DEPARTMENT OF
ECOLOGY
State of Washington

Draft Environmental Impact Statement

Short-term modification of total dissolved gas criteria in the Snake and Columbia Rivers

January 2019

Publication 19-10-013

Publication and Contact Information

This document is available on the Department of Ecology's website at:
https://fortress.wa.gov/ecy/publications/summarypages/1910013.html

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Draft Environmental Impact Statement

Short-term modification of total dissolved gas criteria in the Snake and Columbia Rivers

Washington State Department of Ecology

Washington State Department of Fish and Wildlife

Olympia, Washington

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DEPARTMENT OF ECOLOGY
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January 28, 2019

Dear Interested Party:

The Washington State Department of Ecology (Ecology) is considering a short-term modification to the total dissolved gas (TDG) criteria in the Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201A) for areas on the lower Snake and lower Columbia rivers. The short-term modification would adjust the TDG criteria during the spring water spill season which typically occurs April 3rd through June 20th (April 3rd – June 20th on the lower Snake River and April 10th – June 15th on the Columbia River). Modifying the TDG criteria using a short-term modification could facilitate more water spill at dams for the purpose of helping juvenile salmonids migrate downstream to the ocean.

Ecology prepared this draft environmental impact statement (EIS) and draft short-term modification language for public review and comment. The purpose of the EIS is to evaluate the risks of adjusting the TDG criteria to allow more water spill in the Snake and Columbia rivers. We are acting on requests from the Washington Department of Fish and Wildlife, the Columbia River Inter-Tribal Fish Commission, and a coalition of Northwest Sportfishing Industry Association, Columbia Riverkeeper, and Save Our Wild Salmon to adjust our TDG criteria for dams that spill water to aid fish passage. Providing a short-term modification could help facilitate increased spill at dams during portions of the day to help juvenile salmonids migrating to the ocean.

For more information on this draft EIS and short-term modification, please visit the water quality standards website at https://ecology.wa.gov/Water-Shorelines/Water-quality/Freshwater/Surface-water-quality-standards/Assistance#mod.

For assistance or questions, please contact Bryson Finch at bryson.finch@ecy.wa.gov or (360) 407-6440.

Sincerely,

Heather R. Bartlett
Water Quality Program Manager

Fact Sheet

Title:	Washington State's short-term modification to the WAC 173-201A total dissolved gas criteria for areas on the lower Snake and Columbia rivers.
Description:	The short-term modification intends to modify the Washington Administrative Code (WAC) 173-201A total dissolved gas (TDG) criteria for areas on the lower Snake and Columbia rivers during the spring spill season that typically occurs April 3rd through June 20th (April 3rd – June 20th on the lower Snake River and April 10th – June 15th on the Columbia River). The purpose of the draft Environmental Impact Statement is to evaluate the risks of adjusting the total dissolved gas criteria to allow more spill in the Snake and Columbia rivers.
Location:	Lower Snake and lower Columbia rivers
Lead Agency:	Washington State Department of Ecology
Responsible Official:	Heather R. Bartlett, Program Manager Water Quality Program Department of Ecology P.O. Box 47600 Olympia, WA 98504-7600
Lead Agency Contact:	Becca Conklin (swqs@ecy.wa.gov or 360-407-6413)
Date draft EIS issued:	January 29, 2019
Date draft EIS comments due:	February 28, 2019

Public Hearings:

We are planning two public meetings. The meetings will start with a short presentation followed by questions and answers. The hearing portion will begin shortly after the questions and answers are finished. During the hearing, you may give oral testimony and written comments. Staff will accept written comments submitted at the in-person hearings, but not via the webinar. Written comments will receive the same consideration as oral testimony.

In-person hearing	***Public hearing via webinar***
Date: February 13, 2019 **Time:** 2:30 p.m. **Facility:** WA State School of the Blind **Room:** Fries Auditorium **Address:** 2214 East 13th Street Vancouver, WA 98661	**Date:** February 19, 2019 **Time:** 6:00 p.m. **Register for the webinar:** https://watech.webex.com/watech/onstage/g.php?MTID=eb3744a5ae8b3954977887909319e7c87

For more information about this short-term modification, visit https://ecology.wa.gov/Water-Shorelines/Water-quality/Freshwater/Surface-water-quality-standards/Assistance#mod.

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Acknowledgements

Ecology would like to acknowledge and thank the Washington Department of Fish and Wildlife (WDFW) for their contributions to sections that discuss the Flexible Spill Agreement and potential positive impacts of increased spill described in models.

Executive Summary

The Department of Ecology (Ecology) is issuing a draft environmental impact statement (EIS) to evaluate the impacts of issuing a short-term modification to the WAC 173-201A total dissolved gas criteria for areas on the lower Snake and Columbia rivers. The short-term modification alternatives considered in this EIS will apply to the spring spill season at the following eight federal dams on the lower Snake and Columbia rivers:

- Lower Granite Dam
- Little Goose Dam
- Lower Monumental Dam
- Ice Harbor Dam
- McNary Dam
- John Day Dam
- The Dalles Dam
- Bonneville Dam

A Flexible Spill Agreement (herein referred to as Spill Agreement) reached for the 2019-2021 spill operations at the eight federal dams on the lower Snake and Columbia rivers was formally announced on December 18, 2018, and signed by the states of Washington and Oregon, the Nez Perce Tribe, the Bonneville Power Administration, U.S. Army Corps of Engineers, and the Bureau of Reclamation. The Spill Agreement is supported by the states of Idaho and Montana and the Columbia River Inter-Tribal Fish Commission.

The focus and intent of the Spill Agreement is to further improve juvenile salmon and steelhead survival rates as they travel downriver through the eight federal dams on the lower Snake and Columbia rivers. The Spill Agreement seeks benefits to salmonid survival in concert with managing the Columbia River system for multiple congressionally authorized purposes, including power generation to ensure the Pacific Northwest of an adequate, efficient, economical, and reliable power supply. The Spill Agreement also intends to provide for a pause in long-running litigation over the impact of the federal dams on Endangered Species Act-listed salmon and steelhead, at least until the Columbia River System Operations National Environmental Policy Act (NEPA) process is complete and a new long-term biological opinion

(BiOp) for the Federal Columbia River Power System (FCRPS) is released by the National Marine Fisheries Service.

The Spill Agreement is contingent on the implementation of a flexible spill operation that increases spill beyond the levels ordered by a federal court for the 2018 salmon migration season at the times of day when regional energy demand is lower, and reduces spill during times of peak energy demand (early morning and late afternoon/evening) and highest energy market values. Recent trends suggest that such flexibility may become more valuable to energy marketers as solar energy continues to be deployed in California and elsewhere in the western United States. The "duck curve" energy demand graph below illustrates the times of day with higher and lower energy demand across the western United States.

Technical analysis conducted by state and tribal fisheries managers concludes that the spill operations outlined in the Spill Agreement will roughly equal (in 2019) or exceed (in 2020 and 2021) fish survival rates obtained through 2018 court-ordered spill operations, which required spill to existing total dissolved gas (TDG) standards of 115% as measured in dam forebays and 120% as measured in dam tailraces on the lower Snake and Columbia rivers. At the same time, the Spill Agreement operations will maintain or improve power generation revenue relative to 2018 operations.

The Spill Agreement implementation is contingent on Washington, through the process described in this document, raising TDG standards on the lower Snake and Columbia rivers to match Oregon's 120% standard as measured in the dam tailrace for the 2019 salmon migration season. For the 2020 and 2021 migration season, the Spill Agreement is contingent on both Washington and Oregon raising TDG standards to 125%. The short-term modification of TDG standards considered in this draft EIS would, if adopted, only apply to 2019 operations, and match Oregon's current TDG standards. A separate process will begin this summer to address a potential rule change.

There have been other requests to increase spill similar to the request in the Spill Agreement on December 18, 2018. For example, the Final Report from the Southern Resident Orca Task Force convened by Governor Jay Inslee includes a recommendation encouraging testing the potential of higher TDG standards and attendant spill to improve salmon survival and abundance, while also considering ways to minimize impacts on the Bonneville Power Administration's Fish and Wildlife Program. Task Force Recommendation 8 reads as follows:

- *Recommendation 8: Increase spill to benefit Chinook for Southern Residents by adjusting total dissolved gas allowances at the Snake and Columbia River dams.*
    - *Direct the Department of Ecology to increase the standard for dissolved gas allowances from 115 percent to up to 125 percent, to allow use of the best available science to determine spill levels over these dams to benefit Chinook and other salmonids for Southern Residents.*
    - *Coordinate with the Oregon Department of Environmental Quality to align standards across the two states.*

- *Maintain rigorous monitoring of impacts to juvenile Chinook and resident fish to ensure any changes in spill levels do not negatively impact salmon or other aquatic species.*
- *Work with tribes, salmon recovery regions, Ecology and WDFW to minimize revenue losses and impacts to other fish and wildlife program funds.*[1]

Ecology is considering a short-term modification to the TDG standard on the lower eight dams on the Snake and Columbia rivers (see Figure 1). The Snake and Columbia rivers have an existing special condition within the surface water quality standards for TDG that pertains to fish passage during the spill season:

> "TDG must not exceed an average of one hundred fifteen percent as measured in the forebays of the next downstream dams and must not exceed an average of one hundred twenty percent 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); and a maximum TDG one hour average of one hundred twenty-five percent must not be exceeded during spillage for fish passage."

Figure 1. The Columbia River Basin.

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

[1] See Southern Resident Orca Task Force Final Report, November 2018, at p. 48.

Additional alternatives to the special condition for the TDG standard during the spill season in the Snake and Columbia rivers are being considered. These alternatives include:

1) No action,

2) Removal of the 115% forebay criterion while maintaining the 120% tailrace criterion,

3) Removal of the 115% forebay criterion and moving to a 125% tailrace criterion.

Studies have demonstrated that outmigrating juvenile salmonids have higher survival rates in the Snake and Columbia rivers when passed through dams via spillways versus through turbines or smolt bypass systems of hydropower projects (Whitney et al. 1997; Muir et al. 2001). Moreover, some models have predicted that the greater the spill over dams, the greater survival of juvenile salmonids (WA DOE, 2009). However, increased water spillage over dams often leads to increased TDG levels, which can be detrimental to aquatic life. The adjusted TDG criteria seek a balance between impacts of fish passage through hydropower projects and adverse impacts due to supersaturated waters as a result of spill.

The short-term modification is based upon information provided by the Comparative Survival Study juvenile fish passage survival model (CSS model), which predicts improvements in salmon survival and abundance as spill is increased up to those levels that would be permitted by a 125% TDG standard. The CSS model is a joint project of the Fish Passage Center, Columbia River Inter-Tribal Fish Commission, U.S. Fish and Wildlife Service, and the Oregon, Washington, and Idaho departments of fish and wildlife/fish and game. Juvenile survival metrics assessed by the CSS model include water transit time (a surrogate for salmon smolt travel time downriver) and powerhouse encounter rates (with powerhouse defined as dam turbines or bypass systems as opposed to a dam spillway, which avoids the powerhouse). The CSS model considers minimizing powerhouse encounters through measures such as spill or dam removal as critical to reducing “delayed mortality” from hydrosystem passage and ultimately increasing adult salmon and steelhead returns. The CSS model predicts a two to 2.5-fold increase in Snake River spring Chinook salmon (*Oncorhynchus tshawytscha*) abundance above 2014 FCRPS BiOp spill levels when spill is increased to 125% TDG 24 hours per day/seven days a week in the spring,[2] and smaller projected increase at 120% TDG 24 hours per day.

The relationship between spill and TDG is important in evaluating risk and benefits to aquatic life. The greater amount of spill over dams, the greater the risk of TDG related impacts to aquatic life. The notion of increased spill and increased survival of juvenile salmonids has been proposed and demonstrated in models. However, continuing to increase spill will eventually lead to diminishing benefits, while increased risk of adverse impacts to aquatic life increases with spill due to TDG levels. This environmental impact statement considers risks of increased spill to aquatic life and data gaps in the science regarding TDG impacts and life history traits of aquatic organisms.

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[2] See CSS 2017 Annual Report at xxxi.

Ecology's preliminary decision is to remove the 115% forebay numeric criterion for a period up to three years. This action coincides with the Spill Agreement that aims to benefit salmon and hydropower. Additionally, Ecology will adjust the 12 hour averaging method to match the State of Oregon's method. This would have little effect in the operations of the federal dams and would ease management of spill operations, as well as TDG monitoring and reporting requirements. Washington would require the TDG 12-hour average compliance to be measured using the twelve highest hourly averages in a day (Oregon method) rather than the highest average calculated from twelve consecutive hourly averages (current Washington method).

Given that dam and salmon managers have not previously provided voluntary spill to 120% due to the potential for higher TDG levels resulting in increased symptoms of gas bubble trauma in juvenile salmon, steelhead, and non-listed aquatic species, monitoring for gas bubble trauma will continue to be required.

SEPA Scoping and Comments

The State Environmental Policy (SEPA) Scoping process began on November 16, 2018, when Ecology issued a threshold determination of significance on the rulemaking actions. SEPA scoping is the process of soliciting input on a proposal to define the scope of the Environmental Impact Statement. Public notice of SEPA scoping was provided via the SEPA Register, Ecology's Water Quality Info ListServ notice, and on our website.

The comments received during the scoping process were considered as the agency identified significant issues, noted elements of the environment that could be affected, developed alternatives, and prepared the draft environmental documents.

Public comments were received through December 14, 2018. Ten public comment letters were received during the comment period. All comments are provided, in full, in Appendix A.

Examples of Comments of Support

- Higher spills benefit salmon that serve as a food source for Orca whales which is essential to preventing Southern Resident Killer Whale extinction.
- Dams reduce river flow and increased spill will help juveniles move downstream faster.
- Besides spill, other actions to help downstream salmon migration are ineffective.
- Columbia River Spring Chinook are important for the fishing industry.
- Spring Chinook are also important food source for Southern Resident Killer Whale.
- Risk of total dissolved gas impacts is outweighed by the benefits to salmon recover.

- Supports the short-term modification to remove the 115% forebay requirement.
- Short-term modification should allow up to 125% in 2019 (removal of the 120% tailrace in 2019 too).
- Higher spill may also help the anadromous Pacific lamprey.
- Total dissolved gas of up to 125% in the tailrace of each dam would lead to a significant increase in smolt-to-adult return rates for Snake River spring/summer Chinook.
- Total dissolved gas levels up to 125 percent would provide the best and safest route of passage for juvenile and adult salmon and steelhead by allowing them to avoid higher turbine and screen bypass mortalities.

Examples of Comments of Disapproval

- Risk of total dissolved gas is too high.
- Why rely on only one model to predict spill benefits to salmon?
- Ecology's action is duplicative of the federal Columbia River Systems Operations EIS actions.
- Benefits to juvenile migration have already been achieved.
- The immense cost of increased spill should lead the department to conclude that the proposal to modify total dissolved gas must be abandoned.
- Modifying total dissolved gas carries a high risk of unintended consequences for fish.
- There is a lack of clarity surrounding the short-term modification EIS process.
- The relationship to the U.S. Army Corps of Engineers waiver process is unclear.
- The proposed waiver does not meet the state's standards for a "short term" waiver.
- A rigorous monitoring program is necessary to ensure compliance with any short-term modification.
- Ecology should assess the impacts of a short-term modification on carbon emissions.

Introduction

Importance

The Columbia River and its tributaries are one of the most productive salmon producing river systems in the world. However, over the last 150 years or so, salmon and steelhead runs that once numbered from 10-16 million per year have generally declined to 1-2 million per year[3], a value that includes a combination of natural and hatchery origin fish. Today, thirteen populations of Columbia Basin salmon and steelhead are listed as threatened or endangered under the Endangered Species Act.[4]

A number of factors have contributed to the decline, including dams, which block or impede access to and from upriver habitat, habitat degradation from development and resource extraction, harvest and hatchery impacts, pollution, and predation due to ecosystem alterations and introduction of non-native species.

The decline of salmon and steelhead in the Columbia Basin has had numerous economic and cultural impacts, including to Native American Tribes and non-tribal commercial and recreational fishers. But even today, commercial and sport-fishing on Columbia Basin fish (primarily based on, but not limited to, salmon and steelhead fishing) is worth $150 million per year.[5]

Meanwhile, hydropower produced by Columbia Basin dams (including many more dams than the eight dams affected by the decision under consideration in this EIS), is worth in excess of $3 billion per year.[6] Spill to benefit salmon and steelhead at the eight federal dams on the lower Snake and Columbia rivers can cost the Bonneville Power Administration (BPA) tens or hundreds of millions of dollars, depending on the water year and market conditions.[7] The changes in spill included in the Flexible Spill Agreement (herein referred to as Spill Agreement) are designed to be revenue neutral or positive for BPA relative to 2018 court-ordered spill operations (see Flexible Spill Agreement section), despite increases in spill during much of the day.

Flexible Spill Agreement

The Spill Agreement regarding 2019-2021 spill operations at the eight federal dams on the lower Snake and Columbia rivers was formally announced on December 18, 2018, and signed by the states of Washington and Oregon, the Nez Perce Tribe, the Bonneville Power Administration,

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[3] https://www.nwcouncil.org/reports/columbia-river-history/salmonandsteelhead
[4] https://www.nwcouncil.org/reports/columbia-river-history/endangeredspeciesact
[5] The Value of Natural Capital in the Columbia River Basin: A Comprehensive Analysis, Earth Economics, 2017 at p. 71. https://ucut.org/wp-content/uploads/2017/12/ValueNaturalCapitalColumbiaRiverBasinDec2017.pdf
[6] Id., at p. 54.
[7] See, e.g., 2016 Columbia River Basin Fish and Wildlife Program Costs Report, https://www.nwcouncil.org/sites/default/files/2017-2.pdf

U.S. Army Corps of Engineers, and the Bureau of Reclamation. The Spill Agreement is supported by the states of Idaho and Montana and the Columbia River Inter-Tribal Fish Commission.

The focus and intent of the Spill Agreement is to further improve juvenile salmon and steelhead survival rates as they travel downriver through the eight federal dams on the lower Snake and Columbia rivers. The Spill Agreement seeks benefits to salmonid survival in concert with managing the Columbia River system for multiple congressionally authorized purposes, including power generation to ensure the Pacific Northwest of an adequate, efficient, economical, and reliable power supply. The Spill Agreement also intends to provide for a pause in long-running litigation over the impact of the federal dams on Endangered Species Act-listed salmon and steelhead, at least until the Columbia River System Operations National Environmental Policy Act (NEPA) process is complete and a new long-term biological opinion (BiOp) for the Federal Columbia River Power System (FCRPS) is released by the National Marine Fisheries Service.

The Spill Agreement is contingent on the implementation of a flexible spill operation that increases spill beyond the levels ordered by a federal court for the 2018 salmon migration season at the times of day when regional energy demand is lower, and reduces spill during times of peak energy demand (early morning and late afternoon/evening) and highest energy market values. Recent trends suggest that such flexibility may become more valuable to energy marketers as solar energy continues to be deployed in California and elsewhere in the western U.S. The "duck curve" energy demand graph below illustrates the times of day with higher and lower energy demand across the western U.S.

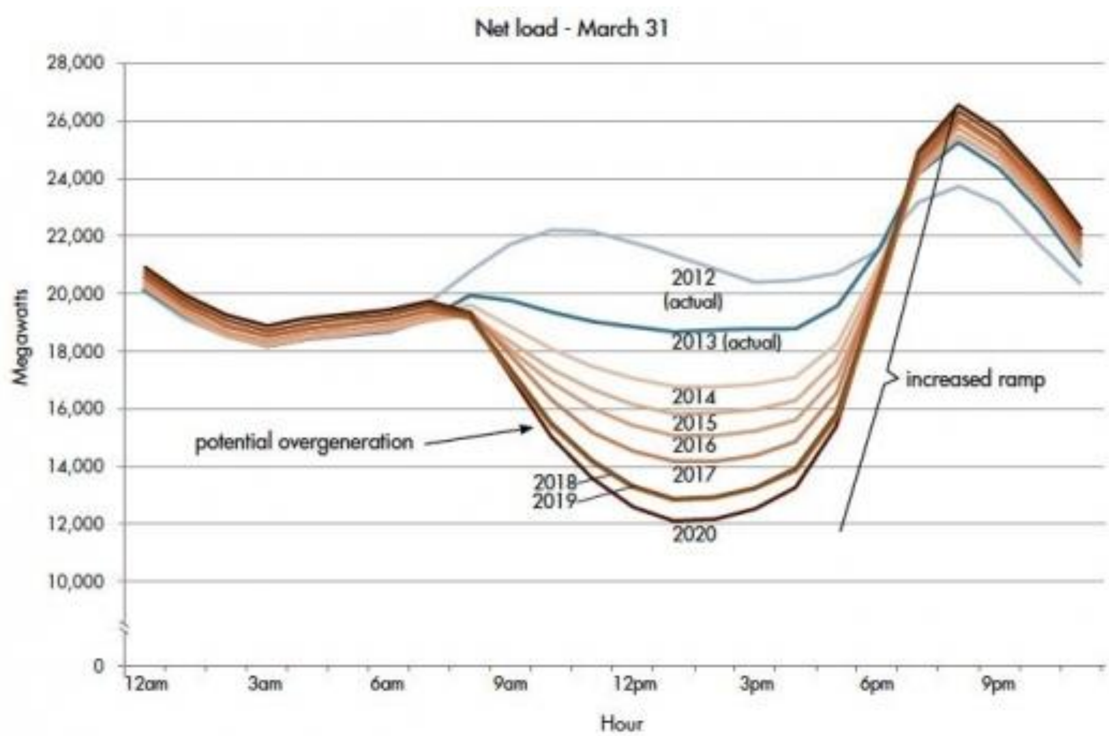

Figure 2. Duck curve energy demand over the course of a day for the western U.S.

Technical analysis conducted by state and tribal fisheries managers concludes that the spill operations outlined in the Spill Agreement will roughly equal (in 2019) or exceed (in 2020 and 2021) fish survival rates obtained through 2018 court-ordered spill operations, which required spill to existing TDG standards of 115% TDG as measured in dam forebays and 120% TDG as measured in dam tailraces on the lower Snake and Columbia rivers. At the same time, the Spill Agreement spill operations will maintain or improve power generation revenue relative to 2018 operations.

The Spill Agreement implementation is contingent on Washington, through the process described in this document, raising TDG standards on the lower Snake and Columbia rivers to match Oregon's 120% standard as measured in the dam tailrace for the 2019 salmon migration season. For the 2020 and 2021 migration season, the Spill Agreement is contingent on both Washington and Oregon raising TDG standards to 125%. The short-term modification of TDG standards considered in this draft EIS would, if issued, only apply to 2019 operations and match Oregon's current TDG standards. A separate process will begin this summer to address a potential rule change.

Water Quality Standards

Under Section 303(c) of the Clean Water Act (CWA) and federal implementing regulations at 40 CFR § 131.4, states and authorized tribes have the primary responsibility for reviewing, establishing, and revising water quality standards, which consist primarily of the designated uses of a waterbody or waterbody segment, the water quality criteria that protect those designated uses, and an antidegradation policy to protect high quality waters.

The Environmental Protection Agency (EPA) has compiled a list of nationally recommended water quality criteria for the protection of aquatic life and human health in surface waters. These criteria are published pursuant to Section 304(a) of the CWA and provide guidance for states and tribes to establish water quality standards and provide the foundation for controlling the release of pollutants and identifying impaired waters. The state water quality standards are federally approved by the EPA and describe the level of protection for Waters of the State.

The states of Washington and Oregon have both adopted water quality standards that limit TDG to 110% relative to atmospheric pressure. These water quality standards were placed into state rules based on the Federal EPA recommendations.

Total Dissolved Gas Criteria and Aquatic Life Uses

Studies have demonstrated that outmigrating juvenile salmonids have higher survival rates in the Snake and Columbia rivers when passed through dams via spillways versus through turbines or smolt bypass systems of hydropower projects (Whitney et al. 1997; Muir et al. 2001). Moreover, some models have predicted that further increasing spill levels up to a certain point will result in greater survival of juvenile salmonids. However, increased water spillage over dams often leads to increased TDG levels, which can be detrimental to aquatic life.

Since the 1990's both states have accommodated levels of TDG above 110% for fish passage spill operations for ESA-listed juvenile salmonids at the Corps' projects on the lower Snake and Columbia rivers. During spill operations for fish passage, the states of Washington and Oregon have authorized exceptions (standard modification and criteria adjustment, respectively) to the 110% TDG criteria for the four lower Snake River (WA) and four lower Columbia River projects (WA and OR).

The allowance of TDG levels higher than the 110% water quality criterion seeks a balance between impacts of fish passage through hydropower projects and adverse impacts due to supersaturated waters as a result of spill.

Current Washington Criteria Adjustment

Chapter 173-201A-200(1)(f) WAC provides the maximum TDG criteria for the protection of aquatic life. Table 200 (1)(f) that states: "Total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection." The criteria also address exceptions and adjustments, including a provision allowing for an adjustment of the TDG criteria to aid fish passage over hydroelectric dams when consistent with an approved gas abatement plan. The gas abatement plan must be accompanied by fisheries management and physical and biological monitoring plans.

Chapter 173-201A-200(1)(f)(ii) WAC provides the following adjusted criteria to aid spill for 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 12 highest consecutive hourly readings in any one day, relative to atmospheric pressure); and
- A maximum TDG one hour average of 125% must not be exceeded during spillage for fish passage.

Requirements for approval to apply the adjusted criteria

- This adjustment may be used when consistent with an approved gas abatement plan.
- The gas abatement plan must be accompanied by fisheries management and physical and biological monitoring plans.

In 2009 Ecology and the Oregon Department of Environmental Quality (ODEQ) issued a joint paper to evaluate the 115% TDG compliance which both states required at that time through their respective adjustment and modification procedures. At that time 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 gas bubble trauma from elevated TDG levels. Ecology also recognized that there would be additional administrative procedure requirements because the 115% requirement was adopted as a water quality standard. By contrast Oregon periodically renews the modification to the TDG criteria to aid for fish passage however, the TDG threshold is not stated in the ODEQ water quality standards. The result of the evaluation was different for each state. Ecology maintained the 115%

forebay requirement for the four lower Snake River dams and the four lower Columbia River dams. Oregon decided to eliminate the 115% forebay requirement for the four lower Columbia River dams based on a determination that the action would not cause excessive harm to the beneficial uses or aquatic species in the river during the spring spill season. All future TDG modifications approvals have been written without the 115% forebay requirement. Oregon's action did not change the spill operations of the dams because the U.S. Army Corps of Engineers operates voluntary spill operations to meet the more stringent Washington State criteria.

The following describes the Oregon modified TDG criteria requirements which align with the short-term modification Alternative 2 considered in this EIS.

Current Oregon Standard Modification

Chapter 340-041-0031 Oregon Administrative Rules (OAR) provides that;

- Spill must be reduced when the average TDG concentration of the 12 highest hourly measurements per calendar day exceeds 120% of saturation in the tailraces of McNary, John Day, The Dalles, and Bonneville dams' monitoring stations.
- Spill must be reduced when instantaneous TDG levels exceed 125% of saturation for any 2 hours during the 12 highest hourly measurements per calendar day in the tailraces of McNary, John Day, The Dalles, and Bonneville dams' monitoring stations.

Requirements for approval of the modified criteria

- Determination that the failure to allow higher spill would result in greater harm to salmon survival through in-river migration than would occur by increased spill.
- Increased spill will provide a reasonable balance of the risk of impairment due to elevated TDG 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.
- Monitoring is sufficient to determine compliance.
- Biological monitoring occurs to document that the migratory salmonid and resident biological communities are being protected.

Compliance of both states' TDG criteria is measured at TDG fixed monitoring stations in the forebay and tailrace of each of the dams which are managed by the U.S. Army Corps of Engineers and U.S. Geological Survey.

Short-term Modifications

The Washington State Water Quality Standards allow for short-term modifications of water quality standards. This EIS will look at short-term modification alternatives for the TDG criteria in the lower eight federal dams on the Snake and Columbia rivers. The intent of the short-term modification alternatives is to allow criteria to be exceeded on a short-term basis for the increased enhancement of fish passage while still protecting other aquatic resources.

The short-term modification language is Chapter 173-201A-410 and this project will be implemented using 410 (1) and (2).

173-201A-410
Short-term modifications.

The criteria and special conditions established in WAC 173-201A-200 through173-201A-260 , 173-201A-320, 173-201A-602 and 173-201A-612 may be modified for a specific water body on a short-term basis (e.g., actual periods of nonattainment would generally be limited to hours or days rather than weeks or months) when necessary to accommodate essential activities, respond to emergencies, or to otherwise protect the public interest, even though such activities may result in a temporary reduction of water quality conditions.

(1) A short-term modification will:

(a) Be authorized in writing by the department, and conditioned, timed, and restricted in a manner that will minimize degradation of water quality, existing uses, and designated uses;

(b) Be valid for the duration of the activity requiring modification of the criteria and special conditions in WAC 173-201A-200 through 173-201A-260, 173-201A-602 or 173-201A-612, as determined by the department;

(c) Allow degradation of water quality if the degradation does not significantly interfere with or become injurious to existing or designated water uses or cause long-term harm to the environment; and

(d) In no way lessen or remove the proponent's obligations and liabilities under other federal, state, and local rules and regulations.

(2) The department may authorize a longer duration where the activity is part of an ongoing or long-term operation and maintenance plan, integrated pest or noxious weed management plan, water body or watershed management plan, or restoration plan. Such a plan must be developed through a public involvement process consistent with the Administrative Procedure Act (chapter 34.05 RCW) and be in compliance with SEPA, chapter 43.21C RCW, in which case the standards may be modified for the duration of the plan, or for five years, whichever is less. Such long-term plans may be renewed by the department after providing for another opportunity for public and intergovernmental involvement and review.

Implementation of the STM Alternatives Considered

The short-term modification alternatives under consideration in this EIS will apply to the spring spill season at the lower Snake and Columbia river dams. This spill season aids the passage of outmigrating juvenile salmonids and aligns with the spring freshet. The Spill Agreement defines the spring spill season as April 3 through June 20. Given the longer duration necessary for this modification, Ecology's action follows Chapter 173-201A-410(2) procedures for modifications requiring a longer duration. Therefore, Ecology is conducting a public involvement and review process that is consistent with the Administrative Procedure Act (chapter 34.05 RCW) and in compliance with Washington State SEPA, chapter 43.21C RCW. This EIS, in part, achieves compliance with SEPA. The concurrent review period of the draft STM and draft EIS, including scheduled public hearings, achieves compliance with the Administrative Procedures Act.

Short-term Modification and Application of the Adjusted TDG Criteria

In accordance with Chapter 173-201A-200(1)(f)(ii) WAC, Ecology periodically issues an approval of the U.S. Army Corps of Engineers' Gas Abatement Plan. This approval acknowledges the operation and structural actions the Federal Columbia River Power System (FCRPS) takes to minimize TDG and allows the federal dams that voluntarily spill to aid fish migration to exceed the 110% TDG criterion. Ecology issued a new gas abatement plan approval in January 2019 that allows the use of adjusted criteria for the 2019, 2020, and 2021 spring spill seasons.

The draft short-term modification developed in conjunction with this EIS is to be issued to the Corps. The conditions of the STM will modify the current TDG adjusted criteria in the water quality standards. The recently issued gas abatement plan approval notes that the Corps is allowed to spill to the current TDG criteria as well as to any forthcoming modification to the adjusted criteria. The modification to the TDG criteria in the Snake and Columbia rivers may be achieved through the use of the short-term modification process or through a subsequent rulemaking to change the adjusted TDG criteria thresholds in the water quality standards.

Summary

Objectives

The objectives of the short-term modification for the TDG criteria for the Snake and lower eight Snake and Columbia River federal dams is based on:

1) The potential increase in smolt-to-adult returns (SARs) for salmonids by allowing more spill over dams for fish passage,
2) Meeting the Flexible Spill Agreement goals to increase fish benefits, and
3) Developing consistent TDG criteria in the Snake and Columbia rivers between the States of Washington and Oregon.

Purpose

The purpose of the environmental impact statement is to evaluate the impacts of adjusting the TDG criteria for the Snake and Columbia rivers.

Conclusion

Increased spill has been proposed and demonstrated in models to increase the survival of juvenile salmonids outmigrating to marine waters. However, because of the greater TDG related risk to aquatic life it is expected that continuing to increase spill beyond a certain threshold would eventually lead to diminished benefits for salmonids. The increased benefits of spill to salmonids should be weighed against the risk of adverse impacts of increased TDG levels that may accompany greater amounts of spill.

At this time, Ecology's preliminary decision is to remove the 115% forebay criterion for a period up to three years. This action coincides with the Spill Agreement that aims to benefit salmon and hydropower. Additionally, Ecology will adjust the 12 hour averaging method to match the State of Oregon's method. This would have little effect on the operations of the federal dams and would ease the ease spill operations, as well as TDG monitoring and reporting requirements. Washington would require TDG limited by the 12 hour average to be conducted using the 12 highest hourly averages in a day rather than the highest average calculated from 12 consecutive hourly averages.

Given that dam and salmon managers have not previously provided voluntary spill to 120% due to the potential for higher TDG levels to increase symptoms of gas bubble trauma in juvenile salmon, steelhead, and non-listed aquatic species, continuing monitoring for gas bubble trauma will occur.

The Regional Debate

Since the 1990s, a significant strand of the regional debate over "dams vs. salmon" has included debate over the best level of spill at the eight lower Snake and Columbia river dams. Questions have involved how much spill benefits salmon migration past the dams and adult returns, especially when factoring in impacts from elevated TDG levels; uncertainty about the effects of higher levels of spill on aquatic life in the river other than salmonids; and concerns about the value of "foregone" power revenue from spill given impacts to electricity ratepayers and/or other potential fish and wildlife investments. In general, conservation and fishing organizations have supported increasing spill, while utility and ratepayer interests have opposed it. This EIS is not related to any dam breaching proposals that the Washington State Orca Task Force recommended to Governor Inslee.

Reasonable Alternatives

Alternative 1: No action. Do not issue a short-term modification. The adjusted TDG criteria for the lower eight dams in the Snake and Columbia rivers will remain at 115% in the forebay and 120% in the tailrace for the spill season. A maximum one hour average of 125% TDG should not be exceeded.

Alternative 2: Issue a short-term modification. The adjusted TDG criteria for the lower eight dams in the Snake and Columbia rivers to maintain 120% in the tailrace and remove the 115% forebay criteria. This will only be for the spill season. A maximum one hour average of 125% TDG should not be exceeded.

Alternative 3: Issue a short-term modification. The adjusted TDG criteria for the lower eight dams in the Snake and Columbia rivers will maintain the maximum one hour average of 125% TDG in the tailrace and remove the 115% forebay and 120% tailrace criteria. This will only be in place for the spill season.

Spill Operations

Existing Spill Conditions

The Snake and Columbia rivers hydrology is heavily modified by the presence of hydropower projects that provide energy for the State. The hydropower projects within the Snake and Columbia river system have been designed for upstream anadromous fish passage. However, operations of the hydropower projects is a tightly regulated process. Reservoirs in the forebay of dams are regulated to endure fluctuations in water levels that account for other hydropower operations, climatic shifts, and hydrological changes.

During the spring season, large amounts of runoff from melting snowpack leads to vast inputs of water into the Snake and Columbia river tributaries and leads to high flows within the Snake and Columbia River system, better known as the spring freshet. When hydropower operations cannot pass all of the incoming water through turbines and cannot store water, water is spilled over dam through spill gates. Voluntary spring spill season typically begins on April 3rd in the lower Snake River and April 10th in the lower Columbia River, and ends on June 15th in the Columbia River and June 20th in the Snake River. Spill occurs regularly during the spring freshet to manage the incoming water at hydropower projects but is also used to pass outmigrating juvenile salmonids downstream to estuarine and marine waters.

In 2008 NOAA issued a 10-year Biological Opinion (BiOp) for the Federal Columbia River Power System (FCRPS) that recommended a reasonable and prudent alternative (RPA) sufficient to avoid impacts for 13 species of salmon and steelhead affected by FCRPS operation. The 2008 FCRPS BiOp describes 10-year operations and configuration plans for FCRPS facilities as well as mainstem effects for other hydroprojects on Columbia River tributaries. The FCRPS actions include additional habitat, hatchery management, predation management, and harvest actions to mitigate for adverse effects of the hydrosystem. The adaptive management implementation plan for the 2008 BiOp, released in 2009, includes accelerated and enhanced action to protect species, enhanced research and monitoring to improve certainty of information, specific biological triggers for contingencies linked to declining abundances of listed fish, contingency actions to improve fish survival, and regional collaboration and independent scientific review to provide ongoing scientific input and actions to support and inform adaptive management decisions.

In 2010 a supplemental FCRPS BiOp was released that summarized and assessed relevant new information and resulted in six new actions to identify and protect against uncertainties associated with climate change, toxics, invasive species, and hatchery fish.

In 2014, a supplemental FCRPS BiOp was released that examined the updated science and data in regards to the biological status of the listed species. The 2014 BiOp concluded that the RPAs are sufficient so as to not jeopardize the continued existence of 13 listed species or modify critical habitat and that additional mitigation actions are not necessary to satisfy the requirements of ESA.

In 2018, a U.S. District Court order mandated hydropower projects to spill water to the 120% tailrace or the 115% forebay gas caps, depending on which was more limiting. The 2018 mandate sought to increase spill for the benefit of fish passage for endangered salmon and steelhead.

Additional Spill for Fish Passage

Threatened Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*) returns rebounded from very low population levels in the 1990s during the 2000s and early 2010s, but more recently have declined. According to the Comparative Survival Study's 2017 annual report, smolt-to-adult return ratios (SARs), a key indicator for the abundance and growth trend in these salmonid stocks, remain below the 2-6% SARs (with a 4% average) necessary for recovery according to the NW Power and Conservation Council's 2014 Fish and Wildlife Plan.[8]

Current SARs for Snake River spring/summer Chinook salmon have been 1.1 since 2000.[9] The CSS has modeled expected changes to SARs from spilling to BiOp standards, 115% forebay/120% tailrace, 120% tailrace-only, and 125%. All spill regimes modeled by the CSS are 24 hours, seven days per week. When spill is increased to 125% TDG 24 hours per day/seven days a week in the spring, the CSS predicts a two to 2.5-fold increase in Snake River spring chinook salmon abundance above the levels resulting from 2014 FCRPS BiOp spill levels,[10] and smaller projected increase when spilling to existing gas standards or 120% TDG 24 hours per

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[8] NW Power and Conservation Council 2014 Fish and Wildlife Program at p. 157. See https://www.nwcouncil.org/sites/default/files/2014-12_1.pdf
[9] CSS 2017 Annual Report at p. 102. http://www.fpc.org/documents/CSS/CSS_2017_Final_ver1-1.pdf
[10] See CSS 2017 Annual Report at xxxi.

day. Steelhead SARs are also predicted to increase significantly, but less dramatically than Chinook salmon.

2019 spill operations under the Spill Agreement are predicted to provide a small improvement in survival and SARs compared to the 2018 court-ordered spill operations to spill to existing gas caps.[11] This is based on a projection that 2019 Spill Agreement operations will result in a reduction in smolts' "powerhouse encounter rate," or the number of dam powerhouses (defined as turbines or bypass systems) a smolt encounters while migrating down river. Spillway passage allows smolts to avoid powerhouses.

2018 operations result in an average of 1.76 dam powerhouses encountered by each smolt, while 2019 Spill Agreement operations will result in an estimated 1.73 powerhouse encounters. That compares to 2.98 powerhouse encounters under 2014 FCRPS BiOp operations, and 1.4 to 1.5 powerhouse encounters expected under the operations anticipated in 2020-2021 under the Spill Agreement.

Total Dissolved Gas in Aquatic Systems

Total Dissolved Gas and Hydropower

Total dissolved gas is the summation of the partial pressures of individual gases in solution. The gas content in water bodies is a function of the partitioning of gases between the atmosphere and hydrosphere. The atmosphere is composed primarily of nitrogen (78%) and oxygen (21%). These two elements, with minor contributions of carbon dioxide, comprise the components of TDG measured in water. When gases in the atmosphere and water are in equilibrium, TDG pressure is 100%. Natural processes can deplete gas content in water, for example, oxygen consumption from respiring aquatic organisms (<100% TDG), while other natural processes such as waterfalls can supersaturate gases in water (>100% TDG).

The entrainment of gases in water from the plunging of highly aerated spill water can trap air in water, forming bubbles, facilitating the dissolution of gases into water. The solubility of gases is a function of temperature, atmospheric pressure, and hydrostatic pressure. The solubility of gases increases with water depth due to greater hydrostatic pressure, thus the deeper the plunge of water, the greater dissolution of gases. The portion of gases not dissolved beneath the water will rise to the surface. This degasification process occurs as a result of the lower density of gases compared to water. Degasification occurs in the aeration zone, where gases are removed from the water column. The expanse of the aeration zone can vary depending on bathymetry of the river, climate, water plunge depth, and dam structure. In the area below the aeration zone, gases can remain in the water column due to hydrostatic pressure, resulting in persistently high TDG concentrations.

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[11] Juvenile Chinook salmon PITPH Index estimates based on Comparative Survival Study (CSS) methods (McCann et al 2015) and https://nptfisheries.shinyapps.io/pitph2/ web application tool.

Hydropower dams can alter the dynamics of gas exchange between the atmosphere and hydrosphere. Dams impede the passage of water, often creating reservoirs. Within these reservoirs, water is diverted through turbines through hydrostatic pressure. When the incoming flow exceeds the capacity of the turbine to pass water, the reservoir can exceed its capacity and the hydropower dam must spill water through gates built into the dam. Spill can result from storm events or operational spill. Operational spills often occur during dam maintenance for when the ability to pass water through turbines is limited or in a negative market when power demand is low. When dams spill, water is released near the top of the reservoir, falling large vertical distances. These dam spill events are similar to supersaturation that occurs at the base of waterfalls. In most natural waterfall settings the impact of TDG is limited in distance downstream of the waterfall as the river naturally degasses in shallower waters downstream. While the nature of spills at dams can vary depending on their structure, gas entrainment can contribute significantly to TDG in the water system. These supersaturated waters can travel long distances downstream in the deeper reservoir of the next downstream dam. This duration and large area of high TDG conditions in reservoirs has the potential to cause health impairments to aquatic life.

Aquatic Life Hydrostatic Depth Compensation

Total dissolved gas is measured in percent saturation. Percent saturation measures the amount of air that water will hold in equilibrium with the atmosphere at the total pressure present at the water's surface. At the water's surface, atmospheric pressure is the only variable influencing pressure in the water. At increasing depths, both hydrostatic and atmospheric pressure contribute to the equilibrium state of gases in water. The result is increased capacity of water to dissolve gases at greater depths. Thus, aquatic life at depths experience different TDG levels than aquatic life near surface waters. The compensation rate is about 10% of saturation per meter of depth (Weitkamp et al. 2008). For example, a fish swimming at a depth of 2 meters when surface water TDG levels are 120% would experience a saturation level of 100%, while a fish at the surface would experience 120% TDG. Vertical movement of aquatic life within the water column is therefore an important consideration when evaluating risks related to TDG. The figure below by Weitkamp et al. (2008) depicts the concept of hydrostatic depth compensation.

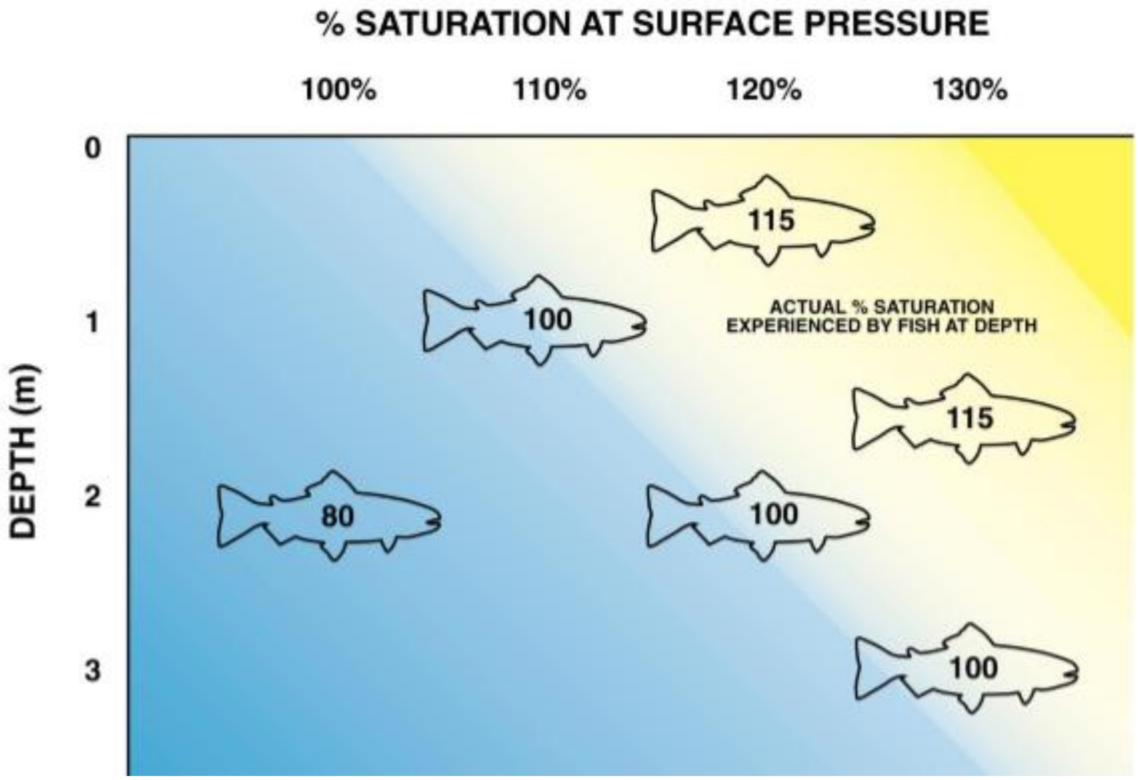

Figure 3. Relationship of measured and actual total dissolved gas levels

Figure 4 shows the relationship of measured and actual total dissolved gas levels experienced by fish at various depths in the river (from Weitkamp et al. 2003a).

Total Dissolved Gas Studies: Laboratory versus Field

Salmonids are often the focal point for impacts of TDG levels in the Snake and Columbia rivers, however, resident fish and aquatic invertebrates should be considered when determining adverse impacts of TDG. When evaluating effects of TDG levels on aquatic organisms, hydrostatic depth compensation should be evaluated. A major criticism of several laboratory studies is the water depth in which studies are conducted. Shallow laboratory studies don't account for depth compensation that is often afforded in deep aquatic systems. Given that some laboratory studies do not allow for hydrostatic depth compensation, effects may be exacerbated compared with field conditions. However, laboratory studies are useful for determining effect levels for different species under controlled conditions. Effect levels determined in laboratory studies can be applied to field conditions to determine if ambient water conditions may be detrimental to particular aquatic species. Field studies represent more realistic exposure scenarios but results are often associated with high data variability, confounding stressors, and uncertainties in study design. Furthermore, little is known about aquatic organism's actual TDG exposures while navigating through aquatic systems. Both laboratory and field studies will be used in this review but limitations of both study types should be noted.

Significant Impacts

Potential Positive Impacts of Increased Spill

Scientific support for increased spill has come primarily from the Comparative Survival Study, a joint project of the Fish Passage Center, Columbia River Inter-Tribal Fish Commission, Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Idaho Department of Fish and Game, and the U.S. Fish and Wildlife Service. The CSS predicts steady improvements in juvenile survival and adult returns as spill increases up to at least 125% TDG.

NOAA Fisheries' COMPASS model is less optimistic about the benefits of additional spill, largely because it does not factor in the same assumptions about delayed mortality as the CSS model due to powerhouse (i.e., non-spillway) passage routes and different conclusions about the relative benefit of fish transportation as an alternative to spill.[12]

The Northwest Power and Conservation Council's Independent Scientific Advisory Board (ISAB) has weighed in on the spill debate at numerous points, critiquing and posing questions of both the CSS and COMPASS models.

The ISAB has not directly compared CSS and COMPASS, but in 2018 reviewed the NOAA Fisheries document A Power Analysis of Two Alternative Experimental Designs to Evaluate a Test of Increased Spill at Snake and Columbia River dams, Using Smolt-to-Adult Returns of Anadromous Salmonids (January 2018 draft). As the ISAB noted, the NOAA analysis "considers two general experimental designs: (1) a before/after design for which there is no variation of spill levels during prospective years and (2) a block design that includes variations between two spill levels during prospective years."[13]

The Spill Agreement described in this document is a version of experimental design (1) above, while NOAA Fisheries was exploring design (2) at the time of the ISAB review. The ISAB review found advantages and disadvantages to NOAA's "block spill design," noting that the "key advantage to the block design is that high year-to-year variation is controlled for by conducting both spill regimes in the same year." At the same time, the ISAB noted that "the advantages [of the block spill design] are somewhat tempered because of several sampling and estimation issues," and that "while a theoretical implementation (i.e., NOAA's block spill paper) may show high statistical power, and implementation may have less power…"[14] ISAB also noted that there was a "[n]eed to acknowledge the consequences of the [block design] experiment on

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[12] See, e.g., Issue Summaries of the 2008 FCRPS Biological Opinion, NOAA Fisheries, at pp. 5-7. https://www.westcoast.fisheries.noaa.gov/publications/hydropower/fcrps/2008fcrps_issuesummaries.pdf

[13] Review of NOAA Fisheries document: *A Power Analysis of Two Alternative Experimental Designs to Evaluate a Test of Increased Spill at Snake and Columbia River Dams, Using Smolt-to-Adult Returns of Anadromous Salmonids (January 2018 draft)*, at p. 1. See https://www.nwcouncil.org/sites/default/files/isab-2018-2-noaa_spillstatisticalpoweranalysis19march.pdf

[14] Id., at p. 1.

migrant survival compared to full spill for entire seasons at 115/120% or 125% spill," noting that "[i]f survival is lower at lower spill rates, the survival that results from the experiment will be lower for ten years than it would have been with the higher spill throughout the entire spill season each year."[15]

In summary, ISAB seems to find value in both the CSS and COMPASS models, and has generally acknowledged that proponents of each model and of different spill tests have merit. The lack of a definitive opinion from the ISAB left spill operations options that increase spill to benefit salmon while also providing opportunities for increased power generation when power demand and corresponding power revenue is the highest.

Model Predictions for Salmonid and Steelhead Survival

The CSS model predicts improvements in salmon survival and abundance as spill is increased up to those levels that would be permitted by a 125% TDG standard. Juvenile survival metrics assessed by the CSS include water transit time (a surrogate for salmon smolt travel time downriver) and powerhouse encounter rates (with powerhouse defined as dam turbines or bypass systems as opposed to a dam spillway, which avoids the powerhouse). The CSS model considers minimizing powerhouse encounters through measures such as spill or dam removal as critical to reducing "delayed mortality" from hydrosystem passage and ultimately increasing adult salmon and steelhead returns. The CSS model predicts a two to 2.5-fold increase in Snake River spring Chinook salmon abundance above 2014 FCRPS BiOp spill levels when spill is increased to 125% TDG 24 hours per day/seven days a week in the spring,[16] and smaller projected increase at 120% TDG 24 hours per day.

In order to provide revenue neutrality or better for hydropower production and associated revenue, the Spill Agreement calls for spilling to 120% TDG in the spring of 2019 for sixteen hours a day, and spilling to lower "performance" spill levels eight hours per day.[17] The CSS model predicts that this operation would slightly benefit salmon relative to 2018 injunction operations (spill to existing gas caps 24 hours a day/seven days a week), while BPA predicts that it would provide similar power revenue. 2019 operations would be an incremental step toward a flexible spill operation that would be expanded in 2020 to include flexible spill (i.e. 16 hours of higher spill and eight hours of "performance" spill) to 125% TDG.[18] Flexible spill operations to 125% TDG are predicted by CSS model to benefit juvenile fish survival and adult returns relative to both 2018 court-ordered operations and proposed 2019 flex spill operations to 120%, but not as much as would be predicted for full-time spill to 125% TDG during the spill season.

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[15] Id., at p. 8.
[16] See CSS 2017 Annual Report at xxxi.
[17] See Agreement, Table 1.1, at p. 17.
[18] The Agreement calls for further refinement of proposed 2020 operations. See Agreement at pp. 5-6 and Tables 1.3.a and 1.3.b, at p. 19.

Potential for Negative Impacts of Total Dissolved Gas

Salmonids

Early Development

Salmonid spawning in the main-stem Snake and Columbia rivers is limited to particular areas due to the lack of suitable habitat and thus, many adults spawn in tributaries of the two rivers and may not be impacted. Dauble and Geist (2000) reported the majority of spawning is concentrated in the Hanford Reach and Hells Canyon reach of the Snake and Columbia rivers. Since the development of hydropower, the fall Chinook salmon habitat has been reduced to 13% and 20% of the historical habitat in the main-stem Snake and Columbia rivers, respectively (Dauble et al. 2003). Chinook salmon are not known to spawn in the area encompassing the lower eight federal dams on the Columbia.

Tracking early development of salmonids in the natural environment presents several difficulties including the long incubation period (>30 days), monitoring logistics, fluctuating ambient water conditions, and detecting and following egg development. Field studies examining early developmental stages of salmonids are limited in the Snake and Columbia rivers. In one of the first comprehensive studies examining TDG, Meekin and Allen (1974), found that eyed Chinook salmon eggs successfully hatched at 122% TDG, while steelhead eggs experienced mortality at 122%, suggesting sensitivity differences in developing embryos between salmonid species. Jensen (1980) found little effect to embryos, alevins, and fry up to 110% TDG. TDG levels of 110-111% in shallow waters led to low incidences of TDG related effects to salmon fry that included burst swim bladders (2.6%) and 1.4% opercular deformities (1.4%).

A few studies have examined TDG effects on early life stages of chum salmon (*Oncorhynchus keta*) in the Columbia River below Bonneville Dam (Geist et al. 2013; Arntzen et al. 2009). Murray et al. (2011) demonstrated that timing of emergence of chum salmon below Bonneville Dam can occur as early as February 10 and can extend to April 9. Thus, early life developmental stages of Chum salmon are likely to be present below Bonneville Dam during fish-spill season.

The most recent study by Geist et al. (2013) examined survival of chum salmon alevins between hatch and emergence (early, middle, and late stages) in shallow laboratory waters at six TDG levels between 100% and 130%. Each life stage was exposed for 49 days (d; early stage), 28 d (middle stage), and 15 d (late stage) through emergence. The estimated median lethal concentration (LC50) was 128.7% for early and middle life stages. The maximum mortality at the 130% TDG treatment for the late life stage was 35%. Early life stage fish were the least sensitive life stage and able to tolerate 120-130% TDG for several days before mortality was observed. Middle and late life stages experienced mortality during the first day of exposure between 120-130% TDG. After 48 hours (h) of exposure to 115% TDG or higher, 20-40% of emerging fish had bubbles in the nares and 50-70% of fish had gas bubbles in their yolk sacs. No gas bubbles in yolk sacs were observed at 100% or 105% TDG. Overall, chum salmon fry exposed to TDG between 100 and 115% survived equally as well to emergence, averaging 92% survival. All developmental stages survival decreased significantly when gas concentrations were at 117% TDG or above. Under field conditions at the TDG levels examined by Giest et al. (2013), early life stage chum salmon will likely be at depths that allow for depth compensation and thus protect developing embryos. Geist et al. (2013) supported existing management guidelines that limit depth-compensated TDG levels to 105% for chum salmon spawning.

In another study by Arntzen et al. (2009), chum salmon spawning sites below Bonneville Dam in the Ives Island and Multnomah Falls areas were monitored to determine environmentally relevant TDG exposure levels. Chum salmon sac fry at Ives Island were exposed to depth-compensated TDG greater than 103% up to 200 h and greater than 105% for up to 100 h primarily during the spring spill. At the Multnomah Falls site, chum salmon sac fry were not exposed to depth-compensated TDG greater than 103%. In the laboratory component of this study, TDG levels up to 113% did not influence survival, growth, or development of chum salmon sac fry (Hand et al. 2009). The first observed effects of TDG to chum salmon fry survival were observed at 121% TDG.

The impacts of TDG to chum salmon sac fry has also been evaluated in-river downstream of Bonneville Dam. Carter et al. (2009) reported that Chum alevins sampled in a wild redds at Ives Island had signs of GBT when depth-compensated TDG exceeded 105%, which also represents the management guidelines to ensure protection of chum salmon. Subsequently, Carter et al. (2009) built an artificial redd north of Ives Island and placed egg tubes to monitoring impacts of developing chum salmon to ambient TDG levels during the Spring season.. The symptoms of GBT, notably bubbles in the eyes, were more prevalent in fish during sampling periods that coincided with depth-compensated TDG at 105% or greater.

Juveniles

Field Studies

Juvenile salmonids outmigration in the Snake and Columbia rivers coincides with high river flows from snowpack melt in the spring. Juveniles passing downstream to the Columbia River estuary and marine waters can incur mortality depending on the route of passage through hydropower dams. Juvenile passage may occur through dam turbines, mechanical bypass facilities, or spillway passage. Of the routes available, studies have shown spillway passage is associated with the lowest mortality (Whitney et al. 1997; Muir et al. 2001). Increasing spill over dams has been proposed as a method for increasing survival of outmigrating juvenile salmonids. However, increasing spill can be accompanied by high TDG levels which may have adverse impacts on salmonids.

The relationship between TDG levels and the incidence of GBT in juvenile salmonids has been recorded in several field studies. Ebel (1969) placed juvenile coho (*Oncorhynchus kisutch)* and Chinook salmon in cages at various depths in the forebay of Priest Rapids Dam for 200-280 h and concluded that at 130-140% TDG, fish must remain below 2.5 m to survive. During the study, coho salmon held between 0.5 -1.5 m experienced 100% mortality and coho in pens at depths of 2-3 m had 70% mortality. In a later study by Ebel (1971), mortality ranged from 45-

68% in 4.5 m deep cages containing spring and fall Chinook salmon at 127-134% dissolved nitrogen (N_2) in the forebay of Ice Harbor Dam.

When summer Chinook salmon eggs were exposed to 100 and 122% TDG in shallow waters, both exposure groups had high survival (Meekin and Allen 1974). The surviving fry were exposed to 122% TDG and displayed behavioral changes such as swimming in circles on their backs and sides, and loss of swimming ability. The first fingerling mortality occurred on the 126^{th} d from test initiation (including egg incubation) and mortalities increased abruptly after the 140^{th} d. At 160 d (test termination), 66 of 87 (76%) juveniles did not survive. In a separate experiment, Meekin and Allen (1974) reported significant mortalities at treatment levels between 120 to 135% TDG, with smaller juveniles surviving longer than the larger fish. Observations showed that fry exposed to 122% TDG were not feeding, while feeding was occurring at 112% TDG. In the 67-d experiment, growth of fingerling Chinook salmon decreased with increasing TDG exposure (48.9 mm at 98%, 45.3 mm 107%, 44.0 mm 112%, and 39.5 mm in 122% TDG).

In a long-term biological monitoring study (1996-1999) at 5 different hydropower projects on the Snake and Columbia rivers, fewer than 2% of juvenile salmonids examined displayed external signs of GBT, with most of those with GBT signs having less than 5% fin occlusion (Backman et al. 2002). Of the salmonids examined, steelhead was the most sensitive species to GBT incidences (2.3%), followed by sockeye (1.4%; *Oncorhynchus nerka*), and then Chinook (0.8%) and coho (0.7%). GBT symptoms exceeded 15% GBT when TDG levels approached 130% but at less than 125% TDG, GBT prevalence was well below 15% (15% GBT represents the action criteria established in the 2000 NOAA Biological Opinion). The prevalence and severity of GBT observed was noticeably higher at TDG levels in the range of 125-130% versus 120-125% but the overall incidence rates were relatively low (Backman et al. 2002).

In another field study at sites downstream of Bonneville, Ice Harbor, and Priest Rapids Dams, juvenile salmonid passage was monitored during the spring freshet of 1993 and 1994 (Dawley 1996). In 1993 below Bonneville Dam, 17 species of fish were collected and examined for external signs of GBT. Among the fish examined in 1993, juvenile salmonids were the most sensitive to TDG. Coho salmon had the highest incidence of GBT at 3%, followed by steelhead (2%), and Chinook salmon (0.1%). Most signs of GBT were only observed when the average daily TDG levels exceeded 120%. In 1994 below Ice Harbor Dam, GBT ranged from 12 to 50% for salmonids held in surface cages and from 0 to 37.5% for salmon held in net pens with depths of 0-4 meters. Salmon held in control cages at 1.5 to 2.5 meter depths, had a 10% GBT prevalence when TDG levels averaged 125%.

Biological monitoring at Rocky Reach and Rock Island for juvenile salmonids occurred extensively for a number of years (Mesa et al. 1997; Grassell and Hampton 2001; Grassell et al. 2000a, 2000b; Hampton 2002, 2003; Murdoch and McDonald 1997; Maitland et al. 2003). TDG levels from 110 to 120% was common and resulted in GBT symptoms in 1-5% of juvenile Chinook salmon and steelhead. In 1997, TDG levels exceeded 120% for approximately two months and led to a GBT incidence of 20-80% in juvenile salmon collected at the two dams, suggesting increased risk during chronic exposures.

Sampling of out-migrating juvenile salmon on Priest rapids has occurred over several years. Hagen et al. (1998) reported GBT signs in 21.5% of sockeye salmon, 9.4% of Chinook salmon, and 8.7% of steelhead at TDG levels of 120-135%. During the summer, when TDG levels dropped to 110-125%, Hagen et al. (1998) reported GBT in only 2.3% of Chinook salmon. In a long-term monitoring program from 1996 to 2002, Duvall et al. (2002) found juvenile salmon had an incidence of GBT from 1.7 to 8.3% during spring spill when TDG averaged 113 to 130%. When TDG levels averaged between 113-120% in 1998, GBT incidence ranged from 1.7-5.8%.

During high spill levels in 1997, Ryan and Dawley (1998) monitored juvenile salmonids at Ice Harbor Dam, and downstream from Ice Harbor and Bonneville Dams. From April 20 to June 23 at Ice Harbor Dam, TDG levels remained near 130% for 2 months and then dropped to roughly 120% for the rest of the period. From April 24 to June 10, GBT prevalence was 13.7% of 738 juvenile salmonids collected 15 km downstream from Ice Harbor Dam. During this same period, prevalence of GBT at Ice Harbor Dam in the juvenile bypass system was 5.2%. Steelhead comprised the majority of the juvenile salmon collected. Steelhead downstream of Ice Harbor Dam had an average 49% higher prevalence of GBT than steelhead examined at Ice Harbor Dam. From March 14 to August 22, 0.6% of juvenile salmonids had signs of GBT downstream of Bonneville Dam when average TDG levels did not exceed 117%.

In 4-d net-pen studies downstream from Ice Harbor Dam, juvenile hatchery Chinook salmon were placed in cages at the surface, 0-4 m, or 2-3 m deep (Ryan and Dawley 1998). Signs of GBT were prevalent in 80% of juvenile Chinook salmon in surface cages, 52% in 0-4 m cages, and 6% in 2-3 m cages when weekly average TDG measured between 122% and 130%. In surface cages (excluding data from July 28-Aug 1) at TDG levels between 126-130%, 94% mortality was observed in Chinook salmon, 71% mortality at 122% TDG, and 3% mortality between 117-118% TDG. In the 0-4 m cages (excluding data from July 28-Aug 1), mortality was 30% at TDG exposure levels of 126-130%, 32% mortality at 122% TDG, and 2% at 117-118% TDG. In the deep (2-3 m) cages (excluding data from July 28-Aug 1), mortality was 20% at 126-130% TDG, 25% at 122% TDG, and 4% at 117-118% TDG. The authors noted disparities between GBT incidences in net pens versus river conditions, with lower incidences of GBT of fish collected in-river.

Toner and Dawley (1995) reported that juvenile salmonids were the most sensitive species to GBT among 17 species of fish. The highest incidence on a single day at Bonneville Dam for smolts was 8% for wild steelhead, 11% for hatchery steelhead, 2.7% for coho, 0.7% for sockeye, and 0.2% for Chinook salmon at TDG levels between 120-125%. Toner et al. (1995) examined juvenile salmonids downstream from Ice Harbor when TDG was >130% for 7-11 h each day and observed GBT incidence in 5-10% of fish captured.

In 1996, Hans and Maule (1997) monitored juvenile salmonids when TDG levels exceeded 120% for a period of eight straight weeks. GBT incidence in fish averaged 2-4% for spring Chinook salmon and 6-7% for steelhead. At John Day Dam, GBT prevalence in spring Chinook salmon was 5.5%. Steelhead reached a maximum of 9.9% GBT incidence at Bonneville Dam. Mesa et al. (1997) concluded within the same report that GBT was not a threat to migrating juvenile salmon when TDG levels were less than 120%.

The Fish Passage Center monitored GBT in juvenile salmonids from 2008 to 2017 and reported greater than 15% GBT in three instances out of 1,004 GBT samples[19]. In all three instances, TDG levels were in excess of 125%.

Laboratory Studies

In field monitoring studies, it is difficult to control extraneous variables, track the progression and severity of GBT, and measure survival. Laboratory studies enable the isolation of variables that can be effective at determining effect thresholds in a controlled environment. However, laboratory bioassays conducted in shallow water may overestimate effects if aquatic test species are not able depth compensate and move to less harmful TDG conditions.

Ebel (1973) placed juvenile Chinook salmon in 2.4 m deep tanks for 60 d and recorded insignificant mortality at 118% TDG but 100% mortality in fish held in 0.25 m of water. Dawley et al. (1976) placed juvenile Chinook salmon in 2.5 m deep water and reported mortalities of 67% and 97% at TDG levels of 124% and 127%, respectively. When the same study was conducted in 0.25 m depth tanks, the same mortalities (67% and 97%) occurred at 115% and 120% TDG. At 110% TDG at water depths of 0.25 m, 15% mortality occurred, while only 5% mortality occurred in 2.4 m water depths at 120% TDG. These studies suggest that hydrostatic depth compensation is important factor in determining risk in supersaturated waters.

During a 50-55 d chronic exposure at 120 to 130% TDG, juvenile salmon and steelhead experienced 11% and 6% mortalities, respectively, in 2.5 m tanks compared to 80% mortality for both species in 1 m deep tanks (Blahm 1974 and Blahm et al. 1976). Mortality was most prevalent near the end of the experimental period when TDG levels ranged between 123% and 127%. Juvenile cutthroat demonstrated less ability to depth compensate, with 42% mortality at 1 m depth and 27% mortality at 2.5 m. To understand the sensitivity of different aquatic organisms to TDG, further research may be necessary to determine the ability for aquatic species to depth compensate.

In a laboratory study by Mesa et al. (2000), juvenile Chinook salmon and steelhead were exposed to treatments of 110% up to 22 d, 120% up to 140 h, or 130% TDG for 11 h in shallow water depths of 28 cm. The study design did not allow for depth compensation typically accompanying field monitoring studies. At the 110% TDG treatment, the prevalence of GBT in Chinook salmon increased over the exposure period of 22 d, with fin occlusion prevalence reaching up to 60% and no observed mortalities. Juvenile Chinook salmon exposed to 120% TDG resulted in 20% mortality within 40 to 120 h, depending on the trial. Moreover, over 50% mortality was observed in 2 of the 3 trials at 120% TDG. At the 120% TDG exposure level, 100% of fish had GBT signs in their lateral line. At the 130% TDG treatment level, 20% mortality was observed within 3 to 6 h, depending on the trial. At 130% TDG, the prevalence of lateral line bubbles reached 100% within hours. For steelhead exposed to 120% TDG, 20% mortality occurred within 20 to 35 h, with about 60% prevalence of bubbles in gills at the end of the experiment. Over 90% mortality was observed within 60 h in 2 of 4 trials at 120% TDG. At

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[19] http://www.fpc.org/documents/memos/25-18.pdf

130% TDG, steelhead mortalities reached 20% after 5 to 7 h. Mortality greater than 50% was observed in all 5 trials at 130% TDG.

Another laboratory study examined the influence of TDG on predator avoidance of juvenile Chinook salmon exposed to 112% TDG for 13 d, 120% TDG for 8 h, or 130% TDG for 3.5 h (Mesa and Warren, 1997). Fish exposed to 130% TDG was the only exposure group that demonstrated a significant increase in susceptibility to predation.

Rainbow trout (*Oncorhynchus mykiss*) exposed to 114%, 118%, 125% at shallow depths (0.25 m) did not show differences in swim bladder over inflation or rupture compared to control fish (Antcliffe et al. 2002). In the 114% treatment group, all fish survived for 6 d and at 110% TDG for 9 d. At 116% TDG, mortality was 9% after 96 h and 42% after 9 d. At the 122% TDG treatment, mortality was 89% after 96 h. At the 140% TDG treatment, mortality was 100% within 24 h. At the 122% and 140% TDG treatment, the mean time to 50% mortality was 55 h and 5.1 h, respectively. When cage depths ranged from 0-1 m at 122% TDG, 96 h mortality was 22% and at cage depths between 0-2.5 m, no mortality observed.

A field laboratory study was conducted using ambient water pumped from the Columbia River and fed into two tanks of different depth containing juvenile Chinook and coho salmon (Blahm et al. 1975). The maximum depth of the shallow water tank was 1 m and the deep test tank had a water depth of 2.5 m. During the 72-d test period in the shallow tank, mortalities of Chinook and coho salmon reached 98.2 and 80.1%, respectively. In the deep tank, mortalities of Chinook and coho salmon were 8.7 and 4.2% respectively. External signs of GBT were first observed in deep tanks when N2 levels reached 120% and above. When N2 levels reached 120-125% and were maintained, the prevalence of GBT symptoms in deep tanks for Chinook salmon ranged between 40-65% in June and 20-55% for coho salmon.

Adults

Field Studies

As mentioned in Backman and Evans (2002), relatively few studies have focused on impacts of TDG to adult salmonids. In one of the first studies on adults by Westgard (1964), Chinook salmon were placed in live boxes at N_2 levels of 104-107% and 116-130%. TDG exposure levels of 116-130% for 10 d resulted in blindness for 34% of fish and 88% of blinded fish died before spawning, whereas only 6% of non-blind fish died before spawning. Effects were not observed in fish exposed to 104-107% N_2.

In 1967, Ebel (1969) monitored 2,300 adult Chinook salmon, 1,600 steelhead, and 1,000 sockeye salmon for GBT symptoms at Bonneville and McNary Dams when TDG levels fluctuated between 104-131%. GBT symptoms were only observed in 1% of sockeye and 0% of Chinook salmon and steelhead.

Meekin and Allen (1974) found that at TDG levels between 125 to 135% occurred from spilling at Grand Coulee Dam and did not equilibrate while passing through Chief Joseph reservoir. Boat searches and aerial surveys found mortalities of unspawned summer Chinook and sockeye salmon during spill season and that these mortalities were not observed after spilling stopped.

In a sampling study in 1995, GBT signs were monitored in an estimated 3-4% of adult salmonids passing Bonneville Dam and reported no visible signs when TDG levels were 114-120% (Fryer 1995). Backman and Evans (2002) examined adult Chinook salmon, sockeye salmon, and steelhead GBT symptoms at Bonneville Dam from 1995 to 1999. Overall less than 2% of salmonids exhibited external symptoms of GBT. Steelhead was the most sensitive to TDG with a GBT incidence of 2.3%, followed by sockeye salmon (1.4%), Chinook salmon (0.8%), and coho salmon (0.7%). Differences in the prevalence and severity of GBT were evident between TDG levels of 120-125% (less than 0.5% of samples) and 125-130% TDG (up to 5% of samples).

In a field spawning study, Gale et al. (2004) exposed mature female Chinook salmon to TDG levels of 114 to 126% in shallow waters (0.5 m) to determine impacts on reproduction. Test exposures were stopped at the first mortality (ranged from 10 to 68 h). No changes to spawning or pre-spawn mortality was observed between controls and TDG treated fish. Fertilization rates and survival of eyed stage salmon were not affected by TDG exposures.

Non-salmonids

Field Studies

While much of the focus of TDG effects in the Snake and Columbia rivers are on salmonids, impacts to resident aquatic species should be considered when evaluating the risk of elevated levels of TDG.

In the Snake and Columbia rivers, smallmouth bass typically spawn during the spring in inshore and slough areas at times corresponding to the annual freshet at depths ranging from 0.7 to 5.6 m (Scott and Crossman 1973; Montgomery et al. 1980). Montgomery and Becker (1980) examined GBT in 179 smallmouth bass (*Micropterus dolomieu*) and 85 northern pikeminnow (*Ptychocheilus oregonensis*) between Lower Monumental Dam on the Snake River and John Day Dam on the Columbia River in May 1975 and May through August 1976. GBT was observed in 72% of smallmouth bass and 84% of northern pikeminnow caught by anglers. GBT was observed when TDG exceeded 115%. In May 1975, TDG levels reached approximately 122% in Ice Harbor and McNary Dams in 1975, whereas Lower Monumental Dam reached approximately 140%. From May to June 1976, average TDG levels were estimated at 125% in Ice Harbor and Lower Monumental Dams, whereas McNary Dam rarely reached 120%. Between July and August 1976, TDG levels were below 120% at all three dams. The authors noted that although resident fish have depth compensating mechanisms, smallmouth bass and northern pikeminnow health condition was reflective of GBT symptoms in a high proportion of fish. The study fails to describe the TDG levels when GBT was observed in fish sampled, making it difficult to determine relationships between TDG and GBT.

In a field monitoring study in 1993 and 1994, resident fish were examined for GBT symptoms. In 1993, less than 1% incidence of GBT was observed in 10 resident species below Bonneville Dam (Dawley 1996). Data indicated that GBT signs were observed when TDG levels exceeded

120%. In 1994, no GBT symptoms were observed in 4,955 non-salmonids sampled below Bonneville Dam. Downstream from Ice Harbor Dam, when TDG levels exceeded 130% TDG, prevalence of GBT was 11.5% in resident fish. Resident fish with the highest prevalence of GBT were smallmouth bass (4.3%), yellow perch (4.0%; *Perca flavescens*), largemouth bass (3.3%; *Micropterus salmoides*), pumpkinseed (3.2%; *Lepomis gibbosus*), and largescale suckers (2.8%; *Catostomus macrocheilus*).

During the spring freshet of 1994-1997, resident fish were collected from reaches of the Snake and Columbia rivers (below Ice Harbor Dam, Priest Rapids reservoir, and below Bonneville Dam) and examined for symptoms of GBT (Ryan et al. 2000). Generally, when TDG was below 120%, GBT signs were not present or observed in less than 1% of fish. When TDG ranged between 120-125%, GBT incidences ranged from 0.9% to 9.2%. When GBT reached 130% or greater, GBT signs were typically around 18%, with daily prevalence reaching 40.8%. In 1996, 1,227 Catostomidae larvae were collected below Bonneville Dam and 14.3% had signs of GBT.

In a study by Schrank et al. (1997) from April to August of 1995, resident fish were collected downstream from Bonneville Dam, in the reservoir and downstream from Priest Rapids Dam, and downstream from Ice Harbor Dam. Downstream from Bonneville, only sculpin (2.6%) had a GBT prevalence greater than 1%. During monitoring TDG reached a maximum of 118%, and GBT incidences in resident fish reached a maximum of 0.7%. At the Priest Rapids Dam reservoir, GBT incidences were most frequent in the sand roller (5.6%; *Percopsis transmontana*), sculpin (4.8%; *Cottus sp.*), and smallmouth bass (1.6%). Daily mean TDG levels reached a maximum of 122% and the highest recorded GBT incidence was 5.4% in resident fish at 121% TDG. Downstream from Ice Harbor Dam, GBT incidence was highest in smallmouth bass (16.5%), crappie (13.6%; *Pomoxis sp.*), brown bullhead (11.8%; *Ameiurus nebulosus*), bluegill (9.2%; *Lepomis macrochirus*), and redside shiner (8.3%; *Richardsonius balteatus*). Daily mean TDG levels between 115-119%, 120-124%, and 125-129% resulted in a GBT prevalence of 2.7-40.8%, 14.3-15.2%, and 10.7-26.6%. The relationship between TDG levels and GBT was inconsistent, making it difficult to discern differences in effects among TDG levels.

Schrank et al. (1998) monitored resident fish species from March to August in 1996 for GBT throughout the lower Snake and Columbia rivers. Downstream from Bonneville Dam, GBT symptoms in resident fish were less than 4%. Downstream of Bonneville Dam, daily mean TDG levels between 115-119%, 120-124%, and 125-129% saturation led to GBT incidences of 0-8.2%, 0-15.8%, and 0-13.8%, respectively. At Priest Rapids reservoir, GBT signs were observed the most frequently in suckers (26.6%; *Catostomus sp.*), bluegill (16.7%), sculpins (15.6%), chiselmouth (6.9%; *Acrocheilus alutaceus*), stickleback (5.9%; *Gasterosteus sp.*), and pumpkinseed (5.1%). Downstream from Priest Rapids Dam, GBT incidences were reported in suckers (13.2%), smallmouth bass (7.7%), chiselmouth (4.5%), and northern pikeminnow (2.1%). Downstream from Priest Rapids Dam and in the reservoir, daily mean TDG levels between 115-119%, 120-124%, 125-129%, and 130-135% resulted in a GBT prevalence of 0-13.7%, 0-23.1%, 0-5.2%, and 6.3-16.7%, respectively. Downstream from Ice Harbor Dam, GBT signs were observed most frequently in suckers (21.6%), sculpin (13.2%), northern pikeminnow (12.3%), yellow perch (12.3%), smallmouth bass (12.0%), and carp (10.9%; *Cyprinus sp.*). Daily mean TDG levels between 115-119%, 120-124%, 125-129%, and 130-135% resulted in a GBT prevalence of 0-35.5%, 3.6-35.3%, 24.3-37.8%, and 18.1-33.3%, respectively. Again, relationships between TDG levels and GBT were difficult to establish, potentially due to highly variability in field studies and fish life history characteristics.

In 1997, Ryan and Dawley (1998) monitored GBT occurrences in resident fish at Ice Harbor Dam reservoir and downstream of Bonneville and Ice Harbor Dams. Prevalence of GBT in Ice Harbor reservoir was highest in bluegill (15.5%), largemouth bass (15.5%), pumpkinseed (14.0%), smallmouth bass (12.3%), sculpin (11.8%), and bullhead (10.8%; *Ameiurus sp.*). When daily mean TDG levels were between 120-125%, GBT prevalence ranged from 0-66.7% in resident fish. Downstream from Ice Harbor Dam, GBT occurrence was highest in bluegill (11.1%), sculpin (8.1%), and pumpkinseed (7.7%), When TDG levels were between 115-119%, 120-124%, and 125-130%, GBT prevalence was 0-20.0%, 0-10.0%, 4.2-30%, respectively. Downstream from Bonneville Dam, the highest occurrence of GBT in resident species was sucker (10.3%), peamouth (7.6%; *Mylocheilus caurinus*), sculpin (5.4%), and northern pikeminnow (5.2%). When TDG levels were between 115-119%, 120-124%, and 125-130%, GBT prevalence was 0-0.9%, 0-18.7%, 11.5-30.1%, respectively.

Laboratory Studies

Meekin and Allen (1974) used hook and line to capture northern pikeminnow from the Columbia River and placed the fish in a 100% TDG control trough or 120% TDG trough in shallow waters (16.5 cm). Northern pikeminnow exposed to 120% became lethargic immediately and had little activity. After 3 d at 120% TDG, bubble formation was observed on fins of all fish. Juvenile Chinook salmon and steelhead (prey) were placed into each trough. Northern pikeminnow at 120% TDG showed no interest in feeding, while all prey were consumed within 48 h in the control trough. After 8 d, the 120% TDG treatment was reduced to 100% and northern pikeminnow immediately became active and started feeding. Saturation levels was increased to 120% TDG again, and fish became lethargic again. After 17 d, no mortalities occurred but northern pikeminnow were in poor condition. In another feeding study, northern pikeminnow food consumption decreased in proportion to increases in TDG levels when held in shallow tanks (0.25 m; Bentley and Dawley 1981). Northern pikeminnows consumed 14.2 g/d at 100% TDG, 6.2 g/d at 117% TDG, and 2.3 g/d at 126% TDG. Both Meekin and Allen (1974) and Bentley and Dawley (1981) studies were conducted in shallow waters, precluding the ability of fish to depth compensate and circumvent TDG related impacts.

In a shallow (26 cm) water laboratory study, resident fish below Grand Coulee Dam were collected and examined for GBT at TDG levels of 115, 125, and 130% (Beeman et al. 2003). At 125% TDG, the most sensitive species was northern pikeminnow, followed by largescale sucker, longnose sucker (*Catostomus catostomus*), redside shiner, and walleye (*Sander vitreus*) and at 130% the order of sensitivity was largescale sucker, northern pikeminnow, longnose sucker, redside shiner, and walleye. Generally, the time to 50% mortality was approximately 2-fold less at 130% as compared to 125% TDG, suggesting duration of exposure is important in evaluating TDG related risks.

When bluegills were acclimated to surface pressures, acute GBT signs were present at 135% TDG and chronic GBT effects at 120% TDG (Abernethy and Amidan 2001). At 135% TDG, bluegill began to die within 10-12 hr. Bluegill exposed to 100, 120, and 135% TDG at pressures simulating 3 m depths had no external signs of GBT. Bluegill were reported as more resistant to TDG effects than fall Chinook salmon or rainbow trout (least resistant).

White sturgeon (*Acipenser transmontanus*) are known to spawn from April to July, during the fish spring spill season when TDG levels are known to increase significantly. Laboratory studies have observed newly hatched white sturgeon larvae swim up in the water column for the first 5 d after hatching and others have captured larvae in plankton nets (Brannon et al. 1985; Parsley et al. 1993). Counihan et al. (1998) exposed white sturgeon larvae to TDG levels of 118% and 131% in laboratory bioassays in shallow water (25 cm). No mortality was observed at 118% TDG for 10 d but 50% mortality occurred at 131% TDG after 13 d (most mortalities were observed by day 4 at 131%). GBT was first observed at stage 34 at 118% TDG and stage 33 at 131% TDG. When GBT signs were first observed, 50% of 20 larvae sampled had GBT at 118% TDG compared with 85% of larvae at 131% TDG. When stage 33 and 34 larvae were exposed to 118% and 131% TDG for the first time, GBT signs developed within 15 min. The authors conclude that little is known about white sturgeon larvae and that the laboratory study results may represent a worst-case scenario, given that the shallow water test conditions preclude depth compensation.

In the only known studies of TDG effects in amphibians, Colt (1984) examined GBT symptoms in bullfrog (*Rana catesbeiana*) tadpoles. Tadpoles placed in shallow water (0.25 m) exhibited gas inflation of the gastrointestinal tract when exposed to TDG supersaturated waters by floating on their sides or upside down. However, these symptoms could be reversed by reducing TDG levels. A 4-d exposure to approximately 122% TDG had no effect on survival but at day 10, increased mortality and the presence of redleg disease was noted. When adult bullfrogs were exposed to TDG of 116.8% for 4-d no mortality was recorded but subcutaneous gas bubbles were observed in webbing and body. Exposures of 132.9% TDG resulted in 40% mortality within one day, while no signs of GBT were recorded in adult bullfrogs exposed to TDG levels of 108.8% for 27 d.

Colotelo et al. (2012) examined juvenile brook (*Lampetra planeri*) and Pacific lamprey (*Entosphenus tridentatus*) to GBT in a laboratory study. Lamprey acclimated to depths of 4.6 m and subject to rapid decompression to a very low pressure. No mortality or GBT signs were observed for lamprey. Colotelo et al. (2012) notes that the lack of a swim bladder may account for the reduced sensitivity to TDG.

Aquatic Invertebrates

In 1994, 23 taxa and a total 4,133 invertebrates were collected near Bonneville (downstream), Priest Rapids (upstream) and Ice Harbor (downstream) dams and evaluated for signs of GBT (Dawley 1996). GBT signs in invertebrate species were rare. Of the invertebrates sampled, only cladocerans (1.5%) had signs of GBT below Ice Harbor Dam. TDG levels exceeded 130% on occasion during the sampling period.

Schrank et al. (1997) examined 804 invertebrates below Bonneville Dam and reported minimal effects to only cladocerans (0.5%) when TDG levels averaged 114%. Below Ice Harbor Dam, only 0.4% of the 499 invertebrates collected showed signs of GBT when TDG levels were recorded between 105-131%. In another study, three species of invertebrates were collected below Bonneville Dam including Asian clams (*Corbicula sp.*), crayfish (*Procambarus sp.*), and dragonfly larvae (*Gomphus sp.*) and no signs of GBT were observed when TDG levels were mostly between 115-125% (Toner and Dawley 1995). Of the 23 taxa collected by Toner and Dawley (1995) in 1994 below Bonneville and Ice Harbor Dam, GBT was only reported in 4% of cladocerans.

White et al. (1991) conducted bioassays with macroinvertebrates at depths less than 1 meter and found that most were affected at TDG levels of 127% or greater. The most susceptible invertebrate was *Baetis tiicaudatus* at 115% TDG, while *Ephemerella inermis* and *Tricorthyodes minutus* showed effects near 118% TDG.

GBT in *Daphnia sp.*, crayfish, and stoneflies (*Pteronarcys sp.*) have previously been reported by Nebeker (1976). *Daphnia magna* were affected by supersaturated waters above 110%. The mean LC50 for Daphnia magna was 122.5% when fed and held in static water. When Daphnia were not fed in flowing water the 96 h LC50 was 114%. The 7-d LC50 was 120% and the 10-d LC50 was 117.5%. In crayfish, effects of supersaturated water were observed at 130% or above. The mean crayfish 96-h LC50 was 147%; the 7-d and 10-d LC50s were 145% and 133%, respectively. The 10-d median effective concentration (EC50) for stoneflies was 135% for *Acroneuria californica*, and greater than 125% for *Acroneuria pacifica*, and *Pteronarcys californica*.

In a laboratory study by Nebeker et al. (1981), the effects of TDG supersaturation were examined on the adult emergence of the mayfly (*Timpanoga Hecuba*), caddisfly (*Dicosmoecus gilvipes*), mosquito (*Culex peus*), and midge (*Cricotopus sp*.). The 96-h median lethal concentration (LC50) for the mayfly was 129% TDG and the median lethal time-to-death (LT50) was 2.7 d. The caddisfly LT50 was 45 d at 135% TDG. The adult midges and mosquitoes emerged at TDG levels greater than 140%, whereas adult mayflies and caddisflies did not emerge or survive at TDG levels of 134% and higher.

Malouff et al. (1972) reported GBT symptoms in bivalves (*Crassostrea virginica, Crassostrea gigas, and Mercenaria mercenaria*) exposed to supersaturated water created by water temperature. A separate experiment indicated that temperature changes do not create GBT symptoms observed. Symptoms included gas-filled conchiolin blisters on valves and gas bubbles in gill filaments in clams and in mantle tissue of oysters.

P. californica, *Isogenus serratus*, *Cloeon ingens*, *Hydropsyche sp.*, Lepidostomatidae, and Tendipedidae were examined for GBT signs after exposure to varying TDG levels at different depths (Fickeisen and Montgomery 1975). The authors found *P. californica* had external bubbles at the 140% TDG level after 1 d and after 5 d at 108% TDG but no mortalities were reported. Hydropsyche, *I. serratus*, *C. ingens* reported high mortality but few signs GBT.

Lepidostomatidae reported two mortalities at 140% TDG but no signs of GBT, while Tendipedidae had no signs of GBT up to 140% TDG.

Evaluating Risks of Total Dissolved Gas

Depth Distribution of Migrating Fish

The migration depth of salmonids is important in determining if hydrostatic depth compensation is adequate to relieve salmonids from TDG levels known to cause adverse effects in the Snake and Columbia rivers. This section describes the available depth migration and distribution data of salmonids. Consideration is given to the behavior of outmigrating juveniles, adult migration, and the use of fish ladders.

Adult Salmon

Johnson et al. (2005) found that adult spring and summer Chinook salmon spend the majority of their time deeper than 2 m, with occasional movement shallower than 2 m. The percentage of time adult Chinook salmon spent below 2 m ranged from 66% at Ice Harbor Dam to 85.1% at Bonneville Dam. Fish were deeper than 1 m 90.7% of the time at Little Goose Dam to 97% at Bonneville Dam. The time adult Chinook salmon spent at depths less than 2 m typically ranged from seconds to minutes. However, the maximum duration spent less than 1 m and less than 2 m by an individual fish was 1.3 and 19.5 h, respectively. The authors concluded that there was minimal potential for GBT on adult spring and summer Chinook salmon under average river conditions, despite the fact that fish tissues were likely supersaturated with dissolved gases. In another study with similar results, Gray and Haynes (1977) reported adult spring Chinook salmon spent approximately 89% of their time at depths greater than 2 m in the Snake River downstream of Little Goose Dam when saturation levels were below 130%.

In another study, Johnson et al. (2007) concluded that adult salmon swam at depths sufficient for hydrostatic depth compensation 95.9% of the time in the Bonneville Dam tailrace and 88.1% of the time in the Ice Harbor Dam tailrace. At higher TDG levels of 125-130%, adult Chinook salmon were exposed to supersaturated conditions 70.7% of the time after accounting for depth compensation. When accounting for depth compensation, 46.5% of the time fish experienced 101-110% TDG, 43.1% of the time exposures were 111-115% TDG, and 10.4% of the time experienced TDG was 116 to 120%.

Juvenile Salmon

Juvenile steelhead were tagged and tracked from Ice Harbor to McNary Dam to determine migration depth (Beeman et al. 1999; Beeman et al. 2000). Median depths of 3 juvenile fish ranged from 1.1 to 4.3 m at locations with TDG ranging from 119.8 to 125.8%. In another study at the McNary Dam forebay median depths of yearling Chinook and steelhead were observed at 2.4 and 2.7 m, respectively (Beeman et al. 2000). Beeman et al. (1999) reported the median TDG experienced by fish ranged between 82.4% and 107.4% after accounting for hydrostatic depth compensation. Mean TDG exposures for juvenile Chinook salmon and steelhead were 89.0% and 94.6% (Beeman et al. 1999). Backman et al. (2002) found juvenile Chinook salmon and steelhead spent more than 60% of their time deep enough to compensate for TDG levels as great as 124%.

In a live cage experiment with juvenile rainbow and cutthroat trout, Weitkamp et al. (2003b) placed cages at depths of 2 m in the lower Clark Fork River when TDG levels were >140% and all fish died within 4 d. Fish that survived more than 2 d exhibited severe signs of GBT but it was noted that most fish that died showed minor or no signs of GBT. When TDG levels were held between 123-128%, less than 20% of fish died over 4 d and GBT signs were observed in 0-28% of fish examined each day.

In analysis of bird predation, Collis et al. (2001) reported that hatchery juvenile salmonids may be more vulnerable to predation by surface feeding birds than wild salmonids because of their tendency to migrate or forage near the surface of the water. The authors concluded that the difference in survival and behavior of wild versus hatchery raised salmonids requires further research.

Ebel and Raymond (1976) concluded that when juvenile or adult salmonids are confined to one meter, mortality may occur at 115% TDG after 25 d of exposure and when salmonids are allowed the option of hydrostatic depth compensation, mortality may occur when TDG levels exceed 120% for more than 20 d. As previously mentioned, the duration of exposure in relation to TDG levels and depth compensation are necessary components when evaluating risk.

In another study, mean migration depths of yearling Chinook salmon in the Columbia River varied by year and ranged from 2.1-2.8 m from 1997-1999. Mean migration depth in the Snake River was 1.5 m (Beeman and Maule 2006). Hydrostatic depth compensation ranged from 12.7% to 16.9% in the Snake River where TDG was highest and 27.0 to 34.6% in the lower Columbia River where TDG was the lowest. Mean migration depths for juvenile steelhead ranged from 2.0 to 2.3 m. Hydrostatic depth compensation ranged from 16.9% to 21.3% for the Snake River and from 19.2% to 24.4% in the lower Columbia River.

Fish Ladders

When fish migrate through fish ladders they are restricted to a maximum depth of approximately 2 m. Observations have indicated that fish frequently move towards the surface in fish ways. However, fish ladders often quickly degas and have reduced TDG levels in comparison to the main-stem river (Bouck 1996). The time spent in fish ways can vary drastically depending on the individual fish, fish ladder design, and salmonid species. Spring Chinook salmon tracked at Bonneville Dam took 4 to 57 h (average 22 h) to pass through fish ladders, while those same fish took 3 to 23 h (average 7 h) to pass Dalles Dam (Monan and Liscom 1975).

Timing of Migrating Salmonids

The timing of salmonid migration is an important factor in determining what salmonid species are present and TDG exposure conditions. Adult salmonid species whose migrating timing overlaps with the spring-spill season (typically April 3rd -June 20th in the Snake River and April 10th-June 15th in the Columbia River) include spring Chinook salmon and sockeye salmon. The adult spring Chinook salmon run begins and ends during the spill season and thus reaches maximum abundance when TDG levels become elevated in the Snake and Columbia rivers (Figures 4 and 5). The timing of the vast majority of juvenile salmonids outmigrating corresponds with spring spill season, including subyearling and yearling Chinook salmon, steelhead, sockeye salmon, coho salmon, and chum salmon (chum rarely pass Bonneville Dam; see Figures 5 and 6).

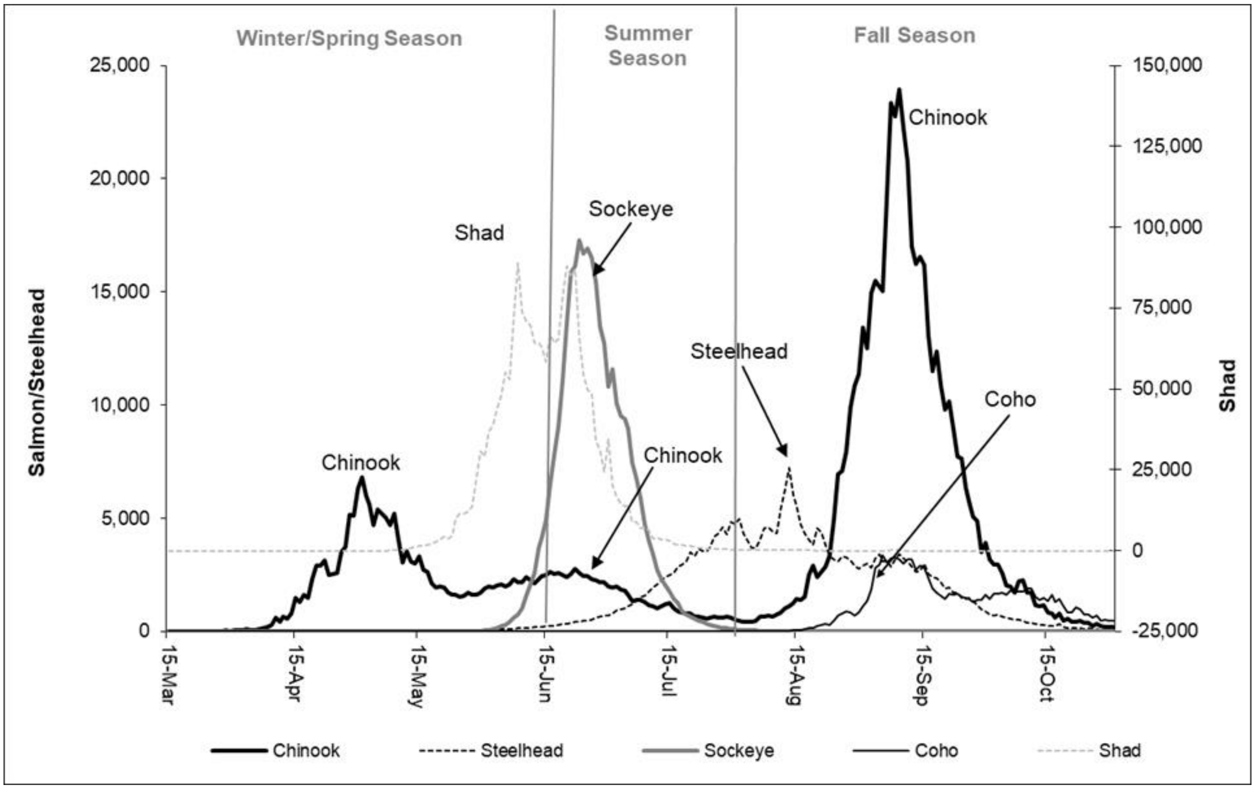

Figure 5. Average daily counts at Bonneville Dam, 2008–2017

Figure 4 shows the average daily counts of salmon, steelhead, and American Shad at Bonneville Dam, 2008–2017 (https://wdfw.wa.gov/publications/01973/wdfw01973.pdf).

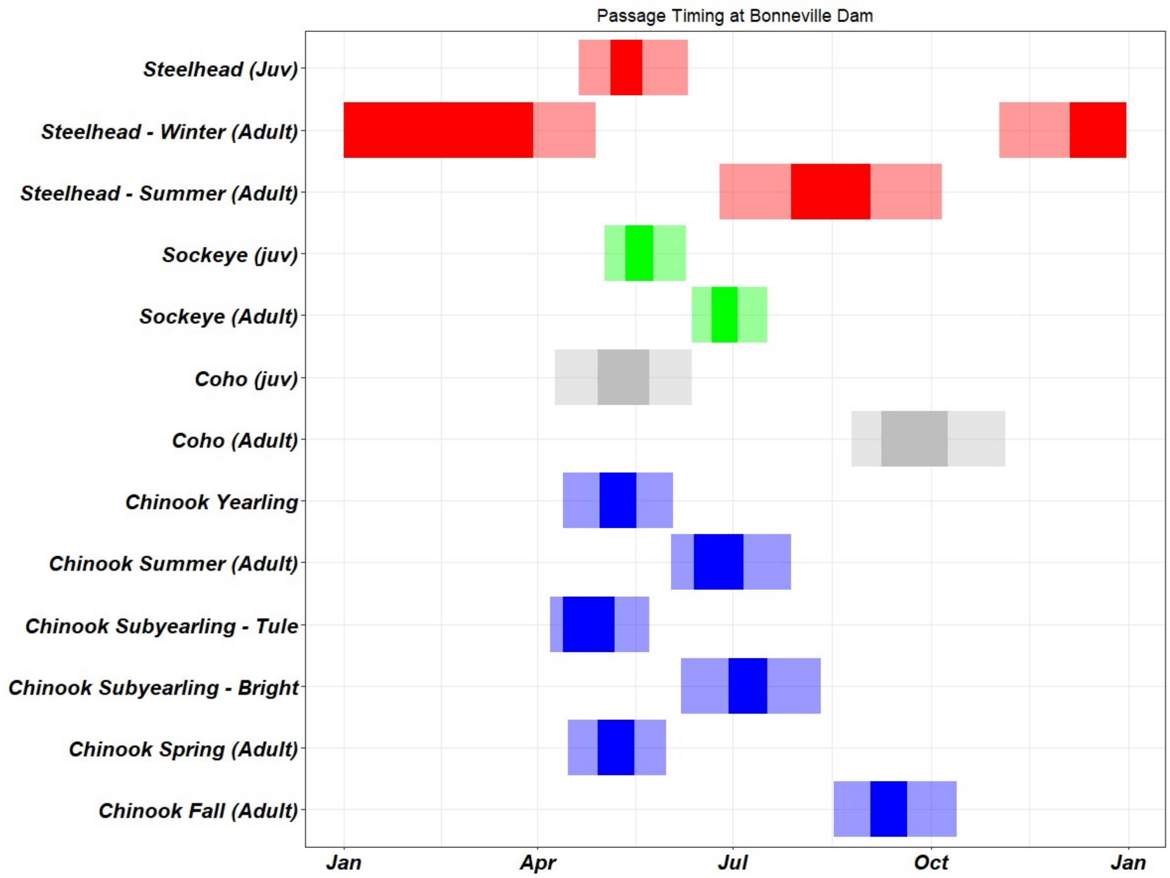

Figure 6. Passage timing by species (and life stage) at Bonneville Dam.

Figure 5 shows the passage timing by species (and life stage) at Bonneville Dam. Shaded regions represent 95% passage (i.e. area between 2.5 and 97.5 percentiles), with darker sections representing the middle 50% of passage (i.e. area between 25 and 75 percentiles). Chinook salmon are represented in blue, coho salmon in gray, sockeye salmon in green, and steelhead in red. Adult timing is indicated by (adult) in y-axis.

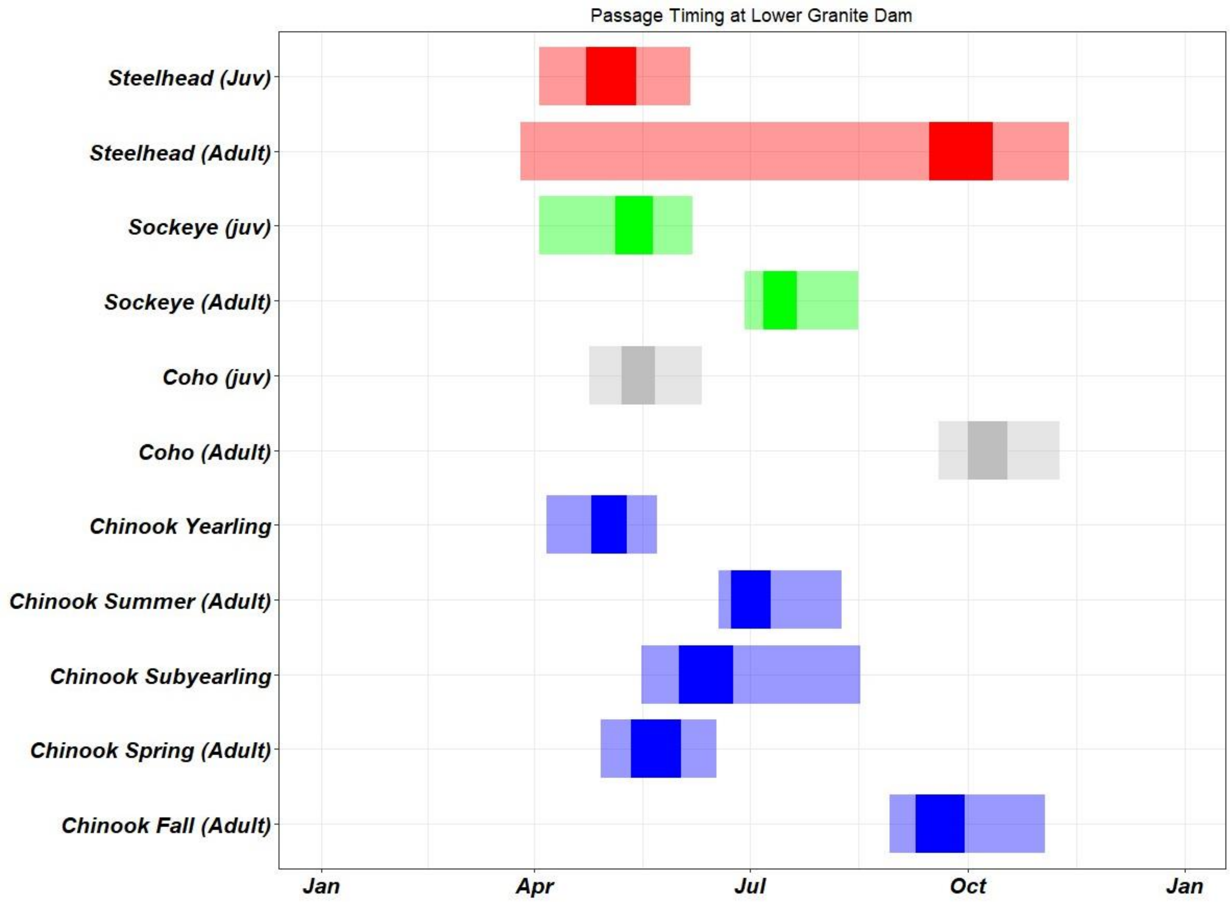

Figure 7. Passage timing by species (and life stage) at Lower Granite Dam.

Figure 6 shows the passage timing by species (and life stage) at Lower Granite Dam. Shaded regions represent 95% passage (i.e. area between 2.5 and 97.5 percentiles), with darker sections representing the middle 50% of passage (i.e. area between 25 and 75 percentiles). Chinook salmon are represented in blue, coho salmon in gray, sockeye salmon in green, and steelhead in red. Adult timing is indicated by (adult) in y-axis.

Fish Movement in Response to Elevated TDG Levels

Several studies have examined behavioral responses of fish exposed to elevated TDG levels and made determinations on whether fish can detect high TDG levels and purposely depth compensate to avoid GBT. There is uncertainty on whether fish have internal mechanisms to detect the need to depth compensate in the presence of high TDG conditions. Shrimpton et al. (1990) described the mechanism of regulating buoyancy in gas supersaturated water. Buoyancy was determined by changes in the volume of the swim bladder which is regulated by pressure. Smaller fish can be subject to positive buoyancy due to the high swim bladder pressure required to force gas out of the pneumatic duct. The smaller the fish, the greater the buoyancy. In smaller fish, swim bladder overinflation must be compensated by depth compensation to attain neutral buoyancy and decompress the swim bladder. Stroud et al. (1975) observed abnormal buoyancy in juvenile Chinook salmon prior to death. If water depth is not adequate for hydrostatic depth compensation, then mortalities may occur (Ebel and Raymond 1976). Shrimpton et al. (1990) suggested that depth compensation behavior is limited to small rainbow trout, as fish weighing less than 10 g increased depth with increases in TDG. Increasing TDG did not have a constant effect on fish above 40 g; some were higher in the column, some lower, and some did not change their mean depth. Larger fish can vent swim bladders and maintain neutral buoyancy at lower pressures than smaller fish. Positive buoyancy in fish requires large expenditures of energy to swim both vertically and horizontally and overcome the upward force of additional drag by the inflated swim bladder (Alexander 1966). Positive buoyancy requires fish to continuously swim to maintain position in the water column if unable to depth compensate. Further research on energy expenditures to maintain preferred water column depths and the consequences are needed.

Beeman (2006) found that with each increase in 10% TDG, the average migration depth of Chinook salmon decreased by 0.2 m and juvenile steelhead increased by 0.3 m. Stevens et al. (1980) also found differences between salmonid species tendency to avoid supersaturated waters. Juvenile Chinook salmon, coho salmon, sockeye salmon, and rainbow trout avoided TDG levels of 125% and 145%, while steelhead did not avoid any TDG levels.

Beeman et al. (2003) reported no correlation between TDG and depths of tagged fish and concluded that fish do not have the ability to detect or avoid supersaturated waters. In support Lund and Heggberget (1985) found no different in depth distribution between rainbow trout held in a 1.6 m deep tank at 115-125% TDG and control fish held in 100% TDG water. At 114% and 125% TDG, laboratory studies involving rainbow trout did not exhibit behavior different from control fish, however, in 2.5 m deep cages trout were observed schooling at depths > 1 m (Antcliffe et al. 2002). Kokanee held in 9 m deep live cages at TDG levels >120% appeared to vertically migrate through the water column based on diurnal changes in lighting rather than a response to TDG conditions (Weitkamp et al. 2003b).

VanderKooi et al. (2003) reported that resident fish of the Snake and Columbia rivers (redside shiner, northern pikeminnow, largescale sucker, longnose sucker, and walleye) had decreased activity and had a tendency to settle or swim near the bottom of shallow tanks (26 cm) as they developed GBT. Behavioral changes in carp and black bullhead were only noted when TDG levels were at exceedingly high values of 146% in 30 cm deep water (Gray et al. 1982; Gray et al. 1983a). When the Atlantic croaker was exposed 145% TDG, movement initially occurred towards the surface of a 2.5 m deep tank but later, movement oscillated up and down to eventually deeper depths (Chamberlain et al. 1980).

Effects of Repeated Exposures to High TDG Levels

Total dissolved gas levels in the Snake and Columbia rivers fluctuate throughout the spill season. Aquatic life may be subject to highly variability TDG levels on a daily or weekly basis resulting in periods of supersaturation and periods below supersaturation when accounting for depth compensation. Few studies have examined the impacts of repeated TDG exposures with relief periods in between TDG exposures.

Anticliffe et al. (2002) acclimated rainbow trout at 122% or 124% TDG to tanks with depths of 0-2.5 m and cycled fish to the surface (max depth of 0.25 m) and recorded lethal times to 10% mortality (LT10) and time to initiation of mortality. Rainbow trout acclimated to 122% for 3 h in deep tanks had LT10s that were on average 6 h less than fish acclimated to 122% for 6 h. This data suggests that longer acclimation periods reduce the onset of TDG related effects. When fish were acclimated to 124% TDG for 6 h, the mean LT10 was about 11 h less than fish acclimated at 122% for 6 h. When examining the first recorded mortality, the first transfer of fish from deep to the surface took substantially longer to achieve the first mortality than subsequent cycles of fish from depth to the surface. However, the re-initiation of mortality with each depth cycle took longer after the second cycle (cycle 1: 18.2 h, cycle 2: 11.4 h, cycle 3: 13.9 h, cycle 4: 16.0 h).

White et al. (1991) found that juvenile brown trout repeatedly exposed to 118% TDG, with 30 d recovery intervals between exposures, developed more severe GBT with each successive exposure. The formation of gas bubbles from previous exposures appeared to lead to faster onset of GBT symptoms during subsequent exposures and tissue damage from earlier exposures may have weakened fish, resulting in increased vulnerability to TDG.

McGrath et al. (2006) discusses the uncertainties associated with repeated and chronic exposures to supersaturated water conditions. The body of literature can be conflicting, where in some studies previous exposure to TDG followed by depth compensation prolonged mortality (Knittel et al. 1980; Fidler 1988; Antcliffe et al. 2002), while other studies indicate decreased resistance (Ebel et al. 1971; White et al. 1991). Knittel et al. (1980) noted that longer holding times at depth increased survival times when juvenile steelhead were moved to high TDG conditions at the surface.

Recovery from Gas Bubble Trauma

Gas bubble formation under high TDG conditions can result in sublethal and lethal effects to aquatic life. Mortality may be from factors other than GBD itself, such as disease, increased vulnerability to predation, or reduced swimming performance. Rapid dissipation of gas bubbles when aquatic species are removed from supersaturated waters has been reported, suggesting GBT symptoms can be reversed.

Hans et al. (1999) reported rapid disappearance of bubbles in gill filaments (2 h) and lateral line (5 h) after transfer into water at TDG levels of 104%. External bubble formation was largely absent after 48 h, however, some bubbles remained as long as 4 d. Fish activity changed from lethargic to near-normal after 30 min after changing from high to lower TDG conditions. The authors concluded that fish can recover quickly from potentially lethal TDG levels if moved into water in equilibrium with atmospheric gases.

When juvenile steelhead were subject to high TDG levels for durations that were nearly lethal and then moved to deeper depths (3 m), complete recovery occurred in 2 h (Knittel et al. 1980). Elston et al. (1997) reported the disappearance of lateral line bubbles after 30 min, with 50% of bubble coverage absent after 5 min. In gills and fins, gas bubbles were negligible after 5 min and 120 min, respectively. Schiewe (1974) reported normal swimming performances after 2 h in recovery water following 120% TDG treatments.

Northern pikeminnow exposed to TDG levels of 120% N_2 immediately became lethargic and GBT signs appeared on day 3 of exposure at shallow water depths (Meekin and Allen 1974). After 8 d, northern pikeminnow were placed at 100% saturation and immediately became active and resumed feeding.

Some studies implicated mortalities in fish that recovered from exposures to elevated TDG exposures to have acquired fungal infections indirectly resulting from GBT (Weitkamp 1976). Weitkamp (1976) recorded fungal infections in the caudal fin of all dead fish and reported degraded fins in live-cage experiments at Bonneville Dam in peamouth, threespine stickleback (*Gasterosteus aculeatus*), and a largescale sucker. Mortality was 10% for juvenile Chinook salmon that were held at 118-126% TDG for 10 or 20 d and then transferred to 3-4 m depths for 20 d (Weitkamp 1976). Of the 10% of fish that died, most had developed fungal infections of the caudal fin which was attributed to lesions in the region that may have been associated with GBT. Jensen (1974) also suggested GBT lesions may have been associated with fungal infections in largemouth bass. Toner and Dawley (1995) acknowledged that caudal fins may be susceptible to secondary fungal infections of GBT damaged tissues and Lutz (1995) linked fin rot and infection to chronic GBT.

Chronic exposure to high TDG levels has been linked to increased susceptibility to infections that may subsequently lead to mortality. Huchzermeyer (2003) suggested that impact on GBT on vulnerability to fungal infections is underestimated. When rainbow trout were exposed to TDG levels at less than 120% in combination with Renibacterium salmoninarum infection (bacterial kidney disease), time to mortality was shortened (Weiland et al. 1999). Weiland et al. (1999) noted that bacterial kidney disease has potential to turn sublethal GBT exposure into a lethal exposure.

Efficacy of Biological Monitoring Programs

Hydropower projects have biological monitoring programs intended to sample adult and juvenile salmonids for the purpose of monitoring GBT impacts from spill on the Snake and Columbia rivers. Criticisms on the methods used in the biological monitoring programs have created uncertainty on whether monitoring methods are adequately capturing GBT symptoms. Furthermore, some studies suggest that symptoms of GBT such as bubble formation may be poorly correlated with TDG levels and that monitoring for GBT may not fully represent the impacts of TDG on aquatic life.

Montgomery Watson (1995) reported that pressurization of juvenile Chinook salmon at pressures experienced by smolt monitoring programs at hydropower projects, can significantly reduce GBT prevalence. Furthermore, Elston et al. (1997) found gas bubble reabsorption during pressurization to occur in a matter of minutes and reported significantly less GBT symptoms. The authors state that current monitoring programs may underestimate the prevalence and severity of GBT to smolts due to pressurization in the smolt bypass system.

Conversely, several studies conducted by Backman and others (Backman et al. 2000; Backman and Evans 2002; Backman et al. 2002) have suggested that smolt monitoring programs overestimate GBT compared with in situ river sampling. Elson et al. (1997b) suggested that smolts need to be monitored immediately for GBT symptoms due to potentially misclassifying lipid structures as gas bubbles. Depths of holding tanks and holding times should be considered when evaluating smolts for GBT symptoms.

The relationship between biological effects of supersaturated waters on aquatic life and the presence of GBT has been questioned. Mesa et al. (2000) described four limitations for using GBT to assess effects of gas supersaturation that included differences in susceptibility of individuals within a species, limited knowledge of the relationship between GBT and TDG exposure concentrations as fish migrate through water systems, persistence of GBT symptoms, and inconsistent relationships between GBT and mortality. Monk et al. (1997) noted that dam passage had complex effects on the incidence of GBT and that GBT severity increased in some individuals and decreased in others. Weiland et al. (1999) suggested that measuring GBT alone may underestimate the effects of high TDG due to the presence of multiple stressors, some of which may have synergistic effects.

A concern with the biological monitoring program is the lack of external GBT symptoms when mortalities have been observed in high TDG conditions. Meekin and Allen (1974) reported that juvenile salmonids did not always show external GBT symptoms when acute toxicity was observed. In a live cage experiment with juvenile rainbow and cutthroat trout, Weitkamp et al. (2003b) observed fish that survived more than 2 d exhibited severe signs of GBT but many fish that died from acute toxicity showed minor or no signs of GBT. Additional research on physiological changes to aquatic live in supersaturated waters may be necessary to determine the full spectrum of TDG related effects and to improve biological monitoring of TDG exposures.

Uncertainty Analysis

There are several uncertainties associated with the science examining the impacts of TDG in aquatic life. Margins of safety or safety factors are often applied when there is uncertainty regarding one or more aspects of the science when developing threshold values for the protection of aquatic life. Setting threshold values or criteria at levels that afford no or little margin of safety has potential to result in less than full protection.

While several studies have collected and examined resident fish (i.e. non-salmonids) for GBT trauma or studied various fish indigenous to the Snake and Columbia rivers in laboratories, several data gaps exist on their life history traits. Knowledge on spawning, early life stage development and movement, coping mechanisms for high TDG conditions, foraging needs, and water column preferences for several resident fish are unknown. To examine potential risks of TDG thoroughly, more information is needed in regards to this information to determine TDG exposure frequency and magnitude, which can then be translated into potential effects. While salmonids are often the focus of research studies in the Snake and Columbia rivers, more information is needed on developing embryos for natural spawning fish that do not return to a hatchery. Wild salmonids continue to decline and thus, further research may be necessary to determine if current TDG levels are having an adverse impact on main-stem salmonid spawning in the Snake and Columbia rivers. Little data exists concerning the impacts of TDG or changes in hydrology of the Snake and Columbia rivers on the anadromous lamprey.

Several studies have demonstrated that depth compensation is a mechanism that protects aquatic life from TDG related effects. However, there is controversy whether fish can detect supersaturated waters and purposely depth compensate or if they haphazardly move through the water column to a preferred depth. Moreover, some studies suggest that depth compensation is more efficient for some fish than others. Significant differences in mortality for different fish at the same water depths and TDG levels, suggest that coping mechanisms for high TDG conditions may differ depending on the species.

Finally, several studies have suggested that GBT may not be an appropriate metric to measure TDG related effects. Some researchers found poor relationships between GBT observations and elevated TDG conditions that result in mortality (Meekin and Allen 1974; Weitkamp et al. 2003b). This further brings in question, the efficacy of biological monitoring programs at hydropower projects and whether observations of GBT accurately depicts the health of aquatic life passing through dams or the resident species residing above or below dams.

Evaluation of TDG Alternatives

Alternative 1: No action. Do not issue a short-term modification. The adjusted TDG criteria for the lower eight dams in the Snake and Columbia rivers will remain at 115% in the forebay and 120% in the tailrace for the spill season. A maximum one hour average of 125% TDG should not be exceeded.

Alternative 2: Issue a short-term modification which will remove the forebay criteria and adjust TDG criteria for the lower eight dams in the Snake and Columbia rivers to maintain 120% in the tailrace. This will only be in place for the spill season. A maximum one hour average of 125% TDG should not be exceeded.

Alternative 3: Issue a short-term modification which will adjust TDG criteria for the lower eight dams in the Snake and Columbia rivers to maintain the maximum one hour average of 125% TDG in the tailrace and remove the 115% forebay and 120% tailrace criteria. This will only be in place for the spill season.

No Action Alternative

The no action alternative assumes that no short-term modification is provided to further adjust TDG criteria for the Snake and Columbia rivers and aquatic life will be as equally protected as in previous years. However, since 2018 a court order mandated hydropower projects to spill water to the 120% tailrace or the 115% forebay gas caps in 2018, depending on which was more limiting. The order to spill to gas caps effectively increased the duration of exposure to TDG at 120% for the lower Columbia and lower Snake river dams. In previous years, the amount of water spilled over dams in the spring season was controlled by FCRPS BiOp requirements pertaining to spill volume, market demand for power generation, and high flow water input into the system. During high power generation, less spill occurs and lower TDG levels result. The no action alternative does not change the allowable TDG levels in the Snake and Columbia rivers but the duration of exposure, an integral part of determining risk, may change depending on hydropower operations and court orders to spill to gas caps.

Removal of 115% Forebay Criterion and Maintain the 120% Tailrace Criterion

Potential Positive Impacts

2019 spill operations under the Spill Agreement are predicted by the CSS model to provide a small improvement in survival and SARs compared to the 2018 court-ordered spill operations to spill to existing gas caps and a larger improvement in survival compared to 2014 BiOp operations.[20] This is based on a projection that 2019 Spill Agreement operations will result in a reduction in smolts' "powerhouse encounter rate," or the number of dam powerhouses (defined as turbines or bypass systems) a smolt encounters while migrating down river. Spillway passage allows smolts to avoid powerhouses.

2018 operations result in an average of 1.76 dam powerhouses encountered by each smolt, while 2019 Spill Agreement operations will result in an estimated 1.73 powerhouse encounters. That

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[20] Juvenile Chinook salmon PITPH Index estimates based on Comparative Survival Study (CSS) methods (McCann et al 2015) and https://nptfisheries.shinyapps.io/pitph2/ web application tool.

compares to 2.98 powerhouse encounters under 2014 FCRPS BiOp operations, and 1.4 to 1.5 powerhouse encounters expected under the operations expected in 2020 under the Spill Agreement.

Potential Negative Impacts

The primary differences between alternatives 1 and 2 is the removal of the forebay standard of 115%. The forebay requirement of 115% primarily serves as a safety factor to ensure dams will not reach or exceed 120% TDG during the hydropower spill season. If TDG enters the forebay at 115%, then the hydropower project is provided a 5% TDG addition as part of hydropower operations as measured in the tailrace downstream of the project (i.e. 120% TDG tailrace requirement). Furthermore, the forebay requirement requires hydropower projects to consider impacts of their operations on downstream projects.

Removal of 115% forebay requirements could allow for additional spill at each upstream dam. The 120% TDG criterion in the tailrace and one hour average of 125% would remain as the maximum TDG level. The TDG levels are anticipated to increase by the removal of the need to meet the 115% TDG forebay target. The increased duration of exposure at TDG levels of 120% may result in an increased risk of GBT to aquatic life, when water depths or organism's life history traits preclude depth compensation.

The body of literature suggests that when adequate water depths are available (generally 1-2 m or greater) at TDG levels of 115-120%, then depth compensation may be sufficient to protect aquatic life from GBT. When aquatic life are present in waters of 1 m or less at TDG levels of 120%, the likelihood of adverse effects increases, especially for chronic exposures.

The removal of the forebay criteria of 115% may slightly increase the risk of TDG related impacts to aquatic life by increasing the duration of exposure at 120% TDG level. Spilling to 120% TDG over long periods is a concern for chronic effects of TDG on aquatic life, given that data suggests that GBT is more prevalent at lower TDG levels when an exposure is prolonged. Literature suggests that fluctuating TDG levels over multi-day periods may provide some relief from TDG symptoms and that chronic TDG levels maintained at the water quality criterion may present greater risk. The Spill Agreement calls for ramping down spill at each dam well below the spill levels creating 120% TDG for eight hours a day every day during the spring spill season.

Removal of the 115% Forebay Criterion and Change to a 125% Tailrace Criterion

Potential Positive Impacts

Current SARs for Snake River spring/summer Chinook salmon have been 1.1 since 2000.[21] The CSS has modeled expected changes to SARs from spilling to BiOp standards, 115%

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[21] CSS 2017 Annual Report at p. 102. http://www.fpc.org/documents/CSS/CSS_2017_Final_ver1-1.pdf

forebay/120% tailrace, 120% tailrace-only, and 125%. All spill regimes modeled by the CSS are 24 hours, seven days per week. When spill is increased to 125% TDG 24 hours per day/seven days a week in the spring, the CSS predicts a two to 2.5-fold increase in Snake River spring Chinook salmon abundance above the levels resulting from 2014 FCRPS BiOp spill levels,[22] and smaller projected benefits when spilling to existing gas standards or 120% TDG 24 hours per day. Steelhead SARs are also predicted to increase significantly, but less dramatically than Chinook salmon.

Potential Negative Impacts

The removal of the 115% forebay and the 120% tailrace criteria and an allowance of a 125% TDG tailrace criterion effectively increasing the maximum TDG level by 5% in the tailrace and 10% in the forebay. This increase in TDG has the potential to cause additional incidences of GBT and TDG related effects in aquatic life. Data suggests that aquatic life at water depths of 2 m or greater may provide adequate protection when TDG levels are at 125%. However, the ability of fish to sense high TDG levels is unknown and thus, there is uncertainty as to whether aquatic life would be fully protected at the 125% TDG level with adequate depth compensation.

Spilling to higher TDG levels than the current standards over long periods would be a concern for chronic effects of TDG on aquatic life, given that data suggests that GBT is more prevalent at lower TDG levels when an exposure is prolonged. Literature suggests that fluctuating TDG levels over multi-day periods may provide some relief from TDG symptoms.

Salmonid Risk

Salmonid spawning in the main-stem Snake and Columbia rivers primarily occurs below Bonneville Dam, in the Hanford Reach of the Columbia River (above the confluence with the Snake and above the lower Columbia River dams), and in the free-flowing Snake River above Lower Granite Reservoir, the uppermost reservoir on the lower Snake River. Field studies examining early developmental stages of salmonids are limited in the Snake and Columbia rivers. Chum salmon spawn below Bonneville Dam during the early spill season and egg incubation and rearing occur throughout the spill season. Giest et al. (2013) stated that the location and depth of Chum salmon redds within the tailwater spawning area can be variable and protection from TDG effects is dependent on depth. Carter et al. (2009) reported Chum alevins sampled in wild redds in the Columbia River had GBT symptoms when depth-compensated TDG exceeded 105%. However, to provide protection managers have set water depths to limit impacts on Chum early life stages. If TDG reached 115% at the surface, then to meet the 105% TDG management goal, 1 m of water is required for adequate depth compensation. Arntzen et al. (2007, 2008, 2009) monitored downstream for Bonneville Dam and found that depth compensated TDG levels can exceed the 105% TDG management guideline when water levels were low but usually for short periods of time.

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[22] See CSS 2017 Annual Report at xxxi.

Juvenile salmonid outmigration in the Snake and Columbia rivers coincides with high river flows from snowpack melt in the spring season. Field monitoring studies are highly variable due to fluctuating TDG conditions that can change TDG exposures on an hourly basis. These highly fluctuating conditions make it difficult to determine TDG exposures to aquatic life and therefore broad generalizations must be made on potential effects. Furthermore, long-term field monitoring studies often summarize data over long study periods that have the potential to mask impacts that occurred within a short time period. Field monitoring studies of outmigration juvenile salmonids highlight the importance of depth compensation at low to moderately high TDG levels (Backman et al. 2002; Duvall et al. 2002; Mesa et al. 1997). However, high incidences of GBT in field monitoring studies have been reported. Hagen et al. (1998) reported GBT signs in 21.5% of sockeye salmon, 9.4% of Chinook salmon, and 8.7% of steelhead at TDG levels of 120-135%. During the summer, when TDG levels dropped to 110-125%, GBT was noted in 2.3% of Chinook salmon. Backman et al. (2002) found GBT symptoms exceeded 15% when TDG levels approached 130% and at <125% TDG, GBT prevalence was below 15%. Maule et al. (1997b) concluded that GBT was not a threat to migrating juvenile salmonids when TDG levels were less than 120%.

Field studies that utilized live cages at various depths in ambient waters generally reported a higher incidence of GBT and mortalities than in situ monitoring studies. Live cage studies offer the advantage of controlling depth and assessing GBT incidence with the assumption that depth compensation can be achieved. In a live cage study, Ebel (1969) concluded that at 130-140% TDG, fish must remain below 2.5 m to survive. High mortalities have been recorded in live cages when juvenile Chinook salmon were exposed to 127-134% TDG at depths (up to 4.5 m) expected to be adequate for depth compensation (Ebel 1971). Dawley (1996) observed GBT incidences from 12 to 50% for salmonids held in surface cages and from 0 to 37.5% for salmon held in net pens with depths of 0-4 meters below Ice Harbor Dam. Salmon held in control cages at 1.5 to 2.5 meter depths, had a 10% GBT prevalence when TDG levels averaged 125%. In 1 m deep tanks, mortalities for Chinook and coho salmon were over 80%, while mortalities in the 2.5 m deep tank was less than 9% for both species. While it is recognized that depth compensation can be protective of salmonids, the ability to detect supersaturated waters remains unclear.

Resident Aquatic Species Risk

Salmonid species often receive more emphasis than other aquatic species when evaluating effects of TDG related to spill. Salmonids must navigate upstream and downstream past hydropower projects to complete their life cycle and thus, have additional impediments to reproduction and survival compared with resident fish species. Moreover, Pacific salmon are an iconic species and a revered natural resource of the Northwest states and tribes. However, resident fish species must be considered as they are also an important part of the aquatic ecosystem.

In a study where anglers used hook and line to sample resident fish, GBT was observed in 72% of smallmouth bass and 84% of northern pikeminnow. GBT was observed when TDG levels exceeded 115%. The authors noted that even though these resident species have the ability to depth compensate, GBT signs were apparent in a large proportion of fish. This study highlights the lack of knowledge on the interactions between resident fish species life histories, tendencies within the water column, and TDG exposures.

GBT signs have been observed in resident fish when TDG levels reach 120% (Dawley 1996). When TDG levels exceeded 130% TDG, GBT reached a maximum incidence of 11.5% in resident fish. Ryan et al. (2000) reported very few signs of GBT in resident fish when TDG was below 120%. When TDG reached 130% or greater, GBT signs were much more prevalent (about 18%). Studies by Schrank et al. (1997) and Schrank et al. (1998) demonstrated the high variability in GBT symptoms among resident fish at varying TDG levels. In one instance, TDG levels averaging 120% led to daily prevalence of 40.8% GBT in resident fish, while most days GBT levels were relatively low at similar TDG levels. Generally, GBT prevalence increased with TDG but the daily incidences of GBT varied greatly. The high variability observed within field studies exemplifies the difficulties of analyzing field data and compiling data from multiple species with distinct life history traits in a fluctuating environment.

Another factor to be considered when aquatic organisms are exposed to supersaturated conditions is feeding behavior and activity. Meekin and Allen (1974) reported a disinterest in feeding and lethargy of northern pikeminnow exposed to 120% TDG in shallow tanks that preclude depth compensation but a return to normal activity when returned to waters at 100% TDG. Food consumption in the northern pikeminnow was also substantially decreased when comparing exposures of 100% TDG to 126% TDG in a shallow water laboratory study (Bentley and Dawley 1981).

Studies examining non-fish resident species is very limited. Amphibian studies by Colt (1984) suggested that amphibians may be vulnerable to GBT. Tadpoles and other amphibians bound to the aquatic environment may be susceptible to GBT, given they remain near surface waters. However, more information is needed on the prevalence of amphibians in the Snake and Columbia rivers and their sensitivity to TDG.

In aquatic invertebrate studies, cladocerans have emerged as one of the more sensitive invertebrates but incidences of GBT were relatively low at environmentally relevant TDG conditions in the Snake and Columbia rivers. Studies have reported successful emergences for several species at high TDG levels (Nebeker et al. 1981) and low incidences of GBT collected in the Columbia River (Schrank et al. 1997). Nebeker et al. (1981) concluded that all insects were more tolerant to TDG than fish.

Mitigation

Timing and Duration of the Short-term Modification

The short-term modification coincides with the spring freshet when large amounts of runoff enter the Snake and Columbia rivers. During this same time period, the majority of juvenile salmon outmigrate to marine waters and adult spring Chinook and sockeye salmon migrate upstream. Studies have demonstrated that outmigrating juvenile salmonids have higher survival rates in the Snake and Columbia rivers when passed through dams via spillways versus through turbines or smolt bypass systems of hydropower projects (Whitney et al. 1997; Muir et al. 2001). Thus, increasing spill during the spring freshet is expected to improve juvenile salmon fish passage downstream.

The STM will apply seasonally during the time when the majority of juvenile salmon outmigrate to marine waters (see Figures 5-6) for the purpose of improving fish passage and increasing the survival of salmon. The STM will apply during the spring spill season which typically occurs from April through June every year (April 3rd – June 20th in the lower Snake River and April 10th – June 15th in lower Columbia River).

Biological Monitoring

The Smolt Monitoring Program has been collecting data on juvenile fish condition and GBT in the Columbia River Basin since 1995. Since the enactment of the GBT monitoring program in 1995, the action criteria for reduction of spill was defined as greater than 15% of fish showing any signs of GBT, or greater than 5% of fish sampled showing severe signs of GBT (NOAA Biological Opinion 2000). Severe signs of GBT are defined as ≥26% of a fin area occluded with bubbles. This action level incorporates a margin of safety based on studies finding significant mortality does not occur in test fish until approximately 60% of a population is showing signs of GBT (Maule et al. 1997a, 1997b). Spill may be curtailed, if possible, when one or both of these action criteria are met.

Aquatic Life Depth Compensation

This STM allows more spill over dams which can increase TDG levels. Aquatic organisms that are mobile or have life history traits with tendencies for deeper habitats in aquatic systems may have the potential to depth compensate to avoid TDG related effects. The ability to depth compensation enables fish to experience reduced TDG levels at deeper depths when compared with TDG levels in surface waters. Therefore, the ability to move vertically in the water column in response to TDG levels may protect an individual from TDG related effects.

Conclusions

Spill Analysis

Spill Agreement spill to a 120% TDG tailrace-only standard would be simpler for the U.S. Army Corps of Engineers to implement, as it is difficult to manage simultaneously to the 115% forebay/120% tailrace standard. In addition, it would harmonize Washington's standard with Oregon's, creating one standard and measurement methodology for the Corps to implement.

In order to provide revenue neutrality or better for hydropower production and associated revenue, the Spill Agreement calls for spilling to 120% TDG in the spring of 2019 for sixteen hours a day, and spilling to lower "performance" spill levels eight hours per day.[23] The CSS model predicts that this operation would provide small survival benefits relative to 2018 injunction operations (spill to existing gas caps 24 hours a day/seven days a week), while BPA predicts that it would provide similar power revenue. 2019 operations would be an incremental step toward a flexible spill operation that would be expanded in 2020 to include flexible spill (i.e. 16 hours of higher spill and eight hours of "performance" spill) to 125% TDG.[24] Flexible spill operations to 125% are predicted by CSS model to improve fish survival and returns relative to 2018 court-ordered operations.

Total Dissolved Gas Analysis

Given that the Snake and Columbia rivers are heavily modified for hydropower and that spilling water over dams benefits the passing of juvenile fish downstream, adjustments have been made to the statewide TDG criterion of 110% in the Snake and Columbia rivers. The relationship between spill and TDG is important in evaluating risk and benefits to aquatic life. The greater amount of spill over dams, the greater the risk of potential TDG related impacts to aquatic life. The notion of increased spill and increased survival of juvenile salmonids has been demonstrated in models. However, continuing to increase spill may eventually lead to diminishing benefits.

Water depths in the Snake and Columbia rivers broadly provide adequate depth to circumvent TDG related impacts, but uncertainties exist on the adverse impacts of high TDG levels to resident species, survival of early developmental stages of resident fish and salmonids, prolonged exposures to elevated TDG levels, and the mechanism of depth compensation for aquatic life.

The current criteria adjustment of 115% TDG in the forebay and 120% TDG in the tailrace, presents a marginal risk when considering depth compensation. The removal of the forebay criteria may increase the duration of exposure to higher TDG levels but will not necessarily change the maximum allowable TDG level. Studies demonstrate that the effects of TDG and the incidence of GBT in aquatic life are greater at 125% compared with 120% TDG. Spilling to

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[23] See Agreement, Table 1.1, at p. 17.
[24] The Agreement calls for further refinement of proposed 2020 operations. See Agreement at pp. 5-6 and Tables 1.3.a and 1.3.b, at p. 19.

125% TDG relies heavily on the ability of aquatic organisms to depth compensate to minimize TDG effects. When evaluating risk to aquatic life at 125% TDG, further research that addresses the uncertainties of the science will help to determine if the potential benefits of spill at 125% TDG outweigh the adverse effects of TDG to salmonids and resident aquatic life.

Decision on Short-term Modification

At this time, Ecology's preliminary decision is to remove the 115% forebay criterion for a period up to three years (Alternative 2). This action coincides with the Spill Agreement that aims to benefit salmon and hydropower. Additionally, Ecology will adjust the 12 h averaging method to match the State of Oregon's method. This would have little effect in the operations of the federal dams and would ease the spill operations, as well as TDG monitoring and reporting requirements. Washington would require TDG limited by the 12 h average to be conducted using the 12 highest hourly averages in a day rather than the highest average calculated from 12 consecutive hourly averages.

Given that dam and salmon managers have not previously provided voluntary spill to 120% due to the potential for higher TDG levels to increase symptoms of gas bubble trauma in juvenile salmon, steelhead, and non-listed aquatic species, continued monitoring for gas bubble trauma will occur.

Appendix A: EIS Scoping Comments

Ecology received SEPA scoping comments from November 16, 2018 through December 14, 2018. This appendix contains all the comments, in full, received during the scoping comment period.

Anonymous Anonymous

If higher levels of TDG are safe for fish and aquatic species, why aren't these levels acceptable for all similar rivers, lakes, streams in Washington? I.e. why is the scope limited to only the lower Columbia and lower Snake areas? Presumably, the current protection levels are in place based on sound science; what has changed? Has TDG research indicated the current protection level is too conservative?

Also, why is only one fish survival model being used for this analysis? The CSS is one fish model, but is not the only one in the region - isn't the purpose of NEPA to disclose anticipated environmental consequences to improve agency decision making? How will a partial biological analysis using just the CSS model align with the purpose of NEPA?

Whale Scout

Spill in the Columbia system is critical to juvenile survival for salmon that can help feed endangered orcas in the near term. The Orca Task Force has recommended this action which garnered broad support. Spill at levels of 125% dissolved gas will also improve water quality which has been a chronic issue in the system. We support increasing spill to levels of 125% and believe this is a vital step in protecting orcas.

Thank you

Defenders of Wildlife

Please find our comments in the attached letter. Please let me know if you have any issues opening the document.

Thank you,

Robb

Northwest Office
1402 Third Avenue, Suite # 930 Seattle, Washington 98101
tel 206.508.5474 www.defenders.org

December 4, 2018

Heather R. Bartlett
Water Quality Program Manager
Department of Ecology
Water Quality Program
P.O. Box 47600
Olympia, WA 98501

Comments submitted electronically

RE: Scope of Environmental Impact Statement for Short-Term Modification to Adjust Total Dissolved Gas Levels in the Columbia and Snake Rivers.

Dear Ms. Bartlett,

Thank you for the opportunity to provide scoping comments to the Department of Ecology (Ecology) related to the proposed short-term modifications to the state's total dissolved gas (TDG) standards. Increasing these standards will allow for more water to be spilled over dams on the Columbia and Snake rivers, both of which support critical salmon runs that southern resident orcas rely on. Ecology has an extremely important role to play in recovering these endangered orcas by reducing stormwater runoff, regulating emerging chemicals of concern, and increasing spill over these dams. Of these actions, increasing spill will provide the most immediate benefits to both salmon and orcas. Defenders of Wildlife (Defenders) strongly supports increasing the state's TDG standards to 125% to provide additional salmon for the southern residents in the near-term.

Defenders is a national non-profit conservation organization with over 1.8 million members and supporters nationwide, including more than 24,000 members and supporters in Washington state. Founded in 1947, Defenders is a science-based advocacy organization focused on conserving and restoring native species and the habitat upon which they depend. We have a long history of contributing to agency-led recovery for endangered species. This past year, our staff participated in the Orca Task Force's Prey Work Group, which helped develop the recommendation to increase the state's TDG standards. We have also worked with schools, cities, counties, and state agencies on programs to reduce toxic pollution throughout the Salish Sea, helping to recover orcas and the salmon they depend on.

As you know, southern resident orcas are one of the most endangered marine species in the United States. Without bold and immediate actions, they are likely to go extinct within our lifetime. While there are several factors that impact southern residents, the most limiting is a lack of their primary prey: chinook salmon. Years of industrial development on rivers in the Columbia Basin caused the precipitous decline and extirpation of salmon runs throughout the region. The large dams and warm, slackwater reservoirs on the Columbia and Snake rivers have made the salmon's journey much more difficult, and in some cases impossible. Juvenile salmon rely on natural, cold, free-flowing rivers to carry them safely to the ocean. As dams slowed the rivers, salmon populations in the basin crashed, severely reducing one of the orcas' most critical and abundant sources of food.

Historically, swift river currents in the Columbia and Snake river basins quickly carried smolts (recently hatched salmon) to the ocean, where they matured and migrated further out to sea. Slackwater created by dams has significantly increased the amount of time it takes for smolts to safely migrate to the ocean and increased their exposure to lethally warm water and predators (particularly invasive piscivorous fish). Spilling water over the dam spillways (instead of through turbines to produce energy) more closely mimics the natural flow of big rivers, like the Columbia and Snake, and delivers smolts more quickly and safely to the ocean. The more fish that are 'spilled', the more fish that return to the river as adults to spawn. Scientific research collected annually since the mid-1990s demonstrates conclusively that additional spill significantly increases juvenile salmon survival and subsequent adult returns (CSS, 2017).

Without spill, smolts are sent through dam turbines or elaborate bypass systems. These dams and reservoirs kill as much as 70 percent of the out-migrating smolts and more than 15 percent of the returning adults. Some smolts die further downstream as a result of cumulative stress and injury. The most recent and best available science suggests that the safest route over dams for smolts is through spill. Other strategies that involve handling and collecting juvenile salmon for transportation down river, such as barging, have been ineffective at meeting salmon recovery goals and in some cases introduce additional stress and mortality (McCann et al. 2016; Budy et al. 2002; Scheuerell et al. 2009, Van Gaest et al. 2011).

Washington's current TDG standards are outdated and no longer reflect the best available science. Recent increases in spill show that we have been overly conservative with our standards. The Comparative Survival Study suggests that increasing TDG standards to 125 percent would result in 2 – 2.5 times more adult chinook salmon returning than current levels (CSS, 2017). In the past, Ecology has expressed concerns that spill up to 125 percent would be detrimental to other aquatic wildlife. This concern is not supported by the most recent science. Data collected by McCann et al. (2017) between 1998 and 2016 found "no evidence that high TDG levels were associated with increased mortality rates or reduced survival probabilities" (CSS, 2018).

Increasing salmon runs in the Columbia Basin is essential to preventing the extinction of the southern resident orcas. During the winter and early spring, these orcas forage on chinook salmon from Cape Flattery to Monterey Bay. Historically, the Columbia Basin produced the most chinook salmon on the west coast, providing a large and critical source of food for the orcas over winter. Increasing spill over the Lower Snake and Lower Columbia dams would benefit seven of the fifteen most important salmon runs in the orcas' current diet (NOAA and WDFW, 2018).

This is one of the few actions that the state can take in the near term to increase the amount of salmon available to these orcas. Several recent studies have shown that management of freshwater systems can affect smolt-to-adult returns, even when taking ocean conditions into account (Schaller et al., 2013; Petrosky and Schaller, 2010; Schaller and Petrosky, 2007; Haesecker et al., 2012). Because the state cannot manage or change ocean conditions, the most effective tool managers have to increase adult returns (particularly in the near-term) is to increase spill.

We greatly appreciate your leadership to recover both salmon and orcas. Increasing spill in the Columbia Basin will further mitigate the impact these dams have had on endangered salmon runs and provide more food to orcas in the near-term. We look forward to providing additional comments on this proposal once the Draft Environmental Impact Statement is released.

Sincerely,

Robb Krehbiel
Northwest Representative
Defenders of Wildlife

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NSIA

On behalf of the Northwest Sportfishing Industry Association, please see attached. Thank you, Liz Hamilton, Executive Director.

NORTHWEST SPORTFISHING INDUSTRY ASSOCIATION
Box 4, Oregon City, OR 97045
503.631.8859 www.nsiafishing.org

November 30, 2018

Director Maia Bellon
C/O Becca Conklin
Washington Department of Ecology
PO Box 47600
Olympia, WA 98504-7600
Via email: http://ws.ecology.commentinput.com/?id=x2M6a

Re: Short-term modification to adjust total dissolved gas (TDG) levels in the Columbia and Snake rivers. Scoping for DEIS

Director Bellon,

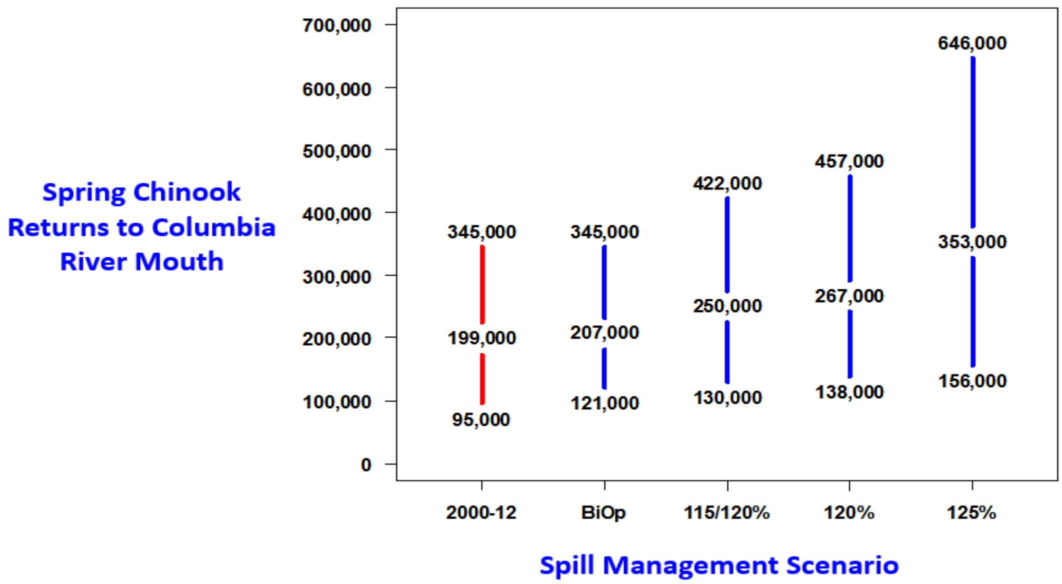
On behalf of the Northwest Sportfishing Industry Association (NSIA), thank you for the opportunity to comment on the scope of your draft Environmental Impact Statement (EIS), which will evaluate potential environmental impacts of a short- modification to adjust total dissolved gas (TDG) levels in the Columbia and Snake rivers. The NSIA consists of hundreds of businesses supporting thousands of family-wage jobs for which the Columbia Basin fisheries are essential to their success.

Specifically, Columbia River Spring Chinook, the primary beneficiaries of the additional spill requested by NSIA, are of critical importance because they are the first salmon of the year. As such, the spring chinook salmon fishery plays an oversized role in enticing nearly 400,000 anglers in Washington and Oregon to purchase an endorsement to fish in the Columbia. For these first salmon, our customers from Illwaco, Washington to Riggins, Idaho spend money to prepare their boats, motors and trailers, purchase fishing gear and licenses with endorsements and start a new year of fishing. Thus, a successful spring chinook season sets the table for a successful year for our industry.

To communities all along the river, Columbia River Spring Chinook are worth their weight in gold. According to the Washington Department of Fish and Wildlife, anglers on average spend over eight days fishing for every Spring Chinook retained. A 2009 study of Columbia River Spring Chinook fishing done by Southwick Associates, calculated that trip expenditures for this fishery weighed in at $115 per trip in 2006 dollars. ***In other words, for every Spring Chinook retained, $920 was spent on trip expenditures by anglers.*** These numbers do not account for boat, motors, trailers and durable goods. It is difficult to overstate the economic importance of Columbia River Spring Chinook to the sportfishing industry.

More recently, our region has learned of the importance of Columbia River Spring Chinook to Southern Resident Orca. SRKW circle off the mouth of the river in March when Spring Chinook are staging to enter the river. The fat-laden Spring Chinook nourish pregnant and traveling SRKW at a time when there are scant other chinook available. But, these spring chinook, so very valuable to communities and critical to Orca are in trouble. The 2018 adult return was the lowest since 2007, and the jack returns were the lowest since 2006, which bodes ill for next year.

Decades of extensive data gathered by the multi-agency, collaborative, Comparative Survival Study (CSS) has demonstrated that the best thing we can do short term to enhance the numbers of returning adult spring chinook is to spill to 125% total dissolved gas. There is no other single action that can be taken in the short term to bring back more salmon. Below is the graph presented to Governor Inslee's SRKW task force by the CSS Manager. It shows clearly the benefits in terms of increased spring chinook returns of allowing TDG levels of 125%.



It is NSIA's firm belief that WADOE must include an alternative that considers TDG levels of 125% in the dam tailraces with no forebay standard in the EIS you prepare. We fully understand that regional discussions are occurring that may decide to utilize a different total dissolved gas level in 2019. Developing, analyzing and considering a 125% TDG alternative will give the region's fishery managers an understanding of the trade-offs among alternative levels of TDG and allow a decision that follows the science. We believe that decision will be to adjust the TDG standards on a short-term basis to allow 125% TDG as it has been clearly demonstrated to provide the greatest benefit to salmonids. Governor Inslee asked us to be bold in our recommendations to increase prey and decrease threats to SRKW. We trust your scoping effort will lead to an EIS that will fully inform managers to you make this important decision.

We thank you for your time and effort on this matter of critical importance to salmon, steelhead, Southern Resident Orca and our industry.

In Service,

Liz Hamilton

Liz Hamilton, Executive Director
NSIA www.nsiafishing.org
503.631.8859

Seattle City Light

Please see attached comments from Seattle City Light.

Thank you,

Lynn Best
Chief Environmental Officer
Seattle City Light

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Seattle City Light

December 7, 2018

HEATHER R. BARTLETT
WATER QUALITY PROGRAM MANAGER
WASHINGTON STATE DEPARTMENT OF ECOLOGY
PO BOX 47600
OLYMPIA, WA 98504-7600

RE: Scope of Environmental Impact Statement for Short-Term Modification to Adjust Total Dissolved Gas Levels in the Columbia and Snake Rivers

Dear Ms. Bartlett,

Thank you for the opportunity to comment on the scope of Ecology's draft Environmental Impact Statement (EIS) concerning the evaluation of potential environmental impacts of a short-term modification to allowable total dissolved gas (TDG) levels on the Columbia and Snake Rivers.

Seattle City Light (City Light) supports an experimental, temporary increase in TDG standards to facilitate testing the potential benefits of increased spill on smolt-to-adult return rates (SARs) and salmonid population recovery. However, we are also concerned that raising the allowable TDG level up to 125 percent may increase the proportion of juvenile salmonids and other native fish species that would suffer sublethal and lethal effects from gas bubble-related trauma. If TDG-related impacts are deemed unacceptably high during the experimental spill period, Ecology should be prepared to lower allowable TDG levels as appropriate to each river reach. There is a fundamental gap in understanding the tradeoffs between the deleterious population-level effect of higher TDG levels and achieving higher SARs for salmon and steelhead that more spill may enable. The Comparative Survival Study (CSS) reported that increased spill could increase SARs, yet the life-cycle model used did not incorporate the impacts of increased rates of stress and mortality due to elevated TDG levels. Furthermore, the CSS did not address ecosystem impacts resulting from elevated TDG levels, including gas bubble trauma impacts to aquatic invertebrates that represent the forage base for juvenile salmonids and adult steelhead. These impacts could have a long-term negative impact on SARs that are not addressed in the current modeling framework.

Specific to the scoping of the EIS, City Light believes Ecology should include an updated literature review concerning the impacts of TDG in the 120% - 125% range to all aquatic life. Ecology published a comprehensive review on TDG impacts on aquatic life in 2008 which formed the basis for the state's TDG criteria. We encourage Ecology to build upon the 2008 review by adding findings of new research and studies conducted over the last decade, including the results of the CSS modeling effort. This updated review will help develop a better understanding of the anticipated impacts of elevated TDG levels to juvenile salmonids and other aquatic life and provide a basis for developing additional research during the proposed flex-spill test period to fill gaps of knowledge.

During the three-year experimental flex spill period, City Light believes the opportunity must be taken to evaluate the complexities related to TDG effects and the ecological cost-benefit to salmon populations. We suggest the following studies be considered as part of the flex spill test period:

- Establish a study to quantify the immediate and delayed impacts of elevated TDG values on juvenile salmon mortality, integrating elements of the established body of literature to evaluate stress and mortality as they relate to duration of exposure.
- Compare the ecological cost of elevated mortality rates of juvenile salmonids due to increased TDG levels with the potential benefits of increased SARs while correcting for outside factors such as ocean conditions.
- Consider the importance of coordinating the timing of planned increased spill and the diel pattern of juvenile outmigration.
- Assess impacts to other aquatic life present in the affected portions of the Columbia and Snake rivers, including all life stages of salmonids, other native fishes, and important aquatic invertebrates.

Considerable debate remains over the primary factors determining SARs of Columbia River salmon populations and why wild Snake River spring Chinook salmon populations exhibit much lower SARs compared to other spring Chinook salmon populations lower in the Columbia River. We believe an experimental period allowing flex spill provides an opportunity to build consensus among researchers through the rigorous and objective monitoring and evaluation of elevated TDG levels.

Thank you again for the opportunity to comment.

Sincerely,

Lynn Best, Ph.D.
Chief Environmental Officer
Seattle City Light

Northwest RiverPartners

Northwest RiverPartners's Comments on Scope of EIS For Short-Term Modification of TDG Levels in the Columbia and Snake Rivers

December 7, 2018

VIA EMAIL

Becca Conklin
Washington State Department of Ecology
PO Box 47600
Olympia, WA 98504-7600

Re: Comments on Scope of EIS For Short-Term Modification of TDG Levels in the Columbia and Snake Rivers

Dear Ms. Conklin:

These comments are submitted on behalf of Northwest RiverPartners ("RiverPartners") in response to the Department of Ecology's ("Ecology") request for scoping comments on a draft Environmental Impact Statement ("EIS"). RiverPartners is an alliance between farmers, utilities, ports and businesses throughout the Columbia River Basin that represents more than 4 million electric utility customers, 40,000 farmers, thousands of port employees, and large and small businesses that provide hundreds of thousands of Northwest jobs.

Ecology is acting expeditiously in response to a request from the Columbia River Inter-Tribal Fish Commission, the Washington Department of Fish and Wildlife, and "non-governmental" groups including plaintiffs in the National Wildlife Federation v. NMFS, Case No., 3:01-cv-00640-SI (D. Or.), seeking to further relax the state's TDG water quality criteria. The purpose of the requested standards modification is to allow increased levels of spill that could produce up to 125% TDG at the tailrace of Lower Snake River and Lower Columbia River federal dams. For reasons outlined in this document below, RiverPartners has serious concerns about the waiver process and the merits of the requested modification and reiterates its request that there be a robust, transparent public process with comprehensive scientific review of the environmental impacts of the proposed waiver. RiverPartners further requests that Ecology extend the public comment period for an additional month to ensure adequate opportunity for stakeholders to submit meaningful comment.

Views on the "Flexible Spill" Proposal

RiverPartners is encouraged by the conceptual proposal animating the proposed standards modification. As we understand it, the proposal is to reduce spill during time periods when carbon-free hydropower is most valuable while also increasing spill during non-peak power generation hours. Given the adverse impacts of the ongoing Federal Columbia River Power System ("FCRPS") litigation, we appreciate the recent collaborative efforts of the states, Tribes and federal action agencies to get out of the courtroom and rally around an operational solution that is good for both the multi-users of the FCRPS and salmon. We appreciate the parties' recognition that it is in everyone's interest to develop a path that will keep BPA competitive so that the agency can continue to meet its statutory obligations to provide reliable, affordable and carbon-free energy to its customers, while funding fish and wildlife programs. We are concerned however that the "devil is in the details" because there is not yet enough information provided in Ecology's scoping document to determine exactly what is being proposed.

It is our understanding that this modified spill operation is due to begin in April of 2019 and continue until the spring spill period ends in June, and that such operations will continue annually for a period of three years. We understand that this proposal is guided by three principles. First, this operation must provide benefits for BPA that will help to preserve the agency's financial health and competitiveness. Second, the proposal will provide benefits for salmon and steelhead survival. And third, this proposed operation will eliminate the need for further litigation of the FCRPS Biological Opinion for the same period. As described more fully below, issues raised by this proposal have been the subject of contentious litigation pending in the District of Oregon Federal Court in *National Wildlife Federation v. NMFS*, Case No 3:01-cv-00640-SI (D. Or), and do not lend themselves to an "easy fix." Along these lines, we have outlined specific procedural and legal concerns below.

Procedural and Legal Concerns

The comment period is too short for adequate evaluation - The time period that Ecology has provided the public for the scoping process is inadequate. As you know, the level and timing of spill required at the federal dams in the Lower Snake and Columbia Rivers has been a very contentious issue in pending litigation challenging the FCRPS BiOp. RiverPartners has been deeply involved in these issues as a party to the federal litigation for the last 13 years. In addition, River Partners has been actively involved in water quality issues surrounding spill, including intervening **in support** of Ecology in past litigation to preserve Ecology's existing TDG WQS and associated "waivers."

According to the best available science from NOAA Fisheries, higher and higher levels of spill at all 8 dams does not significantly improve salmon survivals and is not justified as a blanket solution for all dams. RiverPartners does not support proposals that seek to increase spill, and thus TDG, at any economic and biological cost without a sound scientific basis. Modeling performed by NOAA of increased spill levels show little to no biological benefit from increased spill.

There is a lack of clarity surrounding the process - Ecology's proposed water quality waiver and scoping document consists of one step: analyzing flex spill operations up to 125% TDG beginning in 2019. RiverPartners has heard that the waiver process will occur in two steps: 1) continue federal hydrosystem operations to 120% TDG in 2019; and; 2) "test" flex spill operations up to 125% TDG in 2020 and 2021. We request that Ecology provide clarity about what operations are proposed to be covered by the wavier and when so that parties can effectively engage in the EIS process.

The relationship to USACE waiver process is unclear - The U.S. Army Corps of Engineers (USACE) water quality waivers for operating the federal hydropower system expire this month. The current TDG spill exemption includes a 115% forebay and a 120% tailrace requirement. Ecology's proposal would further increase the exemption to allow for even higher levels of TDG in the tailrace but are unclear about what levels, if any, will be required in the forebay. One component of the proposal would eliminate the forebay requirement, and another would eliminate both components to allow for as much as 125% saturation in the tailrace.

The proposed waiver does not meet the state's standards for a "short term" waiver - Ecology describes the TDG proposal as a "short-term" modification of WAC 173-201A-200(1)(f) (ii), and defines "short-term" to include up to three full years. Ecology appears to be relying on a regulation found at WAC 173-201A-410 entitled ("short-term modifications") as the legal authority for the water quality standard modification itself. But that provision defines "short term" as "hours or days rather than weeks, months or years." *Id*. While we understand that the proposal would allow a variation from the TDG standard for 16 hours each day, the proposed "flex spill" would occur each and every day for 16 hours during the spring months of April, May and part of June. The proposed "short term" increased spill level is then proposed to repeat over a period of three years. That lengthy duration is clearly not what is intended by the plain language of "short term modification" regulation established under WAC 173-201A-410. Accordingly, Ecology's legal authority for the proposed modification appears to be seriously lacking, and RiverPartners is very concerned with the potential precedent this may set for any future proceedings.

Monitoring and metrics - Ecology's scoping document needs to describe how the proposed operations and spill "test" will be monitored and what metrics will be used. A rigorous monitoring program is absolutely essential to gather adequate data to determine whether the waiver is being complied with, and whether migratory salmon and other biological communities are being protected – or harmed. Otherwise, the entire purpose of implementing a waiver to conduct "test" spill operations is undermined. Ecology also needs to make clear what metrics will be used to measure impacts of higher spill levels. Our understanding is that Ecology intends to use the Fish Passage Center's CSS modeling as the basis for the waiver and smolt-to-adult returns (SARs) as a key metric. As described more fully below, RiverPartners has serious concerns with the use of SARs.

Specific Issues or Analysis That Should Be Addressed in the EIS:

- Ecology should identify the biological basis for removing the compliance requirement provided by the forebay monitors. The scoping document states: "Modifying the TDG criteria as described may also facilitate alignment of TDG criteria with Oregon. By doing so, it could simplify implementation of the spill program by the U.S. Army Corps of Engineers." RiverPartners' understanding is the opposite: the USACE relies on Washington's forebay monitors to help control spill levels and impacts on fish as they pass each project. RiverPartners questions why the agency would want to monitor less of a known pollutant that can adversely affect salmon and other aquatic species.

- The impacts of increased spill on carbon emissions and climate change need to be analyzed. Washington's stated policy is to significantly reduce carbon emissions. The Northwest Power and Conservation Council ("Council") conducted an analysis of the impacts of removing the four Lower Snake River dams, "Carbon Dioxide Footprint of the Northwest Power System", Council Document 2007-15 (attached as Ex. A). The Council, modeled a scenario assuming that the Lower Snake dams would be removed, found that carbon dioxide emissions in the western power grid would increase by 4.4 million tons per year. In this study the Council also estimated the impacts of the summer spill program that was under court order at that time. The Council found that the summer spill program increased carbon dioxide production in the west by 2.4 million tons in comparison to a situation where the dams operate *without* summer spill.

- The EIS should include analysis of the impacts of increased TDG on the entire river ecosystem including other critical species such as lamprey, sturgeon, and the entire aquatic food web that salmon depend on.

- As previously noted, the waiver proposal states: "it relies on and will test" the FPC's CSS analysis to gauge anticipated fish benefits. The FPC's proposal to increase spill levels to 125% TDG was submitted to the Independent Science Advisory Board (ISAB) in 2014 for review (attached as Ex. B). The ISAB pointed out the proposal could result in higher juvenile mortality – not less. RiverPartners' understanding is that the FPC has not corrected flaws identified by the ISAB in its analysis, yet Ecology proposes to use it as the basis for the waiver.

Given the ISAB concerns, Ecology also should also evaluate changes in smolt survivals based on NOAA modeling of the entire lifecycle using the COMPASS model. NOAA is the relevant agency responsible for issuing Recovery Plans and Biological Opinions for the ESA listed salmon and Steelhead in the Columbia and Snake Rivers. Their analysis and modeling should be given great weight in the EIS process.

- The use of SARs to measure the effects of spill is flawed. The federal hydrosystem continues to be held wholly accountable for meeting SAR's goals. SARs are affected by far more than the hydrosystem including ocean conditions, predation, habitat, harvest, and hatchery impacts, among other factors. It is well recognized amongst the scientific community that the overwhelming factor affecting adult returns is ocean conditions. We have serious technical concerns with measuring survival benefits from changes in spill with the lifecycle metric of SARs.

- The EIS should review actual reported reach survivals from Lower Granite to Bonneville over the last 20+ years to determine changes in fish survivals during periods of high and low spill. NOAA produces an annual report reporting reach survivals for juvenile salmon and steelhead every year. The latest report (attached as Ex. C) shows that for both 2017 and 2018 juvenile survivals were lower in the last two years than the 10 average except for Snake River steelhead which increased survival in 2018, for no apparent reason. However, spill levels in both years were above the levels ordered by the Court due to unusually high flows that exceeded power generation capability for much of the spring period.

- Evaluate the impacts on adult passage and survival of high levels of spill at each dam.

- Evaluate the impacts of high continuous spill levels on dam safety.

- Evaluate impacts on power and revenue loss and how it will impact BPA's economic viability. This should include analysis of the potential rate impacts on Northwest ratepayers, especially the disadvantaged groups such as low income and tribal members.

In summary, given serious scientific uncertainties, a long history of litigation, and the grave risks posed by ever increasing levels of accumulated TDG on adult and juvenile salmon the scope of the proposed EIS needs to be comprehensive and the analysis needs to be very detailed to properly inform Ecology's decisions. RiverPartners reiterates that it *does* support the goals articulated in Ecology's waiver of improving salmon survivals while keeping BPA's costs contained. However, Ecology's current scoping document is short on critical details necessary to understand and gauge the prospects for a comprehensive EIS to guide future regulatory decisions.

Thank you for the opportunity to comment. RiverPartners' interest is to ensure Ecology procedurally, publicly and scientifically approaches the proposed EIS in a way that recognizes and protects endangered fish and other aquatic species while preserving the critical climate change, renewable energy and other multiple, critical benefits afforded by the federal hydropower and Columbia and Snake river systems.

Very truly yours,

Terry Flores
RiverPartners Executive Director

EXHIBIT A

CARBON DIOXIDE FOOTPRINT OF THE NORTHWEST POWER SYSTEM

November 2007

Northwest Power and Conservation Council

Council Document 2007-15

This report summarizes the results of an analysis of CO_2 production from the Pacific Northwest power system. It compares 2005 CO_2 production to levels in 1990 and to forecast future levels. The analysis explores how future growth in CO_2 production would be affected by various resource development scenarios and other policies of interest.

Summary of Findings

Following a 2006 staff analysis of the marginal carbon dioxide (CO_2) effects of conservation called for in the Council's Fifth Power Plan, the Council requested additional analysis of the CO_2 production of the Northwest power system under various future resource development scenarios. The scenarios included the recommended resource portfolio of the Fifth Power Plan (the base case), a low-conservation scenario in which the conservation targets of the Fifth Power Plan are not achieved, and a high-renewables scenario based on state renewable energy portfolio standards. A scenario based on the resource acquisition recommendations of utilities' integrated resource plans (IRPs) was dropped following the release of several revised utility IRPs that closely matched the recommendations of the Fifth Power Plan. In addition, the Council asked for sensitivity analysis of several specific policies related to hydro system operations to understand how related scenarios could affect the CO_2 production of the power system. The analysis does not address CO_2 production from other sources such as transportation or industrial processes.

The actual CO_2 production of the Northwest power system in 1990 is estimated to have been about 44 million tons.[1] By 2005, production of CO_2 from the regional power system rose to an estimated 67 million tons. However, 2005, unlike 1990, was a poor water year, requiring more than normal operation of CO_2-producing fossil power generation. Under normal water conditions, the CO_2 production in 2005 would have been about 57 million tons, which is a 29 percent increase over the 1990 level. For perspective, the annual CO_2 output of a typical 400-megawatt coal-fired power plant is about 3 million tons, and the CO_2 output of a typical 400-megawatt gas-fired combined-cycle power plant is about 1.2 million tons.[2]

Factors contributing to the increase from 1990 to 2005 include economic growth, the addition of fossil-fueled generating units, lost hydropower production capability, and retirement of the Trojan nuclear plant. The year 1990 is used for comparison because 1990 has been adopted as a baseline by many climate-change policy proposals, including Washington Governor Gregoire's climate-change executive order, Oregon HB 3543, and national legislation proposed by Senators Lieberman and Warner.

Due to the large share of hydroelectric generation in the Pacific Northwest, CO_2 production here is much less than that of other regions when compared to electricity produced. For example, under normal water conditions, in 2005 the Pacific Northwest would have produced about 520 pounds of CO_2 for each megawatt-hour of electricity generated, compared to 900 pounds for the entire Western interconnected power system (WECC). However, because the Northwest has essentially the same set of future resource options available as other areas of WECC, it may be more difficult for the Northwest to maintain or reduce its average per-megawatt-hour CO_2 emission rate. In the base case of this study, which assumes implementation of the Council's Fifth Power Plan, the WECC CO_2 emission rate increases about 3 percent to about 920 pounds per megawatt-hour by 2024, whereas the Northwest rate, with aggressive development of conservation and renewables also increases 3 percent to about 530 pounds.

The future growth rate of annual regional CO_2 production would be even higher if the conservation, wind, and other resource development called for in the Council's Fifth Power Plan were not accomplished. With implementation of the Council's plan in the base case, the annual CO_2 production of the regional power system in 2024 under normal conditions would be about 67 million tons, an 18 percent increase over normal 2005 levels.

This paper explores the difficulty of reducing CO_2 production from electricity generation by assessing the effects of several scenarios on CO_2 production. The scenarios include some that would increase CO_2 production and some that would decrease it. These

[1] Unless otherwise noted, quantities are expressed as short tons (2,000 pounds) of carbon dioxide.
[2] A 400-megawatt pulverized coal-fired plant of 10,000 Btu/kWh heat rate operating at 80 percent capacity factor will produce about 3 million tons per year of carbon dioxide. A 400-megawatt combined-cycle plant fueled by natural gas of 7,000 Btu/kWh heat rate operating at 80 percent capacity will produce about 1.2 million tons per year of carbon dioxide.

scenarios were selected to develop a “scale-of-effects” sensitivity analysis that includes alternative resource development scenarios and hypothetical changes to the hydroelectric system. The hydroelectric sensitivity analyses address two hypothetical river condition alternatives: “no summer spill” and breaching the four lower Snake River dams. The controversial nature of these two scenarios is recognized, but has no relevance in this paper other than the CO2-related data the alternatives generate as a result of their respective scenario parameters.

An important finding of the analysis is that achieving the renewable portfolio standard goals and eliminating all summer spill would reduce the region’s projected growth in power system CO2 production by only 75 percent, even if counting the resulting net CO2 reduction for the entire WECC. Failure to achieve the conservation targets in the Fifth Power Plan, or removing the lower Snake River dams and replacing the power in a manner consistent with the Fifth Power Plan could more than offset the potential savings from the scenarios that reduce CO2 production. The effects of these scenarios, positive or negative, on CO2 production are the equivalent of only one or two coal-fired plants, whereas the forecast regional CO2 production for 2024 in the Fifth Power Plan case exceeds 1990 levels by an amount equivalent to eight typical coal-fired plants.

The findings of this study are depicted in Figure 1 and compiled in Table 1. Figure 1 depicts changes from base case projected CO2 emissions from WECC power systems for each of the scenarios. Table 1 shows the CO2 emissions in 1990, 2005, and projections for 2024 in each scenario, both for the Pacific Northwest and the WECC as a whole. Changes to the 2024 levels are shown in parentheses for each scenario.

These results illustrate the difficulty of actually reducing CO2 production with policies that affect only new sources of electric generation. CO2 production from electricity generation is dominated by existing coal-fired generating plants. To stabilize CO2 production at 2005 levels or to reduce CO2 production to 1990 levels would require substituting low CO2-producing resources or additional conservation for some of these existing coal-fired power plants. In addition, the scenario analysis shows that policy choices that are made for purposes other than CO2 reduction (in this case fish and wildlife policy) can also have significant effects on CO2 production; enough effect to negate policies such as renewable portfolio standards. Such unintended effects often go unexplored in important policy debates that focus narrowly on only one objective.

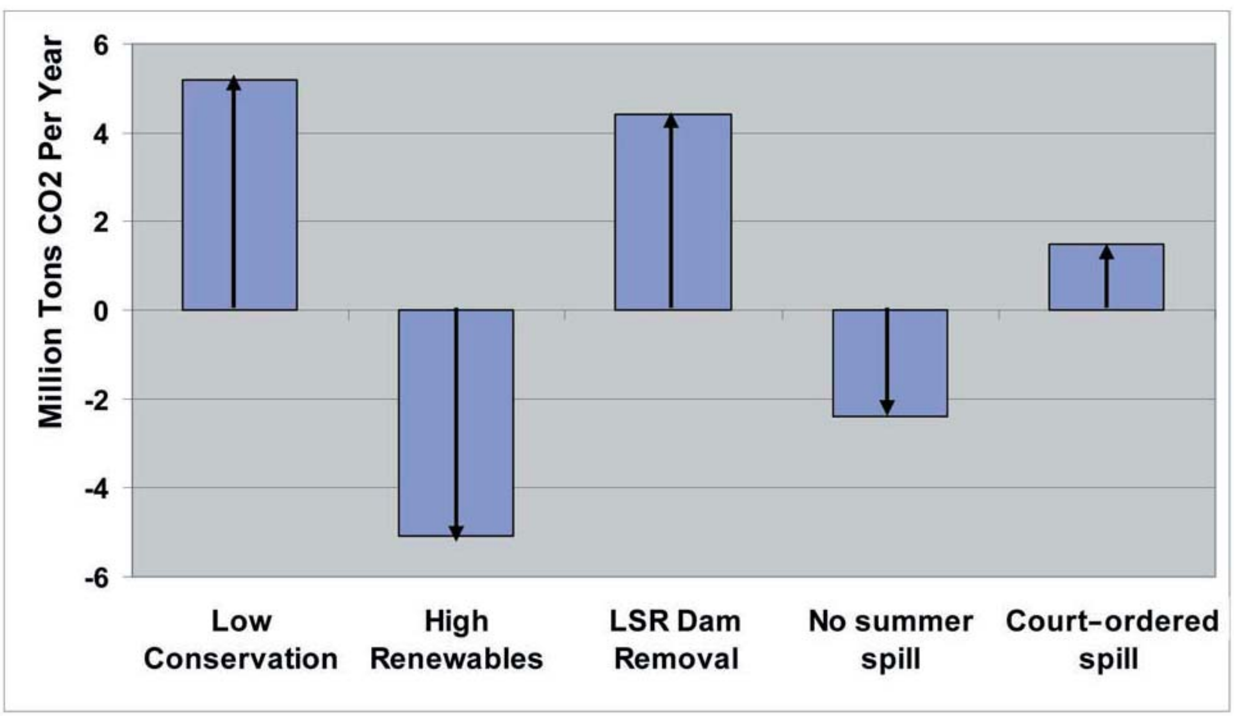

Figure 1: Changes from the base case projected CO2 production in alternative scenarios (WECC)

	Northwest Sources	WECC Sources
Historical values		
Actual 1990	44	Not estimated
Actual 2005	67	Not estimated
Simulated 2005 w/average hydro	57	378
Forecast 2024 rates and change from base case		
Base Case (5th Plan Portfolio)	67	531
Low Conservation	71 (+4.4)	536 (+5.2)
High Renewables	63 (-4.2)	526 (-5.1)
Remove LSR Projects, Replace w/Gas Generation	70 (+3.6)	536 (+4.4)
No Summer Spill	66 (-1.1)	529 (-2.4)
Court-ordered Spill	67 (+0.5)	533 (+1.5)

Table 1: Historical and projected CO_2 production and effects of alternative scenarios

As perspective, it is useful to understand regional CO2 emissions in a global context. In 2005, the world production of CO2 from the consumption and flaring of fossil fuels is estimated to have been about 28,000 million metric tons (30.8 billon short tons). The United States accounted for 21 percent of these emissions. The U.S. production of CO2 per capita is about 5 times the world average, largely reflecting its advanced state of development. However, the U.S. production of CO2 relative to its state of development as measured by Gross Domestic Product is substantially lower than the world average; about 70 percent of the world average.[3]

Electric power generation accounts for about 40 percent of the U.S. production of CO2. The electric power share is much lower in the Western U.S., however, at about 31 percent, and even lower for the Pacific Northwest where the 2004 (a fairly normal water year) share was 23 percent.

Greenhouse gas reduction targets, such as the Western Climate Initiative, typically target all sources of greenhouse gas emissions. Carbon dioxide is the dominant greenhouse gas. It accounted for 84 percent of all greenhouse gas emissions in 2005.[4] Sources of CO2 emissions other than electricity generation will need to be reduced to meet greenhouse gas reduction targets. For the U.S. as a whole, electricity generation is the largest producer of CO2. It is followed closely by the transportation sector, which accounts for one-third of emissions, and then by the industrial sector contributing 18 percent. The residential and commercial sectors combine to account for 10 percent.

Although electricity generation is the largest source of CO2 emissions in the U.S., in the West transportation is the largest. Transportation accounts for 43 percent of the CO2 emission in the West compared to 33 percent in the U.S. as a whole. In the Pacific Northwest, the transportation share is even larger at 46 percent.

The diversity of CO2 emission shares should be an important consideration in structuring CO2 reduction policies. In the West, with a smaller contribution to CO2 emission coming from electricity production, other sectors will need to carry a larger burden in reaching overall CO2 reduction targets. In addition, as discussed later in this paper, the CO2 production for electricity generation in the Pacific Northwest can vary significantly with changing hydroelectric supplies. This variability will need to be accounted for in setting CO2 reduction targets and in any cap and trade allocation system.

Background

Increasing concerns regarding the impact of CO2 production from the electric power system on global climate and heightened prospects of mandatory

[3]Data on CO2 emission from energy are from the U.S. Energy Information Administration.
[4]U.S. Environmental Protection Agency. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005.

controls on the production of CO_2, led the Council in the summer of 2006 to request a forecast of the CO_2 produced from alternative future resource portfolios. Four scenarios were identified: the recommended resource portfolio of the Fifth Power Plan (the base case), a low-conservation scenario in which the conservation targets of the Fifth Power Plan are not achieved, a high-renewables scenario based on state renewable energy portfolio standards, and a scenario based on the resource acquisition recommendations of utilities' integrated resource plans (IRPs). The utility plans scenario was removed from the final paper following the release of several revised utility IRPs that closely matched the recommendations of the Fifth Power Plan. Two additional sets of studies were subsequently requested: 1) the CO_2 effects of removing the federal dams on the lower Snake River; and 2) the CO_2 effects of summer spill at the lower Snake River and lower Columbia River dams.

The purpose of these alternative scenarios is to quantify the sensitivity of results to plausible changes in the power system and to some related policies that have received attention. No new Council position on any of these policies is intended by this analysis, nor should any be inferred.

Historical Carbon Dioxide Production of the Northwest Power System

The year 1990 is frequently used as a benchmark in policies for the control of greenhouse gases.[5] The 1990 production of carbon dioxide from the Pacific Northwest power system is estimated to have been about 44 million tons, based on electricity production records of that year. Load growth, the addition of fossil-fuel generating units, the loss of hydropower production capability, and the retirement of the Trojan nuclear plant resulted in growing CO_2 production over the next 15 years. By 2005, the most recent year for which electricity production or fuel consumption data are available, CO_2 production increased 52 percent to 67 million tons (Figure 2). This is approximately the CO_2 output of 23 400-megawatt conventional coal-fired power plants, 56 400-megawatt gas-fired combined-cycle plants or about 11.7 million average U.S. passenger vehicles.

The regional CO_2 production estimates from 1995 through 2005 shown in Figure 2 are based on the fuel consumption of Northwest power plants as reported to the Energy Information Administration (EIA). Because fuel consumption data were not available before 1995, estimates for 1990 through 1995 are based on plant electrical output as reported to EIA and staff assumptions regarding plant heat rate and fuel type. Estimates based on plant electrical production are likely somewhat less accurate than estimates based on fuel consumption because of multi-fuel plants and uncertainties regarding plant heat rates. However, the two series of estimates are within 2 percent in the "overlap" year of 1995.

[5]For example, California Assembly Bill (AB) 32, passed by the legislature and signed by the governor in 2006, calls for enforceable emission limits to achieve a reduction in CO_2 emissions to the 1990 rate by 2020. Washington Governor Gregoire's climate-change executive order includes the same target for CO_2 reductions. Oregon House Bill 3543, passed by the legislature and signed by Governor Kulongoski in August, declares that it is state policy to stabilize CO_2 emissions by 2010, reduce them 10 percent below 1990 levels by 2020, and 75 percent below 1990 levels by 2050.

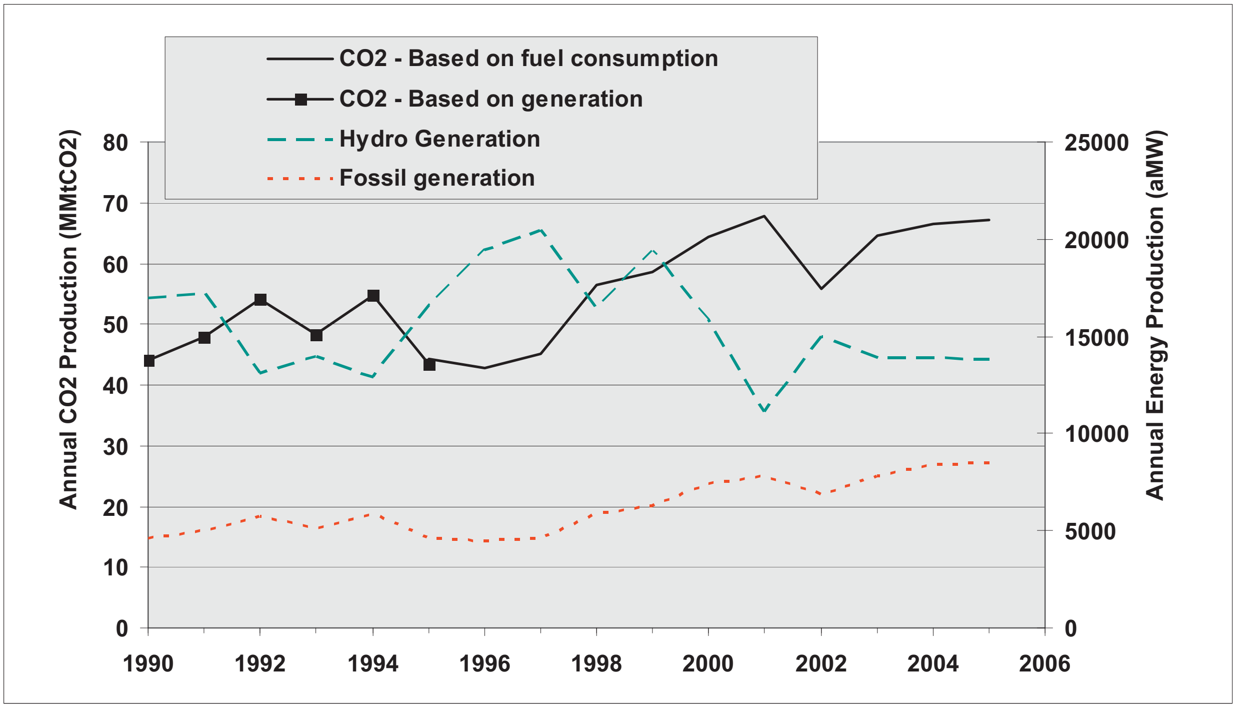

Figure 2: Historical CO2 and energy production of the Northwest power system[6]

Annual hydropower conditions can greatly affect power system CO2 production. Average hydropower production in the Northwest is about 16,400 average megawatts. As shown by the plot of Northwest hydropower production in Figure 2, the 1990 water year was nearly 17,000 average megawatts, slightly better than average. Other factors being equal, this would have slightly reduced CO2 production that year by curtailing thermal plant operation. Conversely, hydro production in 2005 was about 13,800 average megawatts, a poor water year. Other factors being equal, this would have increased thermal plant dispatch, raising CO2 production. The effect of hydropower generation on thermal plant generation and CO2 production is shown in Figure 2.[7]

If normalized to average hydropower conditions, actual generating capacity, and the medium case loads and fuel prices of the Fifth Power Plan, the estimated CO2 production in 2005 would have been 57 million tons, a 29 percent increase over the 1990 rate. This is the value used for comparison in this paper.

The Base Case - The Fifth Power Plan's Portfolio

The recommended resource portfolio of the Fifth Power Plan was used as the base case for all studies. Because the recommended resource portfolio of the Fifth Power Plan is defined in terms of "option by" dates rather than in-service dates, assumptions must be made to translate the portfolio into the fixed resource schedule needed for the AURORA™ model.[8] For this work, the "mean value resource development" schedule of the preferred resource portfolio of the Fifth Power Plan was represented in AURORA. The resulting resource development schedule was then tested against the Resource Adequacy Forum's recently proposed pilot capacity adequacy standard, using the capacity addition mode of the AURORA model. The resulting resource development schedule, illustrated in Figure 3 and enumer-

[6] Estimated CO2 production from 1995 through 2005 is based on power plant fuel consumption as reported to the U.S. Energy Information Administration (EIA). Fuel consumption information before 1995 is not readily available. CO2 production for these years was based on reported generation and estimated plant heat rates. As evident in Figure 1, the two methods result in reasonably consistent estimates for the overlap year of 1995. Incomplete reporting of generation for the increasing amount of non-utility power plant capacity makes comparisons less reliable for subsequent years. Estimates are based on all utility-owned power plants and non-utility plants selling under contract to utilities. Included in the definition of "Northwest" are the Jim Bridger plant in Wyoming and the Idaho Power share of the North Valmy plant in Nevada. The output of this capacity is dedicated to Northwest loads.

[7] In Figure 1, it is evident that Northwest thermal generation does not decline as much as Northwest hydro generation increases in above average water years, e.g. 1994 - 1997. This is likely due to the fact that the abundant hydropower of good water years creates a regional energy surplus that can be sold out of the region where it displaces thermal generation, which often consists of older, less efficient gas-fired units.

[8] The use of the AURORA model in preparing these forecasts is described in the Appendix A of this paper.

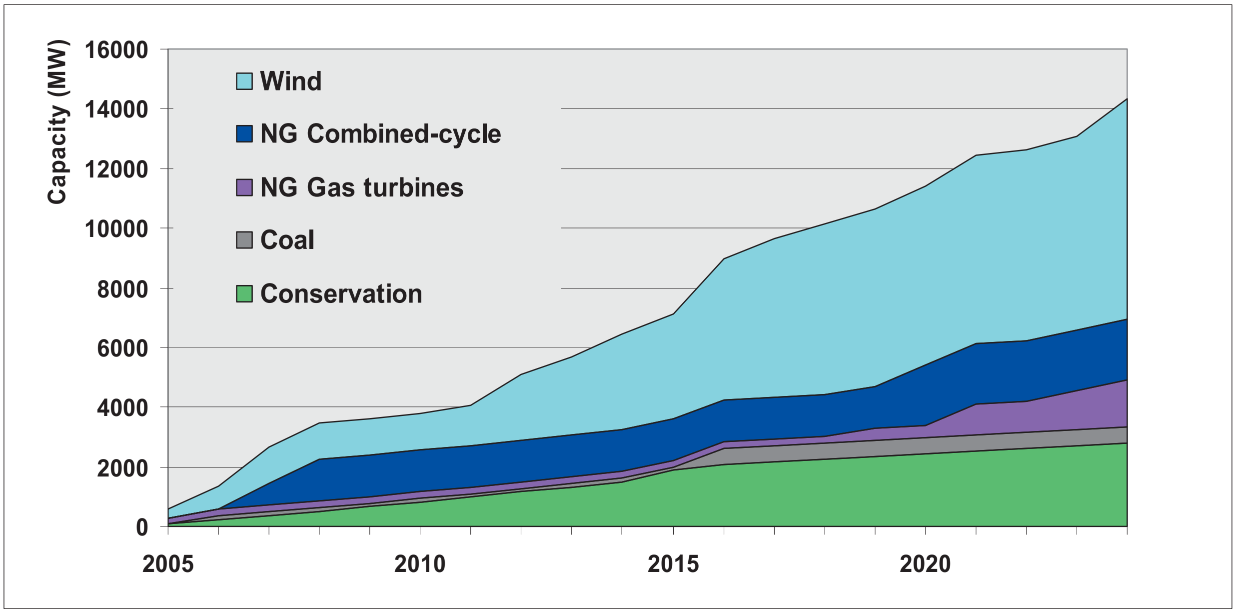

Figure 3: Base case Northwest resource development

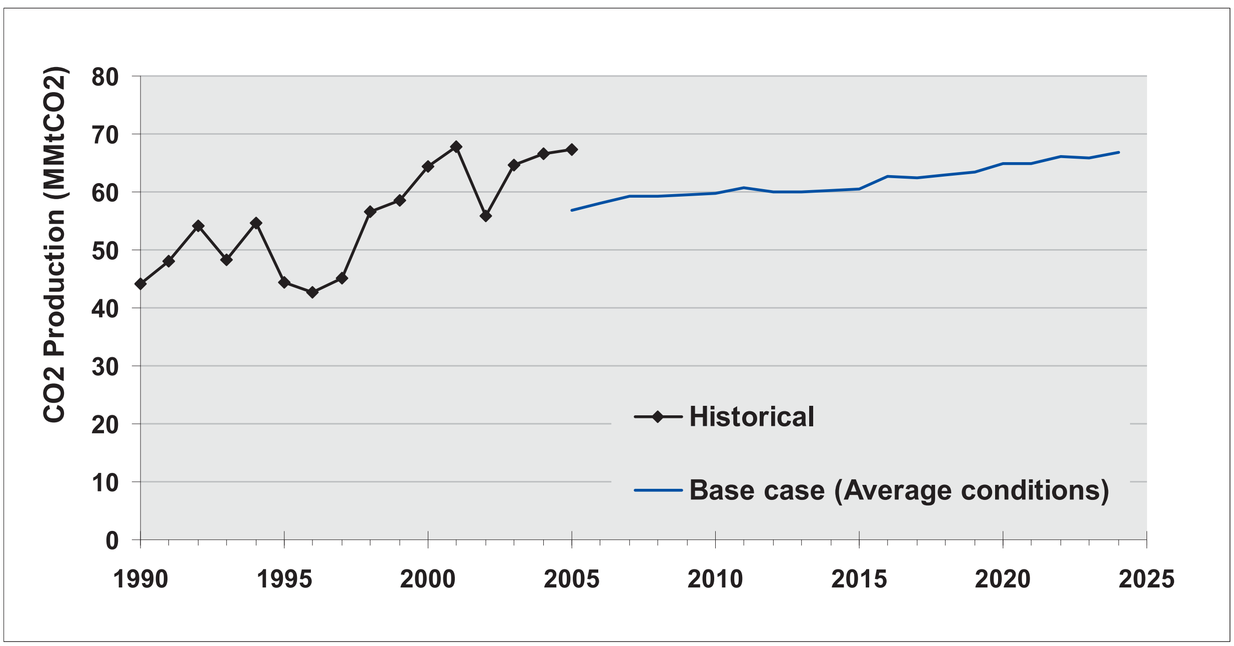

Figure 4: Forecast and historical CO2 production of the Northwest power system

ated in Appendix B, contains additional simple-cycle gas turbine capacity needed to maintain the proposed Northwest pilot capacity reserve standards. The schedule also contains several recently constructed wind projects not included in the resource portfolio of the Fifth Power Plan, so it includes a somewhat larger amount of wind capacity by 2024 than the original Fifth Plan portfolio. The AURORA capacity expansion run was also used to define resource additions and retirements for WECC areas outside the Northwest.

Forecast CO2 production of the Northwest power system for 2005-24 is compared to historical production in Figure 4. The forecast is normalized to average hydro, fuel prices, and loads, leading to the difference between actual and forecast values for the low water year 2005. Annual CO2 production under average conditions is forecast to increase from 57 million tons in 2005 to 67 million tons in 2024. This represents an 18 percent increase over the planning period of the Fifth Power Plan, an average annual rate increase of 0.8 percent. The forecast annual rate

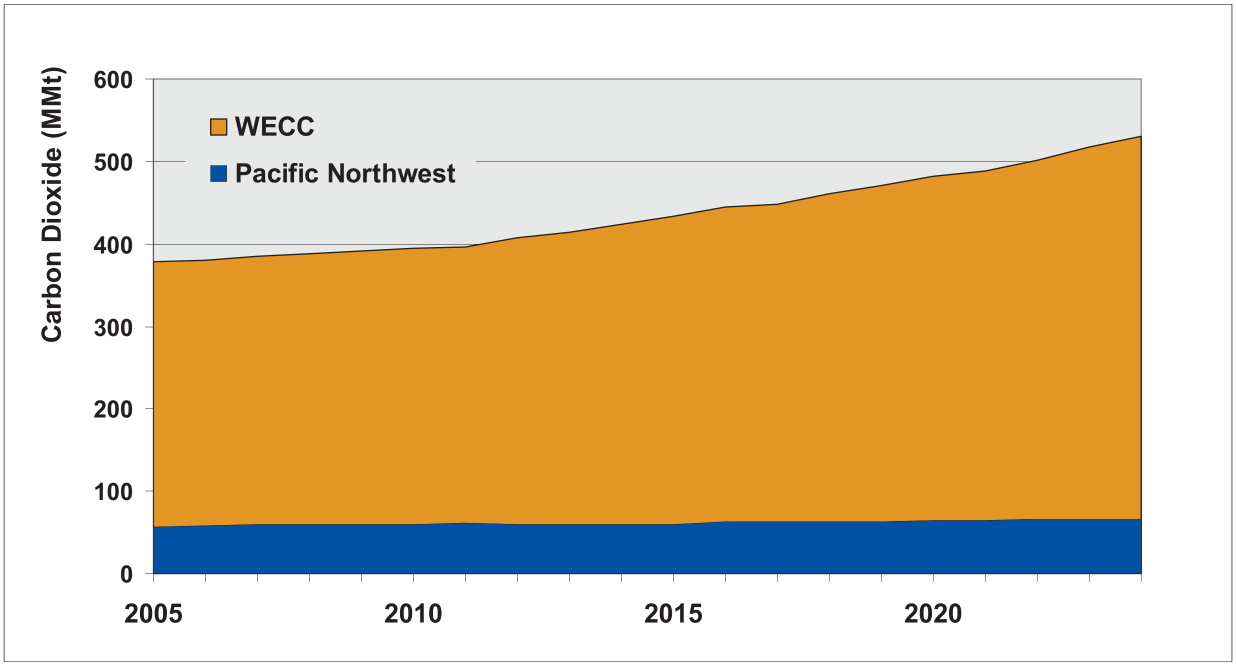

Figure 5: Forecast WECC and Northwest power system CO2 production

of 67 million tons in 2024 represents an increase of 51 percent over the historical annual rate of 44 million tons in 1990. The forecast average annual rate of increased CO2 production of 0.8 percent for the planning period of the Fifth Power Plan is half of the 2 percent average rate for 1990 - 2004 (2004 normalized).

Figure 5 compares forecast annual CO2 production for the Northwest and the WECC as a whole. In 2005, the normalized annual CO2 production by the Northwest power system represented 15 percent of the total WECC production. Because of its high proportion of hydropower, aggressive development of conservation, and recent additions of wind power and other non-hydro renewable resources, the Northwest enjoys a much lower per-kilowatt-hour CO2 production rate than WECC as a whole (0.52 lb/kWh vs. 0.90 lb/kWh in 2005). The forecast average annual growth rate for WECC as a whole is 1.7 percent, compared to 0.8 percent for the Northwest, so that by 2024, the production in the Northwest will have declined to 13 percent of the total WECC production. Because these estimates do not include the possible effects of the renewable portfolio standards in place in many Western states (including the Northwest states), the future growth of CO2 production for WECC may be less than forecast here.

Figure 6 illustrates the source of CO2 production in the Northwest in the base case forecast. By 2024, and assuming no retirements of existing thermal plants, 79 percent of Northwest power system CO2 production will be from existing coal-fired power plants, 4 percent from new coal-fired plants, 9 percent from existing gas-fired plants, and 7 percent from new gas-fired power plants. Though the aggressive acquisition of conservation and renewable resources called for in the Fifth Power Plan will hold the rate of growth in Northwest CO2 production to half the growth rate experienced from 1990 through 2004, serious efforts to reduce or even stabilize CO2 production beyond 2005 will likely require replacing existing coal-fired power plants with low CO2-emitting resources.

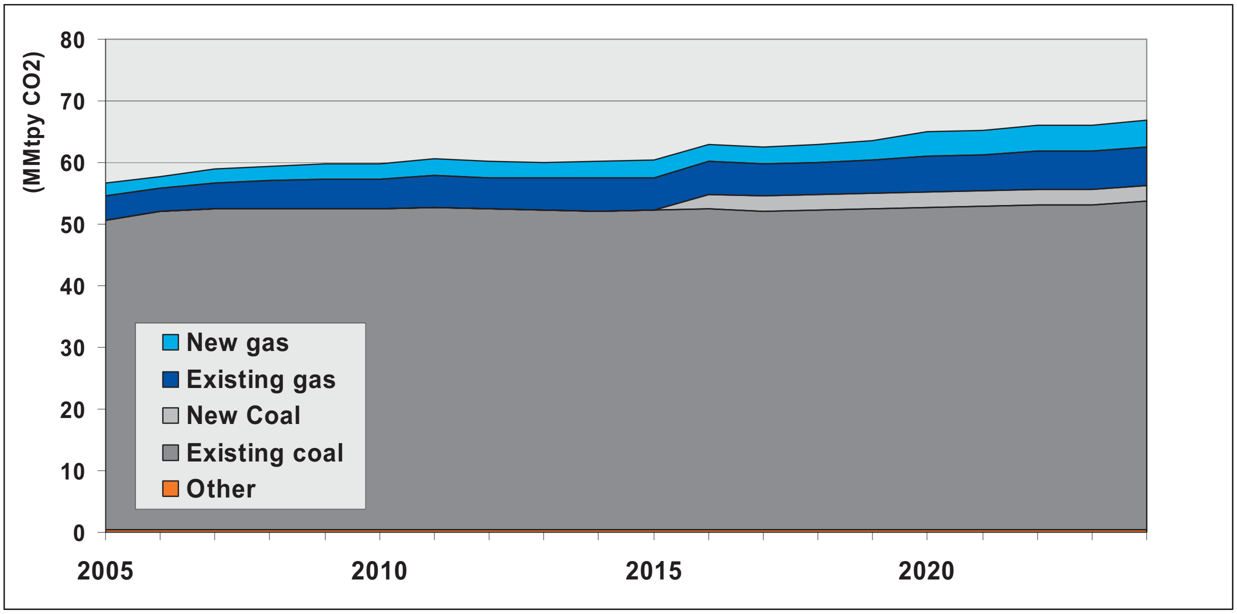

Figure 6: Sources of Northwest power system CO2 production

Alternative Resource Development

The CO2 production of two scenarios of alternative future resource development was forecast and compared to the base case forecast described earlier. The Northwest resource-development assumptions for each scenario are described below. Resource-development assumptions for WECC areas outside of the Northwest are the same as the base case. The impacts of all of the scenarios analyzed in this paper are assessed under average water conditions.

Alternative resource-development scenarios

A low-conservation scenario assumes that only 70 percent of the long-term conservation goals of the Fifth Power Plan are met by 2024. A resource portfolio (the "status quo" portfolio) representing this situation, developed during preparation of the Fifth Power Plan, was adopted for this scenario. As shown in Figure 7, this portfolio includes 800 fewer megawatts of conservation, 200 fewer megawatts of wind, and 275 fewer megawatts of simple-cycle capacity compared to the base case.[9] An additional 275 megawatts of coal and 610 megawatts of combined-cycle capacity make up for the energy and capacity of the unachieved conservation, wind, and gas turbine capacity.

A high-renewables scenario approximates full achievement of the Montana, Oregon, and Washington renewable portfolio standards (RPS). This scenario also includes a hypothetical RPS for Idaho, generally comparable to those adopted by the other states but with a lag of several years. Although these additional renewable resources were not found to be cost-effective in the Council's Fifth Power Plan, their acquisition has been mandated by many states, including Montana, Washington, and Oregon. Renewable-resource acquisitions to meet RPS goals are modeled as a combination of wind and biomass in the approximate proportions of wind currently being developed compared to other renewable energy resources. Though some geothermal, hydropower, solar, and marine energy resources are expected to be developed in response to renewable portfolio standards, the wind and biomass assumed for this scenario adequately represent the performance of the expected mix of intermittent and firm renewable energy resources for this purpose. The conservation-acquisition targets of the Fifth Power Plan were also assumed to be met. New coal-fired generation is excluded from this scenario. As shown in Figure 7, the high-renewables scenario includes an additional 500 megawatts of biomass, 1,600 megawatts of wind,

[9] In Figure 7 and following figures, column sections above the zero line represent resource capacity in excess of the amounts included in the base case, and column sections below the zero line represent resource capacity less than included in the base case. Conservation energy savings are shown as equivalent capacity.

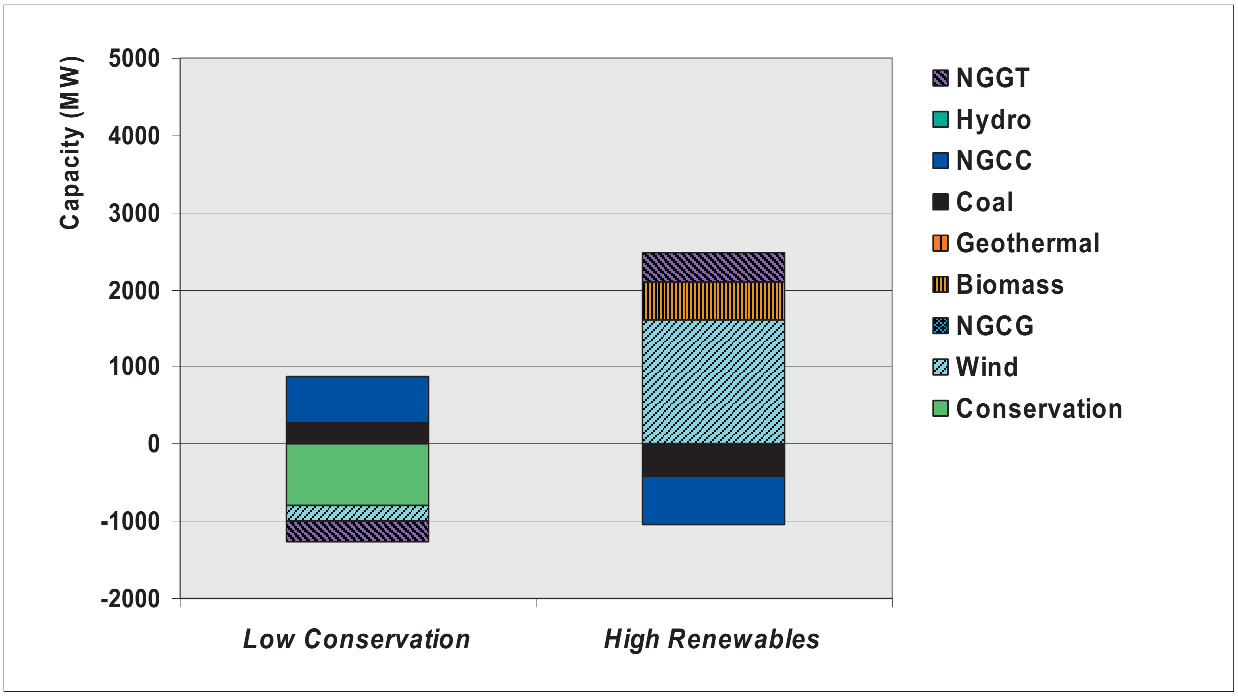

Figure 7: Incremental 2005-24 capacity compared to the base case

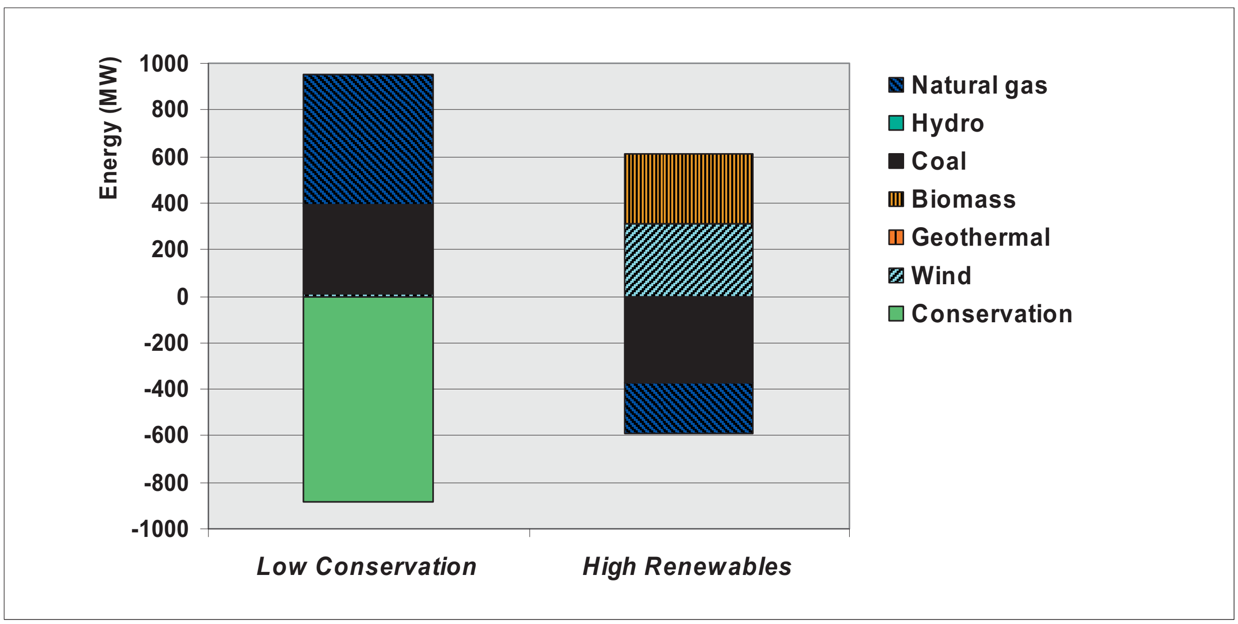

Figure 8: Average annual change in resource output vs. base case (WECC, 2015-24)

and 370 megawatts of gas turbines compared to the base case. The peaking capacity and energy balance of the base case was maintained by eliminating the 425 megawatts of new coal in the base case.

Effects of alternative resource-development scenarios

The production of CO2 is a function of the fuel and efficiency of resources dispatched to meet load. Alternative resource mixes will lead to changes in dispatch because of differing variable costs of operation and physical operating characteristics. Net changes for the entire WECC must be evaluated because of the effects of Northwest resources on resource dispatch in interconnected areas. A comparison of the average annual change in energy production by type of resource for 2015-24 for the two alternative resource-development scenarios compared to the base case is illustrated in Figure 8.

Low Conservation

Additional energy from coal (370 average megawatts) and natural gas (560 average megawatts) substitute for the reduced conservation of the low-conservation scenario. By 2024, annual CO_2 production from Northwest sources would be 71 million tons per year (MMtpy), 4.4 million tons greater than the base case and a 61 percent increase over the 1990 rate. Annual net CO_2 production for 2024 across the entire WECC system would increase 5.2 million tons compared to the base case, nearly the equivalent of two typical 400-megawatt coal-fired power plants. By 2024, this scenario includes about 770 fewer average megawatts of conservation than the base case. Each average megawatt of unachieved conservation would increase average net annual CO_2 production by about 6,700 tons per year.

Wholesale power prices are forecast to be higher on average in the low-conservation scenario compared to the base case. Higher prices result from the dispatch of higher variable-cost resources, such as gas turbines to serve the additional load resulting from lower conservation achievement.

High Renewables

Additional energy from wind (310 average megawatts) and biomass (300 average megawatts) in the high-renewables scenario would reduce energy production from coal by 370 average megawatts and natural gas by 220 average megawatts. By 2024, annual CO_2 production from Northwest sources would be 63 MMtpy, 4.2 million tons less than the base case. Although this would reduce the 2005-24 growth of CO_2 production rates by 44 percent, the resulting rate still represents a 41 percent increase over the 1990 rate. Annual net CO_2 production for 2024 across the entire WECC system would decline 5.1 million tons compared to the base case.

Wholesale power prices are forecast to be slightly lower on average in the high-renewables scenario compared to the base case. Lower prices result from the displacement of high variable-cost resources, such as gas turbines by the additional low variable-cost renewable resources of this scenario.

Removal of the Lower Snake River Hydroelectric Projects

Analysis of breaching the four federal hydroelectric projects on the lower Snake River[10] indicates the loss (on average under current river operations) of about 1,020 average megawatts of carbon-free energy and 2,650 megawatts of sustained peaking capacity. The impact of this loss on the production of CO_2 depends on the nature of the replacement resources. The resource replacement depends on the particular resource-development strategy, as illustrated in the resource-development scenarios described earlier.

Resource replacement

Three possible approaches to replacing the reduced hydroelectric output of the dams were considered. These were: replacement with market purchases, replacement with natural gas resources, and replacement with conservation and renewable energy resources and natural gas capacity. The results of the second approach are reported because they are considered the most consistent with the base case and the Fifth Power Plan. Replacement with market purchases would compromise system adequacy and reliability by reducing the amount of resource available to meet load. Replacement of the power lost by breaching the lower Snake River dams by increased acquisition of conservation and renewable energy could, at least in the near term, delay some of the CO_2 impacts of dam breaching. However, tying the increased development of conservation and renewables to dam breaching is misleading. If additional conservation and renewables are available and desirable, they should be pursued as part of a regional strategy to reduce CO_2 emissions. Thus, the effects of changes in renewable development and conservation achievements have been addressed in the resource-development scenarios discussed earlier. Removal of the lower Snake River dams will not make additional CO_2-free energy resources available to meet future load growth or retire any existing coal plants. More than 1,000 megawatts of emission-free generation eventually will have to be replaced unless the supplies of renewables and conservation are considered unlimited. Given the difficulty of reducing CO_2 emissions, discarding existing CO_2-free power sources has to be considered counterproductive

The lower Snake projects were assumed to ter-

[10]The projects are Ice Harbor, Lower Monumental, Little Goose, and Lower Granite.

minate production on December 31, 2014, and replacement resources were assumed to commence operation on January 1, 2015. This permitted the development of 10-year (2015-24) averages consistent with the other studies of this analysis. Resource-development assumptions for WECC areas outside of the Northwest were held constant.

The analysis assumes that the average energy output of the projects is replaced by natural gas-fired combined-cycle plants. The balance of the sustained peaking capacity of the projects is replaced by natural gas-fired simple-cycle gas turbines. The combined capacity of three combined-cycle units (1,830 megawatts) and 18 simple-cycle gas turbine units (846 megawatts) slightly exceeds the sustained peaking capacity of the four hydro projects. The analysis did not address replacement of ancillary services such as regulation, load following, and power factor control provided by the projects.

Effects of lower Snake dam replacement

When the operation of the changed power system is simulated, the lost hydro energy is replaced with the additional production of 170 average megawatts from existing coal-fired units and about 810 average megawatts from new and existing natural gas units. By 2024, annual CO2 production from Northwest sources would be 70 MMtpy, 3.6 million tons greater than the base case and a 59 percent increase over the 1990 rate. Annual CO2 production for 2024 across the entire WECC system would increase 4.4 million tons compared to the base case.

A modest increase in wholesale power prices is forecast, resulting from replacement of the hydro energy with higher variable-cost thermal energy. Significant capital expenditures would be incurred for replacement resources and costs associated with dam removal, which would increase cost-based utility electricity prices. System reliability should be relatively unaffected because of the capacity value and energy capability of the replacement resources. While the supply of ancillary services should be unaffected because of the replacement capacity, ancillary service prices may increase because of the higher operating costs of the replacement thermal resources.

Summer Spill Operations

The summer spill program at the lower Snake River and lower Columbia River hydroelectric projects is intended to facilitate the downstream migration of anadromous fish. The original summer spill requirements date to the 1990s and were incorporated in the 2000 Biological Opinion (BiOp). The 2004 BiOp incorporated the summer spill operation of the 2000 BiOp with minor changes. In 2005 and subsequent years, summer spill was increased further by court order (Preliminary Injunctive Relief Operation). The base case (the Fifth Power Plan portfolio) is based on 2004 BiOp operations, and thereby represents an intermediate level of summer spill.

This study estimates the CO2 production impacts of the two summer spill regimes by comparing the average Western system dispatch and net CO2 production for no summer spill operation and court-ordered summer spill operation to the average Western system dispatch and net CO2 production of the base case (2004 BiOp). The comparison in all scenarios is average dispatch and CO2 production for the period 2015-24.

The base case is as described earlier and includes summer spill operation as called for in the 2004 Biological Opinion.

The no summer spill scenario is based on the energy shape and output of the hydropower system without summer spill at the lower Snake River and Columbia River projects. In all other respects, the scenario is identical to the base case. About 550 average megawatts of hydropower energy would be gained under this operation compared to the base case.

The additional court-ordered spill scenario is based on the energy shape and output of the hydropower system under 2006 court-ordered spill operation. In all other respects, the scenario is identical to the base case. About 360 average megawatts of hydropower energy are lost under this operation compared to the base case.

No summer spill

In the no summer spill scenario, the additional hydro energy would displace about 190 average megawatts from coal-fired power plants and about 330 average megawatts from natural gas power plants (Figure 9). This would reduce average annual CO2 production for 2024 from Northwest sources by 1.1 million tons compared to the base case (2004 BiOp). By 2024, 66 MMtpy of CO2 would be produced directly from Northwest sources, a 48 percent increase over the 1990 rate. Annual CO2 production for 2024 across the entire WECC system would decrease 2.4 million tons compared to the base case.

Sensitivity Cases

Comments on the draft of this analysis requested sensitivity cases on some of the basic assumptions used in all of the scenarios. These included the effects of higher CO2 costs, higher fuel prices, and wind variability.

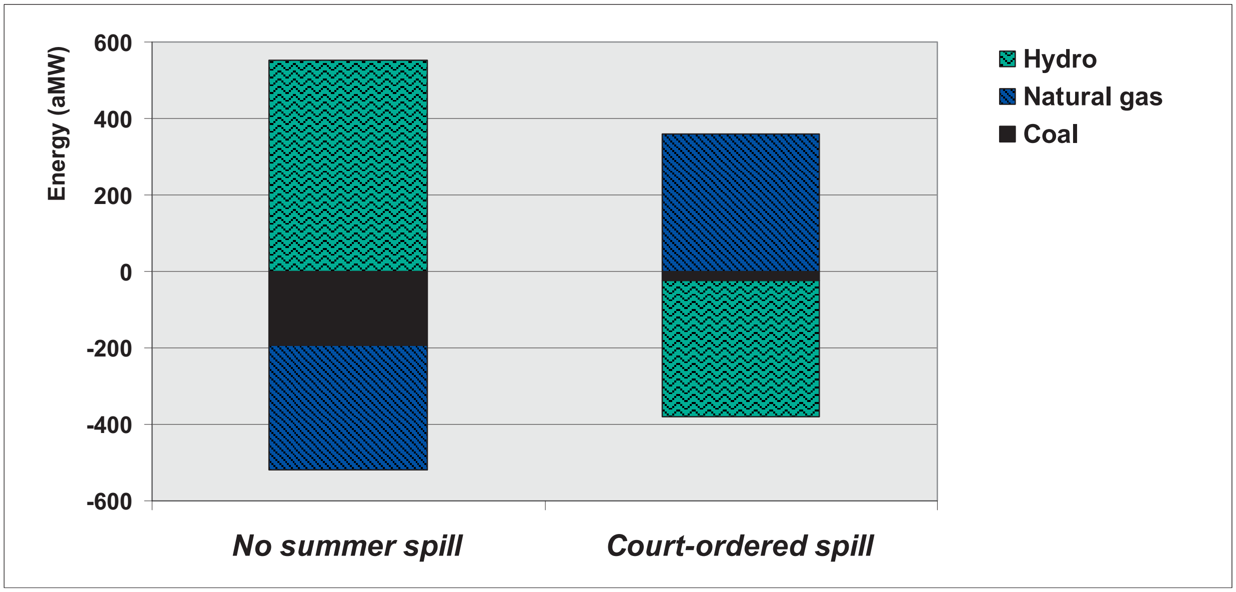

Figure 9: Average annual change in resource output vs. base scenario (WECC, 2015-24o

Court-ordered spill

About 20 average megawatts from coal-fired power plants and about 360 average megawatts from gas-fired power plants are needed to compensate for the lost hydro energy of the court-ordered spill scenario. This increases average annual CO2 production for 2024 from Northwest sources by 0.5 million tons compared to the base case (2004 BiOp). By 2024, 67 MMtpy of CO2 would be produced directly from Northwest sources, a 52 percent increase over the 1990 rate. Annual CO2 production for 2024 across the entire WECC system increases 1.5 million tons compared to the base case.

The overall effect of court-ordered spill compared to no summer spill operation within the Northwest is to increase the average annual CO2 production for 2015-24 by 2.1 million tons. For WECC as a whole, court-ordered spill increases average annual CO2 production 5.2 million tons compared to no summer spill operation.

Higher CO2 costs

All scenarios investigated in this study included the mean value CO2 prices from the portfolio risk assessment of the Fifth Power Plan. This price, representing a carbon tax or the cost of carbon allowances under a cap and trade system, appears in 2009 and gradually rises to about $9.00 per short ton of CO2 by 2024 (2006 dollars). A sensitivity case with doubled CO2 price was run to explore the possible effect of increased CO2 price on resource dispatch and CO2 production. The resource mix was held constant for this case, so the impacts of the higher CO2 prices are generally limited to shifting from coal to natural gas fueled plants. Higher power prices might also induce demand response and load curtailment.

With doubled CO2 prices, WECC-wide dispatch of coal declined 9 percent, with the difference largely met with increased dispatch of natural gas plants. A slight increase in demand response was also observed. Northwest CO2 production in 2024 does not significantly change from the base case, but for WECC in its entirety, 2024 CO2 production declined 9 million tons.

Higher fuel costs

All scenarios investigated in this study were based on the medium case fuel price forecast of the Fifth Power Plan. Current forecasts of fuel prices, including the recent revision of the Council's fuel price forecast, are generally higher than earlier forecasts, including that of the Fifth Plan. Though the Council's revised fuel price forecast had not been adopted when the base case analysis was under development, a sensitivity analysis was run using the medium-high fuel price forecast case of the Fifth Power Plan. North American wellhead gas prices in the Fifth Power Plan medium-high fuel price forecast are $5.20/MMBtu in 2024, compared to $4.60/MMBtu in the medium case (2006 dollars). The equivalent western mine mouth coal prices are $0.67 and $0.59 per MMBtu. The resource mix was held constant for this case, so the impacts of the higher fuel prices are generally limited to shifting between natural gas and coal. As in the higher CO2 price case, higher power prices might also induce demand response and load curtailment.

For WECC as a whole, the overall dispatch of coal and natural gas plants was essentially unchanged in the medium-high fuel price case. A slight increase in demand response was observed, as was increased dispatch of geothermal plants (geothermal plants are modeled as dispatchable with a variable fuel cost). Higher fuel prices did not significantly affect CO2 production in the Northwest or for WECC as a whole.

Windpower volatility and intermittency

Wind is currently modeled in AURORA with a flat energy output equivalent to annual capacity factor. A sensitivity case in which the hourly intermittency of wind was modeled using historic hourly output of several geographically diverse Northwest wind projects resulted in an insignificant change in CO2 production. Further testing of the impact of hourly intermittency may be desirable as more extensive actual and synthetic wind output data becomes available from the Northwest Wind Integration Action Plan.

Though hourly wind volatility did not significantly affect CO2 production in this sensitivity case, it is possible that sub-hourly wind volatility might impact CO2 production. In the later years of the study period, increasing loads and higher levels of wind penetration may increase the demand for regulation and load following services beyond the capability of the hydro system to provide these services. Fossil resources such as simple-cycle gas turbines may be called upon to provide regulation and load following, which would increase CO2 production.

Achieving Significant Reductions in CO2 Production

The findings described in this paper illustrate the difficulty of reducing CO2 production to rates considered necessary for climate stabilization. Current rates of conservation acquisition, and policies such as renewable portfolio standards mandating acquisition of low carbon resources, will help reduce growth of CO2 production. However, as discussed earlier, these activities are likely to be insufficient to maintain current levels of CO2 production, much less to reduce CO2 production to levels sought by greenhouse gas control policies. Achieving these goals will require deep cuts in the CO2 production from existing fossil plants or equivalent offsets from other sectors or geographic areas.

To give some perspective to the challenge of meeting proposed CO2 reduction targets, we have calculated the amount of CO2 emissions that would need to be reduced from the base case (Fifth Power Plan) forecast for 2020. Two cases are illustrated to give some perspective on the size of the challenge. One is the Western Climate Initiative (WCI) target of reducing CO2 emissions to 15 percent below 2005 levels by 2020. Another is to reach 1990 levels by 2020, which is both Washington's target and the target in the proposed Lieberman-Warner "America's Climate Security Act."

Assuming the Northwest power system met similar percentage reductions in its 2020 CO2 emissions, what is the magnitude of the reduction in terms of million tons per year and how can that be put into perspective?

Taking the WCI target first, the required reductions would depend on how the 2005 CO2 emissions were determined. As illustrated earlier, 2005 was a poor water year. Actual CO2 production from the power system was estimated to be 67 million tons per year. The WCI target, if based on actual emissions, would be 57 million tons per year. To reduce the base case forecast of CO2 production in 2020, which is 65 million tons, down to actual 2005 levels would require a reduction of 7 million tons of CO2. However, if based on normal hydro conditions, the WCI target would be 48 million tons per year. Achieving a WCI target based on normal hydro would require a reduction of 17 million tons.

One way to put this into perspective is to calculate how much coal capacity would have to be replaced with a carbon-free source or with conservation, as shown in Table 2. More existing capacity than indicated in the table would require replacement if a portion of the replacement resource were low-carbon, such as coal gasification plants with partial CO2 separation and sequestration. Further analysis would be needed to estimate the amount of replacement capacity needed, as this depends on the CO2 and economic characteristics of the replacement resources.

Policy	2020 Target (MMtCO2)	Reduction Needed (MMtCO2)[11]	Equivalent Coal Capacity (MW)
WCI - 15% below actual 2005 by 2020	57	7	910
WCI - 15% below normal 2005 by 2020	50	17	2330
WA - 1990 by 2020[12]	44	21	2780
OR - 10% below 1990 by 2020	40	25	3300

Table 2: CO2 reductions from base case (Fifth Power Plan) forecast to achieve various 2020 policy targets

A multipronged effort is required for the industry to cost-effectively achieve the goals of greenhouse gas control policies.[13] This effort must include the following elements:

- Reduction in demand through more aggressive improvements in end-use efficiency.
- Shifting new resource acquisitions to low-carbon resources.
- Reducing the CO2 production of existing fossil generation through efficiency improvements, carbon capture and sequestration, and substituting low-carbon baseload generating capacity.
- Marketing and credit transfer mechanisms to help secure CO2 reductions in other economic sectors and geographic areas where cost-effective.

In short, achieving greenhouse gas control targets economically requires broadening cost-effective resource planning and acquisition to consider a global scope of CO2-reduction options.

While developing mechanisms to facilitate cost-effective global CO2 reduction lies largely outside the control of the Northwest power industry, the following options can be cultivated within the industry:

Expand the supply of cost-effective energy-efficiency measures: An expanded inventory of end-use efficiency options will reduce the growth in demand for electricity, thereby reducing CO2 production from generating resources. Historically, conservation has been among the most cost-effective and abundant of new resource options. New conservation opportunities have continued to unfold even as older opportunities are developed. Production of CO2 from power generation can be reduced by aggressive implementation of existing conservation measures and development of new measures with a focus on those most effective during the hours that CO2 -intensive generating resources are on the margin.

Existing low-carbon generating resources: The efficiency, energy output, and operating life of existing low-carbon resources can be improved. For example, each percentage point increase in the capacity factor of Columbia Generating Station will offset approximately 0.05 million tons of CO2 per year.[14] Opportunities to improve the efficiency and capacity, and extend the life of the region's existing biomass, hydropower, and nuclear resources can be explored and pursued where cost-effective.

New renewable generation: Expanding the supply and improving the cost-effectiveness of new renewable resources involves concurrent efforts: First, the

[11] Reduction from base case (Fifth Power Plan) 2020 forecast.
[12] Also the target of the proposed Lieberman-Warner America's Climate Security Act.
[13] A recent study by the Electric Power Research Institute provides a very useful illustration of the challenge to significantly reduce power system CO2 emissions. See EPRI, "The Power To Reduce CO2 Emissions: The Full Portfolio," August 2007.
[14] Based on an average systemwide marginal CO2 production rate of 0.9 lb/kWh as estimated by the Council ("Power System Marginal CO2 Production Factors," Northwest Power and Conservation Council, April 2006).

supply of regulation, load following, shaping, and storage capability needed for integrating intermittent resources such as wind, tidal currents, wave, and solar need to be expanded through the development of improved methods of marketing and transferring these services within the existing system. Because the supply of these services will eventually need to be augmented, options for supplying these services, including generation, storage, and load-side proposals such as plug-in hybrid vehicles need to be better understood. Secondly, the capacity of the existing transmission system to serve new renewable resources needs to be expanded by developing products such as a conditional-firm service that more effectively utilizes the existing transmission capacity. New transmission will be needed to serve increasing amounts of remote renewable capacity and to improve the geographic diversity of wind and other intermittent renewable resources. Mechanisms are needed to facilitate planning, financing, and construction of new transmission, including "merchant" transmission primarily serving new resources. Finally, new renewable resources and technologies, including wave and tidal current power production, low temperature and engineered geothermal resources, dedicated energy crops, and more efficient biomass technologies need to be developed.

New fossil generation: Even with aggressive conservation measures and an expanded supply of renewable resources, new, lower-carbon fossil generation may be the most cost-effective source of baseload power. Moreover, gas turbines may be needed to augment the supply of integration services for intermittent renewable resources. Improving the efficiency of conventional gas turbine and pulverized-coal power plants, and commercializing coal gasification and other advanced coal technologies will extend fuel supplies and lower CO2 production at the source.

Carbon capture and sequestration: CO2 capture technology suitable for coal gasification plants is commercially available. However, while technically feasible, CO2 capture for conventional and advanced coal-steam plants and gas turbine plants is at the early demonstration stage. Development and commercialization of CO2 capture technology for all forms of fossil generation need to be accelerated to provide options for both new and retrofit applications.

Bulk CO2 transportation and sequestration has been demonstrated for depleted oil and gas reservoirs. While some oil and gas reservoirs are present in Montana, a greater potential in the Northwest are the basalt flows of the Columbia Basin and Snake River Plain. Additional Northwest potential may be available in deep coal seams, carbonate saline aquifers, oceanic storage, and soil carbon sequestration in croplands, grazing lands, and forests. Work needs to proceed on investigating and field-testing promising sequestration options for the Northwest.

New nuclear generation: A new generation of nuclear plants could provide bulk quantities of carbon-free baseload power. Approximately 30 new nuclear units are proposed for construction in the United States. The license application for the first two has recently been filed with the Nuclear Regulatory Commission and license applications for additional units are expected in 2008. While the first new units completed are likely to be located in the Southeast (a region with less favorable renewable resource potential than the Northwest) and not be completed until 2014-15, new nuclear plants may become attractive to the Northwest once new units are successfully operating and resolution of the spent fuel disposal issue is achieved.

Appendix A: Methodology and Analytical Issues

The CO2 production of each scenario was forecast using the AURORAxmp™ Electric Market Model. Though primarily used to forecast wholesale electricity prices, AURORA is also capable of forecasting pollutant emissions and CO2 production resulting from system operation. AURORA forecasts power prices by simulating the economic dispatch of individual generating units as needed to meet system load. Fuel consumption is tracked because fuel prices are a major component of the variable cost of electricity production with which plant dispatch is evaluated and power prices determined.

CO2 production was calculated using the following emission factors: natural gas 117 lb/MMBtu, fuel oil 166 lb/MMBtu, coal 212 lb/MMBtu, and petroleum coke 225 lb/MMBtu. Complete conversion of fuel carbon to CO2 was assumed. Biomass fuels, including municipal solid waste, are assumed to produce no net CO2. While some of the combustible content of municipal solid waste fuels is of petroleum or non-closed carbon cycle derivation, the small consumption of municipal solid waste for power production in the

Northwest has a negligible effect on net CO_2 production. The CO_2 output of fossil-fueled cogeneration units is based on "fuel charged to power" heat rates—the portion of fuel consumption attributable to electricity production.

With the exception of a sensitivity analysis on water conditions, described later, this work was based on 50-year average hydropower conditions, the medium-case fuel price forecasts, and the medium-case load growth forecasts of the Fifth Power Plan. As a result, the CO_2 production forecasts are representative of long-term averages (to the extent that forecast fuel prices and demand are realized). Actual CO_2 production will vary from the average depending on hydropower conditions, actual fuel prices, and actual loads. As illustrated earlier in Figure 2, CO_2 production is sensitive to hydropower conditions, including runoff patterns. In general, hydropower displaces more thermal energy in good water years than in poor. Heavy spring runoff may displace coal-fired power plants during light springtime load periods, whereas delayed runoff may displace natural gas combined-cycle plants during heavier early summer loads. While economically beneficial because of the higher cost of natural gas, the later runoff would have less impact on CO_2 production because of the lower carbon content of natural gas and the higher thermal efficiency of combined-cycle plants.

A question has been raised regarding the symmetry of the incremental effects on CO_2 production of good and poor hydropower years of equal probability. If incremental CO_2 production effects are not symmetrical, the estimates reported here may be biased, as they are based on average water conditions. A comparable effect has been observed, and is adjusted for, in the Council's electricity price forecasting. While time did not permit comprehensive testing, a limited comparison of forecast CO_2 production in a very good water year to that of a very poor water year indicated a slight increase in the incremental CO_2 production for the poor water year compared to the good water year. While further analysis would be required to confirm the consistency and magnitude of this effect, if true, the CO_2 production estimates reported in this paper would tend to be slightly low.

The geographic scope of the analysis is the WECC interconnected system. Northwest resource development and operational decisions result in operational effects outside the Northwest because of transmission interconnections and Westwide markets. For this reason, CO_2 production results are reported on a WECC basis. "Northwest" results, where reported, include the CO_2 production of units physically located within the four Northwest states, plus the production from large thermal units outside the region dedicated to serving Northwest loads. These include the Jim Bridger plant in Wyoming and the Idaho Power share of the North Valmy plant in Nevada.

The net changes in CO_2 production estimated in this study are the direct effects of power plant fuel consumption. Secondary impacts, not assessed here, may be present (e.g., CO_2 from diesel oil combustion for the rail transportation of additional coal).

Price elasticity may result in reduction of demand due to higher prices caused by carbon taxes, higher-cost low carbon resources, cost of CO_2 allocations, or other factors associated with climate change and policies addressing climate change. While the evaluation of this is beyond the scope of the current study, price elasticity will be considered in the Sixth Power Plan.

California, Oregon, and Washington have adopted policies prohibiting the long-term acquisition by utilities of resources or resource output where the associated CO_2 production exceeds certain defined levels (generally exceeding the CO_2 production of a natural gas-fired combined-cycle plant). Partial account of these carbon content policies is included in current analysis by permitting no new conventional coal plants to be located in California, Oregon or Washington when using the AURORAxmp capacity expansion feature. However, because AURORAxmp does not permit differentiation by resource type of economic inter-regional transfers, there appears to be no effective method of modeling carbon content policies.

Sufficient simple or combined-cycle gas turbine capacity was added in each scenario to maintain the pilot capacity reserve targets of the Resource Adequacy Forum. (The capacity value of wind power was set at 15 percent for these assessments.) This gas turbine capacity would also provide "system flexibility" suitable for integrating intermittent resources. However, it will not be possible to accurately estimate the amount of flexibility augmentation needed to accommodate the intermittent resources of these portfolios until the capability of the existing system to provide intermittent resource integration is better understood. Estimates of the intermittent resource integration capability of the existing system are being refined as part of the Northwest Wind Integration Action Plan. The needed capacity composition of future resource portfolios can be refined as better estimates of the capabilities of the existing system (and likely flexibility demands of future intermittent resources) become available. This information may also support estimates of the likely CO2 production resulting from possible operation of fossil capacity for intermittent resource integration purposes.

Appendix B

	Conservation (aMW)	Coal (MW)	Gas (MW)	Hydro	Wind (MW)	Other (MW)
2005	96		178 (SC)		300	(26) Oil
2006	136	109 (PC)	47 (SC)	14 Hyd (26) Hyd	487	10 Geo 12 Bio
2007	139		745 (CC)	2 Hyd (29) Hyd	440	20 Bio (32) Oil
2008	147		650 (CC)	(23) Hyd		
2009	150			(23) Hyd		
2010	159			(23) Hyd		
2011	161			(23) Hyd	100	
2012	169			(23) Hyd	900	
2013	172			(23) Hyd	400	
2014	176			(23) Hyd	600	
2015	378			(23) Hyd	300	
2016	185	425 (IGCC)		(23) Hyd	1200	
2017	105			(23) Hyd	600	
2018	93			(23) Hyd	400	
2019	89		184 (SC)	(23) Hyd	200	
2020	86		610 (CC)	(23) Hyd	100	
2021	85		644 (SC)	(23) Hyd	300	
2022	84			(23) Hyd	100	
2023	86		276 (SC)	(23) Hyd	100	
2024	85		276 (SC)	(23) Hyd	900	

Table B1: Pacific Northwest resource development schedule for the base case (MW)[15]

[15] Values in brackets are retirements.

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EXHIBIT B

INDEPENDENT SCIENTIFIC ADVISORY BOARD

Review of the Proposed Spill Experiment

February 20, 2014
ISAB 2014-2

Independent Scientific Advisory Board
for the Northwest Power and Conservation Council,
Columbia River Basin Indian Tribes,
and National Marine Fisheries Service
851 SW 6th Avenue, Suite 1100
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Cover photo: McNary Dam spillway by Tony Grover.

ISAB Review of the Proposed Spill Experiment

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ISAB Review of the Proposed Spill Experiment

Review Charge

On December 16, 2013, the Northwest Power and Conservation Council requested that the ISAB review the spill experiment proposed by the State of Oregon, the Nez Perce Tribe, and others for inclusion in the Council's Fish and Wildlife Program. The Council asked that the ISAB consider the following questions:

1. Is the spill experiment proposal, and the postulated increases in fish survival, consistent with scientific methods?[1]

   (a) Does the experiment include an adequately researched hypothesis?
   (b) Is the experiment appropriately designed to test the hypothesis?
   (c) Is the proposed duration of the experiment sufficient?
   (d) Is it possible to isolate spill as the causative factor for changes in fish survival?

2. If not, what adjustments will ensure that the proposal is scientifically based?

3. What are the potential biological risks and/or benefits, particularly focusing on increased total dissolved gas effects on other aquatic species, associated with the proposal?

4. Is the proposed spill experiment likely to add to our existing knowledge regarding spill, juvenile dam passage survival, and adult fish returns (SARs)?

Background

The Council provided the following background information in their review request to the ISAB:

> As part of the Fish and Wildlife Program amendment process, the Council received recommendations, based on CSS studies, from Oregon Department of Fish and Wildlife (ODFW), the Nez Perce Tribe (NPT), the Pacific Fishery Management Council (PFMC), environmental and fishing groups, and individuals calling for implementation of an experimental spill management test. This proposal would increase spring spill levels at each mainstem federal Snake and Columbia River hydropower project up to 125% of total dissolved gas level in the tailrace of each dam or biological constraints, and then monitor survival effects over ten years compared to the current court-ordered spill program. Since 125% total dissolved gas exceeds the Clean Water Act water quality standard, modifications to the standard through regulatory processes by the states of Washington and Oregon would be required.

[1] The ISAB changed the wording of the Council's question from "the scientific method" to "scientific methods."

As proposed, the key elements of the experimental spill management would include:

1. Implementing voluntary spill levels greater than historical levels, particularly in lower flow years. Implementation is proposed to include these facets:

    - What: Increase spill to 125% of total dissolved gas level or biological constraints. As 125% total dissolved gas exceeds water quality criterion, criteria modifications through regulatory processes are required.

    - When: During spring operations (3 April through 20 June) for a period of 10 years with a comprehensive assessment after 5 years.

    - Where: At federal Lower Snake and Lower Columbia River Hydroelectric projects – Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles and Bonneville dams.

2. Utilizing the Comparative Survival Studies (CSS) PIT-tag monitoring framework.

3. Monitoring Smolt-to-Adult survival rates.

4. Comparing survival rates against both past survival rates and prospective model predictions.

5. Evaluating whether empirical observations are consistent with the predicted benefits of higher voluntary spill levels.

6. Inclusion of sideboards or “off-ramps” to ensure hydrosystem power generation viability as well as “on-ramps” that facilitate non-hydro renewable energy sources into the power system to offset impacts from increased spill levels.

Review Approach

To conduct the review, the ISAB received briefings and reviewed scientific documents explaining, supporting, and critiquing the spill study. On November 15, 2013, the Comparative Survival Study (CSS) team presented analyses related to the spill test to the ISAB. This presentation was part of the ISAB’s ongoing role in reviewing CSS and Fish Passage Center reports and analyses, primarily annual reports. This presentation occurred before the Council’s December 2014 review request but proved effective in introducing the ISAB to the spill study and supporting analyses. On January 17, 2014, the Bonneville Power Administration (BPA) and the U.S. Army Corps of Engineers (COE) briefed the ISAB on the performance standards, monitoring efforts, and study results related to dam and reach specific survival. Dr. John Skalski also briefed the ISAB on the results of his statistical analysis of the proposed spill test. The ISAB created a file accessible to the public containing the ISAB’s review materials. This proved effective in creating a dialogue and facilitating sharing of literature among the ISAB and entities involved in salmon passage studies, hydrosystem operations, and dissolved gas regulation. The ISAB greatly appreciates the briefings, literature shared, and robust exchange of information.

Overview

Potential Biological or Other Benefits

- Prospective modeling of the proposed spill test by the CSS team suggests that increasing spill levels up to 125% total dissolved gas may enable smolt-to-adult-return ratios (SARs) to reach the 4% biological goal for steelhead and approach the 4% goal for Chinook.
- Knowledge gained through experimental spill management could be generalized to inform operations at other dams.

Potential Biological or Other Risks

- The spill test may *not* result in increased SARs as the justification for the proposed test is based on correlative models that do not establish causality.
- There may be inadequate information gained to justify the cost due to study design limitations and lack of a detailed study and monitoring plan.
- The spill test could result in unintended consequences, including:
    - greater adverse gas bubble disease (GBD) effects on salmonids, native resident fish and/or aquatic life;
    - increased delay and/or predation of juvenile fish in tailraces;
    - increased fallback and/or passage delays of adult salmon at the dams;
    - difficulty in holding spill levels at desired levels, for example in a low water year;
    - increased spillway erosion problems;
    - possible navigation issues for commercial and juvenile fish transportation barges at dams;
    - possible effect on Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) operations or smolt transportation actions because increasing spill will reduce the number of fish collected for transportation;
    - future engineering changes to juvenile fish passage at dams could confound results from this spill test.

Additional Issues

- A detailed study plan needs to be developed by the proponents. The lack of details and lack of synthesis in the material presented leads the ISAB and others to raise questions (see unintended consequences listed above) that might have otherwise been addressed if a comprehensive study plan was developed.
- The Oregon and Washington water quality standards for total dissolved gas (TDG) would need to be modified with NOAA Fisheries concurring.
- Regional work and agreement would be needed on:
    - the study design including how long the test should run to provide convincing evidence of an increase in SARs that is due to increased spill;
    - an monitoring and evaluation plan for TDG, biological and physical parameters; and
    - changes to dam-specific spill patterns.

ISAB Answers to Council Questions

1. **Is the spill experiment proposal, and the postulated increases in fish survival, consistent with scientific methods?**

    (a) Does the experiment include an adequately researched hypothesis?

The spill experiment proposal does not provide enough evidence for the ISAB to conclude that the experiment includes an adequately researched hypothesis. A complete study design, including detailed hypotheses and review of the literature, was not presented to the ISAB. Additional effort is needed to fully vet the experimental spill hypotheses and methodology. An action of this importance requires development of a complete description of the study design that addresses issues presented in this ISAB review and those raised by other stakeholders in the region (Skalski et al. 2013; BPA/COE 2014 and Skalski 2014, presentations to the ISAB).

The effects on salmonids of passing through dam spillways, turbines, and fish bypass routes have been investigated for decades including analyses by CSS that are documented in annual reports and peer-reviewed publications, reach survival studies by NOAA Fisheries, and dam passage survival evaluations by the Corps of Engineers. The results of these studies need to be synthesized and integrated into a more complete proposal as a means to evaluate the regression analyses and modeling presented by the CSS.

In the proposed spill test, recent regression analyses (Haeseker et al. 2012) are used to support the hypothesis that an increased percentage of water spilled over dams leads to higher survival of in-river migrants. Presumably, the experimental spill hypothesis is that increasing spill targets up to 125% TDG will lead to higher SARs of spring-summer Chinook and steelhead compared with SARs observed in years leading up to the spill test period, after adjusting for confounding variables such as ocean conditions and other juvenile fish passage improvements at the dams. Simulation modeling, based on recent peer-reviewed models and assumptions within, suggests that increasing spill levels up to 125% TDG in each of the dam tailraces would lead to considerably higher SARs of spring-summer Chinook and steelhead compared with observed SARs and SARs estimated based on simulations of BiOp operations (see Fig. 1 below from Schaller PPT to ISAB, Nov 15, 2013). This modeling effort, based on existing data, should be used to establish specific quantitative hypotheses for testing. The model simulations should be updated with recent years of data prior to beginning the potential spill test. Furthermore, the degree to which the hypotheses rely on extrapolation should be discussed. For example, in the published modeling reports, how frequently were SAR estimates available when spills were at or near 125% TDG? Also, it may be worthwhile to compare model predictions with expectations from studies directly examining survival of salmonids passing through spill, turbines, and the bypass system (Muir et al. 2001, Marotz et al. 2007, WA Dept. of Ecology 2008). The extent to which results from the CSS simulation studies are consistent with the findings in other studies should be evaluated.

Further scrutiny of the analyses and interpretation of the data and models used to justify the spill test is warranted. The spill test was generated primarily in response to regression models that showed that changes in spill percentage were correlated with increases in SARs. There is a potential problem in using the results of a regression equation as the basis for an experiment, especially if sample sizes are small. Regression models based on small sample sizes often overfit the data so the resulting relationships are not applicable to other sets of data. Selection of explanatory variables for multiple regressions must be carefully considered (Skalski et al. 2013) and the resulting models should be interpreted with caution. That said, six freshwater and marine variables examined by Haeseker et al. (2012) – water transit time (WTT), spill, date of migration, upwelling, sea surface temperature (SST), and Pacific Decadal Oscillation (PDO) – had all been identified as important in other studies, so the choice of these variables has support in the literature (Muir et al 2001, Scheuerell and Williams 2005, Schaller and Petrosky 2007, Petrosky and Schaller 2010). Nevertheless, to address alternative hypotheses additional candidate variables need to be evaluated, for example, biological measures of top-down (predation) and bottom-up (primary and secondary productivity) forcing, individual fish (age, growth, and condition), density-dependent effects, and anthropogenic forcing (habitat, harvest, and hatchery).

Some of the explanatory variables in the model operate at the year level (e.g., PDO, upwelling and SST) whereas others operate at the week or period of release level. A more complex model including multiple random effects is likely needed to fully account for the internal correlation structure. By ignoring the multi-level variation, estimates of residual error are likely underestimated, which also may lead to errors in model predictions.

It is assumed that the survival rate experienced by each release group within a year was independent of survival rates experienced by other groups within the same year. However, in reality, survival rates are likely correlated among groups within the same year, as well as autocorrelated over time. Such correlations reduce the effective sample sizes in tests of statistical significance, and failure to account for these effects will increase the uncertainty of the model predictions. The Durbin-Watson test is not appropriate to evaluate autocorrelation as it fails to account for the two levels of explanatory variables needed in the model.

Despite these concerns with the statistical analyses used to support implementation of the spill test, it appears that the increased spill hypothesis stands as a possible candidate for testing. Other changes to hydrosystem operations have so far been inadequate to meet SAR targets required to conserve endangered salmon populations, even with structural changes that have been made at the dams such as surface spill weirs. It appears that increasing the amount of water spilled at lower Columbia and Snake River dams has merit as a hypothesis to test, but additional review of literature and analysis of data would be worthwhile.

Increasing spill is expected to allow a greater proportion of migrants to avoid the powerhouse intakes and speed their migration through forebays. It is uncertain if the proportion of fish that avoid powerhouse intakes continues to increase as spill increases, and how this proportion is affected by changes in flow. That is, how does each project's spill efficiency change with changing flow conditions, and is there a point of diminishing returns in terms of spill and percentage of fish passed over the spillway?

Hypotheses should be developed for how increasing spill levels will affect returning adult salmonids, downstream-migrating steelhead repeat spawners (kelts), adult and juvenile lamprey, and sturgeon that may be influenced by TDG and changes in hydraulic flow patterns at the dams. The level of effort to monitor gas and adult migration effects would depend on a review of the literature and resulting uncertainty about potential adverse effects. The CSS and others presented the ISAB with some ongoing review of TDG effects, but this information should be summarized and presented in the proposal. As well, the spill test should consider whether effects from the proposed increase in spill might compromise the results from other ongoing studies in the basin.

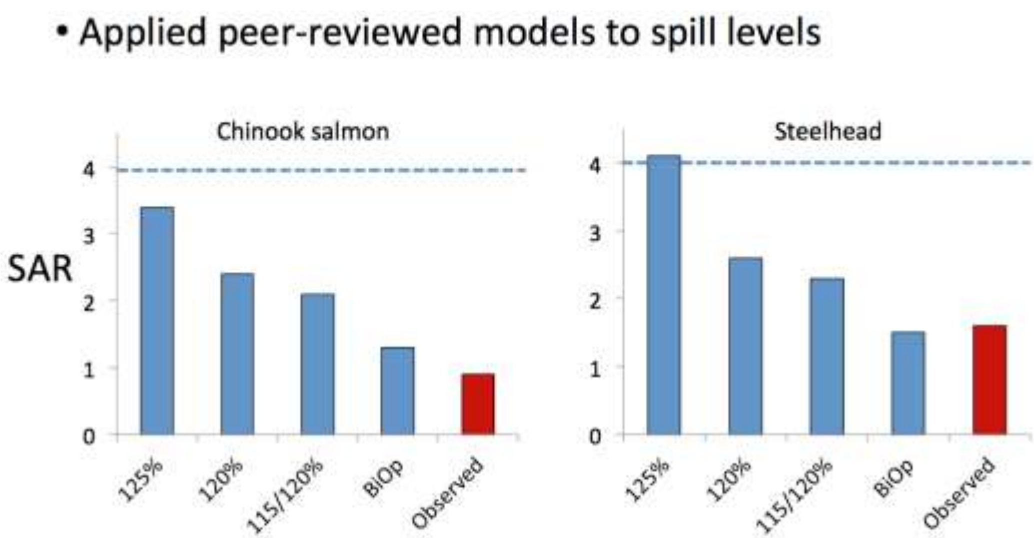

Fig. 1. Modeled SAR estimates of spring Chinook and steelhead in relation to spill levels, based on recent publications by CSS members. Source: Schaller PPT to ISAB, Nov 15, 2013. These charts presumably describe the spill hypothesis. Values in these charts should be updated with the latest data.

(b) Is the experiment appropriately designed to test the hypothesis?

Details of the proposed experiment are not adequately described or documented in a written proposal, so it is premature for the ISAB to determine if the study design is appropriate. First, as discussed above, the specific hypotheses to be tested are not adequately described. Second, due perhaps to practical limitations in devising controls for treatments, what is proposed is not a rigorous experiment but a test of a management action whose effects, ideally, will be evaluated.

It is not clear why a more rigorous experiment with controls has not been proposed. The proposed action is limited to levels of spill at each dam which result in 125% TDG in the tailrace rather than to vary the spill more systematically or consider designing a regime of alternating high/low spill years. This proposal does not discuss the merits of alternative designs, for example varying the level of spill in some years or split-spill studies where only some dams have increased spill. Such a discussion would illustrate the constraints under which such experiments operate and why some may not be feasible. If these and other experimental designs have been considered and discarded, then these efforts should be noted and the reasons for dismissing them identified.

A problem in comparing SARs during the experimental period (with spill targets set at 125% TDG) to SARs during the pre-spill test period is that the pre-spill test period may not be an adequate control because ocean and environmental conditions are likely to be considerably different. Ocean conditions have a major impact on SARs beyond in-river factors. The models attempt to account for ocean effects with independent variables such as the PDO, but considerable variability undoubtedly remains, which will lower the power and reliability of the test. The CSS may be aware of this, but it would be worthwhile to discuss the issue in a proposal and justify the use of SARs to assess results and testing hypotheses in a realistic time frame. Presumably, in-river survival also will be measured, as in past CSS studies. In-river survival estimates are more direct measures of the spill effect, though they cannot detect changes in delayed mortality.

Multiple lines of evidence based on different approaches should be considered. SARs for John Day, Mid-Columbia, and Snake populations could be compared to better estimate the magnitude of the effect of higher spill on reach survivals and SARs. SARs for John Day River populations (passing 3 dams) and Snake River populations (passing 8 dams) were previously compared to infer the deleterious effects of dams. Although this historical comparison was potentially confounded by other factors associated with location in the basin and stock differences, an experimental contrasting manipulation of spill levels that changed SARs in the predicted direction would provide some evidence of the influence of spill. In addition, other modeling approaches should be considered such as using the ratio of SAR for transported fish to SAR for in-river fish (TIR). Although transported fish are influenced by in-river conditions upstream of the transportation collection site and below Bonneville Dam that are positively correlated with percentage spill, most of these fish do not directly experience any spillway passage.

The proposed study offers an opportunity to use adaptive management that might improve SARs of threatened and endangered salmon ESUs and increase knowledge for future decisions. This situation seems to fit the criteria for true adaptive management, as outlined in papers like those by Kendall (2001), Runge (2011) and Tyre et al. (2011). First, there is certainty about the goal (increase SARs), but uncertainty remains about the ecological in-river and ocean survival processes that affect SARs. Therefore, the project should be designed to reduce critical uncertainties. Second, there are competing models that make contrasting predictions. Alternative actions could be identified and applied, and then the models updated periodically, using for example Bayesian analysis, leading to learning that feeds back to management.

(c) Is the proposed duration of the experiment sufficient?

The question of whether the study duration is sufficient to conclude that increased spill to the 125% TDG provides a meaningful increase in SARs for spring/summer Chinook and steelhead should be evaluated by the CSS in a study proposal. Existing data and hypothesized effects can be used to evaluate whether 10 years is adequate.

Ocean conditions are not controllable, so some estimate of the expected change in SARs due to increased spill under poor, average, or good ocean conditions is needed. For example, suppose that a warm phase of the PDO was to begin at the start of the test and last for many years. Or, what if a PDO regime shift occurs several times during the 10-year study period? Would this improve or hinder the chances of detecting effects after 10 years?

(d) Is it possible to isolate spill as the causative factor for changes in fish survival?

It is unlikely that overall changes in SARs can be isolated to conclude that spill is the causative factor for the system. The CSS approach uses correlations which do not by themselves determine cause and effect. There are many confounding factors and indirect effects of spill on fish survival including predation and other mortality in the reservoirs, deployment of new spillway weirs, delayed mortality, ocean conditions, habitat restoration activities, changes in toxic contaminants and other factors.

Nevertheless, multiple lines of evidence including correlations can help support or refute whether spill is a major factor affecting survival of salmonids. Experimental studies in the Basin provide additional information on survival of salmonids passing through spill versus turbines versus the turbine bypass (e.g., Muir et al. 2001). What do these experimental studies tell us and are differences in survival consistent with the CSS study results?

2. If not, what adjustments will ensure that the proposal is scientifically based?

The proponents should be encouraged to prepare a more complete and detailed proposal that addresses issues and concerns that have been put forward by the Action Agencies and stakeholders, partly because details of the study have yet to be described in a document. Several iterations of the proposal may be needed to fully vet issues while providing a rigorous scientific review. The main conceptual issues are 1) lack of an experimental control group, and 2) low statistical power to detect effects given empirical estimates of variation in survival estimates and the survival process itself.

The ISAB appreciates that some options for improving whole system survival cannot be tested with rigor because of practical limitations (they lack controls and sufficient power or sample size). However, such limitations should not, in principle, negate consideration of less rigorous tests. Regardless, proposed actions and monitoring opportunities should be thoroughly considered, with strong adherence to a strategy for adaptive management. Development of a detailed monitoring plan is recommended and needed, especially for areas of high uncertainty, such as the following:

(a) improving detection rates to get better estimates of smolt survival estimates through the hydropower dams and reservoirs. Estimates of the survival of juvenile fish passing the dams via spill or other passage routes are available through COE funded acoustic tag (JSATS) studies of dam passage survival, although dam performance standard studies are not conducted every year. Association of direct juvenile survival past dams with spill should be discernible with appropriately designed monitoring;

(b) monitoring to assess condition of juvenile fish after various passage options to see if the increased spill is having a detrimental effect on fish condition. The issue of possible selectivity of the bypass system whereby fish that enter the dam bypass facility may be injured or somehow weaker than those that pass dams through other passage routes should also be examined;

(c) monitoring of adult salmonids, steelhead kelts, and other fish and other aquatic life to determine the impact of a long period of increased spill and increased total dissolved gas;

(d) evaluation of the proportion of fish passing via spill and all other routes with increased spill;

(e) evaluation of the effect of increased levels of spill on upstream passage of adult fish. New spill patterns could be tested in the hydraulic scale models at Vicksburg and also monitored at the dams during the spill period. Advance testing of the effects of increased spill in hydraulic scale models would be useful not only for estimating impact on upstream fish passage but also for identifying paths that juvenile fish might prefer and to reduce predation risk to juvenile fish in downstream eddies and tailwaters;

(f) related to (d), monitoring predation risk of fish in relation to increased spill;

(g) at this time models probably cannot predict fish survival at 125% TDG levels since empirical data on such high spill levels over the 2.5 month spring migration period are not available. However, collecting appropriate data that can be used in models will enable predictions in the future.

3. What are the potential biological risks and/or benefits, particularly focusing on increased total dissolved gas effects on other aquatic species, associated with the proposal?

The proposed spill test should consider the potential impact on other species, such as fall Chinook and sockeye salmon, sturgeon, lamprey, and other aquatic life. Hypotheses should be developed on how spill maintained at 125% TDG for several months might affect each species and life stage, and a detailed biological monitoring plan should be developed to test the hypotheses.

Consideration of potential biological risks will not be easy because the effects of TDG are influenced by variables in the physical environment and the development and behavior of animals of concern. Foremost among these variables is the depth at which the organisms are exposed. Generally, one meter of depth protects aquatic organisms from the effects of 10% TDG via hydrostatic compensation (Weitkamp et al. 2003). For example, if TDG is 120% at the surface, fish at a depth of 2 m will experience 100% TDG. Backman et al. (2002) found that juvenile salmon collected from the forebays (where TDG was 115%) or tailraces (TDG = 120%)

of Columbia River dams had fewer signs of gas bubble disease (GBD) than did fish from the bypass systems of those dams. The authors attributed this disparity to the shallow water in the bypass systems. Steelhead kelts might be particularly affected as the majority passes FCRPS dams through traditional spill routes and spillway weirs (Colotelo et al. 2013). Fish depth behavior may protect them from adverse effects when they come to the surface. That is, time spent at depth protects fish from time spent at the surface (Knittel et al. 1980). This relation between GBD and depth also confounds interpretation of field and laboratory studies because most aquatic organisms are collected in shallow water (Weitkamp 2008) and, in order to control for the effects of hydrostatic compensation, most laboratory studies have been completed in shallow water tanks, for example depths of 0.25m (Mesa et al. 2000; Beeman et al. 2003).

Field studies can offer some insight into potential biological risks associated with high levels of TDG on aquatic organisms, especially fish. Field studies using cages in which fish were able to go to various depths attempt to approximate fish in the wild. Kokanee fry in 9-m deep cages suffered no mortalities even though TDG reached 125% (Weitkamp et al. 2000 cited in Weitkamp 2008, page 10). Schrank et al. (1997, 1998) held juvenile salmonids and several non-salmonid resident fish species in cages with various depths and found that even at TDG as high as 130 to 138%, GBD was low (~6%) in fish held 2 to 3 m deep for four days. Backman et al. (2002) looked at GBD in over 20,000 juvenile salmonids collected from the Snake and Columbia rivers and dams and regressed the incidence of GBD against TDG that varied from 100% to greater than 130%. Their regression suggests that at 125% one would see GBD in fewer than 5% of the fish. Backman and Evans (2002) examined over 8,000 adult steelhead, sockeye, and Chinook salmon below Bonneville Dam when TDG varied between 111% to greater than 130% and found less than 1% with GBD until TDG exceeded 126%. When TDG was between 126% and 130%, incidence of GBD increased in steelhead (~4%) and sockeye (~8%), but in Chinook salmon incidence of GBD stayed < 1%.

Uncontrolled spill at the high-head Libby Dam resulted in TDG between 124% and 131% (Martoz et al. 2007). Signs of GBD in five resident salmonid species and four non-salmonids increased to greater than 90% over the 19 days of spill. However, there were no differences in population estimates or growth of bull trout or *Oncorhynchus* spp. sampled two years before and a year after the high spill (Marotz et al. 2007). Weitkamp (2008) pointed out that, in most studies, signs of GBD are poorly correlated with rate of fish mortality. He points out, however, that historically when TDG has caused significant mortalities in the wild, dead fish were seen. In the Columbia River, a low proportion of fish have been observed with GBD, and it is unlikely that significant mortalities have occurred. However, it is possible that fish condition or health is compromised leading to increased predation.

Studies that have tracked fish depth using radio telemetry showed that juvenile salmonids emigrate at 1.5 to 3.2 m depth (Beeman and Maule 2006), adult salmonids immigrate greater than 2 m deep (Johnson et al. 2005) and a variety of resident fish were found between 2 to 6.8 m deep (Beeman et al. 2003). Thus, it appears that the migratory behavior of juvenile and adult salmonids will help protect them from adverse effects of TDG. There is, however, recent research conducted during uncontrolled spill in 2011, when water below Bonneville Dam had

TDG as high as 134%. The researchers used acoustic telemetry to examine survival of juvenile salmonids in two tests: (1) fish were collected, tagged and transported from Lower Granite Dam then released approximately 10 km below Bonneville Dam into water with TDG at about 115% (low exposure) or about 125% (high exposure); and (2) fish were collected, tagged and released at Bonneville Dam into water with TDG about 118% (low) or about 132% (high). In the Bonneville Dam comparison, daily mortality rate in the lower river was higher in fish when TDG was greater than 130%. In the transported groups, daily mortality rates did not differ in fish as they migrated in the lower river. Daily mortality rates of the high exposure groups were higher than that of the low exposure group in both tests during the fish's migration in the Columbia River plume (Ian Brosnan, Cornell University, personal communication of unpublished data). While these data have not yet been published (they are in review for publication), they suggest that mortality of smolts exposed to TDG greater than 125% may lead to decreased survival beyond the Columbia River, that is, delayed mortality.

Few studies have considered the effects of TDG on amphibians, invertebrate species, or other fish species. Colt et al. (1984, 1987) studied effects of elevated TDG and reported no mortalities in tadpoles (*Rana catesbeiana*) held at about 122% TDG for 4 days. Adult bullfrogs suffered no mortalities at about 117% after 4 days, but 40% died after 1 day at about 132%. Several studies indicated that aquatic invertebrates are much less sensitive to high TDG than are fish (Nebeker et al. 1981; Schrank et al. 1997; Ryan et al. 2000). Ryan et al. (2000) collected over 5,400 invertebrates from the Columbia and Snake rivers at depths less than 0.6 m. They reported finding signs of GBD in only 7 (0.1%) individuals when TDG ranged from 120% to more than 135%. White et al. (1991, as cited in McGrath et al. 2006) found a shift in abundances of some invertebrate species before and after exposure to TDG. However, these effects could have been the result of increased water velocity or changing water temperature (White et al. 1991 as cited in Weitkamp 2008). There is also concern for larval/fry fish in shallow areas with elevated TDG. Studies have shown that bubbles formed in sturgeon larva (Counihan et al. 1998) and sucker fry (Schrank et al. 1998) and interfered with their buoyancy, which could lead to displacement in the habitat or increased vulnerability to predation. While it is assumed that lamprey migrate near the benthos, it is not clear if studies have documented the depth at which lamprey migrate and, thus, the degree to which hydrostatic compensation protects them from GBD.

4. **Is the proposed spill experiment likely to add to our existing knowledge regarding spill, juvenile dam passage survival, and adult fish returns (SARs)?**

It is likely that a spill test would enhance knowledge about spill, juvenile passage survival, and SARs. A spill test could also increase knowledge in other ways if appropriate monitoring is conducted. The ISAB agrees with the 2013 CSS Workshop conclusion that the experimental design and implementation should "focus on maximizing the amount of learning that can be achieved," where "learning" is the "likelihood of detecting a response." Here again, this situation seems to fit the need for true adaptive management as mentioned above. Alternative covariates and analytical approaches need to be identified and discussed. A preferred alternative action could be identified and applied, and then the models updated periodically, leading to learning that feeds back to management.

Currently, water quality standards and the desire to produce hydropower constrain the amount of water spilled over the dams. CSS annual reports and published papers, however, suggest that increased spill will lead to higher survival of spring Chinook and steelhead. This is a reasonable hypothesis. Nevertheless, as noted under Question 1.A., a detailed and adequately researched hypothesis for the spill experiment is needed, including consideration of alternative hypotheses. Given the potential importance of this study and concerns raised by the Action Agencies and a variety of stakeholders, further vetting of the study design and methodology in a study proposal would be worthwhile as a means to maximize knowledge gained by an experiment. Without a carefully designed experiment that reflects consideration of all possible alternative outcomes, an unexpected result might preclude drawing firm conclusions about the effect of increasing spill.

The ISAB cannot assess whether the ten-year study proposed by CSS is sufficient to detect a meaningful improvement in salmon survival because a detailed proposal has yet to be prepared. However, if adequate monitoring is implemented along with the spill, there should be increased knowledge regarding spill, juvenile salmonid dam passage survival, impacts on adult fish passage and other species, and total dissolved gas effects.

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EXHIBIT C

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September 19, 2018

MEMORANDUM FOR: F/NWR5 – Ritchie Graves

FROM: F/NWC3 - Richard W. Zabel   Richard W. Zabel

SUBJECT: Preliminary survival estimates for the passage of spring-migrating juvenile salmonids through Snake and Columbia River dams and reservoirs, 2018

This memorandum summarizes conditions in the Snake and Columbia Rivers and preliminary estimates of survival of PIT-tagged juvenile salmonids passing through reservoirs and dams during the 2018 spring outmigration. We also provide preliminary estimates of the proportion of Snake River smolts that were transported from Snake River dams in 2018. Our complete detailed analyses and report for the spring migration will follow this memo at a later date. As in past years, changes in the database between the time of our annual summer memo and the publication of our final report may result in differences of up to 3 or 4% in estimated survival values.

Summary of Research

For survival studies funded by BPA in 2018, NOAA Fisheries PIT tagged 20,249 river-run hatchery steelhead, 15,396 wild steelhead, and 11,823 wild yearling Chinook salmon for release into the tailrace of Lower Granite Dam.

Survival estimates provided in this memorandum are derived from data from fish PIT tagged by or for NOAA Fisheries, as described above, along with fish PIT tagged by others within the Columbia River Basin. Note that for technical reasons, the statistical model for survival estimation can produce estimates that exceed 100%. When this occurs, we report the actual estimate, but for practical purposes these estimates should be interpreted as representing survival probabilities which are less than or equal to 100%.

We have estimated survival probabilities for migrating PIT-tagged salmonids since 1993. In this memo, we compare 2018 estimates in various river segments to averages over periods of years. Estimates are not available for every reach in every year. Unless otherwise noted, when we refer to a long-term average for a particular river segment, the average is across all years for which estimates are available.

PIT-tagged yearling Chinook salmon have been released from the seven Snake River Basin hatcheries Dworshak, Kooskia, Lookingglass/Imnaha Weir, Rapid River, McCall/Knox Bridge, Pahsimeroi, and Sawtooth every year from 1993 through 2018 (except Pahsimeroi in 1996). Across these “index” hatcheries, the annual mean estimated survival from release to Lower Granite Dam has been relatively stable since 1998 (Figure 1, Table 1). In 2018, the mean was 64.8%; this estimate is close to last year’s mean survival to Lower Granite of 65.0% and the overall mean from 1998 through 2018 of 65.1%. The annual mean has ranged from 49.4% in 1997 to 71.7% in 2016 (Figure 1).

Downstream of Lower Granite Dam, mean estimated survival for Snake River yearling Chinook salmon (hatchery and wild combined) in 2018 was slightly above average in the Lower Granite to Little Goose and the Lower Monumental to McNary reaches, and close to average in the Little Goose to Lower Monumental reach (Table 2, Figure 2). However, estimated survival in the McNary to John Day and John Day to Bonneville reaches was substantially lower than average (Table 2, Figure 3). These estimates resulted in average survival from Lower Granite to McNary, but below average survival in the remaining combined reaches of interest (Table 3).

Mean estimated survival for yearling Chinook salmon from Lower Granite Dam tailrace to McNary Dam tailrace in 2018 was 73.3% (95% CI: 68.4-78.2%). Mean estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was 59.0% (50.2-67.8%). Mean estimated survival for yearling Chinook salmon from Lower Granite Dam tailrace to Bonneville Dam tailrace was 43.2% (36.2-

50.3%). Estimated survival for the Lower Granite project (head of reservoir to tailrace) was 88.0%, based on fish PIT tagged at and released from the Snake River trap. The combined yearling Chinook salmon survival estimate from the Snake River trap to Bonneville Dam tailrace was 38.1% (31.6-44.6%), substantially below the long-term average of 48.9%.

For wild Snake River yearling Chinook, mean estimated survival from Lower Granite Dam tailrace to McNary Dam tailrace was 76.0% (95% CI: 69.9-82.1%), and from McNary Dam tailrace to Bonneville Dam tailrace was 76.2% (48.0-104.4%). Estimated survival from the Snake River trap to Lower Granite Dam tailrace was 87.1%, which resulted in estimated survival from the Snake River trap to Bonneville Dam tailrace of 50.4% (31.0-69.9%). This estimate is above the long-term average of 44.8%.

For Snake River steelhead (hatchery and wild combined), mean estimated survival in 2018 was above average in every individual reach and all resulting combined reaches, though the estimate for the John Day to Bonneville reach was very uncertain (Table 4, Figures 2 and 3). Mean estimated survival for steelhead from Lower Granite Dam tailrace to McNary Dam tailrace was 73.3% (95% CI: 67.2-79.4%). Mean estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was 72.7% (50.8-94.7%). The combined Snake River steelhead survival estimate from the Snake River trap to Bonneville Dam tailrace was 52.4% (35.8-69.0%), which was above the long-term average of 45.6% (Table 5).

For wild Snake River steelhead, mean estimated survival from Lower Granite Dam tailrace to McNary Dam tailrace was 73.6% (95% CI: 58.9-88.3%), and from McNary Dam tailrace to Bonneville Dam tailrace was 82.2% (55.5-108.9%). Estimated survival from the Snake River trap to Lower Granite Dam tailrace was 84.8%, which resulted in estimated survival from the Snake River trap to Bonneville Dam tailrace of 51.3% (30.5-72.1%).

For PIT-tagged hatchery yearling Chinook salmon originating from the upper Columbia River in 2018, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was 74.9% (95% CI: 60.2-93.2%; Table 6), which was below the long-term average of 81.4%.

For PIT-tagged hatchery steelhead originating from the upper Columbia River in 2018, estimated survival from McNary Dam tailrace to Bonneville Dam tailrace was 116.1% (95% CI: 85.0-158.6%; Table 6). This estimate has high uncertainty; however, unlike Columbia River Chinook, even the low end of the confidence range is above the long-term average of 77.4%.

For fish released from upper Columbia River hatcheries, we cannot estimate survival in reaches upstream from McNary Dam (other than the overall reach from release to McNary Dam tailrace) because of limited PIT-tag detection capabilities at Mid-Columbia River PUD dams.

Estimated survival in 2018 of Snake River sockeye salmon (hatchery and wild combined) from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam was 64.3% (95% CI: 30.4-50.8%; Table 7). Estimated survival in 2018 of Columbia River sockeye salmon (hatchery and wild combined) from the tailrace of Rock Island Dam to the tailrace of Bonneville Dam was 66.7% (40.7%-61.5%; Table 7). Both estimates were above their respective long-term averages of 40.6% and 51.1%.

Our preliminary estimates of the percentage transported of non-tagged wild and hatchery spring-summer Chinook salmon smolts in 2018 are 44.1% and 45.4%, respectively. For steelhead, the estimates are 47.5% and 46.4% for wild and hatchery smolts, respectively. These estimates represent the percentage of smolts that arrived at Lower Granite Dam that were subsequently transported, either from Lower Granite Dam or downstream at Little Goose or Lower Monumental Dam.

Discussion

For Snake River yearling Chinook salmon in 2018, estimated survival from Lower Granite Dam tailrace to Bonneville Dam tailrace was 43.2%; this estimate is substantially below the long-term (1999-2018) average of 52.1%. Yearling Chinook survival through the hydropower system has been consistently below the mean for the past four years, despite a range of different environmental conditions within these years. These low system survival estimates seem to be driven mostly by poor survival in the McNary to Bonneville reach.

For Snake River steelhead in 2018, estimated survival from Lower Granite Dam tailrace to Bonneville Dam tailrace was 53.3%; above the long-term mean of 47.0% (Table 5). This above-average estimate follows three consecutive years of survival estimates below the mean.

Estimated survival of Snake River sockeye between Lower Granite Dam and Bonneville Dam tailrace was 64.3%, which is the third highest estimate we have in our time series (1998-2018). The component survival estimates for the Lower Granite Dam to McNary Dam reach and the McNary Dam to Bonneville Dam reach were both above average. This above-average estimate follows three consecutive years with very low survival. The Idaho Department of Fish and Game has adjusted their acclimation methods this year in order to address the causes of the low Snake River Sockeye survival from the past three years; their efforts almost certainly contributed to the higher survival estimate this year. Survival of juvenile Upper Columbia River sockeye in the McNary to Bonneville Dam reach was also above average.

Environmental conditions in 2018 resulted in a year with average water temperatures, but high flow and very high spill for most of the migration season. Mean flow at Little Goose Dam in 2018 during the main migration period (1 April–15 June) was 110.8 kcfs, which was well above the long-term (1993-2018) mean of 92.6 kcfs. Daily flow values were above long-term daily means for most of the migration period; daily flow approached the mean for a brief period in early May and fell below the mean after the beginning of June (Figure 4). Mean water temperature at Little Goose Dam in 2018 during the migration period was 11.5 °C, which was near the long-term mean of 11.2 °C. Daily water temperatures generally tracked the long-term daily mean, alternating between slightly above and slightly below the mean through April and May, then remaining slightly above the long-term mean during June (Figure 4).

Mean spill discharge at the Snake River dams during the 2018 migration was 41.3 kcfs, which was substantially above the long-term (1993-2018) mean of 27.7 kcfs. Daily spill discharges remained above the long-term daily mean throughout April and May, with peaks in early May and again near the end of May (Figure 5).

Spill as a percentage of flow at Snake River dams averaged 37.2% in 2018, which was above the long-term (1993-2018) mean of 27.2. Daily mean spill percentages in 2018 were above the long-term daily means for almost the entire migration period (Figure 5), with higher percent spill during early April than in any previous year.

Estimated percentages of yearling Chinook salmon and steelhead transported from Snake River dams in 2018 were substantially higher than in most recent years; 2018 saw one of the highest transportation rates since 2006 (Figure 7). This reversed the recent trend of very low transportation rates seen from 2015-2017.

In 2018, collection of transportation began on 23 April at Lower Granite, Little Goose, and Lower Monumental Dams, which was 8 days earlier than the May 1st start date from most recent years, and the earliest start date for the transportation program since 2006. We estimate that 45% of the annual total passage of wild yearling Chinook and 24% of hatchery yearling Chinook occurred at Lower Granite Dam before transportation began (Figure 6), compared to averages between 2006-2014 of 42% and 31%, respectively. It is worth noting that the percentages passing in 2018 are near average, despite the fact that transportation began earlier in 2018 than in any year in that period except 2006. We estimate that 38% of wild steelhead arrived before transportation began in 2018 (Figure 6), versus the 2006-2014 average of 29%, and 24% of hatchery steelhead versus the average of 33%.

After the beginning of transportation in 2018, higher-than-average proportions of smolts were collected for transportation. This was due to the combination of spill operations and river conditions experienced by the fish as they passed the collector dams. The combination of early transportation start date and relatively higher collection proportions during transportation resulted in the increased percentages of smolts transported in 2018.

Median estimated travel times for both species between Lower Granite Dam and Bonneville Dam in April in 2018 continued the trend from recent years and were substantially shorter than the long-term mean for most of the migration period (1997-2017; Figure 8). These short travel times coincided with the generally high flows and spills in 2018. When flow levels declined at the beginning of June, travel times converged with the mean of recent years.

Since the institution of court-ordered spill in 2006, and the concurrent installation of surface collectors at four additional federal dams during that period, travel times have decreased on average between Lower Granite and Bonneville dams for steelhead, but the effect is less apparent for Chinook (Figure 8). Differences in travel times for low-flow years versus other years are not so well pronounced for either species (Figure 8). Day in season is a stronger predictor of travel time for Chinook than either flow or spill. Some of the lowest flow years were also low-spill years that occurred before the new spill regime, so the effect of average flow on travel time is difficult to separate from that of spill by simply inspecting the figures without the assistance of a statistical model. Flow and spill also vary within season, so categorizing years by seasonal averages is not optimal, but it does allow for some simple visual comparisons.

cc: F/NWC3 – Faulkner
F/NWC3 – Marsh
F/NWC3 – Smith
F/NWC3 – Widener
F/NWC3 – Zabel

Table 1. Estimated survival and standard error (s.e.) for yearling **Chinook** salmon released at Snake River Basin and Upper Columbia River hatcheries to Lower Granite Dam tailrace (LGR) and McNary Dam tailrace (MCN), 2016 through 2018.

	2016		2017		2018[a]	
Hatchery	Survival to LGR (s.e.)	Survival to MCN (s.e.)	Survival to LGR (s.e.)	Survival to MCN (s.e.)	Survival to LGR (s.e.)	Survival to MCN (s.e.)
Dworshak	0.714 (0.007)	0.538 (0.014)	0.693 (0.013)	0.402 (0.015)	0.744 (0.015)	0.546 (0.023)
Kooskia	0.684 (0.012)	0.499 (0.029)	0.565 (0.025)	0.351 (0.040)	0.633 (0.030)	0.438 (0.044)
Lookingglass (Catherine Cr.)	0.371 (0.005)	0.300 (0.016)	0.420 (0.014)	0.303 (0.024)	0.314 (0.008)	0.232 (0.024)
Lookingglass (Grande Ronde)	0.429 (0.016)	0.326 (0.044)	0.398 (0.032)	0.352 (0.096)	0.347 (0.013)	0.238 (0.043)
Lookingglass (Imnaha River)	0.704 (0.007)	0.526 (0.022)	0.585 (0.020)	0.438 (0.041)	0.651 (0.012)	0.429 (0.034)
Lookingglass (Lostine River)	0.586 (0.017)	0.419 (0.039)	0.553 (0.029)	0.409 (0.067)	0.600 (0.014)	0.418 (0.057)
McCall (Johnson Cr.)	---	---	---	---	0.487 (0.029)	0.370 (0.104)
McCall (Knox Bridge)	0.654 (0.006)	0.514 (0.014)	0.700 (0.012)	0.528 (0.021)	0.702 (0.011)	0.519 (0.026)
Pahsimeroi	0.772 (0.008)	0.512 (0.026)	0.746 (0.012)	0.560 (0.041)	0.634 (0.015)	0.342 (0.034)
Rapid River	0.815 (0.005)	0.632 (0.015)	0.652 (0.010)	0.528 (0.020)	0.651 (0.009)	0.491 (0.023)
Sawtooth	0.676 (0.006)	0.474 (0.015)	0.606 (0.010)	0.466 (0.025)	0.519 (0.013)	0.372 (0.029)
Entiat	---	0.631 (0.024)	---	0.639 (0.040)	---	0.572 (0.037)
Winthrop	---	0.577 (0.022)	---	0.578 (0.031)	---	0.587 (0.046)
Leavenworth	---	0.501 (0.016)	---	0.540 (0.022)	---	0.658 (0.038)

a. Estimates are preliminary and subject to change.

Table 2. Annual weighted means of survival probability estimates for yearling **Chinook** salmon (hatchery and wild combined), 1995–2018. Standard errors in parentheses. Reaches with asterisks comprise two dams and reservoirs (i.e., two projects); the following column gives the square root (i.e., geometric mean) of the two–project estimate to facilitate comparison with other single–project estimates. Abbreviations: Trap–Snake River Trap; LGR–Lower Granite Dam; LGO–Little Goose Dam; LMO–Lower Monumental Dam; IHR–Ice Harbor Dam; MCN–McNary Dam; JDA–John Day Dam; TDA–The Dalles Dam; BON–Bonneville Dam. Simple arithmetic means across all available years (1993–2018) are given.

Year	Trap–LGR	LGR–LGO	LGO–LMO	LMO–MCN*	LMO–IHR IHR–MCN	MCN–JDA	JDA–BON*	JDA–TDA TDA–BON
1995	0.905 (0.010)	0.882 (0.004)	0.925 (0.008)	0.876 (0.038)	0.936	NA	NA	NA
1996	0.977 (0.025)	0.926 (0.006)	0.929 (0.011)	0.756 (0.033)	0.870	NA	NA	NA
1997	NA	0.942 (0.018)	0.894 (0.042)	0.798 (0.091)	0.893	NA	NA	NA
1998	0.925 (0.009)	0.991 (0.006)	0.853 (0.009)	0.915 (0.011)	0.957	0.822 (0.033)	NA	NA
1999	0.940 (0.009)	0.949 (0.002)	0.925 (0.004)	0.904 (0.007)	0.951	0.853 (0.027)	0.814 (0.065)	0.902
2000	0.929 (0.014)	0.938 (0.006)	0.887 (0.009)	0.928 (0.016)	0.963	0.898 (0.054)	0.684 (0.128)	0.827
2001	0.954 (0.015)	0.945 (0.004)	0.830 (0.006)	0.708 (0.007)	0.841	0.758 (0.024)	0.645 (0.034)	0.803
2002	0.953 (0.022)	0.949 (0.006)	0.980 (0.008)	0.837 (0.013)	0.915	0.907 (0.014)	0.840 (0.079)	0.917
2003	0.993 (0.023)	0.946 (0.005)	0.916 (0.011)	0.904 (0.017)	0.951	0.893 (0.017)	0.818 (0.036)	0.904
2004	0.893 (0.009)	0.923 (0.004)	0.875 (0.012)	0.818 (0.018)	0.904	0.809 (0.028)	0.735 (0.092)	0.857
2005	0.919 (0.015)	0.919 (0.003)	0.886 (0.006)	0.903 (0.010)	0.950	0.772 (0.029)	1.028 (0.132)	1.014
2006	0.952 (0.011)	0.923 (0.003)	0.934 (0.004)	0.887 (0.008)	0.942	0.881 (0.020)	0.944 (0.030	0.972
2007	0.943 (0.028)	0.938 (0.006)	0.957 (0.010)	0.876 (0.012)	0.936	0.920 (0.016)	0.824 (0.043)	0.908
2008	0.992 (0.018)	0.939 (0.006)	0.950 (0.011)	0.878 (0.016)	0.937	1.073 (0.058)	0.558 (0.082)	0.750
2009	0.958 (0.010)	0.940 (0.006)	0.982 (0.009)	0.855 (0.011)	0.925	0.866 (0.042)	0.821 (0.043)	0.906
2010	0.968 (0.040)	0.962 (0.011)	0.973 (0.019)	0.851 (0.017)	0.922	0.947 (0.021)	0.780 (0.039)	0.883
2011	0.943 (0.009)	0.919 (0.007)	0.966 (0.008)	0.845 (0.012)	0.919	0.893 (0.026)	0.766 (0.080)	0.875
2012	0.928 (0.012)	0.907 (0.009)	0.939 (0.010)	0.937 (0.016)	0.968	0.915 (0.023)	0.866 (0.058)	0.931
2013	0.845 (0.031)	0.922 (0.012)	0.983 (0.014)	0.904 (0.022)	0.951	0.938 (0.058)	0.827 (0.043)	0.909
2014	0.905 (0.015)	0.940 (0.007)	0.919 (0.010)	0.894 (0.017)	0.946	0.912 (0.053)	0.752 (0.104)	0.867
2015	0.909 (0.103)	0.857 (0.036)	0.964 (0.057)	0.802 (0.033)	0.896	0.724 (0.069)	0.937 (0.160)	0.968
2016	0.936 (0.015)	0.956 (0.006)	0.912 (0.100)	0.872 (0.013)	0.934	0.796 (0.039)	0.871 (0.047)	0.933
2017	NA	0.916 (0.009)	0.908 (0.013)	0.912 (0.024)	0.956	0.720 (0.041)	0.871 (0.200)	0.933
2018[a]	0.880 (0.022)	0.942 (0.013)	0.917 (0.019)	0.877 (0.036)	0.936	0.770 (0.074)	0.743 (0.100)	0.862
Mean[b]	**0.930 (0.008)**	**0.928 (0.006)**	**0.922 (0.009)**	**0.863 (0.011)**	**0.929 (0.006)**	**0.860 (0.019)**	**0.806 (0.024)**	**0.896 (0.014)**

a. Estimates are preliminary and subject to change.
b. For each river segment, simple arithmetic mean is across all years for which estimates are available for that segment. Annual estimates for 1993 and 1994 are omitted from the table for space.

Table 3. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River yearling **Chinook** salmon (hatchery and wild combined), 1997–2018. Standard errors in parentheses. Abbreviations: Trap–Snake River Trap; LGR–Lower Granite Dam; MCN–McNary Dam; BON–Bonneville Dam.

Year	Trap–LGR	LGR-MCN	MCN-BON	LGR–BON	Trap–BON
1997	NA	0.653 (0.072)	NA	NA	NA
1998	0.924 (0.011)	0.770 (0.009)	NA	NA	NA
1999	0.940 (0.009)	0.792 (0.006)	0.704 (0.058)	0.557 (0.046)	0.524 (0.043)
2000	0.929 (0.014)	0.760 (0.012)	0.640 (0.122)	0.486 (0.093)	0.452 (0.087)
2001	0.954 (0.015)	0.556 (0.009)	0.501 (0.027)	0.279 (0.016)	0.266 (0.016)
2002	0.953 (0.022)	0.757 (0.009)	0.763 (0.079)	0.578 (0.060)	0.551 (0.059)
2003	0.993 (0.023)	0.731 (0.010)	0.728 (0.030)	0.532 (0.023)	0.528 (0.026)
2004	0.893 (0.009)	0.666 (0.011)	0.594 (0.074)	0.395 (0.050)	0.353 (0.045)
2005	0.919 (0.015)	0.732 (0.009)	0.788 (0.093)	0.577 (0.068)	0.530 (0.063)
2006	0.952 (0.011)	0.764 (0.007)	0.842 (0.021)	0.643 (0.017)	0.612 (0.018)
2007	0.943 (0.028)	0.783 (0.006)	0.763 (0.044)	0.597 (0.035)	0.563 (0.037)
2008	0.992 (0.018)	0.782 (0.011)	0.594 (0.066)	0.465 (0.052)	0.460 (0.052)
2009	0.958 (0.010)	0.787 (0.007)	0.705 (0.031)	0.555 (0.025)	0.531 (0.025)
2010	0.968 (0.040)	0.772 (0.012)	0.738 (0.039)	0.569 (0.032)	0.551 (0.038)
2011	0.943 (0.009)	0.746 (0.010)	0.687 (0.065)	0.513 (0.049)	0.483 (0.046)
2012	0.928 (0.012)	0.790 (0.016)	0.802 (0.051)	0.634 (0.042)	0.588 (0.040)
2013	0.845 (0.031)	0.781 (0.016)	0.792 (0.071)	0.622 (0.052)	0.525 (0.048)
2014	0.905 (0.015)	0.768 (0.015)	0.715 (0.107)	0.549 (0.083)	0.497 (0.075)
2015	0.909 (0.103)	0.680 (0.035)	0.629 (0.043)	0.428 (0.037)	0.389 (0.055)
2016	0.936 (0.015)	0.752 (0.011)	0.672 (0.060)	0.505 (0.046)	0.473 (0.043)
2017	NA	0.743 (0.019)	0.643 (0.157)	0.478 (0.117)	NA
2018[a]	0.880 (0.022)	0.733 (0.025)	0.590 (0.045)	0.432 (0.036)	0.381 (0.033)
Mean[b]	**0.930 (0.008)**	**0.738 (0.012)**	**0.695 (0.019)**	**0.521 (0.020)**	**0.489 (0.020)**

a. Estimates are preliminary and subject to change.
b. For each river segment, simple arithmetic mean is across all years for which estimates are available for that segment. Annual estimates for 1993-1996 are omitted from the table for space.

Table 4. Annual weighted means of survival probability estimates for **steelhead** (hatchery and wild combined), 1995–2018. Standard errors in parentheses. Reaches with asterisks comprise two dams and reservoirs (i.e., two projects); the following column gives the square root (i.e., geometric mean) of the two–project estimate to facilitate comparison with other single–project estimates. Abbreviations: Trap–Snake River Trap; LGR–Lower Granite Dam; LGO–Little Goose Dam; LMO–Lower Monumental Dam; IHR–Ice Harbor Dam; MCN–McNary Dam; JDA–John Day Dam; TDA–The Dalles Dam; BON–Bonneville Dam. Simple arithmetic means across all available years (1993–2018) are given.

Year	Trap–LGR	LGR–LGO	LGO–LMO	LMO–MCN*	LMO–IHR IHR–MCN	MCN–JDA	JDA–BON*	JDA–TDA TDA–BON
1995	0.945 (0.008)	0.899 (0.005)	0.962 (0.011)	0.858 (0.076)	0.926	NA	NA	NA
1996	0.951 (0.015)	0.938 (0.008)	0.951 (0.014)	0.791 (0.052)	0.889	NA	NA	NA
1997	0.964 (0.015)	0.966 (0.006)	0.902 (0.020)	0.834 (0.065)	0.913	NA	NA	NA
1998	0.924 (0.009)	0.930 (0.004)	0.889 (0.006)	0.797 (0.018)	0.893	0.831 (0.031)	0.935 (0.103)	0.967
1999	0.908 (0.011)	0.926 (0.004)	0.915 (0.006)	0.833 (0.011)	0.913	0.920 (0.033)	0.682 (0.039)	0.826
2000	0.964 (0.013)	0.901 (0.006)	0.904 (0.009)	0.842 (0.016)	0.918	0.851 (0.045)	0.754 (0.045)	0.868
2001	0.911 (0.007)	0.801 (0.010)	0.709 (0.008)	0.296 (0.010)	0.544	0.337 (0.025)	0.753 (0.063)	0.868
2002	0.895 (0.015)	0.882 (0.011)	0.882 (0.018)	0.652 (0.031)	0.807	0.844 (0.063)	0.612 (0.098)	0.782
2003	0.932 (0.015)	0.947 (0.005)	0.898 (0.012)	0.708 (0.018)	0.841	0.879 (0.032)	0.630 (0.066)	0.794
2004	0.948 (0.004)	0.860 (0.006)	0.820 (0.014)	0.519 (0.035)	0.720	0.465 (0.078)	NA	NA
2005	0.967 (0.004)	0.940 (0.004)	0.867 (0.009)	0.722 (0.023)	0.850	0.595 (0.040)	NA	NA
2006	0.920 (0.013)	0.956 (0.004)	0.911 (0.006)	0.808 (0.017)	0.899	0.795 (0.045)	0.813 (0.083)	0.902
2007	1.016 (0.026)	0.887 (0.009)	0.911 (0.022)	0.852 (0.030)	0.923	0.988 (0.098)	0.579 (0.059)	0.761
2008	0.995 (0.018)	0.935 (0.007)	0.961 (0.014)	0.776 (0.017)	0.881	0.950 (0.066)	0.742 (0.045)	0.861
2009	1.002 (0.011)	0.972 (0.005)	0.942 (0.008)	0.863 (0.014)	0.929	0.951 (0.026)	0.900 (0.079)	0.949
2010	1.017 (0.030)	0.965 (0.028)	0.984 (0.044)	0.876 (0.032)	0.936	0.931 (0.051)	0.840 (0.038)	0.917
2011	0.986 (0.017)	0.955 (0.004)	0.948 (0.010)	0.772 (0.014)	0.879	0.960 (0.043)	0.858 (0.051)	0.926
2012	1.001 (0.026)	0.959 (0.006)	0.914 (0.011)	0.811 (0.022)	0.901	0.814 (0.048)	1.021 (0.148)	1.010
2013	0.973 (0.032)	0.921 (0.020)	0.977 (0.020)	0.739 (0.031)	0.860	0.799 (0.025)	1.026 (0.154)	1.013
2014	1.018 (0.028)	0.953 (0.009)	0.947 (0.024)	0.836 (0.032)	0.914	1.082 (0.080)	0.982 (0.147)	0.991
2015	0.874 (0.046)	0.848 (0.039)	0.834 (0.060)	0.939 (0.073)	0.969	0.792 (0.066)	0.842 (0.050)	0.918
2016	0.998 (0.016)	0.990 (0.007)	0.918 (0.016)	0.813 (0.025)	0.902	0.927 (0.074)	0.709 (0.071)	0.842
2017	NA	0.962 (0.008)	0.943 (0.015)	0.849 (0.022)	0.921	0.941 (0.020)	0.643 (0.040)	0.802
2018[a]	0.983 (0.025)	0.953 (0.007)	0.950 (0.016)	0.823 (0.036)	0.907	0.847 (0.068)	0.949 (0.137)	0.974
Mean[b]	**0.952 (0.011)**	**0.930 (0.010)**	**0.909 (0.012)**	**0.775 (0.027)**	**0.876 (0.018)**	**0.833 (0.038)**	**0.804 (0.032)**	**0.893 (0.018)**

a. Estimates are preliminary and subject to change.
b. For each river segment, simple arithmetic mean is across all years for which estimates are available for that segment. Annual estimates for 1993 and 1994 are omitted from the table for space.

Table 5. Hydropower system survival estimates derived by combining empirical survival estimates from various reaches for Snake River **steelhead** (hatchery and wild combined), 1997–2018. Standard errors in parentheses. Abbreviations: Trap–Snake River Trap; LGR–Lower Granite Dam; MCN–McNary Dam; BON–Bonneville Dam.

Year	Trap–LGR	LGR-MCN	MCN-BON	LGR–BON	Trap–BON
1997	0.964 (0.015)	0.728 (0.053)	0.651 (0.082)	0.474 (0.069)	0.457 (0.067)
1998	0.924 (0.009)	0.649 (0.013)	0.770 (0.081)	0.500 (0.054)	0.462 (0.050)
1999	0.908 (0.011)	0.688 (0.010)	0.640 (0.024)	0.440 (0.018)	0.400 (0.017)
2000	0.964 (0.013)	0.679 (0.016)	0.580 (0.040)	0.393 (0.034)	0.379 (0.033)
2001	0.911 (0.007)	0.168 (0.006)	0.250 (0.016)	0.042 (0.003)	0.038 (0.003)
2002	0.895 (0.015)	0.536 (0.025)	0.488 (0.090)	0.262 (0.050)	0.234 (0.045)
2003	0.932 (0.015)	0.597 (0.013)	0.518 (0.015)	0.309 (0.011)	0.288 (0.012)
2004	0.948 (0.004)	0.379 (0.023)	NA	NA	NA
2005	0.967 (0.004)	0.593 (0.018)	NA	NA	NA
2006	0.920 (0.013)	0.702 (0.016)	0.648 (0.079)	0.455 (0.056)	0.418 (0.052)
2007	1.016 (0.026)	0.694 (0.020)	0.524 (0.064)	0.364 (0.045)	0.369 (0.047)
2008	0.995 (0.018)	0.716 (0.015)	0.671 (0.034)	0.480 (0.027)	0.478 (0.028)
2009	1.002 (0.011)	0.790 (0.013)	0.856 (0.074)	0.676 (0.059)	0.678 (0.060)
2010	1.017 (0.030)	0.770 (0.020)	0.789 (0.027)	0.608 (0.026)	0.618 (0.032)
2011	0.986 (0.017)	0.693 (0.013)	0.866 (0.038)	0.600 (0.029)	0.592 (0.030)
2012	1.001 (0.026)	0.698 (0.020)	0.856 (0.196)	0.597 (0.138)	0.598 (0.139)
2013	0.973 (0.032)	0.645 (0.026)	0.798 (0.112)	0.515 (0.075)	0.501 (0.075)
2014	1.018 (0.028)	0.740 (0.021)	1.023 (0.088)	0.757 (0.069)	0.771 (0.073)
2015	0.874 (0.046)	0.628 (0.033)	0.663 (0.039)	0.416 (0.033)	0.364 (0.034)
2016	0.998 (0.016)	0.730 (0.020)	0.608 (0.040)	0.444 (0.032)	0.443 (0.032)
2017	NA	0.759 (0.019)	0.605 (0.037)	0.459 (0.030)	NA
2018[a]	0.983 (0.025)	0.733 (0.031)	0.727 (0.112)	0.533 (0.085)	0.524 (0.085)
Mean[b]	**0.952 (0.011)**	**0.660 (0.028)**	**0.677 (0.038)**	**0.470 (0.035)**	**0.456 (0.038)**

a. Estimates are preliminary and subject to change.
b. For each river segment, simple arithmetic mean is across all years for which estimates are available for that segment. Annual estimates for 1993-1996 are omitted for space.

Table 6. Estimated survival and standard error (s.e.) through reaches of the lower Columbia River hydropower system for hatchery yearling **Chinook** salmon and **steelhead** originating in the upper Columbia River, 1999–2018. Abbreviations: Rel–Release site; MCN–McNary Dam; JDA–John Day Dam; BON–Bonneville Dam.

	Yearling Chinook Salmon				Steelhead			
Year	Rel–MCN	MCN-JDA	JDA-BON	MCN–BON	Rel–MCN	MCN-JDA	JDA-BON	MCN–BON
1999	0.572 (0.014)	0.896 (0.044)	0.795 (0.129)	0.712 (0.113)	NA	NA	NA	NA
2000	0.539 (0.025)	0.781 (0.094)	NA	NA	NA	NA	NA	NA
2001	0.428 (0.009)	0.881 (0.062)	NA	NA	NA	NA	NA	NA
2002	0.555 (0.003)	0.870 (0.011)	0.940 (0.048)	0.817 (0.041)	NA	NA	NA	NA
2003	0.625 (0.003)	0.900 (0.008)	0.977 (0.035)	0.879 (0.031)	0.471 (0.004)	0.997 (0.012)	0.874 (0.036)	0.871 (0.036)
2004	0.507 (0.005)	0.812 (0.019)	0.761 (0.049)	0.618 (0.038)	0.384 (0.005)	0.794 (0.021)	1.037 (0.112)	0.823 (0.088)
2005	0.545 (0.012)	0.751 (0.042)	NA	NA	0.399 (0.004)	0.815 (0.017)	0.827 (0.071)	0.674 (0.057)
2006	0.520 (0.011)	0.954 (0.051)	0.914 (0.211)	0.871 (0.198)	0.397 (0.008)	0.797 (0.026)	0.920 (0.169)	0.733 (0.134)
2007	0.584 (0.009)	0.895 (0.028)	0.816 (0.091)	0.730 (0.080)	0.426 (0.016)	0.944 (0.064)	0.622 (0.068)	0.587 (0.059)
2008	0.582 (0.019)	1.200 (0.085)	0.522 (0.114)	0.626 (0.133)	0.438 (0.015)	NA	NA	NA
2009	0.523 (0.013)	0.847 (0.044)	1.056 (0.143)	0.895 (0.116)	0.484 (0.018)	0.809 (0.048)	0.935 (0.133)	0.756 (0.105)
2010	0.660 (0.014)	0.924 (0.040)	0.796 (0.046)	0.735 (0.037)	0.512 (0.017)	0.996 (0.054)	0.628 (0.038)	0.626 (0.033)
2011	0.534 (0.010)	1.042 (0.047)	0.612 (0.077)	0.637 (0.077)	0.435 (0.012)	1.201 (0.064)	0.542 (0.101)	0.651 (0.119)
2012	0.576 (0.012)	0.836 (0.035)	1.140 (0.142)	0.953 (0.115)	0.281 (0.011)	0.862 (0.047)	1.240 (0.186)	1.069 (0.159)
2013	0.555 (0.013)	0.965 (0.050)	1.095 (0.129)	1.056 (0.117)	0.384 (0.020)	0.957 (0.071)	0.974 (0.104)	0.932 (0.099)
2014	0.571 (0.013)	0.974 (0.047)	0.958 (0.122)	0.933 (0.114)	0.468 (0.043)	0.883 (0.124)	0.807 (0.153)	0.712 (0.130)
2015	0.512 (0.015)	0.843 (0.043)	1.032 (0.081)	0.870 (0.062)	0.351 (0.019)	0.807 (0.084)	0.707 (0.073)	0.570 (0.043)
2016	0.610 (0.009)	0.857 (0.027)	0.942 (0.068)	0.807 (0.055)	0.416 (0.011)	0.771 (0.037)	0.633 (0.046)	0.487 (0.032)
2017	0.582 (0.013)	0.853 (0.030)	1.107 (0.142)	0.944 (0.120)	0.437 (0.025)	0.880 (0.062)	1.095 (0.210)	0.964 (0.188)
2018[a]	0.608 (0.016)	0.914 (0.044)	0.820 (0.096)	0.749 (0.084)	0.416 (0.021)	0.942 (0.062)	1.232 (0.194)	1.161 (0.186)
Mean[b]	**0.559 (0.012)**	**0.900 (0.022)**	**0.899 (0.042)**	**0.814 (0.031)**	**0.419 (0.014)**	**0.897 (0.029)**	**0.872 (0.057)**	**0.774 (0.050)**

a. Estimates are preliminary and subject to change.
b. For each river segment, simple arithmetic mean is across all years for which estimates are available for that segment.

Table 7. Estimated survival and standard error (s.e.) for **sockeye** salmon (hatchery and wild combined) from Lower Granite Dam tailrace to Bonneville Dam tailrace for fish originating in the Snake River, and from Rock Island Dam tailrace to Bonneville Dam tailrace for fish originating in the upper Columbia River, 1996–2018. Note that this table represents all available data on sockeye; estimates are provided regardless of the precision, which in some years was very poor. Abbreviations: LGR–Lower Granite Dam; MCN–McNary Dam; BON–Bonneville Dam; RIS–Rock Island Dam.

	Snake River Sockeye			Upper Columbia River Sockeye		
Year	LGR-MCN	MCN-BON	LGR-BON	RIS-MCN	MCN-BON	RIS-BON
1996	0.283 (0.184)	NA	NA	NA	NA	NA
1997	NA	NA	NA	0.397 (0.119)	NA	NA
1998	0.689 (0.157)	0.142 (0.099)	0.177 (0.090)	0.624 (0.058)	1.655 (1.617)	1.033 (1.003)
1999	0.655 (0.083)	0.841 (0.584)	0.548 (0.363)	0.559 (0.029)	0.683 (0.177)	0.382 (0.097)
2000	0.679 (0.110)	0.206 (0.110)	0.161 (0.080)	0.487 (0.114)	0.894 (0.867)	0.435 (0.410)
2001	0.205 (0.063)	0.105 (0.050)	0.022 (0.005)	0.657 (0.117)	NA	NA
2002	0.524 (0.062)	0.684 (0.432)	0.342 (0.212)	0.531 (0.044)	0.286 (0.110)	0.152 (0.057)
2003	0.669 (0.054)	0.551 (0.144)	0.405 (0.098)	NA	NA	NA
2004	0.741 (0.254)	NA	NA	0.648 (0.114)	1.246 (1.218)	0.808 (0.777)
2005	0.388 (0.078)	NA	NA	0.720 (0.140)	0.226 (0.209)	0.163 (0.147)
2006	0.630 (0.083)	1.113 (0.652)	0.820 (0.454)	0.793 (0.062)	0.767 (0.243)	0.608 (0.187)
2007	0.679 (0.066)	0.259 (0.084)	0.272 (0.073)	0.625 (0.046)	0.642 (0.296)	0.401 (0.183)
2008	0.763 (0.103)	0.544 (0.262)	0.404 (0.179)	0.644 (0.094)	0.679 (0.363)	0.437 (0.225)
2009	0.749 (0.032)	0.765 (0.101)	0.573 (0.073)	0.853 (0.076)	0.958 (0.405)	0.817 (0.338)
2010	0.723 (0.039)	0.752 (0.098)	0.544 (0.077)	0.778 (0.063)	0.627 (0.152)	0.488 (0.111)
2011	0.659 (0.033)	NA	NA	0.742 (0.088)	0.691 (0.676)	0.513 (0.498)
2012	0.762 (0.032)	0.619 (0.084)	0.472 (0.062)	0.945 (0.085)	0.840 (0.405)	0.794 (0.376)
2013	0.691 (0.043)	0.776 (0.106)	0.536 (0.066)	0.741 (0.068)	0.658 (0.217)	0.487 (0.155)
2014	0.873 (0.054)	0.817 (0.115)	0.713 (0.096)	0.428 (0.056)	0.565 (0.269)	0.242 (0.111)
2015	0.702 (0.054)	0.531 (0.151)	0.373 (0.037)	0.763 (0.182)	0.446 (0.200)	0.340 (0.130)
2016	0.523 (0.047)	0.227 (0.059)	0.119 (0.030)	0.807 (0.082)	0.545 (0.126)	0.448 (0.144)
2017	0.544 (0.081)	0.324 (0.107)	0.176 (0.055)	0.719 (0.113)	0.611 (0.181)	0.500 (0.332)
2018[a]	0.684 (0.061)	0.940 (0.151)	0.643 (0.088)	0.560 (0.112)	0.839 (0.095)	0.667 (0.144)
Mean[b]	**0.628 (0.034)**	**0.566 (0.070)**	**0.406 (0.052)**	**0.668 (0.031)**	**0.729 (0.074)**	**0.511 (0.053)**

a. Estimates are preliminary and subject to change.
b. For each river segment, simple arithmetic mean is across all years for which estimates are available for that segment.

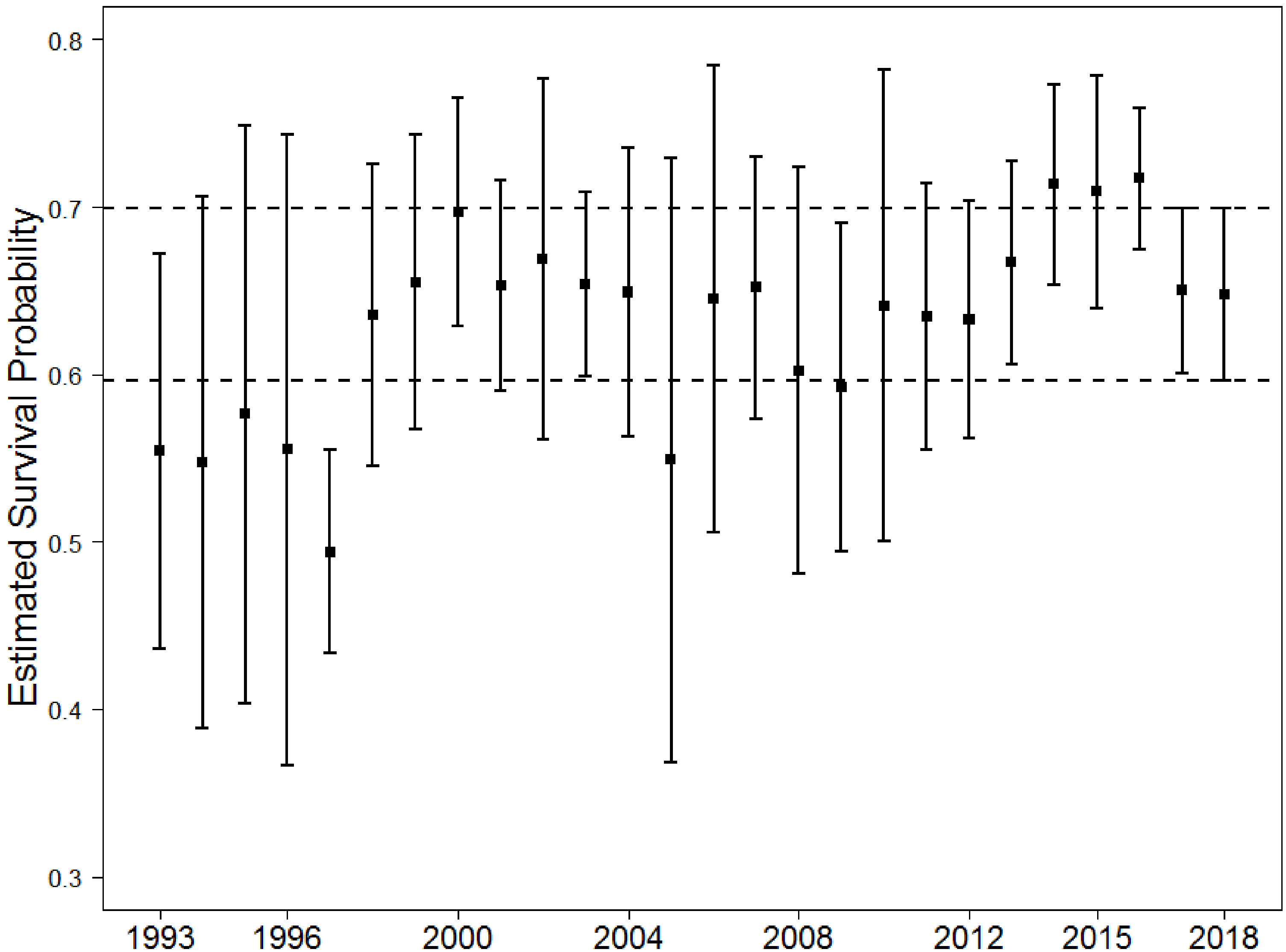

Figure 1. Annual average survival estimates from release to Lower Granite Dam for PIT-tagged yearling **Chinook** salmon released from Snake River Basin hatcheries, 1993-2018. Hatcheries used for average (index groups) are those with consistent PIT-tag releases through the series of years shown. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are the 2018 confidence interval endpoints and are shown for comparison to other years.

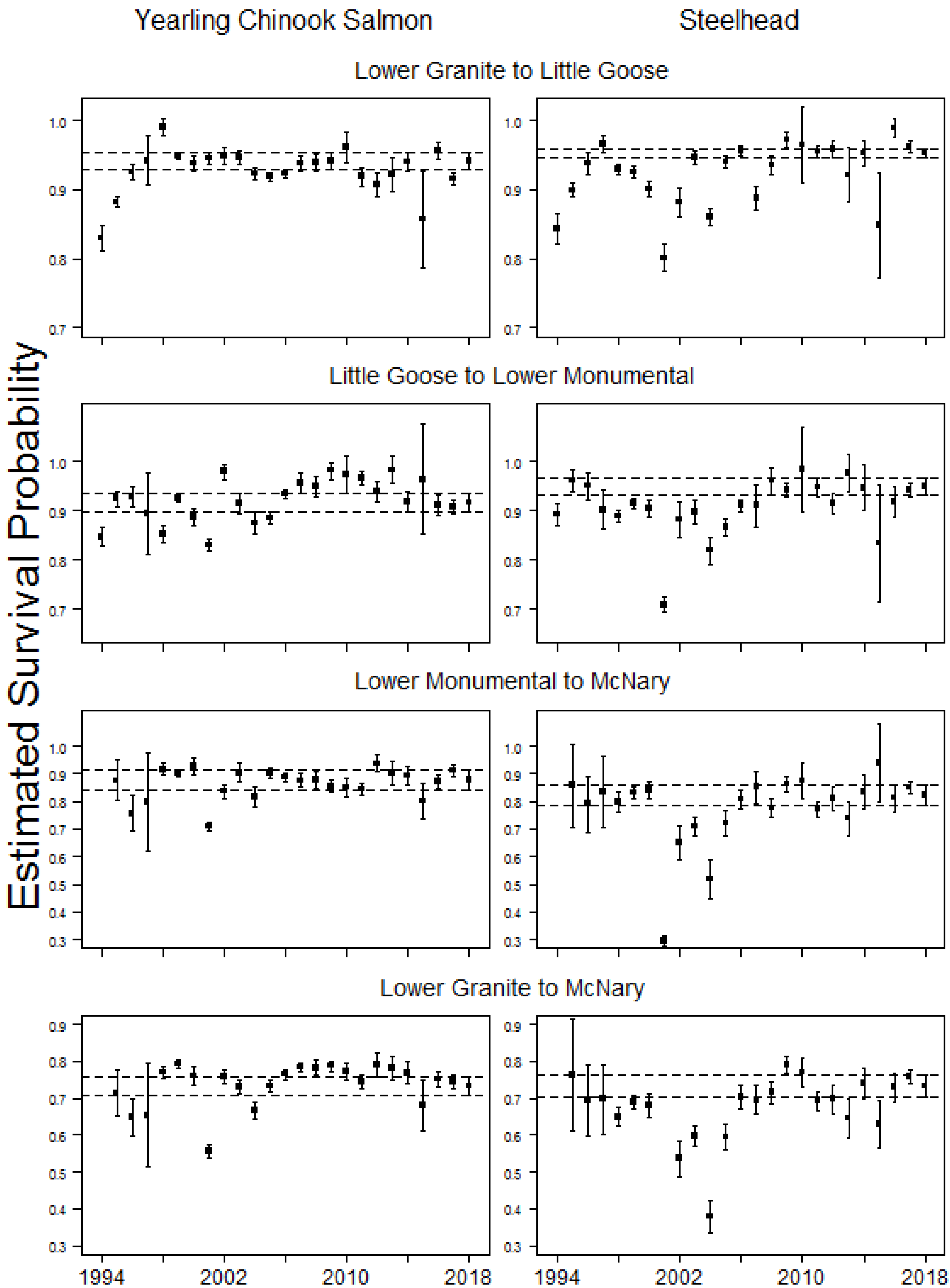

Figure 2. Annual average survival estimates for PIT-tagged yearling **Chinook** salmon and **steelhead**, hatchery and wild fish combined. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are 95% confidence interval endpoints for 2018 estimates.

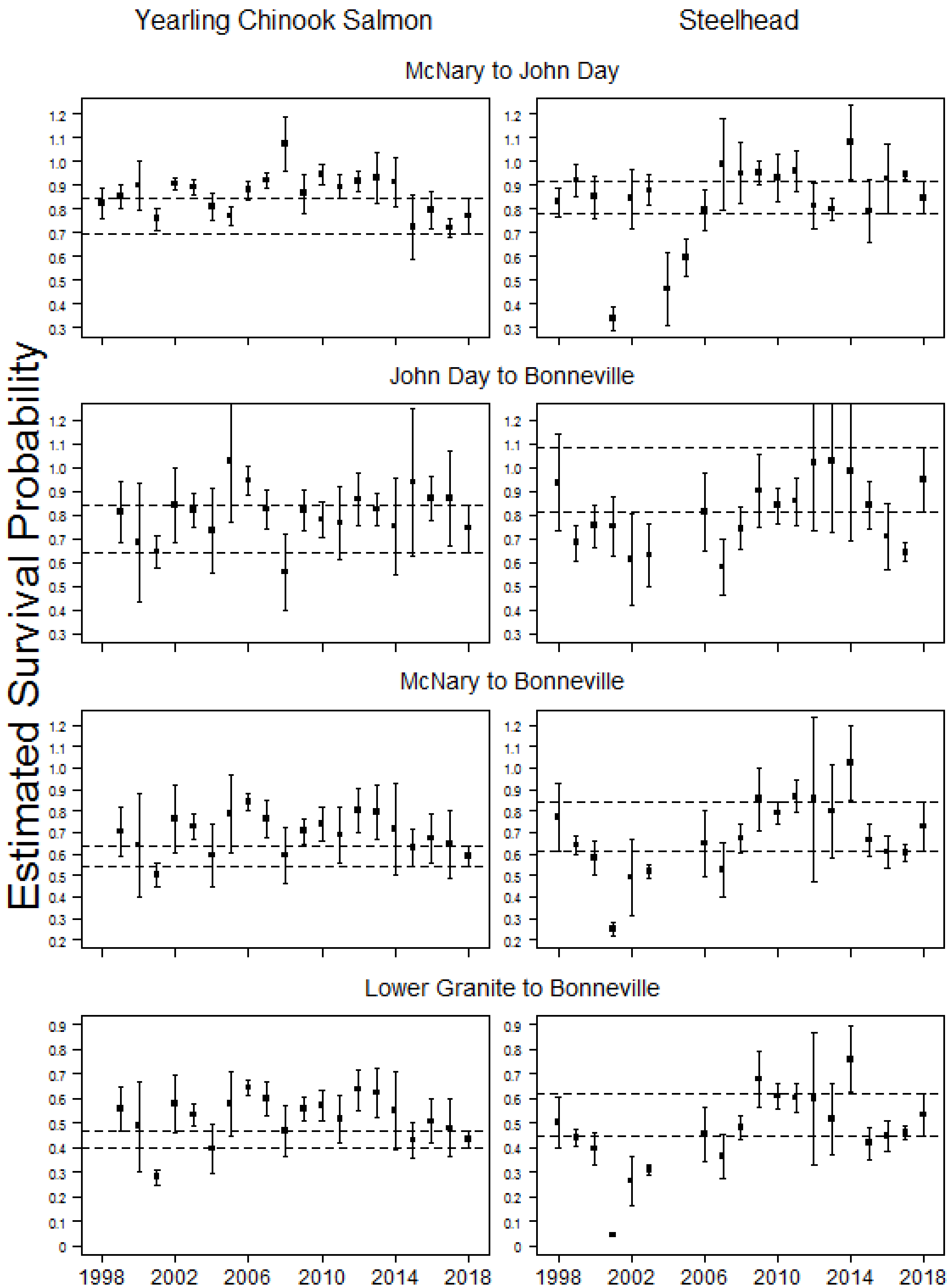

Figure 3. Annual average survival estimates for PIT-tagged yearling **Chinook** salmon and **steelhead**, hatchery and wild fish combined. Vertical bars represent 95% confidence intervals. Horizontal dashed lines are 95% confidence interval endpoints for 2018 estimates.

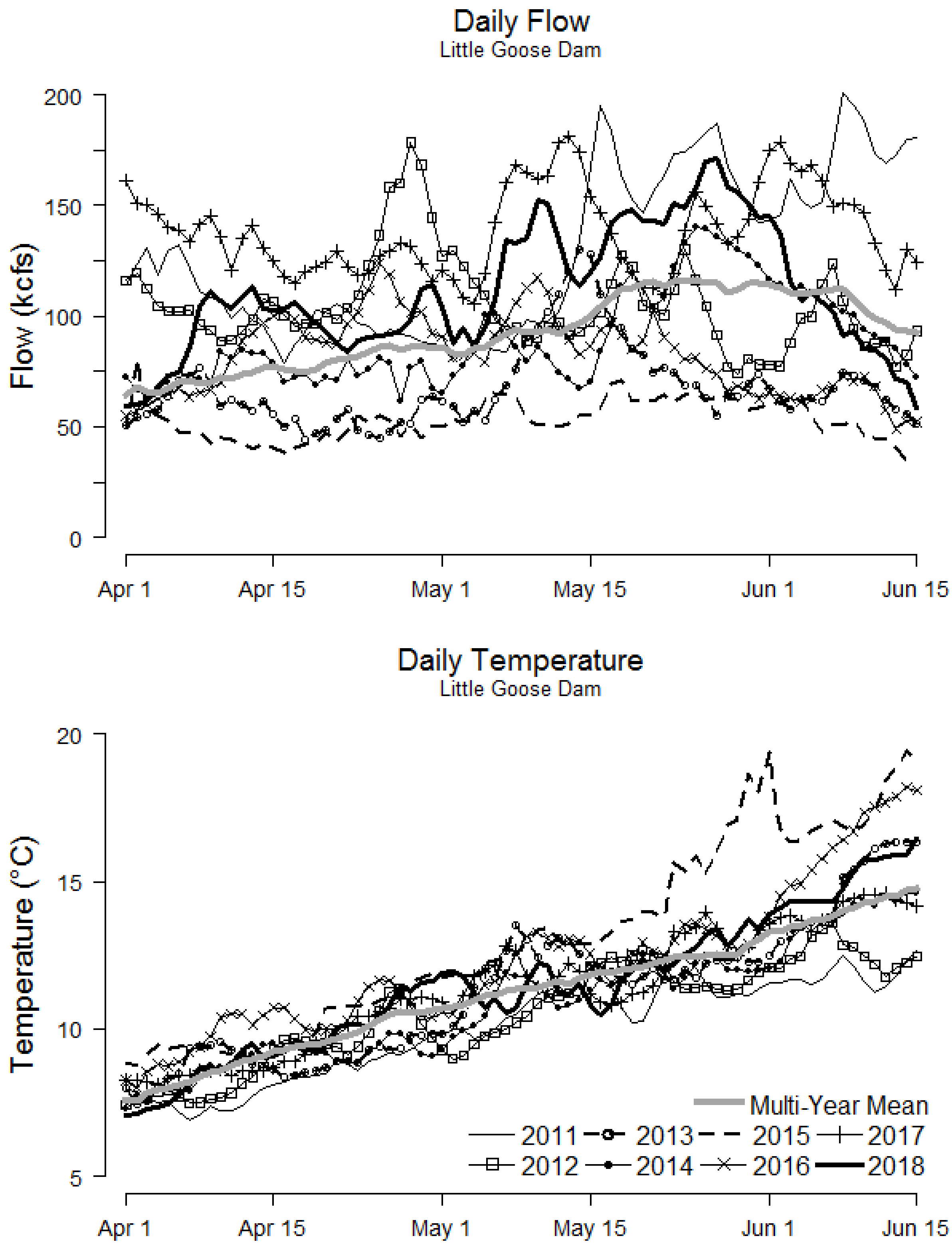

Figure 4. Snake River flow (kcfs; top panel) and water temperature (°C; bottom panel) measured at Little Goose Dam during April and May, 2011-2018, including daily long-term means (1993-2018).

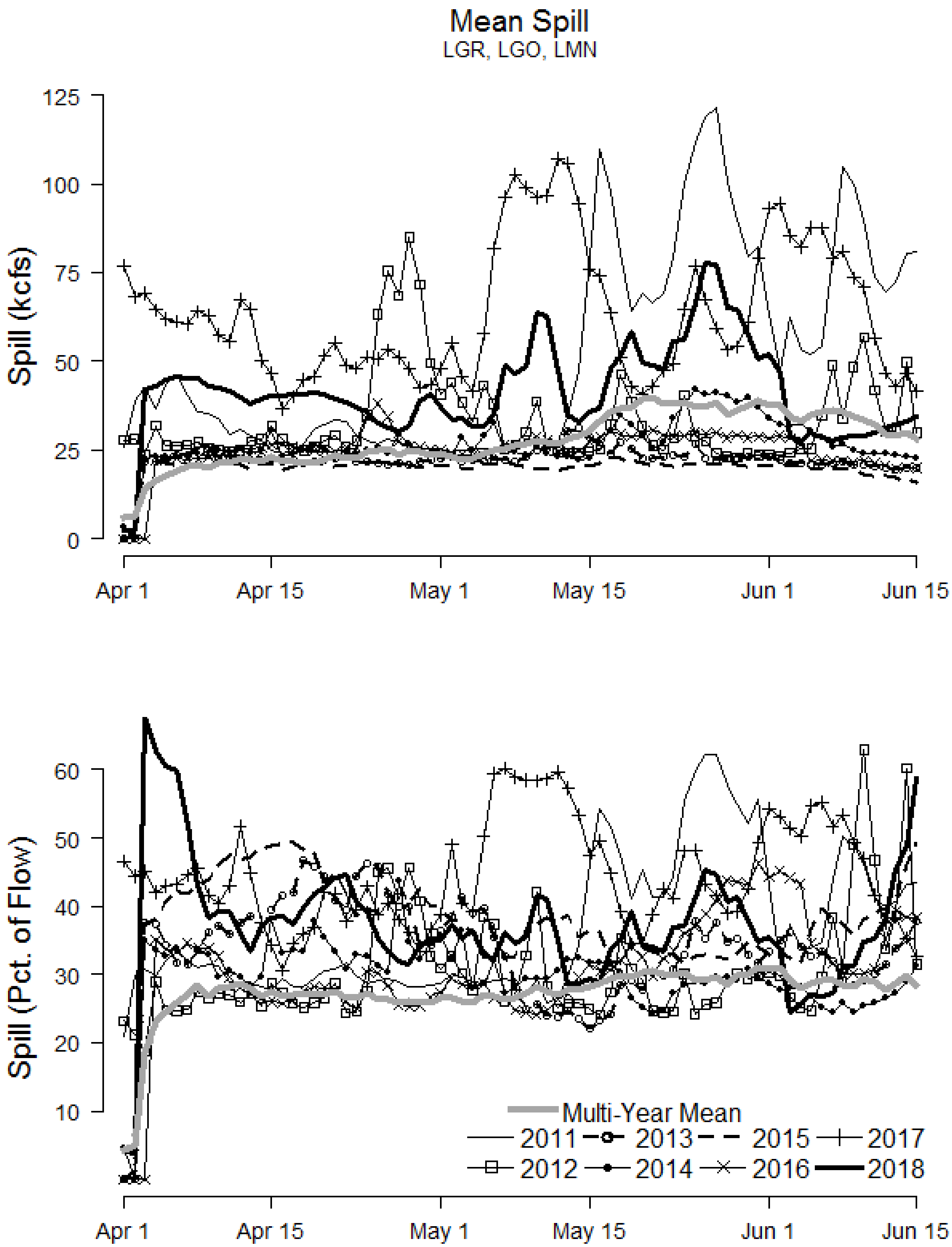

Figure 5. Mean spill (top panel shows kcfs; bottom panel shows percentage of total flow) at Snake River dams during April and May, 2011-2018, including daily long-term means (1993-2018).

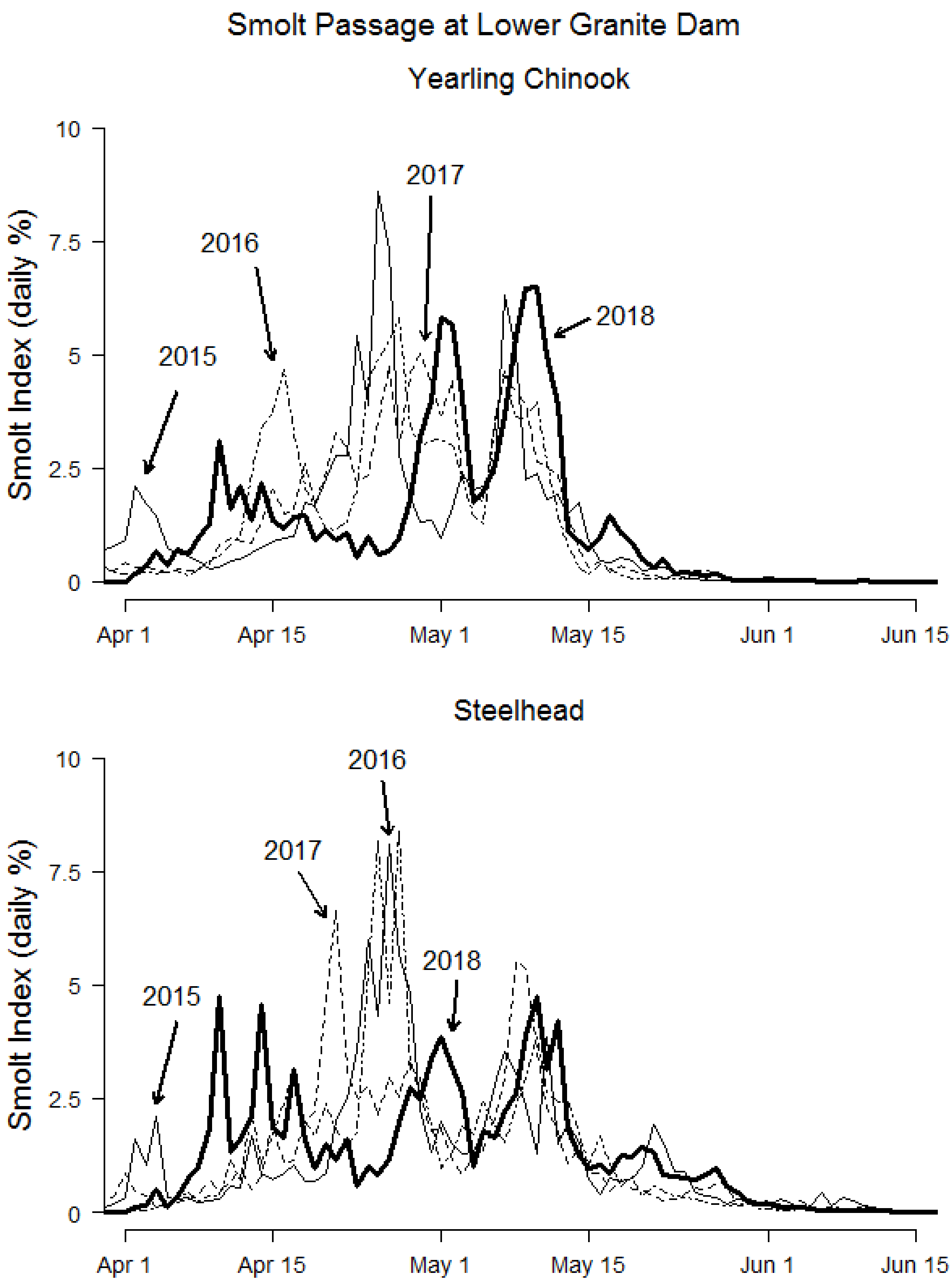

Figure 6. Smolt index as daily percentage of total passage at Lower Granite Dam 2015-2018 for hatchery and wild combined yearling **Chinook** and **steelhead**.

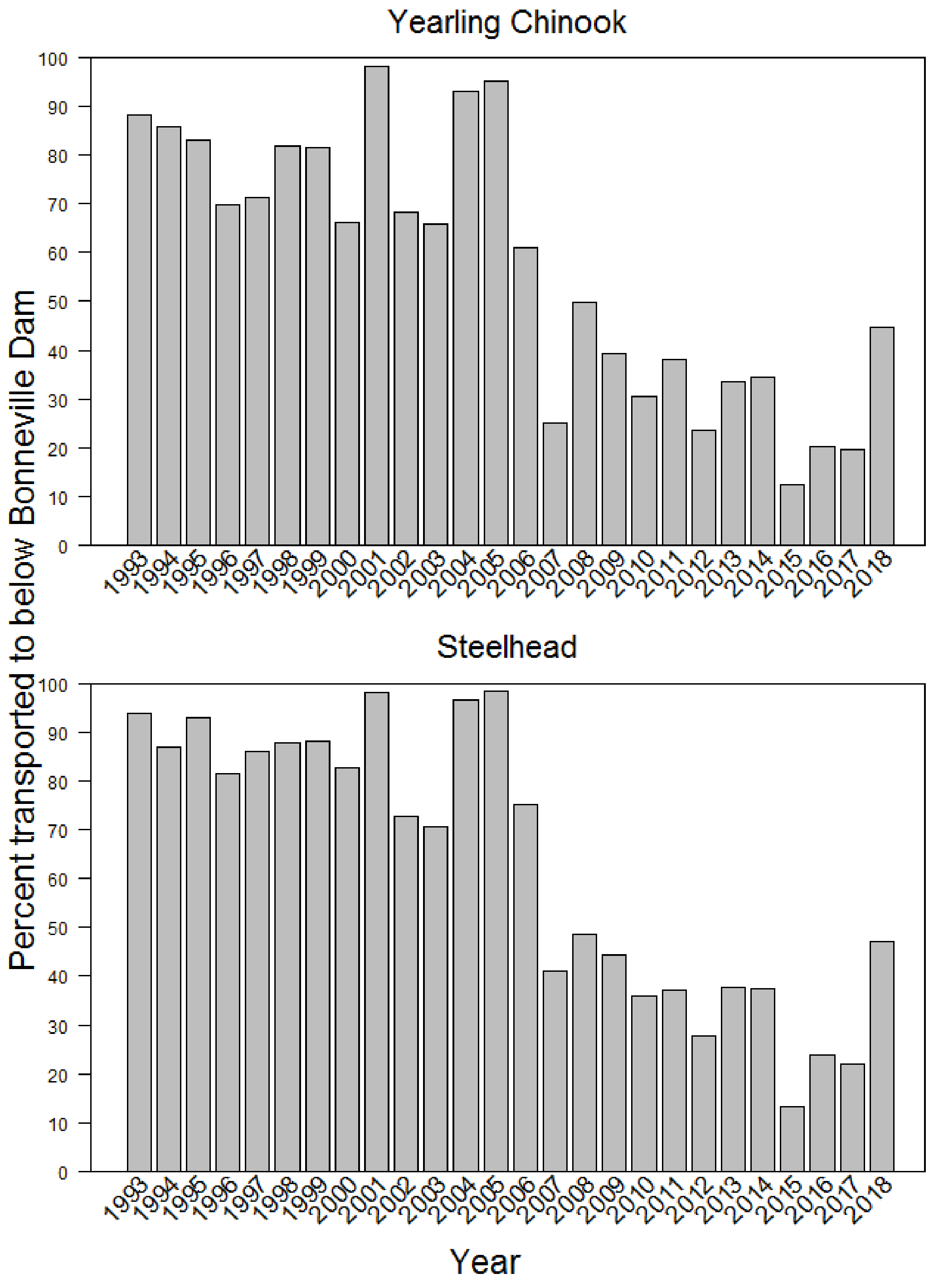

Figure 7. Estimated percent of yearling **Chinook** salmon and **steelhead** (hatchery and wild combined) transported to below Bonneville Dam by year (1993-2018).

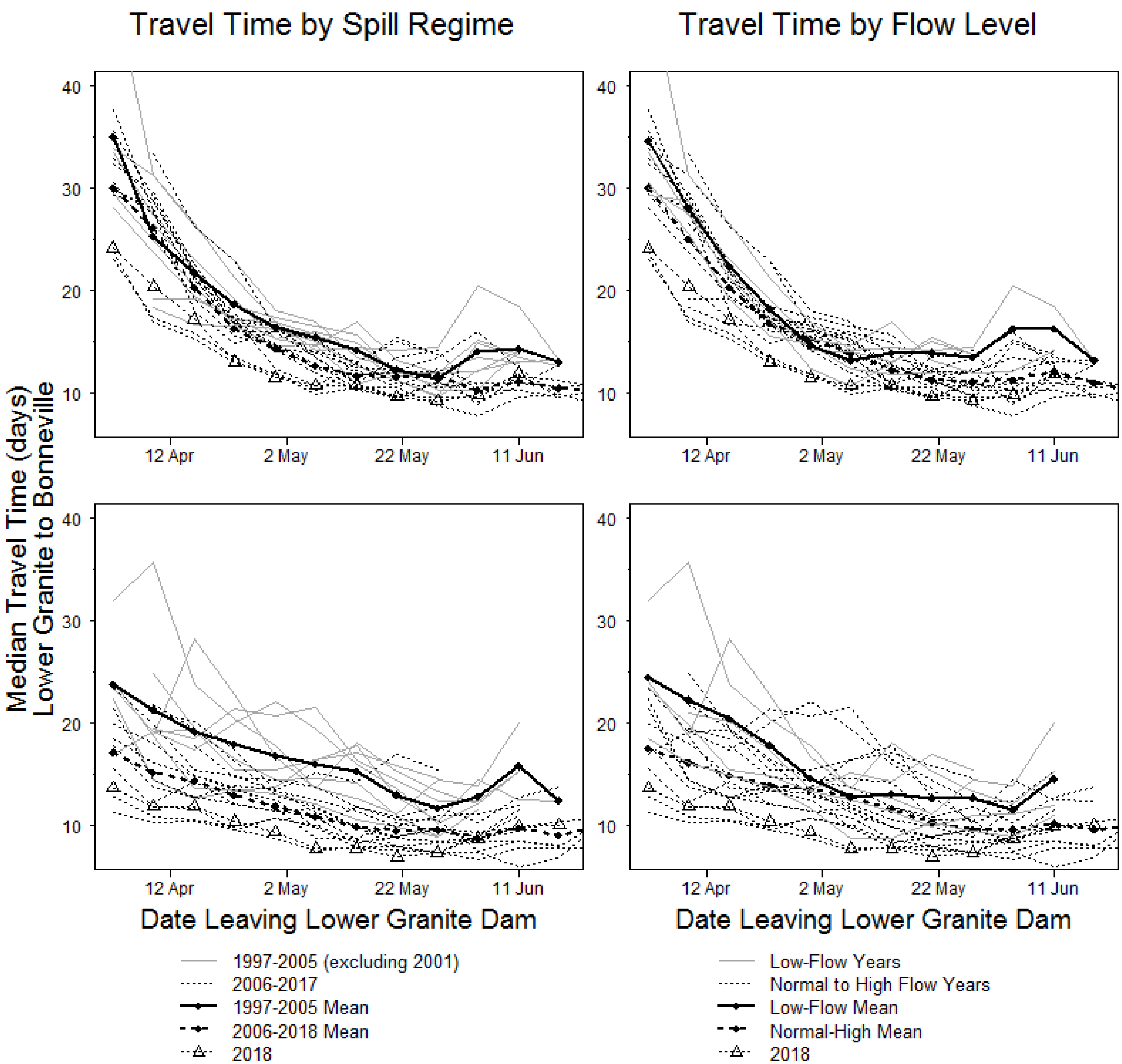

Figure 8. Median travel time from Lower Granite Dam to Bonneville Dam for yearling **Chinook** salmon and **steelhead** by spill regime (left) and mean flow category (right) in the period 1998-2018 (excluding 2001), with long-term mean for the same period. Here spill regime is defined by court-ordered spill starting in 2006 and the concurrent installation of additional surface collectors, and low-flow years are those with mean of 70 kcfs or less for the period of 1 April through 15 June. The 2001 migration year is excluded from the individual years and means due to its unusual combination of low flow and no spill and the influence that has on the group means.

American Rivers ◆ Center for Law and Policy ◆ Columbia Riverkeeper
Institute for Fisheries Resources ◆ National Wildlife Federation
Natural Resources Defense Council ◆ Northwest Sportfishing Industry Association
Pacific Coast Federation of Fishermen's Associations
Save Our wild Salmon Coalition ◆ Sierra Club

December 7, 2018

Maia Bellon, Director
Heather Bartlett, Water Quality Program Manager
P.O. Box 47600
Olympia, WA 98504-7600

Re: Scoping Notice for Short-term Modification of Total Dissolved Gas Standards for Federal Dams on the Lower Snake and Lower Columbia Rivers (Nov. 16, 2018)

Dear Director Bellon and Program Manager Bartlett:

The undersigned organizations submit these scoping comments in response to your Department's scoping notice of November 16, 2018 for a short-term modification of total dissolved gas (TDG) water quality standards for federal dams on the lower Snake and lower Columbia rivers through 2021.

A number of organizations, including some of the organizations signing this letter, submitted to you a request for a short-term modification of the TDG standards on September 13, 2018. A copy of that request is attached to these scoping comments and incorporated into these comment by this reference. We believe this letter describes the legal and scientific basis for a short-term modification of the TDG standards at the lower Snake and lower Columbia River dams for the "spring spill season" (from approximately April 1 through June 20) beginning in 2019 and continuing through spring 2020 and 2021.

As explained in that letter, your Department should eliminate on a short-term basis the current 115% forebay TDG limit at each dam and replace the existing 120% tailrace TDG limit with a limit of 125% for up to at least 16 hours per day or more starting in 2019. We urge you to include such an alternative in the forthcoming environmental impact statement pursuant to the above referenced scoping notice. We believe that upon examination of the best currently available scientific information about the effects of TDG levels up to 125% in the dam tailraces, and analysis of any other alternatives you chose to evaluate, you will conclude that a short-term modification of the TDG standards to 125% starting in 2019 is the best alternative to protect beneficial uses in the lower Snake and lower Columbia Rivers and that such a standard poses minimal or no risks to any designated use. It also will not have significant adverse environmental impacts.

As you acknowledge in your scoping notice, such a short-term modification is consistent with requests from the Washington Department of Wildlife, the Columbia River Inter-Tribal Fish Commission and recommendations from the Governor's Southern Resident Killer Whale Task Force. It could also easily be coordinated with a parallel modification of TDG standards by the State of Oregon that affect the federal dams on the lower Columbia River. Oregon's standards currently already allow TDG up to 120% as measured in the tailrace of the lower Columbia River dams on a 24-hour basis (the only dams directly affected by Oregon's standards). We understand that Oregon is in the process of considering increasing this tailrace TDG level to 125% on a flexible basis. Even if Oregon does not complete this change in time for the 2019 spring spill season, we expect it will complete such a change in time for the 2020 and 2021 spring spill seasons. In any event, a change in the TDG standards in Washington to allow spill up to 125% starting in 2019 on a flexible basis would still benefit juvenile salmonid survival and protect designated uses.

Basis for Considering a Short-term Modification of Water Quality Standards to Allow TDG Levels of Up to 125% on a Flexible Basis During the Spring Juvenile Salmon Migration Season Beginning in 2019 Through 2021.

We briefly summarize below our basis for asking you to develop and consider an alternative that would eliminate the current forebay TDG standard and allow TDG levels of up to 125% on a flexible basis below.

First, recent analyses by the Fish Passage center (FPC) confirm that voluntary spring spill at TDG levels of 125% in the tailrace of each dam is safe for downstream migrating juvenile salmon and steelhead and will further improve juvenile survival – and ultimately adult return rates – as compared to the lower levels of spill allowed under the current TDG exemptions. The most recent such analysis is set out in the FPC's Comparative Survival Study (CSS) 2017 Annual Report, especially in Chapter 2, "Life Cycle Modeling Evaluation of Alternative Spill and Breach Scenarios" and Chapter 3, "Effects of the In-River Environment on Juvenile Travel Time, Instantaneous Mortality Rates and Survival." As explained in this report, the CSS analysis is based on extensive data collected over many years and life cycle modeling that has been developed and reviewed by experts within the region since at least 2013. Rather than fully summarizing the technical details of this analysis here, we refer you to the CSS 2017 Annual Report which is available at: http://www.fpc.org/documents/CSS/CSS_2017_Final_ver1-1.pdf, and http://www.fpc.org/documents/CSS/CSS_2013_Workshop_Report_-_FINAL_w_presentations.pdf (containing detailed smolt-to-adult returns at various spill levels, flows and ocean conditions). As that analysis explains, allowing TDG of up to 125% in the tailrace of each dam would lead to a significant increase in smolt-to-adult return rates for Snake River spring/summer Chinook.[1] In addition, the 2017 CSS analysis concludes that TDG levels well above 125% are only a weak or non-factor in instantaneous mortality rates. Together, these conclusions are (a) more robust than similar conclusions Ecology has previously reviewed in connection with requests to modify its TDG standards; (b) have been reviewed by the Independent Scientific Advisory Board with suggestions for additional steps to strengthen the conclusions but without any fundamental disagreement with the CSS findings; and, (c) confirm that a short-term modification of Ecology's current TDG water quality standards for the lower Snake and lower Columbia River dams is scientifically well supported.

We would also refer you to the draft 2018 CSS Annual report for additional information. It is available at http://www.fpc.org/documents/CSS/DRAFT2018CSSReportv1-1.pdf. We would encourage you and your staff to schedule an in-person meeting with staff from the FPC to discuss any questions you may have about their analysis. After you review all of this evidence, we believe you will conclude that the spill volumes allowed by TDG levels up to 125 percent would provide the best and safest route of passage for juvenile and adult salmon and steelhead by allowing them to avoid higher turbine and screen bypass mortalities, reducing passage delay, and dispersing predators. Even though excessive spill *can* cause excessive TDG levels, which can in turn harm fish and other aquatic life, we believe state and federal laws require Ecology to set TDG limits that maximize

[1] *See* CSS 2017 Annual Report at 50 (Figure 2.10).

salmon survival by balancing the benefits of increased voluntary spring spill with the minimal or non-existent risks of harm from Gas Bubble Trauma ("GBT") to salmonids and other species.

Moreover, we are not aware of any scientific study in the last ten years or any anecdotal evidence that any non-salmonid aquatic biota in the Snake or Columbia Rivers have suffered harm from TDG levels above 125% even though these levels of TDG occur frequently in the lower Snake and lower Columbia rivers in the spring due to involuntary spill. This absence of evidence of harm suggests risks to any non-salmonid biota if TDG levels up to 125% is minimal or non-existent. In the absence of compelling new field evidence that the risks of higher levels of TDG, including 125 percent of saturation, are harmful to non-salmonid aquatic biota, the more robust evidence of the benefits to salmonids of increased spill as a result of a short-term modification of Ecology's TDG standards to 125 percent in the tailrace of each dam should lead Ecology to develop and choose an alternative in its SEPA process that approves a short-term modification of water quality standards to allow TDG up to 125% of saturation on a flexible basis during the spring salmon migrations season starting in 2019.

Of course, salmon are not the only anadromous species migrating through the hydrosystem. Pacific lamprey (*Lampetra tridentata*), for example, may also benefit from the short-term modification of the forebay and 120 percent tailrace TDG standards, a benefit to aquatic biota that Ecology may not have previously fully considered. Pacific lamprey have shown widespread decline since the 1960s in the Columbia River system due to habitat loss, water pollution, ocean conditions, and problems with dam passage.[2] Lamprey decline is of particular concern in the Northwest because of their importance to Native Americans' cultural heritage and tribal fisheries.[3] In fact, the lamprey's situation is perilous enough that the Oregon Natural Resources Council petitioned the USFWS to list the species under the Endangered Species Act in 2002. Although the USFWS denied the petition, claiming a lack of information, the USFWS has continued to voice concern over the status and distribution of Pacific lamprey.

We recognize that little information is available about precise juvenile lamprey survival benefits from increasing spill levels. However, it is highly likely that juvenile lamprey will benefit indirectly from increased spill. Juvenile lamprey are frequently impinged, and are injured or die, on the turbine intake screens meant to divert juvenile salmon into the bypass system; one study estimated a juvenile lamprey mortality rate of as high as 25 percent at dams with extended-length turbine intake screens.[4] When spill is reduced, more juvenile lamprey are forced through the screened bypass routes.[5] Indeed, the FPC has highlighted that reducing spill during spring lamprey migration:

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[2] Close, D.A., M. Fitzpatrick, H. Li, B. Parker, D. Hatch & G. James. 1995. Status report of the Pacific lamprey (*Lampetra tridentata*) in the Columbia River Basin.

[3] *Id.*; *see also* Nez Perce, Umatilla, Yakama and Warm Springs Tribes. 2008. Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin. Formal Draft, p. 4.

[4] CRITFC, Pacific Lamprey Passage Design, Project No. 2008-524-00. FY 2008-2009 F&W Program Accords (MOA) Proposal Review. pp. 10 – 11; *see also* BioAnalysts, Inc. 2000. A Status of Pacific Lamprey in the Mid-Columbia Region. Rocky Reach Hydroelectric Project. FERC Project No. 214, pp. 26–27.

[5] Fish Passage Center, "Review of the NOAA Transportation analyses and potential effects of reducing spill for fish passage in May and beginning the transportation program earlier in the spring and supporting analyses". Feb. 9, 2010. pp. 2, 10–12. Available online at: http://www.fpc.org/documents/memos/15-10.pdf.

will be detrimental to lamprey, since elimination of spill will result in additional juvenile lamprey passage through screened power house bypass systems (Starke and Dalen 1995,1998; Moursand et al., 2000, 2001, 2002, 2003; Bleich and Moursand, 2006). Impingement of juvenile lamprey on turbine intake screens is a serious regional problem.[6]

We would encourage you to consult with the FPC and with the Nez Perce and other Tribes about the benefits of increased spill for lamprey as you develop your EIS for a short-term modification of the TDG standards.

As reflected in the recommendations of Governor Inslee's Orca Task Force, the increased spill allowed by a short-term modification of TDG standards to allow TDG up to 125% on a flexible basis would also provide immediate benefits for endangered Southern Resident Killer Whales. These whales rely on adult chinook salmon from the Columbia and Snake Rivers as an important prey resources at certain times of the year and these whales are nutritionally stressed. Whale scientists believe that increasing prey availability for these whales is crucial to halting and reversing their decline. Attached to this letter is a letter from a number of leading orca scientists addressing the importance of increased spill to orca survival. As they explain, allowing higher levels of TDG, and in turn higher levels of voluntary spring spill, will lead to higher juvenile survival and increased adult chinook return to the Columbia, especially spring/summer chinook, a priority prey resource for the whales.

A Short-Term Modification of Water Quality Standards to Allow TDG Levels of Up to 125% on a Flexible Basis is Consistent With and Supported by Washington law.

A short-term modification of WAC 173-201A-200(1)(f)(ii) to allow TDG levels of up to 125% is consistent with the requirements of the regulations that allow such a modification. First, the modification is short-term. It is for a period of approximately 120 days each year for the next three years at each of the eight lower Snake and lower Columbia river dams. The actual periods of higher and lower TDG (and spill) pursuant to the short-term modification at each dam would depend on the details of the annual Spring Fish Operation Plan (FOP) for these dams developed and adopted in collaboration with the State of Washington and other sovereigns by the relevant federal agencies each year. The short-term modification would provide the flexibility for longer periods of spill to the higher 125 percent TDG level and other, shorter, periods of lower spill, likely during peak electricity demand hours. In addition, and in accordance with WAC 173-201A- 410(2), the duration of the short-term modification would only be for the spring juvenile salmon migration season, which may run from about March 1 to about June 30 each year depending on the details of the Spring FOP, and the modification would only be in place for three years or until Ecology adopts any permanent modification of the requirements of WAC 173- 201A-200(1)(f)(ii), whichever occurs sooner.

Second, a modification of the TDG standards to allow spill up to 125% is necessary to accommodate the essential activity of securing beneficial dam passage conditions for migrating juvenile salmon and steelhead in the spring while also allowing appropriate hydropower generation. Most of the salmonids that pass the dams and would be affected by the short-term modification have been listed as threatened or endangered under the Endangered Species Act for many years. As described above, increasingly robust scientific evidence indicates that increased spill, up to at least 125% TDG, increases salmonid survival. For this reason, a short-term modification also is in the public interest.

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[6] *Id.* at 10.

Third, a short-term modification to allow TDG levels up to 125% is conditioned to minimize or eliminate any degradation of water quality, existing uses, and designated uses in the affected waters. The modification would only apply during the spring juvenile salmonid migration season. During this time, TDG levels in the tailrace of each dam are often 125 percent or higher anyway, because of involuntary spill resulting from high spring runoff and low electricity demand. We are not aware of any field evidence that these annually occurring high levels of TDG—which vary from year-to-year depending on weather, snowpack and other factors—have significantly harmed water quality or existing or designated uses. Accordingly, due to the frequent unavoidable exceedances of the current TDG standards, the short-term modification we seek would likely affect dam operations and TDG levels for a considerably shorter time than indicated by the terms of the proposed modification.

Fourth, a short-term modification to allow TDG levels up to 125% in the dam tailraces would not reduce or remove the Corps' responsibility to otherwise comply with Washington's water quality standards at all times not subject to the short-term modification or alter the Corps' obligations and responsibilities under other federal, state, or local rules and regulations. In fact, such a short-term modification may help facilitate dam operations over the next few years under a biological opinion developed pursuant to the federal Endangered Species Act in order to avoid jeopardy to species of salmon and steelhead that are protected by that Act.

CONCLUSION

Voluntarily spilling water over the dams on the Snake and Columbia rivers during the spring juvenile migration season undeniably benefits salmon and steelhead. While spill can pose a risk to salmonids if TDG levels are too high, biological monitoring conducted over the last decade and more, as well as anecdotal evidence, demonstrates that tailrace TDG levels of 125 percent do not negatively impact migrating salmonids, resident fish, or invertebrates. By contrast, the TDG levels currently allowed under Washington's water quality standards unnecessarily limit the benefits of spill for juvenile salmon and steelhead migrating downstream in the spring. We thus urge you to develop and carefully consider in your EIS a short-term modification of water quality standards to allow TDG levels up to 125% of saturation in the tail race of each of the eight dams on the lower Snake and lower Columbia Rivers during the spring juvenile salmon migration season beginning in 2019 and continuing through at least 2021.

Thank you for your consideration of these scoping comments. Please contact Joseph Bogaard (joseph@wildsalmon.org / 206-300-1003) if you have any questions.

Sincerely,

Joseph Bogaard, executive director
Save Our wild Salmon Coalition
Seattle, Washington

Wendy McDermott, Salish Sea and Columbia Basin Director
American Rivers
Bellingham, Washington

Trish Rolfe, executive director
Center for Law and Policy
Seattle, Washington

Brett VandenHeuvel, Executive Director
Columbia Riverkeeper
Hood River, Oregon

Glen Spain, Northwest Regional Director
Institute for Fisheries Resources
Pacific Coast Federation of Fishermen's Associations
Eugene, Oregon

Giulia Good Stefani, attorney
Natural Resources Defense Council
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National Wildlife Federation
Missoula, Montana

Liz Hamilton, executive director
Northwest Sportfishing Industry Association
Oregon City, Oregon

Bill Arthur, Northwest Salmon Campaign Director
Sierra Club
Seattle, Washington

September 13, 2018

Via Email and U.S. Mail

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State of Washington
PO Box 47775
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Ms. Heather Bartlett
Water Quality Program Manager
Department of Ecology
State of Washington
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RE: Request for Short-Term Modification of WAC 173-201A-200(1)(f)(ii)

Dear Ms. Bellon and Ms. Bartlett:

Pursuant to WAC 173-201A-410(1) and (2), the Northwest Sportfishing Industry Association, Columbia Riverkeeper, and Save Our Wild Salmon (hereinafter collectively referred to as "NSIA") respectfully request that the Washington State Department of Ecology ("Ecology") grant a short-term modification of WAC 173-201A-200(1)(f)(ii), which Ecology promulgated pursuant to RCW 90.48.035. The existing rule sets water quality standards ("WQSs") for total dissolved gas ("TDG") in Washington's fresh surface waters. Generally, the rule requires that TDG levels not exceed 110 percent saturation. However, the rule includes exemptions to facilitate fish passage past hydroelectric dams on the Snake and Columbia rivers as follows:

> 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 one hundred fifteen percent as measured in the forebays of the next downstream dams and must not exceed an average of one hundred twenty percent 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); and a maximum TDG one-hour average of one hundred twenty-five percent must not be exceeded during spillage for fish passage.

By this letter, NSIA seeks a short-term modification of this particular provision pursuant to WAC 173-201A-410(1) and (2) to allow more flexibility in the management of total dissolved gas levels at eight dams on the lower Snake and lower Columbia rivers in order to aid fish passage and hydropower generation while minimizing interference with or injury to other aquatic resources. This request will also aid the efforts of Governor Inslee's Orca Task Force by increasing downstream juvenile salmon survival through higher levels of spill and, consequently, increase abundance of adult salmon that are important prey for orcas.

This request is made in the context of on-going discussions among the State of Washington and other entities about increasing the allowable levels of total dissolved gas to improve juvenile salmonid passage survival, provide flexibility for increased power generation during periods of peak demand, an increase orca prey availability at critical times—all goals that NSIA supports, so long as the actions taken actually improve upon past operations and increase salmon returns.

Specifically, NSIA asks Ecology to adopt a short-term modification that would (a) eliminate Washington's current forebay TDG standard at all eight lower Snake and lower Columbia river dams; and, (b) allow voluntary spring spill up to 125 percent TDG (as read at tailrace) during some or all non-peak power generation hours at some or all of the eight dams, beginning March 1, 2019, and continuing as described below for a period of at least three years or until replaced by a permanent change to the TDG standards through appropriate rulemaking. The goal of this short-term modification is to create a new TDG ceiling for voluntary spring spill operations without requiring spill to a specific level at all times, thus allowing increased upward flexibility for both voluntary spill and power generation.

Rather than specify the exact details of such a short-term modification, we suggest below one version of such a modification that we believe would be appropriate and achieve both better fish passage at the dams (by providing more spill at certain times than is allowed under current TDG standards) and provide more flexible power generation (by allowing periods of lower spill during peak demand hours):

> Between March 1 and June 30 each year, TDG may not exceed an average of one hundred twenty-five percent as measured in the tailrace of each dam on the lower Snake River in Washington and the lower Columbia River to which WAC 173-201A-200(1)(f)(ii) currently applies. This average is measured as an average of the twelve highest consecutive hourly readings in any one day.
>
> During the period from March 1 through June 30, TDG also should remain at lower levels as measured in the tailrace of each dam for a limited number of hours in each twenty-four-hour period to accommodate increased hydropower generation.

We believe there may be other versions of a short-term modification, starting in 2019, that would also accomplish our goals, so long as TDG levels up to 125 percent of saturation are allowed on an appropriate basis.

We seek this short-term modification for a period of no more than three years, or until such time as Ecology completes a rulemaking to permanently modify WAC 173-201A-

200(1)(f)(ii) to eliminate the existing 115 percent TDG limit in the forebay of each dam and allow TDG levels up to 125 percent in the tailrace at each dam.

The basis for this request for a short-term modification of WAC 173-201A-200(1)(f)(ii) pursuant to WAC 173-201A-410 is set forth below.

BACKGROUND

I. SPRING SPILL IS VITAL TO SALMON AND STEELHEAD PROTECTION.

There is broad and longstanding scientific agreement that voluntary spill past eight federal dams on the lower Snake and lower Columbia rivers provides substantial survival benefits to endangered salmon and steelhead. Indeed, Ecology has acknowledged that spill is important for salmon and steelhead.[1] We review some of this evidence below, including recent evidence that spill to 125 percent of saturation in the tailrace at each of the lower Snake and lower Columbia river dams is beneficial to salmon and steelhead survival.

For juvenile salmon and steelhead migrating in the Snake and Columbia rivers, non-powerhouse passage (spill and powerhouse surface passage) indisputably provides the safest passage through the Federal Columbia River Power System ("FCRPS") dams.[2] Substantial evidence also shows that spill can be managed to avoid impeding adult salmon and steelhead passage though dams.[3] Allowing increased water over the spillways at these dams allows juvenile salmon to avoid traveling through the power turbines—a passage route that increases mortality by subjecting these fish to rapid pressure changes and direct impacts with turbine blades. Increased spill also results in lower mortality than the practice of diverting fish from the turbine intakes and "bypassing" them through a series of screens, pipes, and tunnels to return to the river on the lower side of the dam.[4]

Experience underscores the beneficial effects of spill. Court injunctions have required the U.S. Army Corps of Engineers ("Corps") to spill additional water at the FCRPS dams to aid downstream fish passage. Court-ordered spill has allowed more juvenile salmon to migrate in the river under better conditions and has had a positive effect on smolt to adult return rates according to analyses by the Fish Passage Center ("FPC").[5]

The FPC's conclusions were questioned by the National Marine Fisheries Service/NOAA Fisheries ("NOAA"), which conducted a separate review concluding that the high sockeye returns in 2008 were generally due to favorable ocean conditions. In response, FPC reviewed

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1 Department of Ecology. August 10, 2009. Response to Petition for Rulemaking – Chapter173-201a WAC – Water Quality Standards. Response to Petition Issue 1.

2 *See* NMFS 2000 Federal Columbia River Power System Biological Opinion ("2000 BiOp") at 6-17.

3 *See* CRITFC. July 3, 2008. Memorandum to the AMT, Review of Adult Passage Through Different Dam Passage Routes.

4 2000 BiOp at 9-83.

5 FPC Memo (July 14, 2008) at 2. The "years analyzed" in FPC's analysis were 1998–2007.

NOAA's analysis, carefully reexamined its own findings, and concluded that:

> There is no doubt that ocean conditions are important, but this does not reduce the importance of migration conditions and fish survival in-river . . . . The NOAA conclusion that attributes the 2008 high return of sockeye salmon to the marine/estuary conditions while discounting the effect of higher in-river survival, lower proportion transported and improved in-river conditions, is flawed because it fails to recognize that fish must reach the oceans/estuary alive to benefit from good ocean conditions. Even the best ocean conditions will not resurrect dead fish.[6]

FPC has also reviewed NOAA's analysis of juvenile steelhead reach survival for 2009, confirmed the agency's findings of 66-69% in-river steelhead survival rates from Lower Granite to Bonneville dams, and concluded that:

> based upon multi-year analysis the most important variables explaining variability in reach survival for steelhead were spill proportion and water transit time (i.e. flow). Higher spill proportions, particularly for the Snake River, are likely the primary factors contributing to the higher juvenile survivals and faster juvenile travel times which occurred in 2007, 2008, and 2009.[7]

Indeed, NOAA has previously acknowledged that, along with removable spillway weirs, "[h]igher survival for in-river migrants in 2006 was likely the result of higher flows and greater volumes of water spilled."[8] NOAA had also concluded as long ago as 2000 that "measures that increase juvenile fish passage over FCRPS spillways are the highest priority" for passage improvements.[9]

More recent analyses by the FPC confirm that voluntary spring spill at TDG levels of 125% in the tailrace of each dam is safe for downstream migrating juvenile salmon and steelhead and will further improve juvenile survival – and ultimately adult return rates – as compared to the lower levels of spill allowed under the current TDG exemptions. The most recent such analysis is set out in the FPC's Comparative Survival Study (CSS) 2017 Annual Report, especially in Chapter 2, "Life Cycle Modeling Evaluation of Alternative Spill and Breach Scenarios" and Chapter 3, "Effects of the In-River Environment on Juvenile Travel Time, Instantaneous Mortality Rates and Survival." As explained in this report, the CSS analysis is based on extensive data collected over many years and life cycle modeling that has been developed and reviewed by experts within the region since at least 2013. Rather than fully summarizing the technical details of this analysis here, NSIA refers Ecology to the CSS 2017 Annual Report which is available at: http://www.fpc.org/documents/CSS/CSS_2017_Final_ver1-

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[6] FPC Memo to Ed Bowles, ODFW (Feb. 18, 2009) at 1. Available online at: http://www.fpc.org/documents/memos/18-09.pdf.

[7] FPC Memo to Ed Bowles, ODFW (Sept. 29, 2009) at 1–2. Available online at: http://www.fpc.org/documents/memos/157-09.pdf

[8] NMFS, Northwest Fisheries Science Center, Preliminary Survival Estimates 2006 Spring Juvenile Migration at 1-4 (Aug. 30, 2006).

[9] 2000 BiOp at 9-82.

1.pdf, and http://www.fpc.org/documents/CSS/CSS_2013_Workshop_Report_-_FINAL_w_presentations.pdf (containing detailed smolt-to-adult returns at various spill levels, flows and ocean conditions).

Briefly, however, the 2017 CSS analysis indicates that, relative to spilling to the current Washington TDG caps of 115% in the forebay and 120% in the tailrace at each dam, allowing TDG of 125% in the tailrace of each dam as requested herein would lead to a significant increase in smolt-to-adult return rates for Snake River spring/summer Chinook.[10] In addition, the 2017 CSS analysis concludes that TDG levels well above 125% are only a weak or non-factor in instantaneous mortality rates. Together, these conclusions are (a) more robust than similar conclusions Ecology has previously reviewed in connection with requests to modify its TDG standards; (b) have been reviewed by the Independent Scientific Advisory Board with suggestions for additional steps to strengthen the conclusions but without any fundamental disagreement with the CSS findings; and, (c) confirm that a short-term modification of Ecology's current TDG water quality standards for the lower Snake and lower Columbia River dams is scientifically well supported.

In short, the spill volumes allowed by TDG levels up to 125 percent would provide the best and safest route of passage for juvenile and adult salmon and steelhead by allowing them to avoid higher turbine and screen bypass mortalities, reducing passage delay, and dispersing predators. Even though excessive spill *can* cause excessive TDG levels which can harm fish and other aquatic life, we believe state and federal laws require Ecology to set TDG limits that maximize salmon survival by balancing the benefits of increased voluntary spring spill with the risks of harm from Gas Bubble Trauma ("GBT") to salmonids and other species. The short-term modification NSIA requests meets this requirement as explained in more detail below.

II. A SHORT-TERM MODIFICATION OF WAC 173-201A-200(1)(f)(ii) WOULD NOT INTEREFERE WITH OR INJURE OTHER AQUATIC RESOURCES.

Based on the evidence described above, NSIA believes that a short-term modification of Ecology's existing TDG standards would better protect migrating juvenile salmon and steelhead and increase adult returns. Based on the discussion below, NSIA also believe that this modification would not interfere with or injure other aquatic biota.

NSIA recognizes that, in the past, Ecology has given weight to the potential for harm to non-salmonid aquatic biota from higher levels of TDG. A 2009 Adaptive Management Team sponsored by Ecology and the Oregon Department of Environmental Quality ("ODEQ") looked in detail at the relationship between increased TDG levels due to spill and the incidence of GBT in aquatic organisms. A joint report by Ecology and ODEQ[11] described three independent literature reviews conducted by Ecology, NOAA Fisheries, and Parametrix. Each review examined the effects of TDG on aquatic life and took special notice of species other than

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[10] *See* CSS 2017 Annual Report at 50 (Figure 2.10).

[11] Adaptive Management Team, Total Dissolved Gas in the Columbia and Snake Rivers; Evaluation of the 115 Percent Total Dissolved Gas Forebay Requirement. 2009. Washington State Department of Ecology and State of Oregon Department of Environmental Quality. Publication No. 09-10-002. p. 68 (hereinafter "AMT Evaluation").

salmonids. NOAA and Parametrix both concluded, at that time, that removing the 115% forebay TDG requirement would have negligible harmful effects on aquatic life.[12] Ecology, however, reached a different conclusion: while it recognized that any aquatic life living deeper than one meter would not be affected if TDG increased to 120 percent, Ecology concluded at that time that there was a potential for a small increase in impacts to aquatic life within one meter of the water surface.[13]

As NSIA and others pointed out in a subsequent petition to Ecology, a number of other studies supported a different conclusion. In addition, the information in some of the studies Ecology did consider may not have been fully addressed. For example, Ecology based its conclusion that invertebrates and other surface-dwelling aquatic life would be harmed by removal of the 115 percent forebay standard on the mortality rates found in experimental studies, and, in NSIA's view, did not give sufficient weight to field studies reaching contrary conclusions.[14] As multiple such field studies have noted, because TDG levels in captive fish can be substantially higher than levels found in the field, these experimental data can systematically overestimate the risk of GBT. NSIA urges Ecology to reconsider this information in light of the requirements applicable to this request for short-term modification discussed below. Such a review should lead Ecology to conclude that the short-term modification requested herein is appropriate.[15]

In addition, NSIA is also not aware of any anecdotal evidence that any non-salmonid aquatic biota have suffered harm from TDG levels above 125% even though these levels of TDG occur frequently in the lower Snake and lower Columbia rivers in the spring due to involuntary spill. This absence of data of harm suggests any non-salmonid biota that may be affected by higher levels of TDG are able to avoid these areas before adverse effects occur. In the absence of compelling new field evidence that the risks of higher levels of TDG, including 125 percent of saturation, are harmful to non-salmonid aquatic biota, the more robust evidence of the benefits to salmonids of increased spill as a result of a short-term modification of Ecology's TDG standards to 125 percent on a twelve-hour basis in the tailrace of each dams should lead Ecology to approve the short-term modification requested herein.

III. ALLOWING HIGHER LEVELS OF TDG WOULD ALSO BENEFIT OTHER SPECIES.

Salmon are not the only anadromous species migrating through the hydrosystem. Pacific lamprey (*Lampetra tridentata*) may also benefit from the short-term modification of the forebay and 120 percent tailrace TDG standards requested herein, a benefit to aquatic biota that Ecology may not have previously fully considered.

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[12] *Id*. at 59.
[13] *Id.*
[14] *Id.* at 46–47.
[15] *See, e.g.*, Ryan, Brad A., E.M. Dawley, & R.A. Nelson. 2000. Modeling the effects of supersaturated dissolved gas on resident aquatic biota in the main-stem Snake and Columbia Rivers. North American Fisheries Management 20:192–204.

Pacific lamprey have shown widespread decline since the 1960s in the Columbia River system due to habitat loss, water pollution, ocean conditions, and problems with dam passage.[16] Lamprey decline is of particular concern in the Northwest because of their importance to Native Americans' cultural heritage and tribal fisheries.[17] In fact, the lamprey's situation is perilous enough that the Oregon Natural Resources Council petitioned the USFWS to list the species under the Endangered Species Act in 2002. Although the USFWS denied the petition, claiming a lack of information, the USFWS has continued to voice concern over the status and distribution of Pacific lamprey.

NSIA recognizes that little information is available about precise juvenile lamprey survival benefits from increasing spill levels. However, it is highly likely that juvenile lamprey will benefit indirectly from increased spill. Juvenile lamprey are frequently impinged, and are injured or die, on the turbine intake screens meant to divert juvenile salmon into the bypass system; one study estimated a juvenile lamprey mortality rate of as high as 25 percent at dams with extended-length turbine intake screens.[18] When spill is reduced, more juvenile lamprey are forced through the screened bypass routes.[19] Indeed, the FPC has highlighted that reducing spill during spring lamprey migration:

> will be detrimental to lamprey, since elimination of spill will result in additional juvenile lamprey passage through screened power house bypass systems (Starke and Dalen 1995,1998; Moursand et al., 2000, 2001, 2002, 2003; Bleich and Moursand, 2006). Impingement of juvenile lamprey on turbine intake screens is a serious regional problem.[20]

Even if lamprey do not pass through the spillway, lamprey are less susceptible to injury or mortality from turbine passage compared with other, particularly larger, fish.[21] Moreover,

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[16] Close, D.A., M. Fitzpatrick, H. Li, B. Parker, D. Hatch & G. James. 1995. Status report of the Pacific lamprey (*Lampetra tridentata*) in the Columbia River Basin.
[17] *Id.*; *see also* Nez Perce, Umatilla, Yakama and Warm Springs Tribes. 2008. Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin. Formal Draft, p. 4.
[18] CRITFC, Pacific Lamprey Passage Design, Project No. 2008-524-00. FY 2008-2009 F&W Program Accords (MOA) Proposal Review. pp. 10 – 11; *see also* BioAnalysts, Inc. 2000. A Status of Pacific Lamprey in the Mid-Columbia Region. Rocky Reach Hydroelectric Project. FERC Project No. 214, pp. 26–27.
[19] Fish Passage Center, "Review of the NOAA Transportation analyses and potential effects of reducing spill for fish passage in May and beginning the transportation program earlier in the spring and supporting analyses". Feb. 9, 2010. pp. 2, 10–12. Available online at: http://www.fpc.org/documents/memos/15-10.pdf.
[20] *Id.* at 10.
[21] Moursund, R.A., M.D. Bleich, K.D. Ham, and R.P. Mueller. 2003. Evaluation of the Effects of Extended Length Submerged Bar Screens on Migrating Juvenile Pacific Lamprey (*Lampetra tridentate*) at John Day Dam in 2002. Final Report prepared for the U.S. Army Corps of Engineers, Portland Oregon under Contract DE-AC06-76RL01830 at p. 4.3.

juvenile lamprey move downstream primarily at night, so increasing nighttime spill would increase juvenile lamprey dam passage when such passage is safest due to the closure of the bypass system. Additionally, if sufficient salmon pass via spill, allowing screens to be removed or lifted at some projects during parts of the year, lamprey mortality due to screen impingement could be reduced even further.

In addition, the increased spill allowed by the requested short-term modification of TDG standards would also provide immediate benefits for endangered Southern Resident Killer Whales. These whales rely on adult chinook salmon from the Columbia and Snake Rivers as an important prey resources at certain times of the year and these whales are nutritionally stressed. Whale scientists believe that increasing prey availability for these whales is crucial to halting and reversing their decline. In this context, allowing higher levels of TDG, and in turn higher levels of voluntary spring spill, will lead to higher juvenile survival and increased adult chinook return to the Columbia, especially spring/summer chinook, a priority prey resource for the whales.

In short, Ecology should also consider the potential benefits to both endangered Southern Resident Killer Whales and Pacific lamprey in deciding to modify TDG standards as requested.

IV. ECOLOGY SHOULD GRANT NSIA'S REQUEST FOR A SHORT-TERM MODIFICATION OF WAC 173-201A-200(1)(f)(ii).

In relevant part, WAC 173-201A-410 provides as follows:

> The criteria and special conditions established in WAC 173-201A-200 through 173-201A-260, 173-201A-320, 173-201A-602 and 173-201A-612 may be modified for a specific water body on a short-term basis (e.g., actual periods of nonattainment would generally be limited to hours or days rather than weeks or months) when necessary to accommodate essential activities, respond to emergencies, or to otherwise protect the public interest, even though such activities may result in a temporary reduction of water quality conditions.

(1) A short-term modification will:

(a) Be authorized in writing by the department, and conditioned, timed, and restricted in a manner that will minimize degradation of water quality, existing uses, and designated uses;

(b) Be valid for the duration of the activity requiring modification of the criteria and special conditions in WAC 173-201A-200 through 173-201A-260, 173-201A-602 or 173-201A-612, as determined by the department;

(c) Allow degradation of water quality if the degradation does not significantly interfere with or become injurious to existing or designated water uses or cause long-term harm to the environment; and

(d) In no way lessen or remove the proponent's obligations and liabilities under other federal, state, and local rules and regulations.

(2) The department may authorize a longer duration where the activity is part of an ongoing or long-term operation and maintenance plan, integrated pest or noxious weed management plan, water body or watershed management plan, or restoration plan. Such a plan must be developed through a public involvement process consistent with the Administrative Procedure Act (chapter 34.05 RCW) and be in compliance with SEPA, chapter 43.21C RCW, in which case the standards may be modified for the duration of the plan, or for five years, whichever is less. Such long-term plans may be renewed by the department after providing for another opportunity for public and intergovernmental involvement and review.

The short-term modification of WAC 173- 201A-200(1)(f)(ii) that NSIA requests in this letter meets these requirements.

First, consistent with the above requirements, NSIA requests a short-term modification for a period of approximately 120 days each year, at each of the eight lower Snake and lower Columbia river dams. The actual periods of higher and lower TDG (and spill) pursuant to the short-term modification at each dam would depend on the details of the annual Spring Fish Operation Plan (FOP) for these dams developed and adopted in collaboration with the State of Washington and other sovereigns by the relevant federal agencies each year. The short-term modification would, however, provide the flexibility for longer periods of spill to the higher 125 percent TDG level and other, shorter, periods of lower spill, likely during peak electricity demand hours. In addition, and in accordance with WAC 173-201A- 410(2), the duration of the short-term modification would only be for the spring juvenile salmon migration season, which may run from about March 1 to about June 30 each year depending on the details of the Spring FOP, and the modification would only be in place for three years or until Ecology adopts any permanent modification of the requirements of WAC 173- 201A-200(1)(f)(ii), whichever occurs sooner.

Second, the modification requested herein is necessary to accommodate the essential activity of securing beneficial dam passage conditions for migrating juvenile salmon and steelhead in the spring while also allowing appropriate hydropower generation. Most of the species that pass the dams and would be affected by the short-term modification have been listed as threatened or endangered under the Endangered Species Act for many years. As described above, increasingly robust scientific evidence indicates that increased spill, up to at least the levels NSIA seeks in this short-term modification, increases salmonid survival. For this reason, the short-term modification also is in the public interest.

Third, the short-term modification NSIA seeks is conditioned to minimize any degradation of water quality, existing uses, and designated uses in the affected waters. The modification would only apply during the spring juvenile salmonid migration season. During this time, TDG levels in the tailrace of each dam are often 125 percent or higher anyway, because of involuntary spill resulting from high spring runoff and low electricity demand. NSIA is not aware of any evidence that these annually occurring high levels of TDG—which vary from year to year depending on weather, snowpack and other factors—have significantly harmed water quality or existing or designated uses. Accordingly, due to the frequent unavoidable exceedances of the current TDG standards, the short-term modification NSIA seeks would likely affect dam operations and TDG levels for a considerably shorter time than indicated by the terms of the proposed modification.

Fourth, the short-term modification NSIA seeks would not reduce or remove the Corps' responsibility to otherwise comply with Washington's water quality standards at all times not subject to the short-term modification or alter the Corps' obligations and responsibilities under other federal, state, or local rules and regulations. In fact, the short-term modification NSIA seeks may help facilitate dam operations over the next few years under a biological opinion developed pursuant to the federal Endangered Species Act in order to avoid jeopardy to species of salmon and steelhead that are protected by that Act.

CONCLUSION

Voluntarily spilling water over the dams on the Snake and Columbia rivers during the spring juvenile migration season undeniably benefits salmon and steelhead. While spill can pose a risk to salmonids if TDG levels are too high, biological monitoring conducted over the last decade and more, as well as anecdotal evidence, demonstrates that tailrace TDG levels of 125 percent do not negatively impact migrating salmonids, resident fish, or invertebrates. By contrast, the TDG levels currently allowed under Washington's water quality standards unnecessarily limit the benefits of spill for juvenile salmon and steelhead migrating downstream in the spring.

For the reasons above, NSIA hereby requests that Ecology approve the short-term modification of WAC 173-201A-200(1)(f)(ii) requested herein under the provisions for such modifications set forth in WAC 173-201A-410(1) and (2), effective on or about March 1, 2019, for a period of three years or until Ecology permanently changes the TDG standards that apply to the lower Snake and lower Columbia rivers.

Respectfully submitted,

Liz Hamilton

Liz Hamilton, Executive Director
Northwest Sportfishing Industry Association

Brett VandenHeuvel

Brett VandenHeuvel, Executive Director
Columbia Riverkeeper

Joseph Bogaard, Executive Director
Save Our Wild Salmon

cc: Richard Whitman

October 15, 2018

Governor Jay Inslee
Office of the Governor
P.O. Box 40002
Olympia, WA 98504

Ms. Stephanie Solien, Co-Chair
Mr. Thomas (Les) Purce, Co-Chair
Southern Resident Killer Whale Task Force
c/o Puget Sound Partnership
326 East D St.
Tacoma, WA 98421

Delivered via e-mail and regular mail

Dear Governor Inslee, Co-Chairs Solien and Purce, and Southern Resident Orca Recovery Task Force Members,

We are writing as scientists and researchers with many decades of collective experience and a deep familiarity with the life history and current status of the Southern Resident Killer Whales. We have also been particularly attentive to, and in certain instances directly involved in, the urgent conversations regarding orca protection and recovery strategies and programs. We offer our expertise and insights as the Southern Resident Orca Task Force compiles its initial list of recommendations this Fall.

While we do not specialize in fisheries biology, we know from studying the Southern Resident Killer Whales that increasing the abundance of spring, summer, and fall populations of Chinook salmon in Northwest marine waters is vital to ensure orca survival. We write to emphasize several critical details about Chinook abundance that at this time may be underappreciated by Task Force members but are nevertheless essential to the success of its work.

Because the Southern Residents need access to abundant chinook salmon on a year-round basis, increasing a wide variety of chinook salmon as quickly as possible must be the top priority for the Task Force and regional policymakers. Vessel-related interference and food chain toxins -- threats in and of themselves -- are intensified by the current prey shortage. While both of these threats also demand immediate action, ensuring an abundant supply of prey will help to minimize and mitigate these other recognized causes of decline. For example, when orcas are forced to metabolize their blubber in times of prey scarcity, they mobilize toxins stored in these fats. This increases rates of reproductive failure, compromising the population's ability to grow. While abundant prey does not eliminate these stored toxins, it does help ensure that they remain stored in the orcas' fat reserves. In fact, that may be why transient killer whales are doing so well compared to southern residents. The transient's rich prey source appears to buffer them from toxin impacts, despite having markedly higher toxin loads relative to southern residents.

Put simply, Orca need more Chinook salmon available on a year-round basis, as quickly as possible. Lack of prey has caused a steady increase in mortality and orca pregnancy failure. These two factors in combination have led to the recent decline in the Southern Resident Orca population which today stands at just 74 individual whales – a 35-year low. The low number of reproductive-age females left – 27 – with less than half of these successfully reproducing in the last ten years, underscores just how little time we have to turn this trajectory around with urgent and effective action.

The Orca Task Force may not yet fully appreciate the important role spring Chinook in particular play in the life history of the Southern Resident orcas. Spring Chinook populations in Northwest watersheds have played a critical role in diet and range of Southern Resident orca due to their historically large numbers, large size, high fat content, and the timing of their return in the winter and early spring months when other Chinook populations are unavailable. These are foremost among the salmon that Southern Residents leave the Salish Sea to hunt for along the west coast in the winter and spring months.

Because spring Chinook require cold, clear, tributary streams to spawn, these salmon have been particularly hard-hit by habitat destruction from human activities like dams, culverts, logging, mining, and urbanization. There are very few watersheds left in the Northwest that support healthy (or potentially healthy) populations of these salmon.

Spring chinook from the Columbia Basin warrant special attention. Once among the largest spring Chinook salmon producing watersheds on earth, the Columbia Basin's spring Chinook have suffered steep declines over the past century from damming and habitat destruction. Despite these impacts, this vast watershed still supports– and has the demonstrated potential to support far more – spring Chinook. Even with the diminished numbers of spring Chinook compared to historic levels, multiple studies demonstrate that the Southern Resident orcas still gather along the Washington State coast and at the mouth of the Columbia River between January and April. Prey event sampling and scat surveys have demonstrated that the orcas are there to feed on the large, fatty adult spring Chinook staging in this area before they return to the Columbia river in search of their natal spawning beds. Rebuilding the spring Chinook population in the Columbia Basin – a fish that we know the Southern Residents depend upon in the winter months – should be a top priority for the Orca Task Force and orca conservation efforts generally. The early spring run also replenishes the whales after a long winter and sustains them until the Fraser River Chinook peak in mid-August.

We recommend two key measures to increase Chinook abundance from the Columbia/Snake system. These measures are described more fully in a recent letter to the Task Force from more than thirty salmon biologists: (1) an immediate increase in spill levels at the federal dams on the Snake and Columbia Rivers to 125% total dissolved gas and (2) permanently restoring the Snake River by removing the lower Snake River dams. These measures will reduce heavy dam-caused salmon mortality for fish throughout the basin and re-establish productive access for Chinook and other salmonids to more than 5,000 miles of upstream stream habitat in the Snake River basin.

Though spring Chinook once inhabited the Columbia River deep into Canada, the Snake River Basin historically produced nearly one-half of all the spring Chinook in the entire Columbia Basin. Unlike many other parts of the Columbia Basin today where habitat restoration is badly needed, the majority of the habitat that supported this abundance – high elevation, cold water streams deep in protected wilderness in central Idaho – remains intact and fully functioning.

In short, the Snake River basin offers the best potential for large-scale spring Chinook restoration in our region. Protecting and restoring salmon access to and from this habitat will have a significant benefit for spring Chinook and should be a top regional priority for addressing orca prey needs.

Of course, Chinook restoration is needed throughout the orcas' year-round range, but based on what we know about the Southern Resident's historic and current reliance on spring and other Chinook salmon in the Columbia Basin, we believe that restoration measures in this watershed are an essential piece of a larger orca conservation strategy. Indeed, we believe that Southern Resident orca survival and recovery may be impossible to achieve without it.

Based on the science and the urgency of the current threats confronting the Southern Residents, we urge the Task Force to recommend to Governor Inslee that he take appropriate steps to change Washington's water quality standards to allow increased spill to 125% of saturation and also convene a process to recommend steps for lower Snake River dam removal as soon as possible as top priorities for orca protection.

We thank you for the opportunity to submit this letter and for your consideration. If you have questions or we can be of assistance, please contact Deborah Giles, giles7@gmail.com / 916-531-1516.

Sincerely,

Deborah A. Giles, PhD
Resident Scientist, University of Washington Friday Harbor Labs
Science and Research Director, Wild Orca
Friday Harbor, WA

Samuel K Wasser, PhD
Endowed Chair In Conservation Biology
Director, Center for Conservation Biology
Research Professor, Department of Biology
University of Washington
Seattle, WA

David Bain, PhD
Chief Scientist, Orca Conservancy
Seattle, WA

Katherine Ayres, PhD
Former researcher, Center for Conservation Biology, Department of Biology
University of Washington.
Los Angeles, CA

Val Veirs, PhD
Professor of Physics/Environmental Science – Emeritus, Colorado College
Friday Harbor, WA

Dr. Scott Veirs, PhD
President, ***Beam Reach, SPC***
Seattle, WA

CC:
Northwest Governors
Northwest Members of Congress

Resources:

NOAA Fisheries, *Species in the Spotlight, Survive to Thrive, Recovering Threatened and Endangered Species* (2015), http://www.nmfs.noaa.gov/stories/2015/05/docs/noaa_recoveringspecies_report_web.pdf.

Ford, JKB, et al., *Linking Killer Whale Survival and Prey Abundance: Food Limitation in the Ocean's Apex Predator?* 6 BIOLOGY LETTERS 141 (2010), p. *3, http://rsbl.royalsocietypublishing.org/content/early/2009/09/14/rsbl.2009.0468. See also NOAA Fisheries, *SRKW Recovery Planning and Implementation* (2011), p. 2.

Ayres KL, et al. (2012) *Distinguishing the impacts of inadequate prey and vessel traffic on an endangered killer whale (Orcinus orca) population*. PLoS One 7: e36842, http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0036842.

NOAA, *SRKW Recovery Plan Recovery Plan for Southern Resident Killer Whales*, (Orcinus orca), National Marine Fisheries Service, Northwest Region, Seattle, Washington (January 2008), p. II-82.

NOAA Fisheries, (2014) *Federal Columbia River Power System Biological Opinion*, http://www.westcoast.fisheries.noaa.gov/fish_passage/fcrps_opinion/federal_columbia_river_power_system.html.

See e.g., *Nat'l Wildlife Fed'n v. Nat'l Marine Fisheries Serv.*, 839 F. Supp. 2d 1117, 1131 (D. Or. 2011) ("[T]here is ample evidence in the record that indicates that the operation of the FCRPS causes substantial harm to listed salmonids. . . . NOAA Fisheries acknowledges that the existence and operation of the dams accounts for most of the mortality of juveniles migrating through the FCRPS.")

U.S. Fish and Wildlife Service. Species profile for Chinook Salmon (*Oncorhynchus tshawytscha*),
http://ecos.fws.gov/speciesProfile/profile/speciesProfile?spcode=E06D.

Hanson et al., Assessing the Coastal Occurrence of Endangered Killer Whales Using Autonomous Passive Acoustic Recorders (November 2013), 3486, 134 J. Acoust. Soc. Am. 5,
http://oceanwidescience.org/cms/wp-content/uploads/2014/12/Hanson-et-al-2013.pdf

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http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0036842.
10 Northwest Fisheries Science Center, NOAA Fisheries. 2013 Southern Resident Killer Whale Satellite Tagging,
http://www.nwfsc.noaa.gov/research/divisions/cb/ecosystem/marinemammal/satellite_tagging/blog.cfm;
2015 Southern Resident Killer Whale Satellite Tagging,
http://www.nwfsc.noaa.gov/research/divisions/cb/ecosystem/marinemammal/satellite_tagging/blog2015.cfm;
2016 Southern Resident Killer Whale Satellite Tagging,
http://www.nwfsc.noaa.gov/research/divisions/cb/ecosystem/marinemammal/satellite_tagging/blog2016.cfm.

Ford, Mike, *Salmon recovery and southern resident killer whale status*. A presentation to the Southern Resident Orca Task Force, NOAA-Fisheries; Northwest Fisheries Science Center, May 2018.

Hanson, Brad et al, *Species and stock identification of scale/tissue samples from southern resident killer whale predation events collected off the Washington coast during PODs 2009 cruise on the McArthur II*, BB0149, unpublished memo, 2010.

Wasser, Sam et al, *Population growth is limited by nutritional impacts on pregnancy success in endangered Southern Resident killer whales (Orcinus orca)*. PLOS ONE. June 29, 2017

Lacy, Robert C. et al, *Evaluating anthropogenic threats to endangered killer whales to inform effective recovery plans.* Scientific Reports, 7:14119. October 26, 2017

John K.B. Ford, *Chinook salmon predation by resident killer whales: seasonal and regional selectivity, stock identity of prey, and consumption rates.* Research Document 2009/101. Fisheries and Oceans Canada, Pacific Biological Station, 2009.

Montgomery, David et al, *Scientists Letter to the Southern Resident Orca Task Force*, August 2018.

Williams, Richard, editor, *Return to the River*, 2006.

Orca Salmon Alliance

Defenders of Wildlife
Save Our wild Salmon Coalition
Washington Environmental Council
Natural Resources Defense Council
Endangered Species Coalition
Whale and Dolphin Conservation
Center for Biological Diversity
Earthjustice
Orca Network
Oceana
Seattle Aquarium
Toxic Free Future.
Whale Scout
Puget Soundkeeper
Sierra Club

December 7, 2018

Maia Bellon, Director
Heather Bartlett, Water Quality Program Manager
Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600

Re: Scoping Notice for Short-term Modification of Total Dissolved Gas Standards for Federal Dams on the Lower Snake and Lower Columbia Rivers (11.16.2018)

Dear Director Bellon and Program Manager Bartlett:

The member organizations of the *Orca Salmon Alliance* submit these scoping comments regarding the Department of Ecology's scoping notice (November 16, 2018) for a short-term modification of total dissolved gas (TDG) water quality standards for federal dams on the lower Snake and lower Columbia rivers through 2021. We support a short-term rule change allowing for an increase in spill up to 125% TDG until Ecology permanently changes those TDG standards, whichever occurs sooner.

Orca Salmon Alliance (OSA) was founded in 2015 to prevent the extinction of the Southern Resident orcas by recovering the wild Chinook salmon populations upon which the whales depend for their survival. OSA members include *Orca Network, Defenders of Wildlife, Save Our wild Salmon Coalition, Washington Environmental Council, Oceana, Natural Resources Defense Council, Sierra Club, Earthjustice, Endangered Species Coalition, Whale and Dolphin Conservation, Puget Soundkeeper, Center for Biological Diversity*, *Seattle Aquarium*, *Whale Scout and Toxic Free Future*.

Southern Resident orcas were listed as endangered under the United States Endangered Species Act in 2005. After 15 years of recovery efforts, they are continuing to decline and in 2018 the population dropped to just 74 individuals, the lowest number in over three decades. Their main threats include prey availability, namely a decline in their primary prey, Chinook salmon; environmental contaminants; and vessel interference. Of these threats, lack of prey is the biggest limiting factor in their recovery. Salmon depletion has led to changes in pod structure, decreased presence in their core summer feeding areas, an increase in stress hormones and a miscarriage rate of almost 70%. There has not been a surviving calf in the population for three years.

As you are aware, Governor Inslee's Orca Task Force recommended Ecology "immediately eliminate the current 115% standard" and allow for increased spill up to 125% TDG on a flexible basis in order to deliver near-term benefits to endangered Southern Resident Killer Whales. These whales are nutritionally stressed and rely on adult Chinook salmon from the Columbia and Snake Rivers as an important prey resource at certain times of the year when their preferred prey can be exceptionally hard to find. Whale scientists believe (link to letter below) that increasing prey availability for these whales is crucial to halting and reversing their decline. As they explain, allowing higher levels of TDG, and in turn higher levels of voluntary spring spill, will lead to higher juvenile survival and increased adult Chinook return to the Columbia, especially spring/summer Chinook, a high-fat priority prey resource for the Southern Residents. *OSA* strongly supports this important advice from the scientific community.

A number of organizations submitted to you a request for a short-term modification of the TDG standards in September. We believe this letter describes the legal and scientific basis for a short-term modification of the TDG standards at the lower Snake and lower Columbia River dams for the "spring spill season" (from approximately April 1 through June 20) beginning in 2019 and continuing through spring of 2020 and 2021.

OSA strongly supports the elimination on a short-term basis of the current 115% forebay TDG limit at each dam and replacement of the existing 120% tailrace TDG limit with a limit of 125% for up to a minimum of 16 hours per day or more starting in 2019. We urge you to include such an alternative in the forthcoming environmental impact statement pursuant to the above referenced scoping notice. We believe that based upon the best currently available scientific information about the effects of TDG levels up to 125% in the dam tailraces, and analysis of any other alternatives you chose to evaluate, that a short-term modification of the TDG standards to 125% starting in 2019 is the best near-term alternative to better protect salmon and other species in the lower Snake and lower Columbia Rivers.

As reflected in your scoping notice, a short-term modification is consistent with requests from the *Washington Department of Wildlife*, the *Columbia River Inter-Tribal Fish Commission* and recommendations from the *Governor's Southern Resident Killer Whale Recovery Task Force*. It could also easily be coordinated with a parallel modification of TDG standards by the State of Oregon that affect the federal dams on the lower Columbia River. Oregon's standards currently allow TDG up to 120% as measured in the tailrace of the lower Columbia River dams on a 24-hour basis (the only dams directly affected by Oregon's standards). We understand that Oregon is in the process of considering increasing this tailrace TDG level to 125% on a flexible basis. Even if Oregon does not complete this change in time for the 2019 spring spill season, we expect it will in time for the 2020 and 2021 spring spill seasons. In any event, a change in the TDG standards in Washington to allow spill up to 125% starting in 2019 on a flexible basis would still benefit juvenile salmonid survival and protect designated uses.

Below we briefly summarize our basis for asking you to develop and consider an alternative that would eliminate the current forebay TDG standard and allow TDG levels of up to 125% on a flexible basis between 2019 and 2021 to benefit juvenile salmon during their out-migration to the ocean – and the critically endangered Southern Resident orcas that rely upon them for their survival and reproduction.

Recent analyses by the *Fish Passage Center* (FPC) confirm that voluntary spring spill at TDG levels of 125% in the tailrace of each dam is safe for downstream migrating juvenile salmon and steelhead and will further improve juvenile survival – and ultimately adult return rates – as compared to the lower levels of spill allowed under the current TDG exemptions. The most recent such analysis is set out in the FPC's **Comparative Survival Study (CSS) 2017 Annual Report.**

As this analysis explains, allowing TDG of up to 125% in the tailrace of each dam would lead to a significant increase in smolt-to-adult return rates for Snake River spring/summer Chinook. These findings are (a) more robust than similar conclusions Ecology has previously reviewed in connection with requests to modify its TDG standards; (b) have been reviewed by the *Independent Scientific Advisory Board* with suggestions for additional steps to strengthen the conclusions but without any fundamental disagreement with the CSS findings; and, (c) confirm that a short-term modification of Ecology's current TDG water quality standards for the lower Snake and lower Columbia River dams is scientifically well supported.

We also refer you to the **draft 2018 CSS Annual Report** for additional information. After review of this evidence, we believe you will conclude that the spill volumes allowed by TDG levels up to 125 percent would provide the best and safest route of passage for juvenile and adult salmon and steelhead by allowing them to avoid higher turbine and screen bypass mortalities, reducing passage delay, and dispersing predators. Even though spill *can* increase TDG levels, which can in extreme cases harm fish and other aquatic life, we believe state and federal laws require Ecology to set TDG limits that maximize salmon survival by balancing the benefits of increased voluntary spring spill with the minimal or non-existent risks of harm from Gas Bubble Trauma ("GBT") to salmonids and other species.

Further, we are not aware of any scientific study in the last ten years or any anecdotal evidence that any non-salmonid aquatic biota in the Snake or Columbia Rivers have suffered harm from TDG levels above 125% even though these levels of TDG occur frequently in the lower Snake and lower Columbia rivers in the spring due to involuntary spill. In the absence of compelling field evidence that the risks of higher levels of TDG, including 125% of saturation, are harmful to non-salmonid aquatic biota, the more robust evidence of the benefits to salmonids of increased spill as a result of a short-term modification of Ecology's TDG standards to 125% in the tailrace of each dam should lead Ecology to develop and choose an alternative in its SEPA process that approves a short-term modification of water quality standards to allow TDG up to 125% of saturation on a flexible basis during the spring salmon migrations season starting in 2019.

Of course, salmon are not the only anadromous species migrating through the hydrosystem. Pacific lamprey (*Lampetra tridentata*), for example, may also benefit from the short-term modification of the forebay and 120% tailrace TDG standards, a benefit to aquatic biota that Ecology may not have previously fully considered. Pacific lamprey have shown widespread decline since the 1960s in the Columbia River system due to habitat loss, water pollution, ocean conditions, and problems with dam passage. Lamprey decline is of particular concern in the Northwest because of their importance to Native Americans' cultural heritage and tribal fisheries. In fact, the lamprey's situation is perilous enough that the *Oregon Natural Resources*

Council petitioned the USFWS to list the species under the Endangered Species Act in 2002. Although the USFWS denied the petition, claiming lack of information, the USFWS has continued concern over the status and distribution of Pacific lamprey.

We encourage you to consult with the *FPC* and the Nez Perce and other Tribes about the benefits of increased spill for lamprey as you develop your EIS for a short-term modification of the TDG standards.

A short-term modification of WAC 173-201A-200(1)(f)(ii) to allow TDG levels of up to 125% is consistent with the requirements of the regulations that allow such a modification. First, the modification is short-term: approximately 120 days each year for the next three years at each of the eight lower Snake and lower Columbia river dams. The actual periods of higher and lower TDG (and spill) pursuant to the short-term modification at each dam would depend on the details of the annual Spring Fish Operation Plan (FOP) for these dams developed and adopted in collaboration with the State of Washington and other sovereigns by the relevant federal agencies each year. The short-term modification would provide the flexibility for longer periods of spill to the higher 125% TDG level and other, shorter, periods of lower spill, likely during peak electricity demand hours. In addition, and in accordance with WAC 173-201A- 410(2), the duration of the short-term modification would only be for the spring juvenile salmon migration season, which may run from about March 1 to about June 30 each year depending on the details of the Spring FOP, and the modification would only be in place for three years or until Ecology adopts any permanent modification of the requirements of WAC 173- 201A-200(1)(f)(ii), whichever occurs sooner.

Second, a modification of the TDG standards to allow spill up to 125% is necessary to accommodate the essential activity of securing beneficial dam passage conditions for migrating juvenile salmon and steelhead in the spring while also allowing appropriate hydropower generation. Most of the salmonids that pass the dams and would be affected by the short-term modification have been listed as threatened or endangered under the Endangered Species Act for many years. As described above, increasingly robust scientific evidence indicates that increased spill, up to at least 125% TDG, increases salmonid survival. For this reason, a short-term modification also is in the public interest.

Third, a short-term modification to allow TDG levels up to 125% is conditioned to minimize or eliminate any degradation of water quality, existing uses, and designated uses in the affected waters. TDG levels in the tailrace of each dam are often 125% or higher already during spring juvenile salmon migration due to involuntary spill resulting from high spring runoff and low electricity demand. We are not aware of any field evidence that these annually occurring high levels of TDG—which vary from year-to-year depending on weather, snowpack and other factors—have significantly harmed water quality or existing or designated uses.

Fourth, a short-term modification to allow TDG levels up to 125% in the dam tailraces would not reduce or remove the Corps' responsibility to otherwise comply with Washington's water quality standards at all times not subject to the short-term modification or alter the Corps' obligations and responsibilities under other federal, state, or local rules and regulations. In fact, such a short-term modification may help facilitate dam operations over the next few years under a biological opinion developed pursuant to the federal Endangered Species Act in order to avoid jeopardy to species of salmon and steelhead that are protected by that Act.

CONCLUSION

Voluntarily spilling water over the dams on the Snake and Columbia rivers during the spring juvenile migration season delivers important near-term benefits to Chinook salmon that, in turn, are critically important to Southern Resident orcas. Improving salmon survival directly benefits the orcas by increasing prey availability during lean winter months when the orcas forage on chinook from the Snake and Columbia Rivers. Biological monitoring conducted over the last decade and more demonstrates that tailrace TDG levels of 125% do not negatively impact migrating salmonids, resident fish, or invertebrates. The TDG levels currently allowed under Washington's water quality standards, however, unnecessarily limit the benefits of spill for juvenile salmon and steelhead migrating downstream in the spring. We urge you to develop and carefully consider in your EIS a short-term modification of water quality standards to allow TDG levels up to 125% of saturation in the tailrace of each of the eight dams on the lower Snake and lower Columbia Rivers during the spring juvenile salmon migration season beginning in 2019 and continuing through at least 2021, while permanent changes to TDG standards are developed. Thank you for your consideration of these scoping comments. Please contact Robb Krehbiel (rkrehbiel@defenders.org), if you have questions or we can be of assistance in any way.

Sincerely,

Robb Krehbiel, Washington State Representative
Defenders of Wildlife
Seattle, WA

RESOURCES:

2017 Comparative Survival Study Annual Report
http://www.fpc.org/documents/CSS/CSS_2017_Final_ver1-1.pdf

Draft 2018 Comparative Survival Study Report
http://www.fpc.org/documents/CSS/DRAFT2018CSSReportv1-1.pdf.

Close, D.A., M. Fitzpatrick, H. Li, B. Parker, D. Hatch & G. James. 1995. ***Status report of the Pacific lamprey (Lampetra tridentata) in the Columbia River Basin.***

Id.; *see also* Nez Perce, Umatilla, Yakama and Warm Springs Tribes. 2008. ***Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin***. Formal Draft, p. 4.

Orca Scientists' Letter to the Southern Resident Orca Recovery Task Force (Oct. 2018)
https://www.documentcloud.org/documents/5002547-Orca-Scientists-Letter-10-15-18-Final.html

Salmon Biologists' Letter to the Southern Resident Orca Recovery Task Force (Aug. 2018)
http://www.wildsalmon.org/images/factsheets-and-reports/2018-Scientist-Ltr-Orca-TF-Aug27.pdf

Washington State Senate

December 5, 2018

Becca Conklin
Washington State Department of Ecology
PO Box 47600
Olympia, WA 98504-7600

Re: Scope of Draft EIS for Modification of Total Dissolved Gas Levels

Dear Ms. Conklin,

We appreciate this opportunity to comment on the scope of the draft environmental impact statement for the department's proposal to modify total dissolved gas levels in the Columbia and Snake rivers. As Washington State Senators, we represent people who will be affected by the increased spill at hydroelectric dams that is the intended result of your proposal to adjust TDG.

Our comments can be summarized in three points:

(1) The immense cost of increased spill should lead the department to conclude that the proposal to modify TDG must be abandoned;

(2) The process the department has initiated to modify TDG is superfluous due to the ongoing federal Columbia River System Operations review; and

(3) Modifying TDG carries a high risk of unintended consequences for fish.

We have already seen the major cost impact of increased spill at hydroelectric dams in Washington. The Bonneville Power Administration's average annual cost to meet increased spill requirements exceeds $38 million.[1] In 2018, BPA redirected $20 million away from fish and wildlife programs to help cover the cost of spill.[2] Increasing spill also affects the price of electricity on the wholesale market throughout the Pacific Northwest because it forces hydroelectric facilities to forgo opportunities to produce electricity, resulting in costs that directly translate into higher electricity bills for Washingtonians.

Furthermore, we question the timing and necessity of the environmental review you are initiating. The ongoing federal CRSO review has been accelerated to meet a new 2020 completion date under the Presidential Memorandum on Promoting the Reliable Supply and

[1] Bonneville Power Administration, Final FY 2018 Spill Surcharge (June 21, 2018).
[2] *Id.*

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Delivery of Water in the West.[3] It is probable that the federal process will conclude before the department's EIS is complete, meaning the process you have initiated will be moot.

Finally, we call your attention to the important discussion of the unintended consequences of adjusting TDG contained in the minority report submitted to Governor Inslee by Commissioner Pittis and Mr. Chandler as part of the Southern Resident Orca Task Force Recommendations.[4] The minority report asserts that modifying TDG levels could increase the risk of gas bubble trauma in salmon.[5] The department must carefully consider how modifying TDG levels might actually work against salmon recovery by creating hazards for the very fish we want to recover.

Modifying TDG levels is a significant policy decision that would have wide-ranging effects for people and fish. Even if your analysis is not superseded by federal actions, we believe that your review will show the costs and flaws of your proposal are too substantial to make it viable by any objective measure.

Sincerely,

Mark G. Schoesler

Sen. Mark Schoesler
9th Legislative District

Sharon R. Brown

Sen. Sharon Brown
8th Legislative District

Jim Honeyford

Sen. Jim Honeyford
15th Legislative District

Judy M Warnick

Sen. Judy Warnick
13th Legislative District

Tim Sheldon

Sen. Tim Sheldon
35th Legislative District

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[3] Presidential Memorandum on Promoting the Reliable Supply and Delivery of Water in the West (Oct. 19, 2018).
[4] Southern Resident Orca Task Force Report and Recommendations p.94 (Nov. 16, 2018).
[5] *Id.*

TIDEWATER
TRANSPORTATION & TERMINALS

DEPARTMENT OF ECOLOGY
DEC 14 2018
WATER QUALITY PROGRAM

December 10, 2018

Becca Conklin
Department of Ecology
PO Box 47600
Olympia, WA 98504-7600

RE: Draft Environmental Impact Statement – Columbia and Snake Rivers
SEPA No. 20806404

Dear Ms. Conklin:

Thank you for the opportunity to provide comments on the scope of the Draft Environmental Impact Statement – Columbia and Snake Rivers ("DEIS"). These comments are submitted on behalf of Tidewater Transportation and Terminals ("Tidewater"), which is headquartered in Vancouver, Washington.

Tidewater has been in business since 1932 and operates a fleet of tugboats, barges and several marine terminals on the Columbia and Snake Rivers. Tidewater has over 280 employees and is the largest inland marine transportation company west of the Mississippi River. Its vessels safely move millions of tons of freight every year on the commercially navigable 465 miles of the Columbia and Snake Rivers, reducing congestion and wear and tear on the state's highways and railroads while producing far fewer pollutants and carbon emissions than trucks and trains transporting equivalent tonnage.

Tidewater has always strongly supported robust salmon recovery efforts, including improvements to hydro, habitat, harvest and hatchery concerns. That being said, we are very concerned with the State of Washington's proposed DEIS for the following reasons:

> First, we believe the State of Washington's DEIS is duplicative of the Columbia River Systems Operations Environmental Impact Statement ("CRSO EIS") process that is already two years underway by the federal agencies. The CRSO EIS is a regional, comprehensive effort to evaluate a range of operational alternatives for the federal hydropower facilities, including spill levels, that exist along the Columbia and Snake Rivers. The CRSO EIS process includes multiple opportunities for public engagement. The State of Washington is already a cooperating agency in this process, which will include an evaluation of the Columbia and Snake Rivers. Furthermore, the result of DEIS effort will not be as comprehensive as the current federal effort, and it is unlikely the DEIS effort will yield new information that would inform the CRSO EIS process or other species recovery activities in the Pacific Northwest.

6305 NW Old Lower River Road, Vancouver, WA 98660 • 360.693.1491 • www.tidewater.com

Second, the DEIS is not necessary as the perceived need to adjust the total dissolved gas ("TDG") levels in the Columbia and Snake River Dams are contrary to sound science. These projects are already among the most advanced, fish-friendly projects in the entire country. For example, the juvenile fish survival rates past the Snake River Dams averages 97%. Major improvements in turbine design, optimized river flow, fish ladders, and habitat restoration have resulted in improvements to salmon returns. Please see the enclosed Snake River Dams Fact Sheet for more information.

Tidewater urges the State of Washington to forgo conducting the DEIS and continue its participation in the existing CRSO EIS process.

Thank you for your time.

Sincerely,

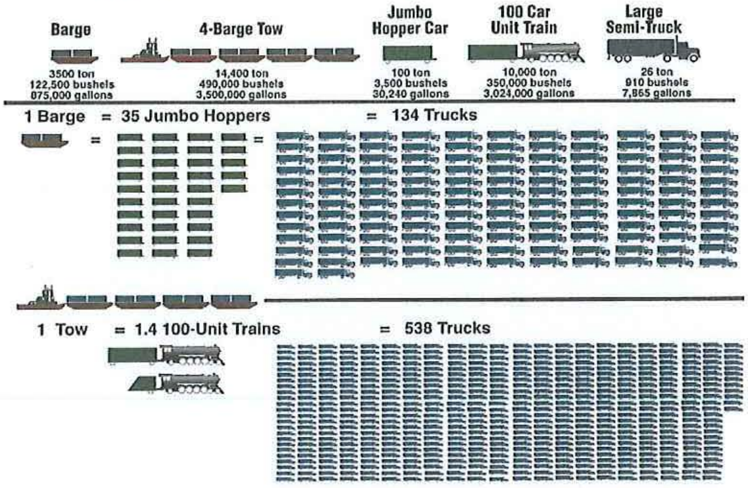
Robert A. Curcio
President & CEO

12/10/18

Enclosure (1)

Snake River Dams

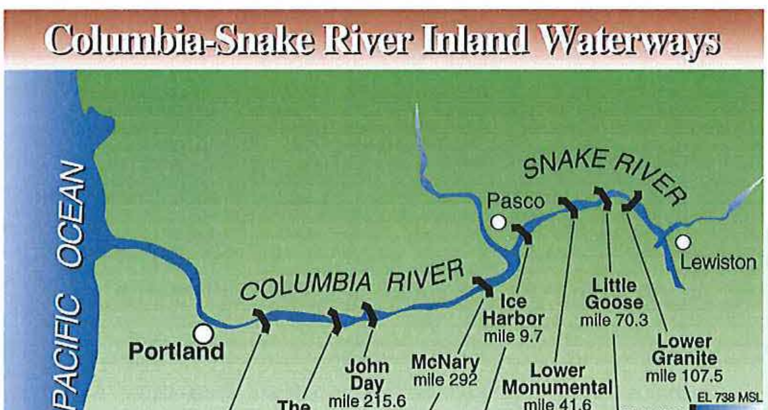
Freight Comparison of Barges, Trains and Trucks



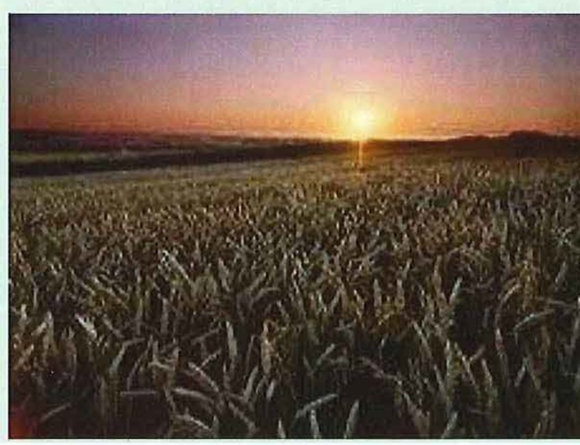
Barging is the most efficient and environmentally friendly mode of cargo transportation

In 2014, it would have taken 43,610 rail cars or 174,440 semi-trucks to move the cargo that went by barge on the Snake

The Columbia Snake River System is a 465-mile commercial waterway that provides farmers as far as the Midwest access to international markets



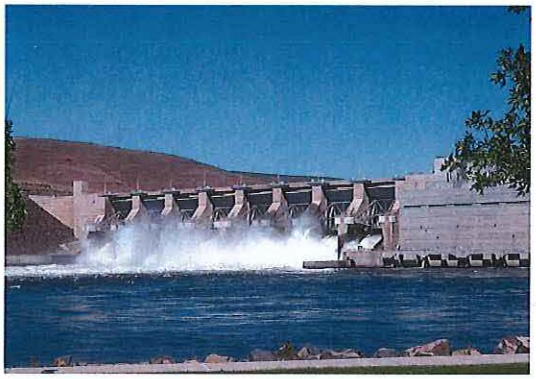
The Columbia Snake River System is the top wheat export gateway in the U.S.



In 2014, nearly 10% of all U.S. wheat exports moved through the Snake River dams

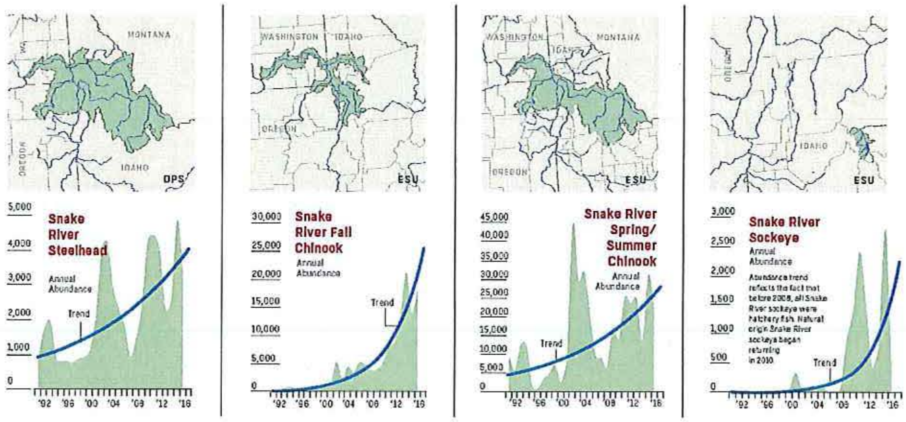
Barging information courtesy of Texas Transportation Institute
Wheat information courtesy of U.S. Department of Agriculture and U.S. Army Corps of Engineers

Snake River Dams



The four Snake River dams provide enough clean energy to power 1.87 million homes

Dam investments have resulted in improved fish returns and a 25 year sustained increase in salmon populations



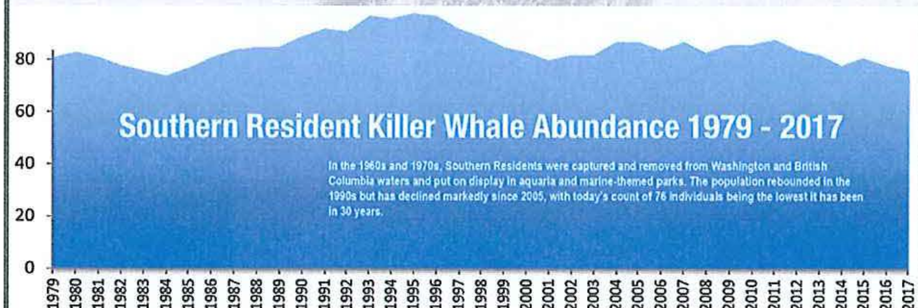
Spotlight on Orcas

The three Southern Resident Killer Whale (SRKW) orca pods have declined since the 1800s

In the 1960s, 47 SRKW orcas were captured for aquarium display, leaving only 67 remaining

Snake and Columbia River Chinook stocks have rebounded, yet orcas continue to decline

Recent NOAA research has highlighted Northern and Southern Puget Sound Chinook as priority orca prey stocks



http://www.westcoast.fisheries.noaa.gov

Juvenile fish survival rates past each of the eight federal dams are between 95% and 98%

Between 2002 and 2011, average wild Chinook salmon populations more than tripled, and average wild steelhead populations doubled

Energy information courtesy of BPA
Salmon and orca information courtesy of BPA, U.S. Army Corps of Engineers, NOAA Fisheries

Appendix B: Executive Summary of the Comparative Survival Study

Appendix B contains the Executive Summary of the annual report of smolt-to-adult salmon and steelhead survival through dams on the Snake and Columbia rivers completed by the Fish Passage Center. The full report, called "Comparative Survival Study of PIT-tagged Spring/Summer/Fall Chinook, Summer Steelhead, and Sockeye, 2017 Annual Report" is available online at http://www.fpc.org/documents/CSS/CSS_2017_Final.pdf.

Comparative Survival Study of PIT-tagged Spring/Summer/Fall Chinook, Summer Steelhead, and Sockeye

2017 Annual Report

BPA Project #19960200
Contract #74406

(12/16-11/17)

Prepared by

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December 2017

EXECUTIVE SUMMARY

The 2017 Comparative Survival Study Annual Report continues to update the historical time series life-cycle monitoring data and includes enhancements to analyses based upon review comments and recommendations from the fishery management agencies, tribes, and the Northwest Power and Conservation Council's Independent Scientific Advisory Board (ISAB).

This CSS Annual Report includes 22 years of SAR data for wild Snake River spring/summer Chinook (1994–2015), 19 years of SAR data for Snake River hatchery spring/summer Chinook (1997–2015), 18 years of SAR data for Snake River wild and hatchery steelhead (1997–2014), and seven years of SAR data for Snake River sockeye (2009–2015). There are seven years of SAR data for Snake River hatchery fall Chinook (2006–2012), and seven years of Snake River wild fall SAR data spanning the years 2006–2011. For mid-Columbia and upper-Columbia fall Chinook there are varying numbers of years available. There are 15 years of SAR data for Hanford Reach wild fall Chinook (2000–2014), four years of SAR data for wild Deschutes River fall Chinook (2011–2014), and seven years of SAR data for both Spring Creek NFH and Little White Salmon NFH fall Chinook (2008–2014). Spring and summer Chinook and sockeye returns from outmigration year 2015 should be considered preliminary, as they include only 2-salt returns and may change with the addition of 3-salt returns next year. Similarly, 2014 migration year fall Chinook returns include only 2-salt adults. The CSS has actively provided Passive Integrated Transponder (PIT) tags for most of these groups since outmigration year 1997.

Mark groups in 2017 were consistent with groups utilized in past years. In addition to overall smolt-to-adult return rates (SARs) for aggregate Snake River wild steelhead and Chinook salmon, the CSS has continued to pursue the development of SAR and life cycle metrics at the Major Population Group (MPG) level when sample size was adequate. These MPG-level SARs are provided for both Lower Granite to Lower Granite and from Lower Granite to Bonneville with and without jacks (1-salt) for Chinook salmon. In addition, Chapter 4 now includes estimates of overall SARs (MCN-to-MCN) for Yakima River wild Chinook salmon, Yakima River hatchery Chinook salmon (i.e., Cle Elum Hatchery), and Yakima River wild steelhead. The CSS continue to strive to improve life cycle monitoring metrics for wild populations of time, instantaneous mortality rates, and survival probabilities for hatchery sockeye in the LGR-MCN reach.

Overall SARs are the net effect of SARs for the different routes of in-river passage and juvenile transportation. Overall SAR and route of passage SARs are consistent with past year's findings. None of the passage routes have resulted in SARs that met the NPCC SAR objectives for Snake River wild spring/summer Chinook and steelhead. The relative effectiveness of transportation has been observed to decline as in-river conditions and survival rates improve. PIT-tag SARs for Middle Columbia wild spring Chinook and wild steelhead generally fell within the 2%–6% range of the NPCC SAR objectives. Incorporating the 2016 adult returns in this Annual Report shows that the trends seen in all but two past years of CSS monitoring continue. The overall SARs for Upper Columbia and Snake River populations of salmon and steelhead are not meeting the 2%–6% regional goal, while middle Columbia populations are meeting the regional SAR goals in most years.

In this report the analyses of SARs relative to estimates of population productivity which began in the 2015 CSS Annual Report has been expanded and is presented in Chapter 5. In 2016 the CSS began a comparison of Snake River SARs and steelhead population productivity for Fish Creek (Clearwater Major Population Group (MPG)) and Rapid River (Salmon MPG), which complement those for Snake River spring/summer Chinook. We have added comparable data for Pahsimeroi River steelhead (Salmon MPG) in this report. In 2017 we have also updated the analysis of pre-harvest SARs and historical productivity for Snake River spring/summer Chinook salmon. This represents the continuation of a longer-term effort, which will incorporate effects of density dependence on observed productivity to evaluate population responses relative to SAR rates. Analyses in this Chapter support objectives of the Columbia River Basin Fish and Wildlife Program (NPCC 2014), encouraging a regional review of the NPCC SAR objectives relative the survival of populations needed to achieve salmon and steelhead recovery and harvest goals. Major population declines of Snake River wild spring/summer Chinook were associated with SARs less than 1% and increased life-cycle productivity occurred when SARs exceeded 2%. Snake River wild steelhead population declines were associated with brood year SARs less than 1%, and increased life-cycle productivity occurred in the years that brood year SARs exceeded 2%. Pre-harvest SARs in the range of 4% to 6% are associated with historical levels of productivity for Snake River wild spring/summer Chinook. Although there are fewer SAR estimates for John Day River spring Chinook, historical levels of productivity appear to be achieved with pre-harvest SARs in the range of 4%-7%

Results of analyses of smolt to adult return, TIR, and delayed mortality for fall chinook were consistent with past year's analyses. These results indicate that the smolt transportation program for juvenile fall Chinook salmon does not adequately mitigate for the adverse effects of development and operation of the Snake and Columbia rivers hydropower projects on fall Chinook survival and adult return. Consistent with past years analyses, overall SARs of fall Chinook salmon were low compared to SARs for spring/summer Chinook salmon and steelhead. As in past years, the need to increase marking of fall chinook in order to address the entire passage distribution and population is needed. The CSS continues to work with the Nez Perce Tribe to improve fall chinook marking coverage.

An update of earlier analyses of age-at-maturity is included in this report. Both stock effects and common year effects were important factors for explaining patterns in mean age-at-maturity and the proportion returning at Age-3, Age-4, and Age-5. Stocks with the highest proportions returning at Age-5 included the wild stocks from the Snake and John Day rivers and hatchery stocks from Leavenworth and Dworshak hatcheries. Stocks with the lowest proportions returning at Age-5 included the Cle Elum, Imnaha, and Catherine Creek hatchery stocks. Across stocks, the proportions returning at Age-5 decreased over the 1997- 2011 juvenile outmigration years analyzed. There was considerable year-to-year variability in age-at-maturity that was shared across stocks, with the oldest age-at-maturity occurring in the 2000, 2004, and 2005 juvenile outmigration years and the youngest age-at-maturity occurring in the 2007, 2008, and 2010 juvenile outmigration years.

New in this CSS Annual Report is analyses of adult upstream migration success. The Comparative Survival Study (CSS) has been assessing adult salmon and steelhead upstream migration success through the Federal Columbia River Power System (FCRPS) beginning with the 2010 Annual Report. These analyses were included in response to regional concerns regarding high stray rates of Snake River steelhead (Oncorhynchus mykiss) and salmon that were transported as juveniles. Early analyses indicated that salmon and steelhead that were transported downstream in the smolt transportation program had lower upstream migration success and higher stray rates. This was considered problematic for some middle Columbia River listed steelhead stocks which were affected by Snake River steelhead straying. National Oceanic and Atmospheric Administration (NOAA) has established performance standards for adult salmon migration success in the Biological Opinions for the FCRPS. In the earlier Biological Opinions, NOAA included Reasonable and Prudent Alternatives that addressed water temperature thresholds for salmon migration corridors. In addition, the Environmental Protection Agency began a basin wide evaluation to establish Total Maximum Daily Load (TMDL) for water temperature. All three species in our analyses showed that the upstream survivals for transported fish were lower than fish that had migrated in-river as juveniles. In addition survival of fish transported as juveniles started to decrease at a lower temperature compared to fish that migrated in-river. These analyses indicate that summer chinook upstream survival began to decrease when water temperatures exceeded 17 degrees centigrade and sockeye and steelhead survival began to decrease when water temperature began to exceed 18 degrees centigrade.

salmon and steelhead, and continue to work with fishery managers to improve tagging coverage of wild populations from tributary traps.

The long-term objective of the CSS is to link stages of the salmon life cycle, the factors influencing survival at each life stage, and understanding how each factor affects survival at later life stages, resulting in smolt-to adult return rates. The analyses presented in Chapter 2 utilize the life cycle model to predict the long-term effects of four experimental spill alternatives under a dam breach scenario of the four lower Snake River dams, and a non-breach scenario, on population recovery. The experimental spill levels are defined in terms of the limits of total dissolved gas (TDG) produced at each project. The prospective analyses considered the relative benefit in adult return and smolt-to-adult return of four operation scenarios, the BiOp, 115%/120%, 120%, and 125% spill levels under high, average and low flow conditions. The analyses do not predict absolute SARs but rather examines the relative change among the four scenarios with increasing spill for fish passage under breach and non-breach scenarios. This analysis predicts that average return abundances and SARs increase at higher levels of spill and when dams are breached, owing to the empirical finding that survival is higher when powerhouse passage and water transit times are lower. The predicted outcomes represent approximations of the relative magnitude of increased survival and return abundance that are predicted relative to expected passage and water transit time values under flow, spill, and breach conditions. In a fully impounded river, we predict a 2-2.5 fold increase in return abundance above BiOp spill levels when spill is increased to 125% TDG. If the lower four Snake River dams are breached and the remaining four lower Columbia dams operate at BioP spill levels, we predict approximately a 2-3 fold increase in abundance above that predicted at BiOp spill levels in an impounded system, and up to a 4 fold increase if spill is increased to the 125% TDG limit. This analysis predicts that higher SARs and long-term abundances can be achieved by reducing powerhouse passage and water transit time, both of which are reduced by increasing spill, and

The time series analyses 1998-2016 of juvenile fish passage characteristics, including fish travel times, instantaneous mortality rates, and reach survival probabilities relative to environmental variables, were updated to include data from the 2016 juvenile outmigration year. Multiple regression analyses, mixed effect model structures, and multi-model inference methods were utilized to evaluate juvenile fish passage characteristics relative to environmental variables. These data time series incorporate a high degree of contrast in the environmental conditions and juvenile fish passage metrics, both within- and across-years. New in this report is the inclusion of Total Dissolved Gas as an environmental variable. Analyses indicated that total dissolved gas was not an important variable affecting instantaneous mortality or survival probabilities. Consistent with past years' findings, conclusions from the 2017 analyses of 2016 migration conditions and migration metrics are that water travel time, spill proportion, Julian date, and water temperature are important variables for predicting fish travel time, instantaneous mortality, and reach survival probability. One exception to this was the 2016 Springfield Hatchery sockeye mark group. The instantaneous mortality rate for Snake River sockeye in 2016 was the highest rate ever observed and was much higher than the average rate in 1998-2014. The survival probability for Snake River sockeye in 2016 was about half the average survival probability 1998-2014. Concerns have been raised over the poor condition and survival of sockeye released from the Springfield Hatchery in 2015 and 2016 (Hassemer 2016). Due to these concerns, only data from 1998-2014 was used to examine the effects of environmental variables on fish travel

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