Appendix 4

Total Dissolved Gas

Management Plan

Updated October 2016

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1.0 Introduction

Throughout the Columbia River System elevated levels of total dissolved gas (TDG) saturation are observed where spill occurs at U.S. Army Corps of Engineers (Corps) dams. A TDG Management Plan is included as Appendix 4 in the annual Water Management Plan. This TDG Management Plan describes voluntary and involuntary spill, use of the Spill Priority List, the process for setting spill caps, TDG management policies, and the TDG monitoring program. This Plan is consistent with the 2000 U.S. Fish and Wildlife Service (USFWS) Biological Opinion, and the NOAA Fisheries 2014 Supplemental Biological Opinion (2014 Supplemental BiOp)[1].

1.1 Background

During the 1990s, Snake and Columbia River salmonids were listed under the Endangered Species Act (ESA). Through ESA consultations, the Corps implemented a variety of operational and structural measures that were called for in biological opinions to improve the survival of listed salmonids. The 2014 Supplemental BiOp calls for the Corps to provide spill for juvenile fish passage at the Corps' four lower Snake River and the four lower Columbia River dams. The Action Agencies (AAs) annually develop a Fish Operations Plan (FOP) that provides detailed information on the implementation of the spill recommended in the BiOp for fish passage operations. The FOP is provided as Appendix E of the Fish Passage Plan[2] which is also updated annually.

1.2 State Water Quality Standards

The Federal Clean Water Act establishes the aquatic life criteria for TDG of 110 percent that have been adopted by the four states (Montana, Idaho, Washington, and Oregon) and regional tribal governments. The states of Washington and Oregon have authorized exceptions (criteria adjustment and standard modification, respectively) to these standards as long as the elevated TDG levels generated by fish passage spill for improved juvenile fish passage survival would not cause more harm to the fish than passing them through other passage routes, such as screened bypasses and turbines.

The five year 2015-2019 Oregon TDG standard modification specifies that from April 1 through August 31 TDG levels are not to exceed 120 percent in the tailwaters, measured as the average of the twelve highest hourly readings in any one day (midnight to midnight). The Washington criteria adjustment specifies that in order to aid fish passage, TDG levels are not to exceed either 120 percent in the project tailwater or 115 percent in the forebay of the next downstream dam. This is measured as the average of the twelve highest hourly (consecutive) readings in any 24-hour period as a rolling average (bulk of hours in day of measurement). The criteria also specify that TDG levels are not to exceed 125 percent on a one-hour basis (State of Washington) or on a two-hour basis (State of Oregon).

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[1] The 2014 Supplemental BiOp considered the Action Agencies' 2014-2018 Implementation Plan (2014-2018 IP) and incorporates both the 2008 NOAA BiOp and the 2010 Supplemental BiOp. References to the 2014 Supplemental BiOp also include, as appropriate, references to the 2008 and 2010 BiOps.

[2] The Fish Passage Plan may be found at the following link: http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/

2.0 Fish Passage Spill and Involuntary Spill

TDG management measures differ depending on whether the spill occurring at Corps and Reclamation dams is voluntary, i.e. spill for the benefit of juvenile fish migration through the Columbia River System; or involuntary, i.e. spill that is dictated by conditions beyond the Corps' control and require implementation of measures to manage TDG levels given these conditions. The following describes circumstances that result in various types of spill.

Voluntary Spill or Fish-passage spill - The Corps provides spill for the benefit of juvenile fish passage at the four lower Snake River and four lower Columbia River dams in accordance with the operative biological opinions and in a manner that is consistent with the Clean Water Act. The 2014 Supplemental BiOp RPA action 29 calls for the Action Agencies to provide spill at these dams to improve juvenile fish passage, while avoiding high TDG supersaturation levels. Specific spill levels are provided for juvenile fish passage at each project, not to exceed established TDG levels (either 110 percent TDG standard, or as modified by State water quality waivers, currently up to 115 percent TDG in the dam forebay and up to 120 percent TDG in the project tailwater, or if spill to these levels would compromise the likelihood of meeting performance standards such as at Lower Monumental - see section 4.1 for more details). The dates and levels for spill at each dam may be modified through the implementation planning process and adaptive management decisions. At some Corps dams, the amount of fish passage spill is a specified level (i.e., flow rate or percent of total river flow), and at others, spill is provided up to the applicable state TDG criteria, referred to as the "gas cap." The maximum spill level at a given dam that meets, but does not exceed, the gas cap is referred to as the spill cap.

Involuntary Spill - Involuntary spill is driven largely by hydrologic capacity at each dam; the quantity of water that exceeds the capacity of a dam to either temporarily store the water upstream of the dam or pass the water through its turbines. In these circumstances, water must be released through the spillway. Involuntary spill occurs due to either **Lack of Load Spill** or **Over Capacity Spill**, but can also occur as a result of the management of reservoirs for flood risk[3], scheduled or unscheduled turbine unit outages or transmission outages of various durations, passing debris, or any other operational and/or maintenance activities required to manage dam facilities for safety and authorized project uses.

a) **Lack of Load Spill:** Occurs when the available market for hydropower is less than the power that could be produced by the current river flow with available turbine capacity. When BPA cannot access sufficient market to sell hydropower and there is insufficient

[3] The Corps directs operations of storage projects in the Columbia Basin to manage flood risk. Storage reservoir pools are drafted in the winter and early spring to provide space to capture part of the spring runoff, reducing peak flows in the river. This flood risk management operation may require spill from storage reservoirs, which may result in elevated levels of TDG in the river system. The Corps and other action agencies work to manage system flood risk operations in a manner that reduces the need to spill at levels that exceed TDG water quality standards; however, there are conditions in which fulfilling the Corps' flood risk management authorities necessitates drafting storage reservoirs.

storage capability, the river flow must be released over the spillway or through other regulating outlets. Lack of load spill generally occurs during times of high flows (e.g., in the spring when power demands are low both in California and the Pacific Northwest). Releases from upstream storage dams during high load periods (generally morning and evening) can result in high flows at downstream dams during low load periods (e.g., middle of the night), causing lack of load spill. Lack of load spill is managed on a system-wide basis to distribute TDG levels across the Federal projects using the Spill Priority List. The Spill Priority List is a lack of load TDG management plan that has been developed for involuntary spill that results in exceeding the 110 percent TDG standard when lack of load conditions require spill. The Corps works with the region to develop the Spill Priority List that identifies the order in which projects spill in order to minimize TDG system wide. See additional information on the Spill Priority List in Section 3.0 below.

b) **Over Capacity Spill:** Occurs when flows exceed the hydraulic capacity of the available power generation facilities at a specific dam. Over capacity spill can be affected by high river flows, planned and unplanned unit outages, planned and unplanned transmission outages, and other transmission constraints. Any of these conditions physically limit the potential for hydropower production. Over capacity spill will generally be the amount of project outflow in excess of the maximum amount that can be released through all available generators and other outlet structures (e.g., sluiceways and fish ladders). In general, when this condition occurs, the affected project will be operating at maximum generation, but within the Fish Passage Plan turbine operating criteria capability to minimize the amount of spill.

   Over capacity spill can also occur when turbines cannot be used because their capacity must be held in reserve to provide mandatory reserve power capacity (reserves) for contingencies and load balancing. **Reserves** (Reserve Power Capacity) are the amount of generation capacity above the amount currently in use that is immediately available to maintain system reliability. At projects that must carry reserve power capacity, these projects can only be loaded to the maximum available generation minus the reserve capacity allocated to that project. Spill for maintaining reserves primarily occurs at Grand Coulee, Chief Joseph, The Dalles, John Day, Bonneville, and occasionally McNary dams.

c) **Miscellaneous spill:** Occurs when water is passed through various dam structures for other purposes. These structures include the fish ladders, juvenile fish bypass, navigation locks, ice and trash sluiceways, Bonneville Powerhouse 2 corner collector, etc. Miscellaneous spill occurs most hours during the year and especially during April through August when fish are migrating.

d) **Special Spill Events:** Occur for the purposes of passing debris or operational and/or maintenance activities required to manage dam facilities for safety and multiple uses. These are infrequent and generally of short duration.

3.0 Spill Priority List

The Spill Priority List identifies the order and amount of spill at the Corps' Columbia River Basin dams and Grand Coulee Dam for management of lack of load spill and the expected TDG production system-wide. The Spill Priority List is used throughout the year.

3.1 Spill Levels

Values on the Spill Priority List serve as a reference for expected TDG production at the dams and are applicable for all spill conditions. Estimated spill levels are grouped into different TDG production levels (spill cap targets) on the Spill Priority List as shown below:

- Voluntary Spill– Target spill levels as described in the Fish Operations Plan (FOP) for fish passage
- Level 1 – Spill flows up to 120 percent TDG in the project tailrace or 115 percent TDG in the next downstream forebay (whichever is less)
- Level 2 – Spill flows up to 120 percent TDG in the project tailrace
- Level 3 – Spill flows up to 122 percent TDG in the project tailrace
- Level 4 – Spill flows up to 125 percent TDG in the project tailrace
- Level 5 – Spill flows up to 127 percent TDG in the project tailrace
- Level 6 – Spill flows up to 130 percent TDG in the project tailrace
- Level 7 – Spill flows up to 135 percent TDG in the project tailrace

3.2 Factors for Setting Spill Priority

When establishing the order dams will spill above that required for BiOp juvenile fish passage, the following factors are considered:

- Location of Fish: Location and number of adult and juvenile fish in the migratory corridor[4] is a factor in establishing the spill priority order on the Spill Priority List.
- Location of High TDG: When TDG levels are elevated (above 120 percent), dams may be shifted on the list to manage system-wide TDG levels.
- Location of Fish Research: When fish research is planned or in progress, those dams are low on the priority list to minimize detrimental impact to the studies.
- River Reaches: Dams are considered in one of three blocks: the lower Snake River, the lower Columbia River, and the middle Columbia River. For example, if several of the lower Snake dams need to be moved to a lower priority on the Spill Priority List, then the whole block of dams (Lower Granite, Little Goose, Lower Monumental and Ice Harbor dams) may be moved to last position on the list.
- Special Operations: Dams with special operations such as construction, maintenance or repair are placed last on priority list.

[4] This type of input is often provided through a regional forum, such as TMT.

- Collector Dams: During low flow years, the collector dams where fish transport occurs (Lower Granite, Little Goose, Lower Monumental and Ice Harbor dams) are placed low on the priority list.
- Special Fish Conditions: If there are special fish conditions, such as disease or a special release, the dam may be moved higher or lower on the priority list depending on circumstances[3].
- System-wide TDG management: Grand Coulee, Chief Joseph, Dworshak and other projects are included on the Spill Priority List to help balance system-wide TDG levels during periods of lack of load involuntary spill.

4.0 Process for Setting Spill Caps

The Corps' Reservoir Control Center (RCC) Water Quality Unit reviews operations and develops daily spill caps[5] for the Columbia River System projects in coordination with NOAA Fisheries with the objective of attaining the BiOp/FOP spill levels consistent with applicable TDG standards, and managing system-wide TDG levels during involuntary spill consistent with the Spill Priority List. Spill caps may vary depending on flow, spill operation, spill pattern, temperature, and other environmental conditions.

The following describes factors considered in setting daily spill caps, including reviewing daily TDG and spill data, evaluating System Total Dissolved Gas (SYSTDG) (see p. 8 for more detail) simulations results and discussing proposed spill caps internally and with NOAA Fisheries.

4.1 Factors Considered in Setting Spill Caps

The determination of spill caps at each individual dam is dependent upon an array of variables:

- FOP Spill Operations: The juvenile fish passage spill released from the projects as prescribed in the BiOp and specified in the FOP are the baseline spill levels in the lower Snake and lower Columbia Rivers. These spill operations can be a percent of total river flow, a fixed level, or up to either the 120 percent TDG (tailwater) or the 115 percent TDG (forebay) "gas cap," whichever is the more restrictive.
- High 12 Hour Average TDG Reading: A review of the previous day's high 12 hour average TDG reading (the Oregon calculation method) or high 12 hour consecutive average (the Washington calculation method) of the dam forebay and tailwater fixed monitoring station (FMS), whichever is more restrictive, is used to indicate whether the spill caps need to be increased or decreased.
- Lower Monumental Spill Approach: The Corps is balancing TDG production with spill for fish passage at Lower Monumental Dam to meet juvenile dam passage survival performance standards. The unique reservoir configuration combined with environmental conditions downstream of Lower Monumental Dam often results in very little degassing of the water spilled at this project once the water reaches the Ice Harbor Dam forebay. As a result, providing fish passage spill to achieve performance standards at Lower Monumental Dam while not exceeding the 115 percent TDG limit in the Ice Harbor Dam

[5] The spill cap is the estimated spill rate to achieve the appropriate level of spill to meet state TDG gas cap levels or to meet target levels of TDG identified in the Spill Priority List (See Section 3.1).

forebay is challenging and often results in TDG levels that exceed 115 percent TDG. Consequently, maintaining performance standard spill for fish passage is prioritized over managing to 115 percent in the Ice Harbor Dam forebay. The TDG instances related to this approach for benefitting juvenile fish migration occurred only at the Ice Harbor forebay gauge.

- Data Reports Used in Spill Review: The Corps has developed web reports that summarize various dam operations, river flows, and water quality data considered in spill review and adjustment decisions as follows:
    - Comparison of the amount of specified FOP spill with actual spill.
    - Calculation of the percentage of spill at certain dams
    - Data on flow, generation, spill, forebay elevation, TDG levels, and water temperature at each dam
    - Tributary flow and temperature data for the Columbia River Basin
    - Unit generation and spill bay data for each dam
    - Water temperature string data at each dam
    - 10-day flow forecasts for the lower Columbia and Snake rivers
    - Wind forecasts for the lower Columbia and lower Snake rivers

- System Total Dissolved Gas (SYSTDG) Model: SYSTDG is a decision support spreadsheet model used to estimate TDG percent of pressure resulting from mainstem dam operations on the Columbia, Snake, and Clearwater rivers. The SYSTDG model assists with dissolved gas abatement measures and spill management decisions associated with the Columbia River System operations and fish passage requirements of the Endangered Species Act.
- Physical Design and Characteristics of Dams: TDG levels that are generated in the tailwater of each dam depend upon many factors including the amount of spill passing through the spillway, the pattern of spill through the spillway, the amount of flow through the powerhouse, structure of the stilling basin, the presence (or absence) and elevation of flow deflectors, the presence (or absence) of divider walls, and river characteristics immediately below each dam. These individual characteristics are taken into account when assigning spill caps.
- Travel Time: The time it takes water to move from one dam to the next depends upon the distance between dams and the flow rate in the river. Because of this, changes in spill at an upstream dam and the resulting change in TDG levels will not be seen in the forebay of the downstream dam for several hours or days.
- Water Temperature: Climatic conditions can cause increases in water temperatures, which in turn can cause increases in TDG levels. The rule of thumb for water temperature is that a $1^{o}C$ ($1.8^{o}F$) increase in water temperature can result in a 2 to 3 percent increase in TDG. The impact of changing climatic conditions on water temperature is difficult to predict so air temperature is used as a surrogate. If a significant increase in air temperature is expected in a specific region, then it is assumed that water temperatures will also be increasing and spill caps will be adjusted appropriately.
- Degassing: As waters flow from one dam to another, degassing can occur. Experience has shown that winds above 10 mph enhance degassing. Therefore, wind conditions (in combination with other ambient conditions) are used to predict levels of degassing and are included in the SYSTDG model used to determine daily spill caps. In addition, with

flows below 200 kcfs, significant degassing of TDG occurs in the river between the Bonneville Dam and the Camas/Washougal fixed monitoring station (FMS). However, when flows increase above 200 kcfs, little or no degassing has been observed.

- Flow Variations: Spill decisions are often affected by forecasts of river flows which vary on a weekly basis.
- Power Demand: On weekends, demand for power is typically lower compared to during the workweek, thus total river flows may be reduced on weekends.
- Maintenance and Repairs: During an average spill season, there are many units that are out of service for various reasons. Scheduled maintenance and repair activities will reduce the amount of powerhouse capacity of a dam. The type of maintenance and repair activity and how it will affect flows through the dam is taken into account in order to assign appropriate spill caps.
- Forebay Debris Removal: Excessive debris can accumulate in the forebay and can impact fish passage, plug of block trash racks, vertical barrier screens (VBSs), gate well orifices, dewatering screens, and facility piping. Spill operations to pass debris don't follow the normal spill schedule or volume limits, but must be coordinated providing detailed spill operations. See the Fish Passage Plan for additional information.
- Experimental Test Schedules: The scheduling of various investigative studies can result in alterations in the normal operation of a dam. Examples of such alterations including modified spill pattern tests, removable spillway weir tests, and modified spill operations.
- Minimum Spill: During low flow conditions, minimum voluntary spill discharges are defined in the FOP, e.g. Removable Spillway Weir (RSW) spill (7-8 kcfs) at Little Goose, 25 percent at John Day and 50 kcfs at Bonneville.
- Minimum Generation: A minimum amount of flow for power generation is needed for electrical grid stability. During low flows, the minimum generation requirement will limit the spill rate from dams.
- Definition of Daytime and Nighttime: The definition of daytime and nighttime hours affects the duration of certain spill levels. Due to shorter nights during summer, a spill cap can be set a little higher, recognizing that it will be in effect for only a few hours.

5.0 TDG Management Policy, Guidance and Considerations

The Corps will consider water quality effects along with the results of spill studies, biological evaluations, and the relationship to achieving BiOp performance standards and incorporate the following TDG management policies in its decision making:

- Manage dam operations to the extent practical in accordance with CWA and state water quality standards, modified through standard modifications and rule adjustments.
- Provide voluntary spill for fish consistent with applicable biological opinion requirements while avoiding high TDG levels or adult fallback problems. Specific spill levels will be provided for juvenile fish passage at each dam consistent with applicable State TDG standard modification or criteria adjustment.
- Operate dams to the authorized project purposes.
- Regulate flows to maximize potential for voluntary/fish passage spill.

- Discontinue or postpone non-critical unit service and maintenance schedules that create (or have potential for creating) high localized TDG levels, especially when and where high numbers of listed fish are present.
- Accommodate special spill requirements/restrictions for research, adult passage, etc. that have been coordinated with the TMT.
- Manage the system in coordination with the Bureau of Reclamation and BPA to avoid involuntary spill and minimize TDG production when possible, without jeopardizing flood control objectives.
- Implement the Spill Priority List discussed in Section 3.0.

The Corps will continue to coordinate with the States of Oregon and Washington on voluntary fish passage spill[6], and provide technical information to inform the process. Future spill operations may be modified through the implementation planning process and adaptive management.

6.0 TDG Monitoring Program

The management of spill at each dam is based on TDG levels measured at specific forebay and tailwater FMS. The current locations of these gauges are based on extensive studies that have been conducted since 1996.

In support of the spill management program, a TDG monitoring program has been established and is described in the Dissolved Gas Monitoring Plan of Action. This monitoring program is revised to include changes in the FMS system and evaluated by regional representatives.

A copy of the 2015 – 2018 Dissolved Gas Monitoring Plan of Action can be obtained from this website: http://www.nwd-wc.usace.army.mil/tmt/wqnew/tdg_monitoring/2015-18.pdf

[6] The Corps coordinates with the State of Washington on voluntary fish passage spill at the lower Snake and lower Columbia River projects; and with the State of Oregon on voluntary fish passage spill at the lower Columbia River projects.