam, like the lower Snake River and Columbia River dams, is run by the USACE. Wells Dam is owned by Douglas County PUD, Rocky Reach and Rock Island Dams are owned by Chelan County PUD, and Wanapum and Priest Rapids Dams are owned by Grant County PUD.

There is far less information on the potential effects of eliminating the 115% forebay requirement on the mid-Columbia River dams compared to the other dams. Many of the mid-Columbia River dams recently completed or are planning structural changes to their dams. These recent changes make it difficult to analyze various spill scenarios based on TDG limits. Currently, these dams rarely manage their spill to the forebay requirement. The biological opinion for the FCRPS does not apply to the PUDs. Wells, Rocky Reach, and Rock Island are covered by a Habitat Conservation Plan (HCP). Wanapum and Priest Rapids are covered by separate biological opinions and incidental take statements. The Department of Ecology addresses water quality issues for PUD-owned dams in 401 water quality certifications. See http://www.ecy.wa.gov/programs/wq/ferc/ for details.

Chief Joseph (USACE)

Chief Joseph Dam recently installed new deflectors to reduce TDG. Spill testing is needed before fully knowing how much TDG will be reduced. This additional testing will also help determine how much of an effect the 115% forebay criterion has on Chief Joseph Dam.

Wells (Douglas County PUD)

During fish spill season at Wells Dam, water is diverted into a juvenile bypass system, a series of modified spill gates. Spill volumes are based on salmon survival criteria set in the HCP. Wells spills about 6-9% of the flow for fish passage as required by the HCP. This spill adds up to 2% TDG to the water Wells Dam receives. Douglas PUD is currently reviewing their ability to meet TDG standards as part of their dam relicensing process, which may result in lowered TDG in the tailrace, and hence, downstream forebay.

Over the past five years, using daily average TDG values (not the same as the water quality standards), Wells Dam had TDG exceedances in the downstream forebay 14% of the days. If the forebay criterion is eliminated and if Wells receives water with higher TDG in its forebay, it may be more difficult for Wells to meet the 120% tailrace standard. If the TDG criterion is changed, it may affect operations at Wells Dam.

Rocky Reach (Chelan County PUD)

Studies performed during relicensing of Rocky Reach Dam showed that the dam would probably meet the 115% downstream forebay levels. Spill volumes at Rocky Reach Dam are managed in accordance with an HCP and are set as a fixed percentage of flow. There are a few exceedances of the 115% forebay criterion due to fish spill operations. Rocky Reach spill rarely needs to be managed to the 115% forebay criterion.

Rock Island (Chelan County PUD)

Like Wells and Rocky Reach Dams, Rock Island operates in accordance with an HCP, where spill volumes during fish passage season are set as a fixed percentage of flow. These spills have included both 10% and 20% of flow. While the 10% would likely not lead to exceedances of the downstream 115% forebay criterion, the 20% level may occasionally cause exceedances.

Wanapum (Grant County PUD)

Wanapum Dam recently installed a new 20 kcfs bypass system, so historical information does not accurately reflect future conditions. As part of the relicensing process for Wanapum Dam, Grant PUD submitted information on proposed TDG improvements. According to these studies, Wanapum Dam would meet the 115% forebay criterion after the bypass and advanced turbines are installed, to be completed by year ten of the new license. For more information on Wanapum Dam, see the Water Quality Certification available at http://www.ecy.wa.gov/programs/wq/ferc/existingcerts/priestrapids/priest_rapids-final_cert040307.pdf.

Priest Rapids (Grant County PUD)

Spill volumes at Priest Rapids Dam for fish management are set on fixed percentages, currently at 61%. The forebay criterion downstream of Priest Rapids is in Pasco, a considerable distance from the Priest Rapids Dam. Priest Rapids has never reduced voluntary spill due to the 115% forebay criterion. As part of the relicensing process for Priest Rapids, Grant PUD submitted information on proposed TDG improvements. According to these studies, Priest Rapids currently (and after currently planned structural modifications) will meet the downstream 115% standard. For more information on Priest Rapids Dam, see the Water Quality Certification available at http://www.ecy.wa.gov/programs/wq/ferc/existingcerts/priestrapids/priest_rapids-final_cert040307.pdf.

Agencies' Decisions

Technical Information

The weight of evidence approach is the process of weighing measurable effects (*measurement endpoints*) against identified values (*assessment endpoints*) in order to evaluate whether a significant risk of harm or benefit is posed to the environment. This method is typically applied when reconciling or balancing multiple lines of evidence pertaining to an assessment endpoint.

Measurement endpoints are the lines of evidence used to evaluate the assessment endpoint. The TDG AMT measurement endpoints are:

- The negative biological impacts (gas bubble trauma) of eliminating the 115% TDG forebay limit on all aquatic life.
- The beneficial increase in anadromous fish that will survive the system if the 115% TDG forebay limit was removed.

Assessment endpoints are the explicit expressions of the actual environmental values that are to be protected. The TDG AMT assessment endpoint is:

- The protection of aquatic species, the most sensitive beneficial use, if the 115% total dissolved gas forebay requirement was removed.

The weight of evidence approach may be qualitative or quantitative. A simplified qualitative weight of evidence approach was used by Ecology and ODEQ in the decision making process. The typical qualitative approach allows the assessor to evaluate the outcome of each measurement endpoint with respect to indication of effect (harm, benefit, or neither); see Table 16.

Table 16: Weight of Evidence for the 115% Forebay TDG Requirement

Magnitude of Effect	Biological Impacts (gas bubble trauma) if the 115% forebay TDG requirement is removed	Fish Survival related to increased spill if the 115% forebay TDG requirement is removed
High Harm	None	None
Low Harm	• **Ecology Literature Review**: The review found potential impacts on aquatic life near the surface (less than one meter). • **GBT Monitoring**: If TDG increases by 5%, signs of GBT would be expected to increase by 1%. With a 1-2% increase in spill, TDG would only increase 0.3% on average, thus the expected increase in GBT would be much less than 1%.	• **NOAA COMPASS Study**: The study predicts that the smolt to adult return for Snake River Steelhead would decrease by 0.02%.
No Harm or Benefit	• **NOAA Fisheries Resident Fish Literature Review**: The review found that any negative effect would be negligible. • **Parametrix Literature Review**: The review found that any negative effect would be negligible. • **Ecology Literature Review**: With depth compensation, aquatic life deeper than one meter would not be affected if TDG increased to 120%.	• **NOAA COMPASS Study**: The study predicts that the smolt to adult return for Upper Columbia River Chinook and steelhead would not change.
Low Benefit	None	• **NOAA COMPASS Study**: The study predicts that the smolt to adult return for Snake River Chinook would increase by 0.007%. It also found that the in-river survival of Mid-Columbia steelhead would increase by up 0.1%. • **CSS Study presented by USFW**: The study predicts that river survival for Steelhead would increase by 1-3% and for Chinook would increase by 0-1% (under FPC spill scenario B and C). • **CRITFC Adult Passage Analysis**: The analysis found that spill and surface bypass provide the safest downstream passage route for adult migrants.
High Benefit	None	• **CSS Study Presented by USFW**: The study predicts that river survival of Chinook and steelhead for increase 4-9% (under FPC spill scenario D).

The AMT included a broad scope of members and attendees who have specific expertise, data, and analyses that contributed to the AMT process. Each presenting AMT member, attendee, and commenter provided evidence for and against each analysis and presented his or her view to the AMT either in person or in writing. The AMT participants each developed a set of overall conclusions and recommendations for each analysis summarized in this document, such as spill volume analysis, fish survival impacts, and gas bubble trauma impacts. Ecology and ODEQ kept record of the AMT discussions and information submitted for and against each analysis and read the evidence for and against each analysis as presented on the AMT website. The water quality agencies used all the information submitted during the AMT process to make an informed decision.

If the 115% requirement was removed, the amount of fish passage spill could be increased, especially at Lower Monumental Dam on the Lower Snake River. The total amount of additional water that could be spilled in the near-term is probably about 1-2%. Due to the expected increased power use in the region, reductions in overgeneration spill are likely. If overgeneration spill is reduced, the 115% forebay requirement limits voluntary spill more frequently. If both the BiOp spill requirements and overgeneration spill volumes change significantly over time, removal of the 115% forebay requirement has the possibility of affecting spill even more significantly (up to a theoretical maximum of 60% more spill in some years).

There is no way to know the exact impacts on fish survival due to the increase in spill. Each method of determining this impact has great uncertainty and controversy. With an increase in spill of 1-2%, each analysis found that there is likely a small, positive effect on Chinook survival percentage (greater than zero but less than 1%). Some analyses found the potential for much greater survival (4-9%) at the higher spill estimates. One analysis found there might also be small negative effects on Snake River steelhead.

Likewise, there is no way to know the exact impacts on aquatic life from increases in TDG due to the increase in spill. With increases in spill of 1-2%, TDG would likely increase by about 0.3% in the forebays and 0.1% in the tailraces. In some forebays in some situations, TDG could increase by as much as 4% (the maximum TDG is estimated at 120% at Ice Harbor Dam forebay on the Lower Snake River). Results from the GBT monitoring program would predict a small increase (less than 1%) in overall GBT in salmon if the 115% requirement was eliminated. Two literature reviews argue that any negative effect would be negligible ("negligible" is defined as so unimportant as to be safely disregarded). The third literature review concludes that with depth compensation, aquatic life at one meter or deeper would not be affected if TDG increased to 120%. However, the same review identifies a potential impact that, while probably small, is not negligible for species at depths between the surface and one meter.

Ecology Decision

Ecology decided not to change its 115% TDG forebay water quality criterion for the Columbia and Snake Rivers. This decision is based on the information provided in this document.

Spilling water over dams increases the level of total dissolved gas (TDG) in the river. Water plunging from a spill entrains air and carries it to a depth where the pressure forces the gas into solution. TDG levels above 110% of saturation can cause gas bubble trauma in fish. Gas bubble trauma is caused by gas bubbles forming in the cardiovascular system of aquatic species. These bubbles block the flow of blood and respiratory gas exchange.

Ecology's statewide total dissolved gas criterion in the water quality standards is 110%. This criterion is designed to fully protect salmon and all other aquatic life. In the 1990s, Ecology added a specific exemption for the Columbia and Snake Rivers for higher TDG levels to allow additional spill of water over the dams to aid salmon migration. Ecology allows TDG up to 120% in the tailrace immediately below the dam and 115% in the forebays behind the dams. While this level of gas is less protective than our statewide criterion, it does allow for additional spill that benefits salmon.

TDG levels in the tailrace are typically higher just after the water plunges over the dam. However, most aquatic life spends more of their time in the forebays. The 115% forebay criterion provides an additional margin of safety for chronic protection against gas bubble trauma in all aquatic life.

Ecology determined that there would be a potential for a small benefit to salmon related to fish spill if the 115% forebay criterion was eliminated, but there would also be the potential for a small increase in harm from increased gas bubble trauma.

The weight of all the evidence from available scientific studies clearly points to detrimental effects on aquatic life near the surface when TDG approaches 120%. The detrimental effects ranged from behavior changes to high levels of mortality after a few days. There were fewer effects on aquatic life at 115% TDG. Ecology strongly encourages implementing actions that increase salmonid survival without further increasing total dissolved gas.

When reviewing the appropriateness of revising a water quality standard, Ecology must carefully consider whether the criteria will adequately protect the designated uses for that water. Designated uses are those water uses (e.g., fishing, boating, aquatic life, water supply) that are specified in water quality standards for protection in a water body. All designated uses and even the most sensitive use must be fully protected. Under section 303(c) of the Act, EPA is required to review and to approve or disapprove state-adopted water quality standards. This review involves a determination of whether (1) the state has adopted criteria that protect the designated water uses and (2) the state has followed its legal procedures revising or adopting standards. NOAA Fisheries and USFW would need to conduct an ESA consultation on any water quality standard EPA approves.

Changing the water quality criterion would trigger additional administrative procedure requirements. In Washington, rule changes must include a cost benefit analysis and a small

business economic impact statement to determine the effects of rule changes on the public and businesses in the state. The benefits of the rule change must outweigh the costs in order to be adopted into rule. A State Environmental Policy Act (SEPA) determination would be needed. Based on that determination, there might be a requirement for an environmental impact statement if the proposed rule change was determined to significantly impact the environment. Based on the information in this document, Ecology does not believe the overall benefits of additional spill versus additional risk of gas bubble trauma are clear and are sufficient for a rule revision.

ODEQ Decision

The Oregon Department of Environmental Quality TDG waiver issued to the U.S. Army Corps of Engineers on June 22, 2007, allows for three key provisions for the purpose of addressing the TDG AMT question regarding the need for the forebay total dissolved gas (TDG) monitoring requirement to regulate spill during fish passage spill season on the Columbia River:

- 3(iii): Spill must be reduced when the average total dissolved gas concentration of the 12 highest hourly measurements per calendar day exceeds 115% of saturation in the forebays of McNary, John Day, The Dalles, and Bonneville Dams monitoring stations.

- 3(vi): The Department may approve changes in the location of forebay and tailrace monitors, use of forebay monitors, and may approve changes to the method for calculating total dissolved gas. Before approving any changes, the Department must consult with the Adaptive Management Team or the Federal Columbia River Power System Water Quality Team or both. The Department is directed to begin this process for consultation immediately and to evaluate and, if appropriate, approve such changes as soon as possible.

- Adaptive Management: The process for reviewing the implementation status of the 2002 Lower Columbia River Total Dissolved Gas TMDL will begin no later than January 1, 2011. The Washington State Department of Ecology will convene an advisory group comprising representatives of Oregon Department of Environmental Quality, tribes, 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. After 2010, the location of total dissolved gas monitors will be consistent with the Adaptive Management implementation strategy for the 2002 Lower Columbia River Total Dissolved Gas TMDL, and may no longer require forebay monitors and may only require tailrace monitors as TMDL implementation transitions from short-term to long-term strategies.

The TDG waiver is available on ODEQ's website:
http://www.deq.state.or.us/WQ/TMDLs/columbia.htm#tdg

Based on the information presented at the TDG AMT, the ODEQ finds that the removal of the forebay monitoring requirement will not cause excessive harm to the beneficial use, aquatic species in the Columbia River, during fish passage spill season. On June 22, 2007, the

Environmental Quality Commission acting under the authority of OAR 340-041-0104(3) modified the total dissolved gas standard for the main stem Columbia River during specified periods in 2008 and 2009. Paragraph 3(vi) of the Environmental Quality Commission's Order gives the Department authority to approve changes to the location and use of forebay monitors, after consultation with the Adaptive Management Team or the Federal Columbia River Power System Water Quality Team or both. The Department consulted with the Adaptive Management Team starting November 2007 until September 2008. Based on these consultations and the findings and conclusions described in this document, the Department proposes to remove the requirement for the use of forebay monitors in 2009. All other provisions of the Environmental Quality Commission's 2007 Order remain in effect.

Sufficient information has been provided to assess the need for the forebay TDG monitoring gauges. The ODEQ has assessed the relative importance of the information presented to the AMT describing the continued disagreement of the placement and representativeness of the TDG forebay monitoring gauges, the role of spill to fish survival, the impacts of TDG based on gas bubble trauma monitoring conducted over the past 14 years, and the expected spill volume changes and survival impacts based on the various modeling approaches.

The Ecology literature review found potential impacts on aquatic life near the surface (less than one meter). Through the successful implementation of ODEQ's TDG shallow water criterion, 105% TDG at depths less than two feet in depth (0.6096 meters), aquatic life at shallow depths have been protected during fish passage spill season. Typically during the early spring, TDG must be reduced below Bonneville Dam to meet ODEQ's shallow water criterion because salmonid redds are present at the Ives Island location at depths less than two feet.

Adult salmonids typically do not exhibit gas bubble trauma when entering shallower water habitat of Columbia River tributaries. Currently, there is no adult monitoring going on for the explicit reason of gas bubble trauma monitoring because handling is harmful to the adults and may cause mortality or stress. Based on the potential for harm and the data collected showing few to no signs of gas bubble trauma in adults under controlled fish passage spill conditions, DEQ has not required adult gas bubble trauma monitoring since 2000. This is likely due to depth compensation. For every meter below the surface water, a reduction of 10% TDG is measured in the water column. This is called "depth compensation". A TDG level of 120% at the surface would mean all aquatic life below one meter would have a depth compensated TDG equivalent to 110%. The movement of the adult fish into tributaries, such as the Deschutes or Umatilla rivers, results in the fish slowly entering shallower water so that the fish continue to benefit from hydrostatic compensation as it also moves to lower TDG tributary waters. The TDG levels in the tributaries are less than the TDG levels in the mainstem Columbia River during fish passage spill, and meet the 110% TDG water quality standard. Even once within the tributary a fish could still be in relatively deep water, allowing for depth compensation, as it begins migration up stream to its spawning ground.

The information collected on the incidence of gas bubble trauma in salmon smolts in the Columbia River from 1995 to 2007 shows that an estimated 1.4% of the salmon smolts would experience gas bubble trauma if the forebay monitoring requirement is removed and if TDG levels were between 115% and 120% in the forebay. This is well below ODEQ's TDG waiver threshold, in which if 15% of the sampled fish experience gas bubble trauma then fish passage spill is to be terminated. The TDG waiver states:

- 3(vii): If 15 percent or more of the juvenile fish examined show signs of gas bubble trauma in their non-paired fins where more than 25 percent of the surface area of the fin is occluded by gas bubbles or that contra-indicatory evidence suggests that fish are being harmed, the Director must terminate the modification.

The monitoring of gas bubble trauma in juvenile fish is implemented by the Fish Passage Center (FPC) under the Smolt Monitoring Program during the fish passage spill season. This program is overseen by the Fish Passage Advisory Committee (FPAC) which is made up of the Federal, State and Tribal fishery managers, including the Oregon Department of Fish and Wildlife. Historically, FPC notifies ODEQ if the incidence of gas bubble trauma in juvenile fish exceeds the TDG waiver threshold of 15% incidence of gas bubble trauma. In order to verify that the beneficial use is not experiencing excessive harm, ODEQ will continue to require gas bubble trauma monitoring during the fish passage spill season. Additionally, annual reporting of both physical and biological data during fish passage spill as identified in the TDG waiver will continue:

- 3(ix): No later than December 31 for each year of this waiver, the Corps must provide an annual written report to the Department detailing the following:
    d) Data results from the physical and biological monitoring programs, including incidences of gas bubble trauma;
    e) Description and results of any biological or physical studies of spillway structures and prototype fish passage devices to test spill at operational levels;

ODEQ's decision to remove the forebay monitoring requirement is in compliance with the Lower Columbia River TDG TMDL and is supportive of the long-term TMDL implementation strategy. Meeting the load allocations in the TMDL falls into two phases. Phase I, short-term implementation, involves improving water quality, while ensuring that salmon passage is fully protected and in accordance with the National Marine Fisheries Service's Federal Columbia River Power System Biological Opinion. The goal for the long-term TMDL compliance is to meet the Oregon DEQ TDG water quality standard of 110% at the specified TMDL tailrace load allocation locations at each dam. For short-term compliance, forebay and tailrace fixed monitoring stations can be used, or new fixed monitoring stations can be established. The fixed monitoring stations were selected by the Endangered Species Act forums and outside the development of the TMDL. Short-term implementation relies primarily on operational changes to be made at the dams to reduce TDG. Short-term compliance can remain adaptive and flexible, while long-term compliance remains fixed to firm goals. Through the adaptive management forum, the TMDL implementation is now transitioning into a long term implementation strategy. Long-term implementation will involve primarily structural and some operational changes to be made at the dams to achieve the water quality standard for TDG while protecting fish passage. Long-term compliance monitoring will occur at the tailrace loading capacity compliance location at each dam, as specified in the TMDL.

In order to implement the decision to remove the forebay TDG monitoring requirement, ODEQ will draft a proposed Departmental Order and allow for a 30-day public comment period, similar to the TDG waiver renewal process. Once public comments are received on the proposed Departmental Order and all appropriate changes made, the ODEQ Director will sign and issue the Departmental Order to the U.S. Army Corps of Engineers. The Departmental Order will

likely be issued prior to the start of the 2009 fish passage spill season, April 1, 2009. Additionally at the June, 2009 EQC meeting, the U.S. Army Corps of Engineers will request a new multi-year TDG waiver for the Columbia River dams. The current TDG waiver expires on August 31, 2009. The June EQC hearing on the TDG waiver renewal will allow for issuance of a new TDG waiver prior to the expiration of the current waiver. For more information on this process, please contact: Agnes Lut, Columbia River Coordinator, Oregon Department of Environmental Quality at 503-229-5247, lut.agnes@deq.state.or.us, or 811 SW 6th Ave, Portland, OR 97204, or Fax: 503-229-6037.

References

The following referenced information is available on the AMT website at http://www.ecy.wa.gov/programs/wq/tmdl/ColumbiaRvr/ColumbiaTDG.html

8th Meeting -- September 9, 2008

- *Agenda* (801) and Meeting Notes (811)
- Oregon and Washington Presentation (802)
- Ecology and ODEQ Evaluation of the 115% Total Dissolved Gas Forebay Requirement (803).
    - USACE Comments:
        - History of Gages. (812)
        - Synthesis Table. (813)
        - SYSTDG Spill. (814)
        - Overall Comments. (815)
            - FPC Response to Figures 13-15. (822)
    - FPC Comments (816)
        - FPC Calculation of Spill Variable. (822)
        - FPC Response to Scenarios. (825)
    - BPA Comments (817)
    - Northwest RiverPartners Comments (818)
    - CRITFC Comments:
        - Comments. (819)
        - Cited ISAB Snake River Spill-Transport Review. (820)
    - ODFW Comments (821)
- Additional background files for the Evaluation of the 115% (excel files used to make the charts and other summaries of information presented to the AMT).
    - FPC Spill Volume. (804)
    - SYSTDG Spill Volume. (805)
    - Importance of Spill. (806)
    - HYDSIM . (807)
    - COMPASS. (808)
    - GBT Monitoring. (809)
    - SYSTDG TDG Levels. (810)
    - FPC Fish Survival Calculations. (823)

July Reports and Comments

- Ecology literature review: Evaluation of Total Dissolved Gas Criteria Biological Effects Research (final) (713)

7th Meeting - June 23, 2008

- Agenda (701) and Meeting Notes. (702)
- Overview Presentation. (703)
- Don Weitkamp literature review:

    - Total Dissolved Gas Supersaturation Biological Effects, Review of Literature 1980-2007. (704)
    - Summary. (705)
    - Presentation. (706)
    - Total Dissolved Gas Literature 1980-2007, an Annotated Bibliography**.** (707)
    - Douglas County PUD comments on Weitkamp literature review (712)
- CRITFC Review of Adult Passage through Different Dam Passage Routes. (709)
    - USACE Comments on CRITFC Review of Adult Passage (714)
    - BPA Comments on CRITFC Review of Adult Passage (715)

6th Meeting - May 13, 2008

- Agenda (601) and Meeting Notes. (602)
- Overview Presentation. (603)
- SYSTDG modeling results and presentation. (604)
- Revised SYSTDG Report. (710)
    - FPC Review of "Report on the SYSTDG Modeling for AMT: With and Without 115% TDG Standard (May 8, 2008)" (620)
- HYDSIM modeling presentation and report. (605)
- COMPASS modeling results. (606)
    - COMPASS report (609) and presentation. (610)
    - ISAB review of COMPASS, 2008 (630)
    - ODFW comments. (711)
    - BPA response to ODFW comments (716)
    - NOAA Fisheries response to ODFW comments (717)
- Gas Bubble Trauma Monitoring Program. (607)
    - Corps comments on FPC gas bubble trauma presentation. (613)
    - FPC response to COE comments on FPC's GBT Presentation (628)
- Resident Fish Literature Review. (608)
    - Corps comments on resident fish report. (614)
    - Updated Resident Fish Literature Review. (708)

5th Meeting - April 8, 2008

- Agenda (501) and Meeting Notes. (502)
- USACE Presentations:
    - Project Configuration and Operation for Fish Passage at Bonneville, the Dalles, and John Day Dams. (503)
    - Fish Passage and Survival at Lower Snake and McNary Dams. (504)
- SYSTDG presentation. (505)
- HYDSIM presentation. (506)
    - HYDSIM report (611) and presentation. (612)
- COMPASS presentation. (507)

4th Meeting - March 11, 2008

- Agenda and Meeting Notes. (401)
- Presentation on Comparable Survivability Study (CSS)
    - BPA comments on CSS Comment #1. (402)
    - USFWS response to previous BPA comments on CSS. (615)
    - Comments forwarded by Northwest RiverPartners:
        - NOAA NWFSC comments on CSS (621)
        - Anderson comments on CSS (622)
        - BPA comments on CSS (623)
        - NOAA comments on CSS (624)
    - FPC response to previous comments by Northwest RiverPartners on CSS. (618)
    - FPC response to CSS comments by Anderson (625)
    - FPC response to CSS comments by NOAA (626)
    - FPC response to CSS comments by BPA (627)
    - Comparative Survival Study of PIT-Tagged Spring/Summer Chinook and Steelhead in the Columbia River Basin: Ten-year Retrospective Analyses Report (629)
- Oregon DEQ and Washington Ecology Draft AMT Schedule. (403)

3rd Meeting - February 12, 2008

- Agenda (301) and Meeting Notes. (302)
- Fish Passage Center's analysis of spill volumes. (303)
- U.S. Army Corps of Engineers draft analysis of spill volumes. (304)
- Literature review for TDG (old draft). (305)
- Fish Passage Center's Importance of Spill presentation. (306)
    - BPA comments on FPS Importance of Spill presentation: Comment 1 and Comment 2.
    - FPC response to previous BPA comments on FPC's importance of spill presentation. (619)
- CRITFC's Weight of Evidence presentation. (307)
- Oregon DEQ and Washington Dept. of Ecology presentation. (308)

2nd Meeting - December 13, 2007

- Agenda (201) and Meeting Notes. (202)
- Ecology and ODEQ review and introduction presentation. (203)
    - No comments received.
- U.S. Army Corps of Engineers draft analysis of spill volumes. (204)
    - No comments received.
- Fish Passage Center's analysis of spill volumes. (205)
    - Comments on the FPC "analysis of spill volumes" and "importance of spill presentation" with Comment #1 (404) and Comment #2. (405)
    - FPC response to previous BPA comments on FPC spill analysis. (616)
    - FPC response to previous Corps comments on FPC spill analysis. (617)
- NOAA Fisheries Literature Review of Resident Fish and Invertebrates. (206)

1st Meeting - November 1, 2007

- Agenda (101) and Meeting notes. (102)
- Presentation. (103)