2020 TOTAL DISSOLVED GAS REPORT

U.S. Army Corps
Of Engineers
Northwestern Division

Spill at Bonneville Dam

Columbia Basin Water Management Division
Reservoir Control Center
Water Quality Unit

January 2021

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COLUMBIA RIVER BASIN

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Reservoir Control Center, Columbia Basin Water Management Division
U. S. Army Corps of Engineers Northwestern Division
Portland, Oregon

Including Material Provided by:
Portland District – U.S. Geological Survey (Portland Office)
Walla Walla District – U.S. Geological Survey (Kennewick Office)
Seattle District – Columbia Basin Environmental
Fish Passage Center

Table of Contents

List of Tables

List of Figures

List of Appendices

The appendices to this report are available on the internet:
http://pweb.crohms.org/tmt/wqnew/tdg_and_temp/2020/

List of Acronyms

The following acronyms are used throughout this report.

BiOp	Biological Opinion
BPA	Bonneville Power Administration
Corps	U.S. Army Corps of Engineers
CRS	Columbia River System
ESA	Endangered Species Act
FCOP	Flood Control Operating Plan
FCRPS	Federal Columbia River Power System
FMS	fixed monitoring station
FOP	Fish Operations Plan
GBT	gas bubble trauma
HEC-ResSim	USACE Hydrologic Engineering Center's Reservoir System Simulation model
kcfs	thousand cubic feet per second
kaf	thousand acre-feet
Maf	million acre-feet
NOAA Fisheries	National Oceanic and Atmospheric Administration, National Marine Fisheries Service
NWRFC	Northwest River Forecast Center
ODEQ	Oregon Department of Environmental Quality
PUD	Public Utility District
QA/QC	quality assurance/quality control
RCC	Reservoir Control Center
Reclamation	United States Bureau of Reclamation
RPA	Reasonable and Prudent Alternative (from the Biological Opinion)
SYSTDG	System total dissolved gas model used to estimate TDG production
TDG	total dissolved gas
TMT	Technical Management Team
TMDLs	Total Maximum Daily Loads
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WDOE	Washington Department of Ecology
WQS	Water Quality Standards
WY	water year

Terminology

The U.S. Army Corps of Engineers (Corps) provides the following definitions used throughout this report.

7Q10 Flows: The average peak annual flows for seven consecutive days that has a recurrence interval of 10 years, and at these flows, the ODEQ and WDOE TDG criteria do not apply.

Action Agencies: The three Federal agencies responsible for the operation of the Columbia River System or FCRPS projects are the Corps, Bureau of Reclamation (Reclamation), and Bonneville Power Administration (BPA).

Agreement: The 2019-2021 Spill Operations Agreement signed by the State of Oregon, the State of Washington, the Nez Perce Tribe, the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, and the Bonneville Power Administration. This Agreement describes planned 2019-2021 spring fish passage spill operations intended to benefit juvenile spring fish passage in concert with managing the Columbia River System for multiple congressionally-authorized purposes.

CRS: The Columbia River System refers to the fourteen federal dam and reservoir projects within the Federal Columbia River Power System that are operated as a coordinated water management system for multiple congressionally-authorized project purposes.

Data Quality Events: Data quality event occur when the Corps cannot evaluate TDG levels because the FMS gauge malfunctioned resulting in missing or erroneous data.

FCRPS: The Federal Columbia River Power System is a series of multi-purpose hydroelectric facilities in the Pacific Northwest region, constructed and operated by the U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation, and a transmission system built and operated by the Bonneville Power Administration to market and deliver electric power.

Fish Passage Spill (Planned 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 and within the state TDG standards. The Corps also provides spill for the benefit of adult fish passage at the four lower Columbia River dams. Spill operations for juvenile fish passage are consistent with the provisions outlined in the 2019 NOAA Fisheries Columbia River System Biological Opinion (2019 BiOp), the 2019-2021 Spill Operation Agreement, the Corps' requirements under the Endangered Species Act, and is the subject of ongoing consultation and communications with the relevant wildlife agencies to ensure consistency with the Act.

Gas Cap: The applicable State TDG WQS (in percent TDG). The TDG standard for the states of Washington and Oregon is 110%. Both states have provided exceptions to the TDG standard for juvenile fish passage spill operations on the lower Snake and lower Columbia rivers. Each state has different calculation methodologies for the different standards, and the Corps applies the more stringent standard when operating under all applicable state TDG standards.

Hydraulic capacity: The maximum water flow rate that a hydropower facility can pass through the turbines. Capacity can be limited by outages, operating limits, and the carrying of mandatory power reserves by the project.

Forced Spill: Forced spill is driven largely by hydrologic capacity at each dam. It is 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. Forced spill occurs due to either **Lack of Load** or **Lack of Turbine**, but can also occur as a result of the management of reservoirs for flood risk[1], 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.

1. **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 markets to sell hydropower and there is insufficient 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.

2. **Lack of Turbine Spill:** Occurs when flows exceed the hydraulic capacity of the available power generation facilities at a specific dam. Lack of turbine 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. Lack of turbine 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

[1] The Corps directs operations of storage projects in the Columbia River 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.

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.

Lack of turbine 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) **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.

NOAA Fisheries 2019 BiOp: The governing NOAA Fisheries Biological Opinion for the Columbia River System during 2020 juvenile fish passage spill season.

Percent TDG: Percent of total dissolved gas saturation (TDG) or concentration in the water-body. This may also appear as %TDG in the text or tables.

Performance Standard Spill – Performance standard spill is a NOAA Fisheries term and refers to spill levels intended to meet NOAA's performance standard testing, as described in the 2008 FCRPS Biological Opinion and accompanying administrative record.

Regulatory Methods - The regulatory method refers the TDG calculation methodology determined by the gas cap that applies on a specific date, at a specific location. When and where multiple calculation methods apply, 'regulatory' represents the calculation that results in the greater value.

Spill Cap – The spill level (flow through the spillway measured in kcfs) at each project that is estimated to maximize spill to a level that meets, but does not exceed, the gas cap in the tailrace and the next downstream forebay (if applicable).

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 during times of forced spill. The Spill Priority List consists of levels based on ascending TDG values, a spill rate for each project that is estimated to produce the TDG values and an order of projects.

TDG Exceedance: An exceedance occurs when TDG levels exceed applicable state water quality standards and applicable TDG modification (Oregon) and criteria adjustments (Washington).

TMT: The Technical Management Team (TMT) is an interagency sovereign technical group responsible for making recommendations on operations for fish to the Federal agencies with authority to operate FCRPS projects. This group is comprised of representatives from sovereign entities including five Federal agencies: BPA, Reclamation, National Oceanic and Atmospheric Administration (NOAA) Fisheries, U.S. Fish and Wildlife Service (USFWS), Corps, four states (Idaho, Oregon, Montana, and Washington), and participating Tribes.

Unit Outage: A unit outage is a period of time when a generating unit cannot be in operation because of maintenance or repairs.

Program Description

Overview

Total Dissolved Gas (TDG) is impacted by the U.S. Army Corps of Engineers' (Corps) projects in the mainstem Columbia and Snake rivers in the states of Oregon and Washington. Flow passing over the spillway of a dam can cause TDG concentrations that are greater than background levels. As TDG travels downstream it is influenced by environmental factors including water temperature and wind.

Juvenile fish passage spill occurs generally from April through August. The volumes and duration of fish passage spill at each project in 2020 were implemented consistent with the 2019-2021 Spill Operations Agreement (Agreement) and consulted on under the Endangered Species Act (ESA), as described in the 2019 NOAA Fisheries Columbia River System Biological Opinion (2019 BiOp).

This report describes the Corps' Columbia River Basin spill and water quality monitoring program for 2020 and addresses the Corps' reporting responsibilities related to the 2020 Oregon Department of Environmental Quality (ODEQ) TDG modification, the 2020 Washington Department of Ecology (WDOE) TDG rule change, and the 2002 and 2003 TDG Total Maximum Daily Loads (TMDLs) for the lower Columbia and lower Snake rivers.

ODEQ requires an annual TDG report summarizing the 2020 spill season and detailing the following: (a) flow and runoff descriptions, (b) spill quantities and durations, (c) quantities of water spilled for fish versus spill for other reasons, (d) data results from the physical and biological monitoring programs, including incidences of gas bubble trauma regardless of sample size, (e) evaluation of the relationship between observation of non-salmonid gas bubble trauma monitoring and exposure to elevated TDG levels, (f) biological or physical studies of spillway structures and prototype fish passage devices to test spill at operational levels, and (f) implementation of gas abatement measures identified through adaptive management. This report also includes documentation on the performance of the TDG monitoring system that is required in the Terms and Conditions outlined in the 2019 BiOp.

2019-2021 Spill Operations Agreement

The intent of the Agreement for fish passage spill operation is to (1) provide fish benefits (increasing spill levels to improve juvenile passage conditions and survival rates and adult returns), (2) provide federal power system benefits, and (3) provide operational feasibility. Per the Agreement, in the spring of 2020, the four lower Snake River dams and two lower Columbia River dams were operated up to 125% TDG Gas Cap spill for a minimum of sixteen hours per day, and each project operated under "performance standard spill" for up to eight hours per day[2]. These performance standard spill blocks provide more flow through turbine units. Higher powerhouse flow allows for power marketing flexibility and

[2] Per the 2020 FOP (Appendix B of this report), fish passage spill at The Dalles Dam will be 40% of total river flow 24 hours per day and spill at Bonneville Dam should not exceed 150 kcfs due to erosion concerns.

can also work to alleviate passage concerns for adult migrants that can have difficulty passing during high spill at some projects. The Gas Cap spill periods are intended to increase spillway passage and reduce powerhouse encounter rates for downstream migrating juvenile salmonids. Spring spill operations occur April 3–June 20 at the four lower Snake River projects, and April 10–June 15 at the four lower Columbia River projects. Daily spill caps were coordinated with NOAA Fisheries and adjusted daily as necessary. The early and late summer fish passage spill operation set spill targets in terms of rate (i.e. kcfs) or percentage of total river flow.

Endangered Species Act

During the 1990s, Snake and Columbia River salmonids were listed under the ESA. Through ESA consultations with NOAA Fisheries and U.S. Fish and Wildlife Service (USFWS), the Corps implemented a variety of operational and structural measures that were called for in biological opinions to improve the survival of listed salmonids.

USFWS 2000 BiOp

According to the actions addressed in the USFWS 2000 BiOp, operational and structural changes were to be made to reduce uncontrolled spill and the effects of high TDG at lower Columbia River dams if it is determined that bull trout are affected by the FCRPS.

NOAA Fisheries 2019 Columbia River System BiOp

NOAA Fisheries issued a final Biological Opinion on the continued operation and maintenance of the CRS on March 29, 2019. The 2019 BiOp is based on the proposed action contained in the Action Agencies' 2018 Consultation Package. The 2018 Consultation Package contained a suite of actions that generally carried forward the action from Reasonable and Prudent Alternative in the 2008 NOAA Fisheries BiOp, as supplemented in 2010 and 2014. The 2019 BiOp also incorporates the spill operation as described in the 2019-2021 Spill Operation Agreement. The NOAA Fisheries 2019 BiOp found that the proposed action would not likely jeopardize the continued existence of listed salmonids. The proposed action and the BiOp were incorporated into the 2020 Fish Operation Plan.

State Water Quality Standards (WQS) for TDG

The Corps manages spill for fish passage consistent with the State of Washington and the State of Oregon TDG WQS.[3,4] WDOE recently adopted a WQS rule change allowing

[3] WASH. ADMIN. CODE § 173-201A-200(l)(f)) provides the maximum TDG criteria for each of the aquatic life use categories and displays Table 200 (I)(f) that states: "Total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection." The code also addresses exceptions and adjustments, including a provision allowing for an adjustment of the TDG criteria to aid fish passage over hydroelectric dams.

[4] OR. ADMIN. R. 340-041-0031 provides in part: "the concentration of TDG relative to atmospheric pressure at the point of sample collection may not exceed 110 percent of saturation." OR. ADMIN. R. 340-

spring juvenile fish passage spill operations to generate specified TDG levels in project tailraces (up to 125% TDG for 12 hours; 126% TDG for 2 hours), so long as the spring juvenile fish passage spill operations do not exceed the spill levels and durations reviewed in applicable ESA consultation documents. The EPA subsequently approved the rule change and found that the ESA consultation documents' language ensures that any spring spill regime using the revised criteria must be performed in accordance with the spill levels and durations evaluated in ESA consultation documents for effects to ESA-listed species of all life stages, including juvenile out-migrating salmonids, resident salmonids, and adult migrating salmonids. EPA's approval of the rule further states that "compliance with the ESA consultation documents is a condition precedent for the revised criteria and so the criteria are not applicable for the purposes of the CWA (i.e. have no effect for CWA purposes) without the ESA consultation documents addressing spill operations that result in TDG saturation levels above the pre-existing criterion." *Letter to WDOE from EPA Re: The EPA's Action on Revisions to the [WDOE]'s Surface Water Quality Standards for the Site-Specific Total Dissolved Gas Criteria in the Columbia and Snake Rivers, and Other Water Quality Standards Revisions dated March 5, 2020, page 9.*

The ODEQ approved a change to its TDG WQS (up to 125% TDG for 12 hours, 127% TDG for 2 hours), so long as spring spill is "applied in a manner consistent with the applicable requirements of the federal [ESA]." *Order Approving a Modification to the Oregon's Water Quality Standard for Total Dissolved Gas in the Columbia River Mainstem dated February 11, 2020, page 4.* Both states have thus accommodated levels of TDG above 110% for fish passage spill operations for ESA-listed juvenile salmonids at Corps projects on the lower Snake and lower Columbia rivers, as follows:

041-104(3) identifies findings the Environmental Quality Commission must make for the purpose of allowing increased spill for salmon migration. *See* https://www.oregon.gov/deq/wq/Documents/columbiaUSACEtmdlorder.pdf

Washington Administrative Code

WAC 173-201A-200(1)(f)(ii) and WAC 173-201A-200(1)(f)(ii)(A)

(ii) The TDG criteria may be adjusted to aid fish passage over hydroelectric dams that spill for anadromous juvenile fish as of the 2020 spill season. The elevated TDG levels are intended to allow increased fish passage without causing more harm to fish populations than caused by turbine fish passage. The following special fish passage exemptions for the Snake and Columbia Rivers apply when spilling water at dams is necessary to aid fish passage:

(A) 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 calculated as an average of the twelve highest hourly readings in a calendar day, relative to atmospheric pressure); and
- A maximum TDG saturation level of one hundred twenty-five percent calculated as an average of the two highest hourly TDG measures in a calendar day during spillage for fish passage.

WAC 173-201A-200(1)(f)(ii)(B)

(B) To further aid fish passage during the spring spill season (generally from April through June), spill may be increased up to the following levels as measured at the tailrace fixed site monitoring location:

- A maximum TDG saturation level of one hundred twenty-five percent calculated as an average of the twelve highest hourly TDG measures in a calendar day; and
- A maximum TDG saturation level of one hundred twenty-six percent calculated as an average of any two consecutive hourly TDG measures. These TDG criteria may be applied in place of (f)(ii)(A) of this subsection during spring spill operations when applied in accordance with the following conditions:

(I) In addition to complying with the requirements of this chapter, the tailrace maximum TDG criteria at hydropower dams shall be applied in accordance with Endangered Species Act consultation documents associated with spill operations on the Snake and Columbia rivers, including operations for fish passage. The Endangered Species Act consultation documents are those by which dams may legally operate during the time that the adjusted criteria in (f)(ii)(B) of this subsection are in use.

(II) Application of the tailrace maximum TDG criteria must be accompanied by a department approved biological monitoring plan designed to measure impacts of fish exposed to increased TDG conditions throughout the spring spill season. Beginning in the year 2021, plans must include monitoring for

non-salmonid fish species and must continue for a minimum of five years, and thereafter as determined by the department.

(III) TDG must be reduced to allowances specified in (f)(ii)(A) of this subsection if the calculated incidence of gas bubble trauma in salmonids (with a minimum sample size of fifty fish required weekly) or non-salmonids (with a minimum sample size of fifty fish required weekly) exceeds:

- Gas bubble trauma in non-paired fins of fifteen percent; or
- Gas bubble trauma in non-paired fins of five percent and gas bubbles occlude more than twenty-five percent of the surface area of the fin.

If gas bubble trauma exceeds these biological thresholds, additional monitoring must demonstrate the incidence of gas bubble trauma below biological thresholds before TDG can be adjusted to allowances specified in this subsection. Gas bubble trauma monitoring data shall be excluded from comparison to biological thresholds when higher than normal river flow contributes to excess spill above the ability to meet (f)(ii)(B) of this subsection. This monitoring data exclusion shall apply for one full calendar day after reduced river flow allows attainment of (f)(ii)(B) of this subsection.

Oregon Water Quality Standard Modification

The Environmental Quality Commission approves the following modification to the statewide standard for total dissolved gas (OAR 340-41-0031(2)) of 110 percent for the lower Columbia River at McNary, John Day, The Dalles and Bonneville dams, as provided for in OAR 340-41-0104(3):

1. The total dissolved gas standard for the Columbia River as measured in the tailraces of McNary, John Day, The Dalles, and Bonneville dams is 125 percent for the period from April 1 through June 15.
2. The total dissolved gas standard for the Columbia River as measured in the tailraces of McNary, John Day, The Dalles, and Bonneville dams is 120 percent for the period from June 16 through Aug. 31.
3. These limits do not apply when the stream flow exceeds the seven-day, ten-year frequency flood.
4. The DEQ Director may approve additional periods of application of this modification, beyond the April 1 to Aug. 31 period, subject to subsections 7.a) to 7.d) for reasons including passing Spring Creek Hatchery fish releases, maintenance activities, and biological or physical studies of spillway structures and prototype fish passage devices. The Corps must notify DEQ in writing describing the purposed action, the purpose of the action and dates of action at least one week prior to the spill. The Corps must obtain written approval from the Director prior to such spill.
5. The modified total dissolved gas standards will apply for five years, 2020, 2021, 2022, 2023 and 2024.
6. Voluntary fish passage spill during the spring spill season, occurring from April 1 through June 15, is subject to the following conditions:
   a. Spill at a dam must be reduced when:

i. Instantaneous total dissolved gas levels exceed 127 percent of saturation, calculated as the average of any two consecutive hourly TDG measurements in the tailrace of the dam; or

ii. The average of the twelve highest hourly TDG measurements in the tailrace of the dam in a calendar day exceeds 125 percent.

b. Spill at a dam must be reduced to 120 percent as calculated in 7.a)i. when:

1. The calculated incidence of gas bubble trauma in salmonids (with a minimum sample size of fifty fish required weekly) or non-salmonids (with a minimum sample size of fifty fish required weekly) exceeds gas bubble trauma in non-paired fins of fifteen percent, or gas bubble trauma in non-paired fins of five percent and gas bubbles occlude more than twenty-five percent of the surface area of the fin. If gas bubble trauma exceeds these biological thresholds, additional monitoring must demonstrate the incidence of gas bubble trauma below biological thresholds before TDG can be increased to the level specified in this order. Gas bubble trauma monitoring data shall be excluded from comparison to biological thresholds when higher than normal river flow contributes to excess spill above 125 percent. This monitoring data exclusion shall apply for one full calendar day after reduced river flow allows attainment of 125 percent TDG levels in the tailrace of the dam.

c. The tailrace maximum TDG criteria for spring spill in this modification will be applied in a manner consistent with the applicable requirements of the federal Endangered Species Act.

d. Physical monitoring must occur and be adequate for implementing the requirements of this order.

e. Application of the tailrace maximum TDG criteria must be accompanied by a DEQ-approved biological monitoring plan designed to measure impacts to fish exposed to increased TDG conditions throughout the spring spill season. Beginning in the year 2021, plans must include monitoring for non-salmonid fish species. Gas bubble trauma monitoring for juvenile salmonids may be halted if there is a high mortality risk due to compounded effects of the evaluation procedure and adverse environmental factors such as high stream temperatures.

7. Voluntary fish passage spill during the summer spill season, occurring from June 16 through Aug. 31, is subject to the following conditions:

a) Spill at a dam must be reduced when:

i. The average of the twelve highest hourly TDG measurements in the tailrace of the dam in a calendar day exceeds 120 percent of saturation; or

ii. Instantaneous total dissolved gas levels exceed 125 percent of saturation in the tailrace of the dam, calculated as the average of the two highest hourly total dissolved gas measures in a calendar day.

b) The DEQ Director may halt the voluntary spill program or require reductions in voluntary spill to reduce TDG levels if voluntary spill results in biological threshold exceedances when:

i. More than 15 percent of salmonids examined show signs of gas bubble disease in their non-paired fins, or
ii. More than five percent of salmonids examined show signs of gas bubble trauma in their non-paired fins where more than 25 percent of the surface area of the fin is occluded by gas bubbles.

c) Physical monitoring must occur and be adequate for implementing the requirements set out in this order.
d) Application of the tailrace maximum TDG criteria must be accompanied by a DEQ-approved biological monitoring plan designed to measure impacts to fish exposed to increased TDG conditions throughout the summer spill season. Beginning in the year 2021, plans must include monitoring for non-salmonid fish species. Gas bubble trauma monitoring for juvenile salmonids may be halted if there is a high mortality risk due to compounded effects of the evaluation procedure and adverse environmental factors such as high stream temperatures.

Implementation of Gas Abatement Measures

The Oregon TDG modification requests an update on the implementation of gas abatement measures through adaptive management. TDG management measures are currently in place for limiting Columbia and Snake River environments to acceptable TDG criteria levels for fish during most of the fish passage season. Significant TDG abatement has been accomplished through structural and operational improvements, but limited opportunities are available for further TDG reduction during flood flow conditions. The 2018 Update to the TDG Gas Abatement Plan and Appendix E of this document provide the status of the Corps' TDG TMDL implementation activities.

TDG Management Operations

The TDG Management Plan is an appendix to the Water Management Plan (found here: https://pweb.crohms.org/tmt/documents/wmp/) and describes forced and planned spill, use of the spill priority list, the process for setting spill caps, TDG management policies, and the TDG monitoring program. During spring and summer spill, WDOE's and ODEQ's WQSs use the same method for calculating a daily value of TDG: the average of the 12 highest hourly readings in a calendar day (termed Ave12hrMax). Daily averages are shown in the web report:

https://pweb.crohms.org/ftppub/water_quality/12hr/.

In 2020, the 12-hour metric was generally more restrictive than the 2-hour metric.

The spill priority list is a lack of load TDG management tool that has been developed for forced spill that results in exceeding the state TDG standards when lack of load conditions require spill. The Corps works with the region to develop the spill priority list identifying the order in which the projects spill in order to minimize TDG systemwide. This list calls for adding spill incrementally across all federally owned projects to prevent excessively

high TDG levels from being generated in concentrated river reaches. Excess spill is spread over Federal projects to hold peak TDG levels to targeted TDG thresholds in 2 to 5 percent increments.

Operating Conditions

Weather

The 2020 Water Year (WY) was slightly warmer and drier compared to long-term averages (Table 1). The El Niño-Southern Oscillation (ENSO) is a recurring climate pattern involving changes in the temperature of waters in the central and eastern tropical Pacific Ocean. ENSO-neutral sea surface temperature conditions prevailed in the tropical Pacific for the 2020 WY. Conditions for both temperature and precipitation were near long-term averages for the 2020 WY with some noteworthy extremes. While temperatures were notably cold in October 2019 and March 2020, and notably warm in November 2019 and January 2020, there were no significant cold snaps during the 2020 WY, and only one brief heat wave in mid-August of 2020.

The cumulative precipitation as reported by the Northwest River Forecast Center (NWRFC) for WY 2020 was 90% of average (1981 to 2010) in the Columbia River above Grand Coulee Dam, 86% of average in the Snake River above Ice Harbor Dam, and 85% of average in the Columbia River above The Dalles Dam. The mild and rather dry fall was followed by a wet late December, January and early February across most of the Columbia Basin. While temperatures remained mild relative to average, snow levels remained low enough for more significant snowpack building across the entire basin.

A return to somewhat dry conditions was noted in March and early April, but some snow continued to fall on windward slopes and mountaintop as March temperatures remained near January and February levels. By 01 April, despite the periods of somewhat dry weather during the fall and early spring, snow-water equivalents in Columbia Basin snowpacks were at around 106% of the long-term average, with snow-water equivalents above Grand Coulee near 110% of average, and parts of the Salmon, upper Snake and northeast Oregon subbasins over 115% of average.

Table 1: Columbia basin weather, WY 2020

Location	Temperature Columbia Basin above The Dalles Departure from the 1981-2010 average (ºC / ºF)	Precipitation Columbia River above Grand Coulee Percent of the 1981-2010 average (%)	Precipitation Snake River above Ice Harbor Percent of the 1981-2010 average (%)	Precipitation Columbia River above The Dalles Percent of the 1981-2010 average (%)
October 2019	-3.7 / -6.7	69%	61%	66%
November 2019	+2.7 / +4.8	45%	25%	33%
December 2019	+3.8 / +6.9	105%	72%	83%
January 2020	+1.8 / +3.2	131%	115%	125%
February 2020	-0.1 / -0.1	81%	106%	97%
March 2020	-0.7 / -1.3	78%	87%	76%
April 2020	-0.1 / -0.1	71%	67%	62%
May 2020	+0.8 / +1.4	153%	117%	137%
June 2020	+0.1 / +0.2	131%	190%	150%
July 2020	+0.8 / +1.5	73%	53%	57%
August 2020	+1.6 / +2.9	38%	33%	31%
September 2020	+2.3 / +4.2	52%	52%	69%
Water Year 2020	**+0.8 / +1.4**	**90%**	**86%**	**85%**

Basin average temperature departures and precipitation percent-of-normal from NOAA/National Weather Service Northwest River Forecast Center.

Water Supply

Although snowpacks were relatively healthy across the basin, water supply forecasts lagged near or slightly below long-term averages heading into April. This was partially the result of below average fall precipitation, which left dry soils heading into the winter. Thus, while snowpacks were above average, hydrologic models projected that initial snowmelt would percolate into recharging soil moisture before runoff would commence. The water supply picture then changed significantly in late April and the first half of May as a series of unusually cold and late winter storms traversed the basin. With snow levels dropping well below seasonal averages, higher elevation snowpacks increased across the entire basin. After a brief dry period in late May, the basin was again impacted by several wet and rather cool storm systems in early June.

The typical summer dry season began in July on a rather muted note as temperatures throughout the region held close to long-term normals with the bulk of precipitation falling mostly in the Canadian portion of the basin.

Unregulated flows provide a general perspective on the water supply from rainfall or snowmelt for that month or year. Table 2 provides WY 2020 average monthly unregulated

streamflow and the percentage of the 1981-2010 average monthly flows for the Snake River at Lower Granite and Columbia River at The Dalles. Spring and summer water supply was average to slightly above average throughout the basin, with October through September flow averages slightly below average. April-August runoff volume, measured at The Dalles was 91.8 Maf or 105% of the 30-year average (1981 – 2010). April-August runoff was 99% of average in the Snake river basin. The average monthly unregulated flow at Lower Granite Dam and The Dalles Dam during the spring runoff was highest in May and June, respectively.

Table 2: Snake and Columbia River average unregulated flows in WY 2020[5]

	Snake River at Lower Granite Unregulated Flow (kcfs)	Snake River at Lower Granite % of Average	Columbia River at The Dalles Unregulated Flow (kcfs)	Columbia River at The Dalles % of Average
October, 2019	23.2	95	80.5	100
November, 2019	21.4	100	58.0	79
December, 2019	19.8	79	63.3	69
January, 2020	22.5	69	80.2	70
February, 2020	34.2	70	112.8	80
March, 2020	35.6	80	94.2	65
April, 2020	61.4	65	176.6	80
May, 2020	124.6	80	467.0	111
June, 2020	99.4	111	491.0	98
July, 2020	40.2	98	263.0	108
August, 2020	17.3	108	117.6	86
September, 2020	18.9	86	79.8	95
Oct - Sept Average	**43.2**	**94.7**	**173.9**	**90**
Apr-Aug Average	**68.6**	**99**	**303.0**	**105**

Note: Unregulated Flows exclude the effects of regulation provided by storage reservoirs. Runoff average period: 1981-2010.

Reservoir Operation

Generally, reservoir operation objectives include reaching the upper rule curve elevation on or about April 10 at the U.S. storage projects; refill on, or about June 30; and drafting reservoirs to summer draft limits. The observed runoff at The Dalles was below average in the early spring, but rose to above average in May and continued to be above average through the summer (Figure 1).

[5] From 2020 National Weather Service Runoff Processor.

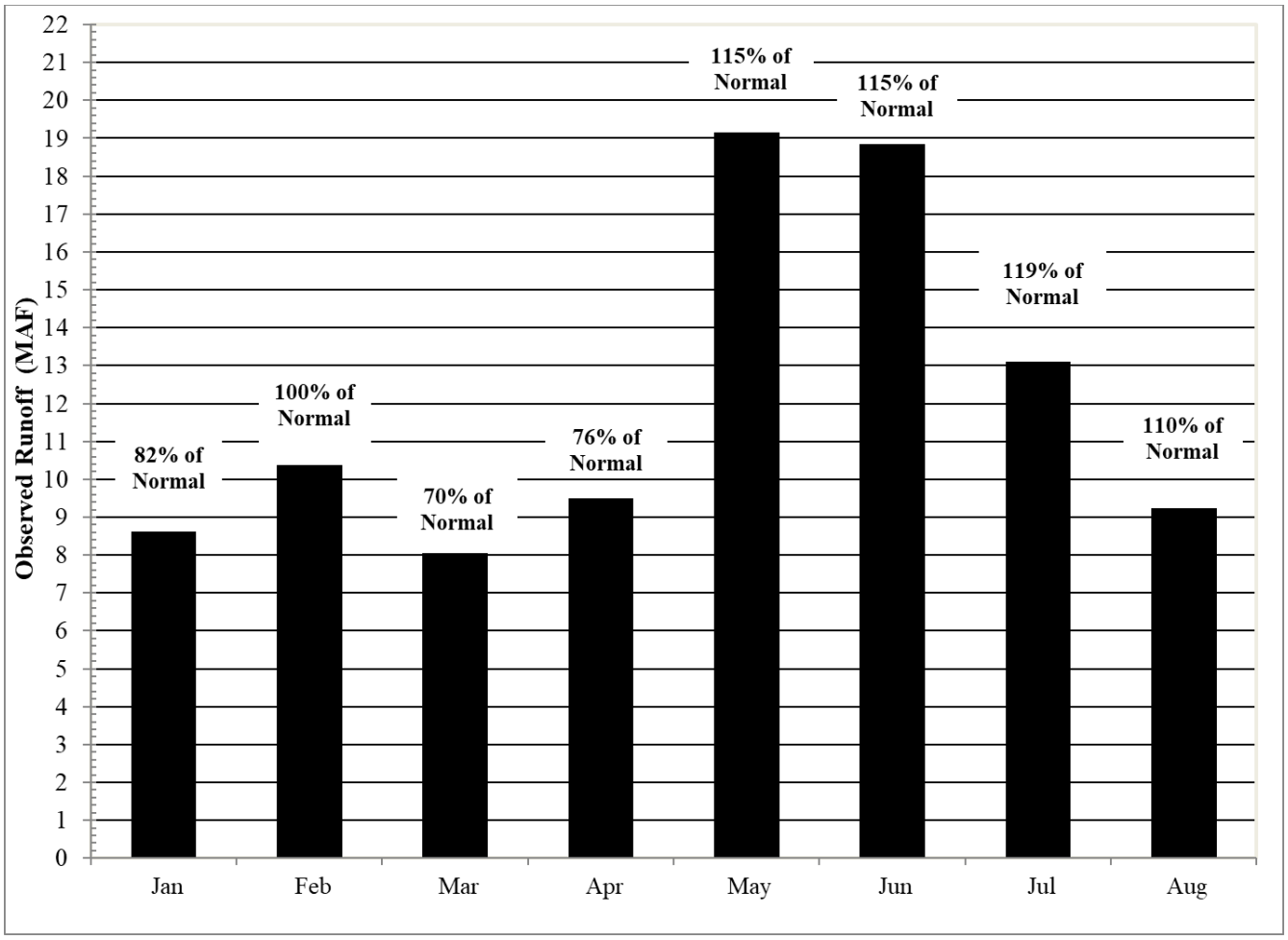

Figure 1: WY 2020 observed monthly runoff at The Dalles

On the lower Columbia River as measured at Bonneville Dam, daily average total river flow from April 1 through August 31 ranged from 113 to 408 kcfs, averaging 234 kcfs and peaking on June 2. A hydrograph for Bonneville Dam representing spill, generation, and miscellaneous flows (summing to total project flow in kcfs) is shown in Figure 2.

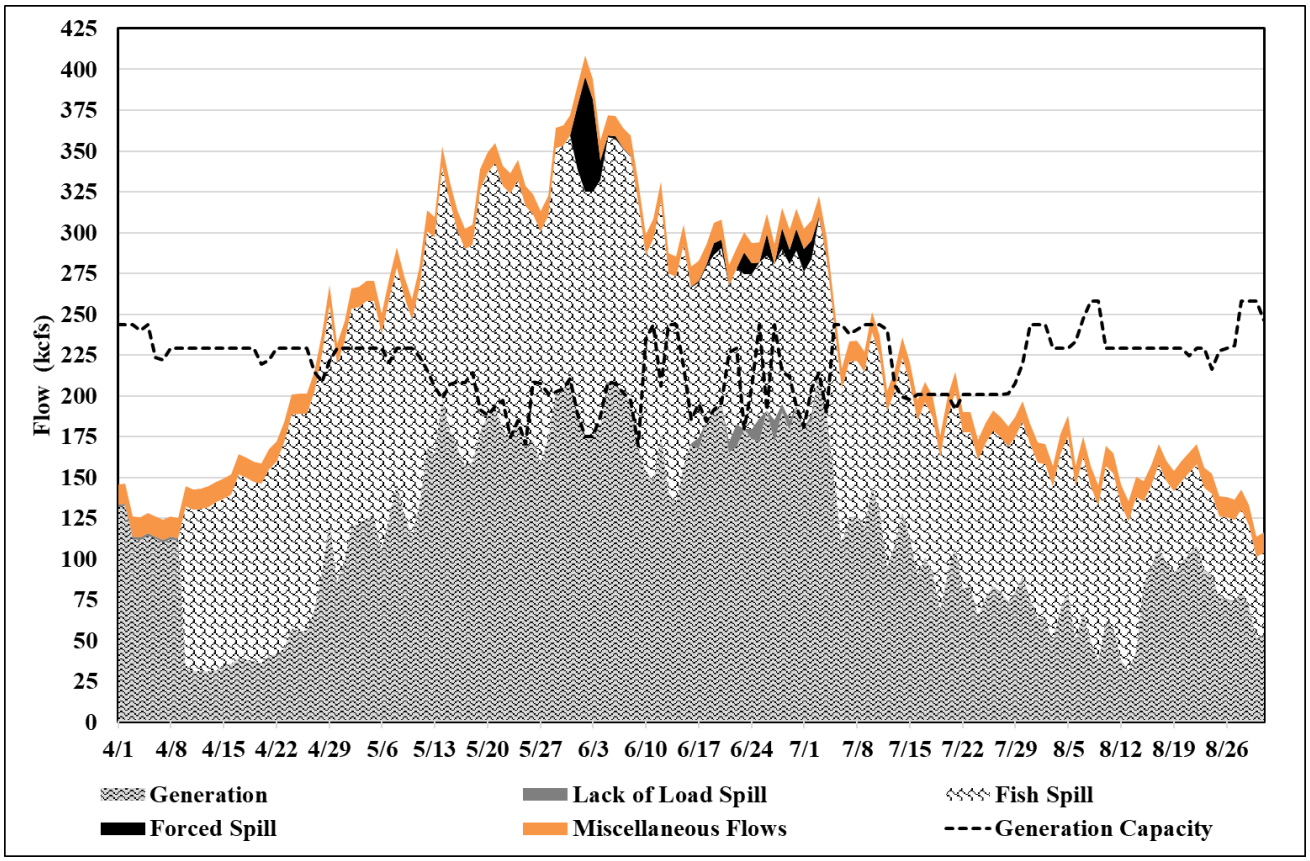

Figure 2: 2020 Bonneville daily project generation flow and spill.

On the lower Snake River as measured at Ice Harbor Dam, daily average total river flow from April 1 through August 31 ranged from 22 - 164 kcfs, averaging 69 kcfs and peaking on June 1 (Figure 3). Hydrographs for the remaining lower Snake and Columbia projects are shown in Appendix I.

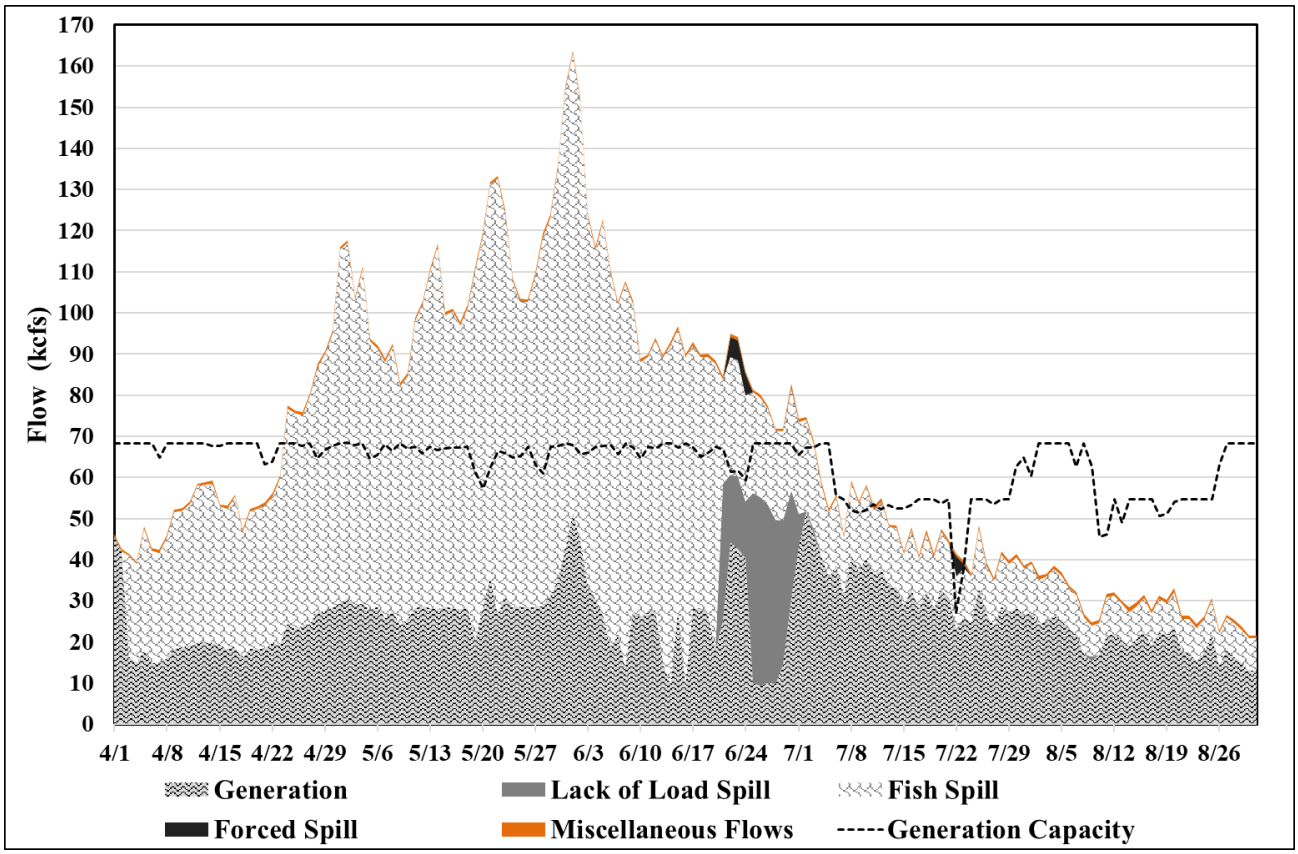

Figure 3: 2020 Ice Harbor daily project generation flow and spill.

Flood Risk Management

The Columbia River Basin storage projects were operated to their specified flood risk management requirements based on the information available during the season. The unregulated peak flow during the freshet (based on the USACE ResSim program output) at The Dalles was 597.3 kcfs, occurring on 02 June 2020, with a regulated daily peak flow of 396.3 kcfs occurring on 03 June 2020.

2020 Observed Flows above 7Q10

Daily average flows did not exceed the 7Q10 criteria at any of the lower Snake or lower Columbia River projects in 2020.

Water Quality Monitoring

The Corps monitors the water quality of reservoir releases at the projects throughout the Columbia River Basin to manage fish passage spill operations at the fish passage projects in the lower Snake and lower Columbia rivers, as well as to manage system-wide water quality. The Corps monitors and tracks instances when TDG criteria are exceeded relative to state standards and applicable TDG modifications and criteria adjustments; and, when feasible, adjustments are made to meet the state criteria.

Fixed Monitoring Stations (FMS)

TDG and water temperature are monitored throughout the Columbia River Basin via the FMS gauges. There are a total of 43 FMSs in the U.S. portion of the Columbia River Basin and 28 are operated by the Corps. Reclamation, and Chelan and Grant County Public Utility Districts (PUDs) each operate four stations. Three stations are operated by the Douglas County PUD. The Corps' Portland, Seattle, and Walla Walla districts operate and maintain the FMSs in the Columbia and lower Snake River basins. Portland District is responsible for eight FMSs on the lower Columbia River from John Day Dam to Camas/Washougal. The Seattle District is responsible for two FMSs in the upper Columbia Basin at Chief Joseph Dam. Walla Walla District is responsible for 15 FMSs in the lower Snake River and Clearwater River basins, and at McNary Dam on the Columbia River. Appendix A contains detailed information on the Corps' FMS system and a map of their locations.

TDG Monitoring Plan

The monitoring performed by the Corps is part of a larger interagency water quality monitoring system described in the TDG Monitoring Plan that includes the Reclamation and the Washington PUD monitoring systems (as conducted by Douglas County PUD, Chelan County PUD, and Grant County PUD). The TDG Monitoring Plan summarizes the Corps' roles and responsibilities with total dissolved gas and temperature monitoring and identifies channels of communications with other cooperating agencies and interested parties. See https://www.nwd.usace.army.mil/CRWM/Water-Quality/ for the most recent version.

Quality Assurance/Quality Control on Fixed Monitoring Stations

The NOAA Fisheries 2019 BiOp, section 2.16.4.1(d), calls for the monitoring of TDG, specifically:

- The CRS Action Agencies shall contribute to regional efforts to monitor the levels of TDG and associated biological impacts in the lower Snake and Columbia Rivers. This annual program will include water quality monitoring and will be developed and implemented in coordination with the Water Quality Team (WQT) and the mid-Columbia PUDs. The TDG pressure and percent saturation, water temperature, and barometric pressure will be sampled on an hourly basis and shared with resource agencies on a real-time basis.
- The water quality sampling methodology should include monitoring TDG levels throughout the Columbia River basin in river reaches. A comprehensive monitoring plan includes monitoring TDG levels in locations in coordination with the WQT for each project in critical reaches. This program will also include a QA/QC component conforming to the Data Quality Criteria developed by the Corps in coordination with the WQT. This data quality control system will involve frequent calibration and maintenance of water quality equipment, daily screening of real time data, and archival storage in a Corps' online database. The QA/QC

components will be reviewed annually and modified as improved information and techniques become available.

The Corps' districts operate the FMSs according to the TDG Monitoring Plan and prepare annual performance reports for the FMS operation. The 2020 reports are included as Appendices F, G, and H. Highlights from these reports are provided below.

Walla Walla District Quality Assurance/Quality Control

Walla Walla District is responsible for maintaining and operating the forebay and tailwater TDG FMS stations at Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, and McNary dams. This work is performed through a cooperative agreement with the U.S. Geological Survey (USGS) Kennewick office. The highlights of the Walla Walla District QA/QC report include:

- COVID-19 travel restrictions frequently delayed response time to diagnose and repair field equipment.
- Data completeness for the combined barometric pressure, TDG, and temperature data received averaged 99.5 percent for the 14 monitoring sites used in 2020.
- The TDG data received from the individual sites ranged from 95.1 percent to 99.9 percent complete. Thirty-three percent of the invalid data was due to measurements that were considered too low, primarily at the Peck (PEKI) and Lower Granite forebay (LWG) stations. The second most frequent cause of missing information was defective sondes at the Lower Monumental tailwater (LMNW) and Dworshak tailwater station (DWQI) that accounted for a combined 29 percent of the total.
- The TDG sensors from the 14 FMS stations were removed from the field and calibrated in the laboratory every three weeks from April 2020 through August 2020. From September 2019 through March 2020, the six annual FMS stations were calibrated at four-week intervals.
- The sensor pre-deployment check had calculated mean ambient pressure, ambient pressure plus 300 mmHg, and temperature differences of -0.31 mmHg, -0.44 mmHg, and 0.03 °C, respectively. The sensor post-deployment check revealed mean ambient pressure, ambient pressure plus 100 mmHg, and temperature differences of -0.03 mmHg, -1.04 mmHg, and 0.01 °C, respectively.
- The calculated median values for the 169 *in-situ* field checks with the replacement probes were:
    - TDG; 0.0 percent with station medians ranging from -0.2 percent to 0.1 percent.
    - BP; 0.00 mmHg with station medians ranging from -0.10 to 0.10 mmHg.
    - Water temperature; -0.01 ºC with station median values ranging from -0.04 ºC to 0.03 ºC.
- Station repairs and maintenance were also completed during the 2020 water year:
    - Repair work to the Lower Monumental Dam tailwater station damaged by fire in 2019 was completed

- The swing arms used to suspend the forebay TDG probes on the Lower Snake and McNary upstream navigation guidewalls were replaced.
- Replacement of the existing Sutron Satlink2 logger/transmitters with new Satlink3 units that are V2 compliant was completed.
- Sediment build-up at 7 of the deployment pipes was purged with compressed air.

A detailed QA/QC report on the Walla Walla District gauges can be found in Appendix F.

Portland District Quality Assurance/Quality Control

Portland District maintains and operates the forebay and tailwater gauges at John Day, The Dalles and Bonneville dams. This work is performed through a contract with the Portland, Oregon Office of the USGS. The highlights of the Portland District QA/QC report include:

- COVID-19 travel restrictions did not delay response time to diagnose and repair field equipment.
- Data received in real-time from the eight individual monitoring sites ranged from 94.6 percent (at Cascade Island) to 100 percent complete.
- Criteria for data completeness (95 percent) were met at all monitoring stations, except for CCIW. Equipment was removed at CCIW from May 20 to 26 and June 1 to 4 in anticipation of high flows at the site, accounting for 95 percent of the annual real-time data loss. TDG and water temperature data were later available for this period from internal-logging sensors that were deployed.
- After three to six weeks of deployment in the river, 87 of 93 TDG sensor field checks were within ±1.0 percent saturation of a secondary standard sensor. Five of the field checks that failed the ±1.0 percent saturation guideline were due to ruptured membranes on the TDG sensors. The other instance (+1.4 percent saturation) was due to slow equilibration of the reference sensor and did not appear to be a true indication of an inaccurate field sensor.
- Four of 91 barometric pressure field checks were greater than ±1 mmHg of a primary standard, ranging from -2.0 to +1.5 mmHg. The offsets within the datalogger or database were adjusted accordingly, and no data were deleted or corrected. All 93 water-temperature field checks were within ±0.2°C of a secondary standard, ranging from -0.08 to +0.04 °C.
- All 90 TDG sensor laboratory checks that were performed after field deployment were within ±0.5% saturation of a primary standard at ambient air pressure and at ambient air pressure plus 300 mmHg.
- The year-round TDG sensors were field-checked monthly from October 2019 through March 2020. The seasonal sensors were installed in mid-March and all field and lab work was completed on a three-week schedule until August. Hazardous air-quality conditions due to regional wildfires delayed the September removal of the seasonal sensors by one week and delayed the September field checks of the year-round sensors until October 2020.

A detailed QA/QC report on the Portland District gauges can be found in Appendix G.

Seattle District Quality Assurance/Quality Control

Seattle District maintains and operates the forebay and tailwater TDG FMSs at Chief Joseph Dam. The highlights of the Seattle District QA/QC report are:

- COVID-19 travel restrictions did not delay response time to diagnose and repair field equipment.
- Data completeness for TDG data received was 100 percent at the forebay station (CHJ) and 95.3 percent at the tailwater station (CHQW). Data completeness for temperature data received was 100 percent at station CHJ and 95.3 percent at station CHQW. Missing TDG and temperature data at both stations were largely due to DCP malfunctions and programming problems.
- For TDG data, at the forebay (CHJ) station a total of 1 hour was rejected due to slow probe response time after recalibration. At the tailwater station (CHQW) a total of 5 hours was rejected due to slow probe response time after recalibration. No temperature data was rejected at stations CHJ and CHQW.
- Laboratory calibration data were good and within 0.1°C for temperature and 1 percent saturation for TDG. Field calibration data were good and generally within 1mm Hg of the secondary standard barometer, 0.1ºC of the secondary standard thermometer, and 1 percent saturation of the secondary standard TDG instrument.
- The TDG sensors were removed from the field after 2 weeks of deployment and calibrated in the laboratory.
- A total of 27 out of 27 (100%) in-situ field checks of total-dissolved-gas sensors with a secondary standard were within ± 2 percent after 2 weeks of deployment in the river.
- A total of 27 out of 27 (100%) in-situ field checks of barometric pressure were within ±2 mm Hg of a secondary standard, and 26 out of 27 (96%) water temperature field checks were all within ±0.2°C.

A detailed QA/QC report on the Seattle District gauges can be found in Appendix H.

Fish Passage Spill Program

Operation of the federal Columbia River System projects to meet multiple authorized purposes can result in exceedances of percent TDG state water quality standards. This section provides detailed information on the implementation of fish passage spill as well as forced spill (e.g., lack of turbine, lack of load, transmission constraints, etc.).

Fish Passage Spill Operations

The 2020 FOP (Appendix B) provides detailed information on the implementation of the 2019-2021 Spill Operation Agreement, the 2019 BiOp spill, and transport operations at the Corps' four lower Snake River and four lower Columbia River projects. Fish passage spill quantity can be a specified level or a spill rate estimated to result in TDG target, referred to

as the "gas cap spill". The maximum project spill level that meets but does not exceed the gas cap is referred to as the spill cap. 2020 target spill operations for spring and summer are summarized in Table 3 and Table 4, respectively.

Table 3: Summary of 2020 spring target spill levels at lower Snake River (April 3 – June 20) and lower Columbia River (April 10 – June 15) projects.

Project	Flex Spill (16 hours per day)[6,7,8,9]	Performance Standard Spill (8 hours per day)[10, 11, 12]
Lower Granite[10]	125% Gas Cap	20 kcfs
Little Goose[11, 12]	125% Gas Cap	30%
Lower Monumental	125% Gas Cap (uniform spill pattern)	30 kcfs (bulk spill pattern[13])
Ice Harbor	125% Gas Cap	30%
McNary	125% Gas Cap	48%
John Day	120% TDG target	32%
The Dalles[14]	40%	40%
Bonneville[15]	125% Gas Cap	100 kcfs

[6]Attempts should be made to minimize in-season changes to the proposed operations; however, if serious deleterious impacts are observed, existing adaptive management processes may be employed to help address serious issues that may arise in-season as a result of implementing these proposed spill operations

[7]Spill may be temporarily reduced at any project if necessary to ensure navigation safety or transmission reliability. In order to operate consistently with state water quality standards, spill may be also reduced if observed Gas Bubble Trauma (GBT) levels exceed those identified in state water quality standards (see WASH. ADMIN. CODE §173-201A-200(l)(f))).

[8] 125% Gas Cap spill is spill to the maximum level that meets, but does not exceed, the TDG criteria allowed under state laws. This includes a criterion for not exceeding 126% TDG for the average of the two greatest hourly values within a day.

[9] The 8 hours of performance standard spill may occur with some flexibility (with the exception of Little Goose and Lower Granite operations described in the next key points). Other than at TDA, performance standard spill occurs in either a single 8-hour block or up to two separate blocks per calendar day. No more than 5 hours of performance standard spill may occur between sunset and sunrise, as defined in Fish Passage Plan (FPP) Table BON-5. Performance standard spill is not be implemented between 2200-0300 hours. No ponding above current MOP assumptions except as noted below.

[10] Lower Granite Exception One - If adult passage delays are observed at Lower Granite Dam, the Corps may implement performance standard spill at Lower Granite Dam for at least 4 hours in the AM (beginning at 0500 hours). Implementation of this modification may also trigger in-season reevaluation of options to balance power principle.

[11] Little Goose Exception One - As soon as practicable (and, in any event, no more than 24 hours) after a cumulative total of 25 adult spring Chinook salmon (not including jacks) pass Lower Monumental Dam, operate Little Goose spill at 30% spill for 8 consecutive am hours (April 3-15 start at 0500 hours; April 16-June 20 start at 0400 hours).

[12] Little Goose Exception Two - During periods of forced spill, spill at 30% for 8 hours/day during the hours described in footnote F above and store additional inflows that exceed hydraulic capacity in the forebay above MOP if necessary. When it is necessary to pond water to achieve the lower spill levels due to high inflow, water stored above MOP should be drafted out over the remaining hours by increasing spill to pass inflow from 1200-1600 hours (or 1300-1700 hours from April 3-15), then increasing spill as necessary from 1600-0400 (or 1700-0500 hours from April 3-15) to draft the pool back to MOP. If it is forecast that the drafting spill will generate TDG levels in the tailrace in excess of 130% TDG, use all 16 hours to return the pool to MOP.

[13] If the specified spill level at bulk pattern exceeds the gas cap, then spill pattern will be changed to uniform.

[14] Fish passage spill at The Dalles should be limited to spillbays 1-8 unless river flow exceeds 350 kcfs, then spill outside the spillwall is permitted. TDG levels in The Dalles tailrace may fluctuate up to 125% TDG prior to reducing spill at upstream projects or reducing spill below 40% at The Dalles.

[15] Fish passage spill at Bonneville Dam should not exceed 150 kcfs due to erosion concerns.

Table 4: Summary of 2020 summer target spill levels at lower Snake River and lower Columbia River projects.

Project	2020 Summer Spill[16] (June 21/16 – August 14) (24 hrs/day)	2020 Summer Spill[16] (August 15 – August 31) (24 hrs/day)
6Lower Granite[17]	18 kcfs	SW flow or ~7 kcfs spill
Little Goose[17]	30%	SW flow or ~7 kcfs spill
Lower Monumental[17]	17 kcfs	SW flow or ~7 kcfs spill
Ice Harbor[17]	30%	SW flow or ~8.5 kcfs spill
McNary	57%	20 kcfs
John Day	35%	20 kcfs
The Dalles	40%	30%
Bonneville	95 kcfs	50 kcfs

The Corps tracks the rate of spill that occurs at the eight fish passage dams as part of the FOP Implementation Report requirements. Fish passage spill quantities are shown in monthly graphs of the flow, FOP spill, and generation for April through August. These monthly graphs are included in the monthly FOP implementation reports (Appendix C).

The daily flow, FOP spill, and generation rates for April through August are further summarized in Tables I-3 through I-10 of Appendix I. The flow, generation, actual and FOP fish passage spill for the 2020 spill season at each dam is graphed for the entire April through August spill season and included in Appendix I as Figures I-1 through I-8.

In addition to spring and summer spill for juvenile fish, surface spill was provided for adult steelhead passage at McNary dam during WY 2020. Spill of approximately 10 kcfs occurred four days per week, for either four or eight hours per day from September 15 through November 15, 2019 and again from March 1 to April 9, 2020.

[16] Spill may be temporarily reduced below the FOP target summer spill level at any project if necessary to ensure navigation safety or transmission reliability, or to avoid exceeding State TDG standards.
[17] Summer spill from August 15-August 31 may be through the SW or through conventional spillbays using the appropriate FPP spill pattern for each project. The SWs will be operated consistent with the SW operational criteria in the FPP.

Long-Term Turbine Outages

Unit outages can affect the spill rate at the dams by causing additional forced spill. Table 5 summarizes the long-term unit outages during the 2020 fish passage season. Not all outages result in spill or elevated TDG levels.

Table 5: 2020 long-term outages

Project	Unit	Start Date	End Date	Reason
Grand Coulee	23	9/30/2019	ongoing	PRC-002-2 Updates
Grand Coulee	21	10/3/2019	4/30/2020	Forced outage due to bad oil sample on transformer
Grand Coulee	22	10/31/2019	ongoing	Major overhaul
Grand Coulee	8	1/31/2020	ongoing	Forced outage due to differential L/O
Chief Joseph	01-04	4/13/2020	5/22/2020	CO_2 Capital Upgrade
Chief Joseph	09-12	5/26/2020	6/26/2020	CO_2 Capital Upgrade
Chief Joseph	17-20	6/29/2020	8/27/2020	Annual service
Little Goose	5	10/23/2019	ongoing	Forced outage due to excessive turbine guide runout
Little Goose	6	7/6/2020	8/20/2020	Annual Service
Little Goose	5, 6	7/27/2020	ongoing	T2 Doble and Isophase Bus Upgrade
Lower Monumental	2	11/7/2019	ongoing	Annual Service/Liner and blade seal replacement
Lower Monumental	3	7/6/2020	8/5/2020	Annual service/Oil Replacement/Headcover Pumps
Ice Harbor	3	10/31/2019	ongoing	Turbine replacement
McNary	5	5/23/2019	7/31/2020	Turbine hub seal repair
John Day	12	8/5/2019	ongoing	Turbine rehab
John Day	6	10/23/2019	ongoing	Forced outage due to unit tripping when brought online.
John Day	7	10/23/2019	ongoing	Forced outage due to CO_2 discharge
John Day	15	6/1/2020	7/13/2020	Annual service
John Day	10	6/22/2020	8/25/2020	5-year overhaul
The Dalles	19, 20	10/31/2019	ongoing	Forced outage due to gassing on T10
The Dalles	8	1/21/2020	ongoing	5-year overhaul
The Dalles	13, 14	6/22/2020	ongoing	T7 GSU Replacement
The Dalles	22	7/8/2020	ongoing	Forced outage due to unknown vibration
Bonneville	2	4/6/2020	6/4/2020	5-year overhaul
Bonneville	12	4/20/2020	6/24/2020	4-year overhaul
Bonneville	8	6/15/2020	8/6/2020	5-year overhaul

TDG Exceedances of the WQS

Exceedance reporting in this section is consistent with the Corps' TDG Management Operations described in previous sections of this document.

125% (Spring) and 115%/120% (Summer) TDG evaluation

Table 6 provides a summary of TDG exceedances and data quality events during the 2020 spill season for the lower Columbia and lower Snake projects except when flows are greater than the 7Q10. There was a total of 69 gauge days in 2020 in which the TDG levels were above the applicable TDG criteria and 9 gauge days in which there was a data quality event and TDG could not be evaluated. TDG exceedances are evaluated by day in Appendix D.

Table 6: Summary of TDG exceedances and data quality events

Fixed Monitoring Stations	Exceedances	Data Quality Events
Lower Granite Forebay (LWG)*	0	0
Lower Granite Tailwater (LGNW)	5	0
Little Goose Forebay (LGSA)*	4	0
Little Goose Tailwater (LGSW)	7	0
Lower Monumental Forebay (LMNA)*	8	0
Lower Monumental Tailwater (LMNW)	3	1
Ice Harbor Forebay (IHRA)*	11	0
Ice Harbor Tailwater (IDSW)	2	0
McNary Forebay (MCNA)*	5	0
McNary Tailwater (MCPW)	10	3
John Day Forebay (JDY)*	1	0
John Day Tailwater (JHAW)	1	4
The Dalles Forebay (TDA)*	5	0
The Dalles Tailwater (TDDO)	2	1
Bonneville Forebay (BON)*	5	0
Bonneville Tailwater (CCIW)	0	0
Total	**69**	**9**

* Evaluated during summer spill only

Recurring High TDG Exceedances

In 2020, two gauge locations had the highest number of TDG exceedances:

- The Ice Harbor tailwater gauge had 11 exceedances: 8 due to high flow causing forced spill and 3 due to model and forecast uncertainties.
- The McNary tailwater gauge had 10 exceedances: 9 due to model and forecast uncertainties and one due to bulk spill during removal of the temporary spillway weirs.

Categories of TDG Exceedances

The Corps tracked the daily TDG exceedance types for the forebay and tailwater of each of the Corps' federal Columbia River projects during the 2020 spill season. Each type of TDG exceedance represents conditions that cause daily average percent TDG to exceed the applicable WQS. The 2020 exceedance tracking results are summarized in Table 7. Daily details by dam can be found in Appendix D. The daily TDG exceedance type designation given for each occurrence is based on the Corps' determination of causation.

Table 7: TDG exceedance type summary

TDG Exceedance Type	Definition	Quantity
Forced Spill Exceedance	TDG levels exceed the TDG standard due to exceeding powerhouse capacity at run-of-river projects resulting in spill above the BiOp fish spill levels.	36
Mechanical Exceedance	TDG exceedances due to the operation or mechanical failure of non-generating equipment.	1
Uncertainty Exceedance	TDG exceedances due to uncertainties when using best professional judgment, SYSTDG model and forecasts.	32

The two primary contributors of TDG exceedances in 2020 were forced spill from high flows that exceeded the powerhouse capacities at run-of-river projects during early summer spill and uncertainty when using best professional judgment, the SYSTDG model, and forecasts. These uncertainties resulted in unpredicted high resultant TDG levels despite compliance with *Procedure for Setting 2020 Spring Spill Caps*.

Oregon and Washington maximum two-hour criteria

During the 2020 spill season, there were 7 days when TDG readings exceeded the Washington two-hour standard of 126% TDG and 3 days when TDG readings exceeded the Oregon two-hour standard of 127% TDG at the tailwater gauges during the spring (Appendix D). There were no days during summer spill in which the two-hour standard of 125% TDG was exceeded.

WQS exceedances outside of juvenile fish passage spill

There are occasional exceedances of the 110% TDG criteria during periods when juvenile fish passage spill is not occurring, typically September through March. There are also occasions when there is missing data. TDG values are reported here: https://pweb.crohms.org/ftppub/water_quality/12hr/

Outside the juvenile fish passage spill period in WY2020, the TDG exceedances are typically due to forced spill from high flows and high TDG levels from fish ladders. The following TDG exceedances are notable either for duration or spatial extent:

- The tailwater gauge at Bonneville Dam, CCIW, measured values exceeding 110% TDG in March and April 2020. Fish ladders allow for adult upstream passage. Bonneville fish ladders have a combined flow of 4.7 kcfs and can produce TDG levels as high as 135% TDG. During juvenile fish passage season, the TDG generated by the fish ladders is diluted with flow from the spillway. The location of CCIW is such that it is measuring the fish ladder discharges without any mixing with powerhouse flow. The Warrendale gauge, WRNO, is located approximately six miles downstream and measures TDG that has been mixed with powerhouse flow. The WRNO exceeded the TDG criteria for only one day during this period.

During the WY 2020 spill for adult steelhead at McNary Dam, there were no exceedances of the TDG WQS.

Gas Bubble Trauma Monitoring

The Fish Passage Center compiles a report of Gas Bubble Trauma (GBT) monitoring results collected in 2020 (Appendix J). The monitoring of juvenile salmonids in 2020 for GBT was conducted at six Columbia and Snake River projects. Sampling occurred two days per week at the Columbia River sites and one day a week at each of the Snake River sites during 2020 spring and summer fish passage spill operations. The goal of the GBT monitoring program was to sample 100 salmonids during each day of sampling at each site, limited to Chinook and steelhead. Of the 12,297 juvenile salmonids examined, 193 had signs of GBT between April and August of 2019 (see Appendix J, Table J-3). In addition, 36 total non-salmonids spanning 14 different species were sampled as part of a pilot program.

The eyes and unpaired fins of specimens were visually examined for the presence of bubble using magnification scopes. The GBT action criteria for spill curtailments is 15% of fish showing any signs of fin GBT, or 5% of the fish showing severe signs of fin GBT. Signs of fin GBT are deemed severe when ≥26% of an unpaired fin is covered with bubbled.

The 15% criterion was met once in 2020, but with a sample size of only five salmonids did not meet the size requirement established by state water quality agencies for the curtailment of spill. The criterion of 5% severe GBT was not met in 2020.