US Army Corps of Engineers®

Northwestern Division

2019 TOTAL DISSOLVED GAS REPORT

Spill at John Day Dam

Columbia Basin Water Management Division
Reservoir Control Center
Water Quality Unit

January 2020

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COLUMBIA RIVER BASIN

January 2020

Water Quality Unit
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

2019 TOTAL DISSOLVED GAS REPORT
COLUMBIA RIVER BASIN

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http://pweb.crohms.org/tmt/wqnew/tdg_and_temp/2019/

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	1973 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, Fisheries
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)
SD	Standard deviation
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 (or Voluntary 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 – refers to 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.

HEC-ResSim: The USACE Hydrologic Engineering Center's Reservoir System Simulation software is used to model reservoir operations with user-defined operational constraints and objectives.

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.

Involuntary Spill: Involuntary 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. Involuntary 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.

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 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.

b) **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

[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.

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 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 current governing NOAA Fisheries Biological Opinion for the Columbia River System. See Section 1.4.2 of this document.

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 involuntary 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.

1. Program Description

1.1 Overview

Total Dissolved Gas (TDG) is the primary water quality parameter 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. Fish passage spill occurs generally from April through August. The volumes and duration of fish passage spill at each project in 2019 were implemented consistent with the 2019-2021 Spill Operations Agreement (Agreement), and consulted on in the NOAA Fisheries 2019 BiOp.

This report describes the Corps' Columbia River Basin spill and water quality monitoring program for 2019 and addresses the Corps' reporting responsibilities related to the 2015 Oregon Department of Environmental Quality (ODEQ) Total Dissolved Gas (TDG) modification, the 2019 Washington Department of Ecology (WDOE) TDG criteria adjustment, 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 2019 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, (e) biological or physical studies, and (f) progress on implementing the gas abatement measures and adaptive management activities. This report also includes documentation on the performance of the TDG monitoring system that is required in the Terms and Conditions outline in the 2019 NOAA Fisheries Columbia River System Biological Opinion (2019 BiOp).

1.2 Water Quality Policy

The Corps' policy is to comply with applicable WQS to the extent practicable regarding nationwide operation of water resources projects. The general policy is summarized in the Corps' Engineering Regulation on Water Quality Management, No. 1110-2-8154, dated 31 May 2018, Section 2-3.b which states:

> The Corps policy is to be a leader alongside other Federal agencies, and the states, in carrying out the goals and objectives of the Clean Water Act and other Federal environmental statutes by managing the nation's water resources that are under the Corps' jurisdiction and control so that they are maintained and restored. As stewards of water resources, the Corps has implemented policy to comply with water quality standards implemented under the Clean Water Act, and seeks not to degrade water quality and environmental resources owned, controlled, regulated, and/or operated by the Corps to the maximum extent practicable, consistent with project authorities, water control manuals, and consistent with meeting or exceeding applicable state and local requirements.

1.3 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 2019, the four lower Snake River dams and the four Columbia River dams operated up to 120% 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. The eight hours of performance standard spill was split into two separate blocks with one beginning in the AM hours, and one in the PM hours. These performance standard spill blocks provide more flow through turbine units. Higher powerhouse flow allows for power marketing flexibility and 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 to meet the 120% tailrace target were coordinated with NMFS and adjusted daily as necessary. The summer fish passage spill operation had spill targets in terms of rate (i.e. kcfs) or percentage of total river flow.

1.4 Endangered Species Act

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.

1.4.1 USFWS 2000 BiOp

According to the actions addressed in the USFWS 2000 BiOp, operational and structural changes are 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.

1.4.2 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 CRS BiOp is based on the proposed action contained in the Action Agencies' 2018 Consultation Package. The 2018 Consultation Package contains a suite of action 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 CRS 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 2019 Fish Operation Plan.

1.5 TDG Water Quality Standards

The following were the applicable TDG WQS by the states of Oregon and Washington during 2019.

State of Oregon:
OAR 340-041-0031:

- Waters will be free from dissolved gases, such as carbon dioxide, hydrogen sulfide, or other gases, in sufficient quantities to cause objectionable odors or to be deleterious to fish or other aquatic life, navigation, recreation, or other reasonable uses made of such water.
- Except when streamflow exceeds the ten-year, seven-day average flood, the concentration of TDG relative to atmospheric pressure at the point of sample collection may not exceed 110% of saturation. However, in hatchery-receiving waters and other waters of less than two feet in depth, the concentration of TDG relative to atmospheric pressure at the point of sample collection may not exceed 105% of saturation.

OAR 340-041-104(3): Total Dissolved Gas. The Commission may modify the total dissolved gas criteria in the Columbia River for the purpose of allowing increased spill for salmonid migration. The Commission must find that:

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

(b) The modified total dissolved gas criteria associated with the increased spill provides a reasonable balance of the risk of impairment due to elevated total dissolved gas to both resident biological communities and other migrating fish and to migrating adult and juvenile salmonids when compared to other options for in-river migration of salmon;

(c) Adequate data will exist to determine compliance with the standards; and

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

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

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

The Corps received a TDG standard modification from the ODEQ on March 17, 2015, effective for the 2015-2019 spill seasons from April 1 through August 31. The Environmental Quality Commission approved the TDG modification to the 110% total dissolved gas water quality standard for fish passage spill at McNary, John Day, The Dalles, and Bonneville dams on the lower Columbia River, subject to the 11 conditions, including:

(iii) 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.

(iv) 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.

State of Washington:

WAC 173-201A-200(1)(f): Aquatic life total dissolved gas criteria. TDG is measured in percent saturation. Table 200 (1)(f) lists the maximum TDG criteria for each of the aquatic life use categories.

TABLE 200 (1)(f)
Aquatic Life Total Dissolved Gas Criteria in Fresh Water

Category	Percent Saturation
Char Spawning and Rearing	Total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection.
Core Summer Salmonid Habitat	Same as above.
Salmonid Spawning, Rearing, and Migration	Same as above.
Salmonid Rearing and Migration Only	Same as above.
Non-anadromous Interior Redband Trout	Same as above.
Indigenous Warm Water Species	Same as above.

(i) The water quality criteria established in this chapter for TDG shall not apply when the stream flow exceeds the seven-day, ten-year frequency flood.

(ii) The TDG criteria may be adjusted to aid fish passage over hydroelectric dams when consistent with a department approved gas abatement plan. This plan must be accompanied by fisheries management and physical and biological monitoring plans. The elevated TDG levels are intended to allow increased fish passage without causing more harm to fish populations than caused by turbine fish passage. The following special fish passage exemptions for the Snake and Columbia rivers apply when spilling water at dams is necessary to aid fish passage:

- TDG must not exceed an average of 115% as measured in the forebay of the next downstream dams during the summer and must not exceed an average of 120% as measured in the tailraces of each dam during the spring and summer. 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.

On November 16, 2018, the Corps submitted a 2018 Update to the TDG Gas Abatement Plan with the intention to secure a TDG criteria adjustment for 2019. On January 25, 2019, WDOE approved the Corps' TDG Gas Abatement Plan and the request to apply the adjusted TDG criteria on the lower Snake River and lower Columbia River dams. The approval is in effect until December 31, 2021 and is subject to five conditions. On March 29, 2019, WDOE issued a short term modification to WAC 173-201A that is in effect for spring spill (typically April 3 through June 20) from 2019 to 2021 and includes the following:

Determining compliance with Washington TDG standards shall rely only on tailrace FSM location data. The TDG criteria for dam tailrace FSM locations shall be as follows:

a. The water quality compliance for TDG established in this Order shall not apply when the stream flow exceeds the seven-day, ten-year frequency flood calculated for each dam in the lower Columbia and lower Snake Rivers (also known as 7Q10 flows).
b. TDG must not exceed an average of one hundred twenty percent as measured in the tailraces fixed-monitoring sites in the tailrace of each dam. These averages shall be measured as an average of the twelve highest hourly readings in a calendar day.
c. TDG must not exceed a two-hour instantaneous level of one hundred twenty-five percent of saturation for any two hours during the twelve highest hourly measurements per calendar day as measured in the fixed-monitoring sites in the tailrace of each dam.

1.6 TDG TMDL Progress

The Oregon TDG modification and the Washington criteria adjustment request an update on the progress of implementing actions recommended in the "TMDL for the Lower Columbia River Total Dissolved Gas (September 2002)" and the "TMDL for the Lower Snake River Total Dissolved Gas (April 2003)" reports. 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.

1.7 Operating Guidelines

The Corps' Northwestern Division, Columbia Basin Water Management Division, Reservoir Control Center (RCC) is responsible for monitoring the TDG and water temperature conditions in the forebay and the tailwater of the Columbia and Snake River dams, and selected river sites. In accordance with the Corps' Northwestern Division operational water management guidelines, spill levels and spill patterns at the dams are

monitored and changed so that TDG levels are consistent with the Agreement, the 2019 FOPs, NOAA Fisheries 2019 BiOp and applicable state water quality standards (WQS), to the extent practicable.

During spring 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). During summer spill, WDOE's WQS uses the following method: an average of the 12 highest consecutive hourly readings in any one day (termed Max12hrMvAve). During summer spill, ODEQ's continues to use the Ave12hrMax calculation. At each project, the 'regulatory' TDG value is reported based on the applicable calculation method, which can switch between Ave12hrMax and Max12hrMvAve. When and where multiple calculation methods apply, 'regulatory' represents the calculation that results in the greater value and will be used throughout this report. The most restrictive daily averages are shown in the web report: https://pweb.crohms.org/ftppub/water_quality/12hr/.

1.8 System TDG Management Operations

The spill priority list is a lack of load TDG management tool that has been developed for involuntary 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 system wide. 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.

The spill priority list utilizes abatement measures (e.g. flow deflectors at Chief Joseph) implemented across the system to minimize TDG production in the CRS. Spill priority lists may also be utilized to inform other decisions such as how to allocate reserves to the projects or manage other system obligations. The Corps' RCC prepares spill priority lists based on the factors described below. Revisions are discussed in the Technical Management Team (TMT) meetings as appropriate.

Chief Joseph Dam is included in the spill priority list because it is an effective tool for managing system TDG levels under conditions that require spill (either lack of load or over capacity spill conditions) when TDG levels exceed the 110% standard. The spillway flow deflectors successfully reduce TDG levels associated with spillway releases when inflow TDG levels approach approximately 120%. In addition, at lower TDG levels, Chief Joseph Dam can spill a significant amount of water without increasing downstream TDG levels.

2. Operating Conditions

2.1 Weather

A weak El Niño was present throughout the 2019 Water Year over the tropical Pacific. As is typical with El Niño conditions, water supply in the Columbia Basin was slightly lower than long term averages with above average temperatures and below average precipitation as a whole. In WY 2019, the Columbia River Basin generally had below average precipitation affecting Columbia River flows and below average in the region affecting Snake River flows (Table 1). The accumulative precipitation as reported by the Northwest River Forecast Center (NWRFC) for WY 2019 was 76% of average (1981 to 2010) in the Columbia River above Grand Coulee Dam, 88% of average in the Snake River above Ice Harbor Dam, and 81% of average in the Columbia River above The Dalles Dam.

TABLE 1
WY 2019 Columbia River Basin Percent Precipitation

Location	Columbia River above Grand Coulee (percent)	Snake River above Ice Harbor (percent)	Columbia River above The Dalles (percent)
October 2018	91%	108%	98%
November 2018	85%	78%	76%
December 2018	88%	72%	84%
January 2019	62%	64%	64%
February 2019	84%	201%	143%
March 2019	23%	41%	31%
April 2019	96%	120%	109%
May 2019	54%	105%	83%
June 2019	49%	33%	41%
July 2019	99%	26%	64%
August 2019	73%	53%	64%
September 2019	147%	154%	157%
Oct - Sept Average	**76%**	**88%**	**81%**

Note: Data, temperature and precipitation maps from NOAA/National Weather Service Northwest River Forecast Center. Basin precipitation as percentage of the 1981-2010 period

For much of the fall and winter, precipitation trended below average, with the overall downward trend resulting in water supplies punctuated by fairly wet and stormy periods in late-October and mid-December, 2018**.** By mid-January, water supply forecasts were hovering near triggers for drought-related system operations. Then a blocking upper level ridge set up over the Gulf of Alaska in late January, 2019 which brought the most impactful weather of the year to the region. Major winter storms struck the southern two-thirds of the basin which increased basinwide snowpacks from 89% of normal to 104% of normal between February 1 and March 5, with Snake Basin snowpacks making the biggest jump from 83% of normal to 118% of normal.

In April, the region experienced a particularly wet start to the month. The widespread heavy rains rapidly melted a sizeable part of the snowpack in the Snake Basin. The combination of the atmospheric river systems and a warm May across the basin led to an early snowmelt cycle. Average annual temperatures were near the long-term mean across the Columbia Basin in 2019, due in large part to the very cold February and early March. That broke a six year streak of above average basin annual temperatures. However, this marked the fourth year in the last five when the daily peak in Snake River flows was a month or more earlier than the peak at Grand Coulee.

2.2 Water Supply

The actual observed runoff volume for January through July at the Columbia River above The Dalles Dam was 90.2 Maf. The April-August runoff at The Dalles totaled 81.0 Maf, or 93% of the 30 year average. WY 2019 is ranked as number 44 out of 59 years of record in total April-August runoff as measured at The Dalles. Runoff in the Snake River Basin was above normal with the observed April-July runoff at Lower Granite totaling 23.4 Maf, or 118% of the 30 year average.

Table 2 provides WY 2019 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 dams. Unregulated flows provide a general perspective on the water supply from rainfall or snowmelt for that month or year. The average monthly unregulated flow at Lower Granite Dam during the spring runoff was highest in April. The average monthly unregulated flow at The Dalles Dam during the spring runoff was highest in May, with daily observed inflows peaking on May 19, 2019, at 334 kcfs, below the median historic runoff peak of near 500 kcfs[2].

[2] Based on the USACE HEC-ResSim model run.

TABLE 2
Snake and Columbia River Flow in WY 2019[3]

Time Period	Snake River At Lower Granite		Columbia River At The Dalles	
	Unregulated Flow (kcfs)	% of Average	Unregulated Flow (kcfs)	% of Average
October, 2018	20.6	89	63.7	77
November, 2018	24.2	89	87.1	92
December, 2018	20.9	73	72.0	79
January, 2019	21.0	65	72.8	74
February, 2019	25.5	63	73.5	64
March, 2019	49.9	91	117.6	79
April, 2019	136.0	177	320.2	138
May, 2019	132.5	118	412.2	100
June, 2019	91.5	90	326.3	74
July, 2019	27.7	75	173.0	73
August, 2019	19.2	95	106.8	86
September, 2019	20.0	100	102.3	118
Oct - Sept Average	**49.1**	**102.5**	**160.8**	**89.2**

Note: Unregulated Flows exclude the effects of regulation provided by storage reservoirs

2.3 Reservoir Operation

The following overview of reservoir operations includes a description of flood risk management, streamflow, operations, calculations of 2019 7Q10 flows, and observed 7Q10 flows (average peak annual flows for seven consecutive days that has a recurrence interval of 10 years).

2.3.1 General

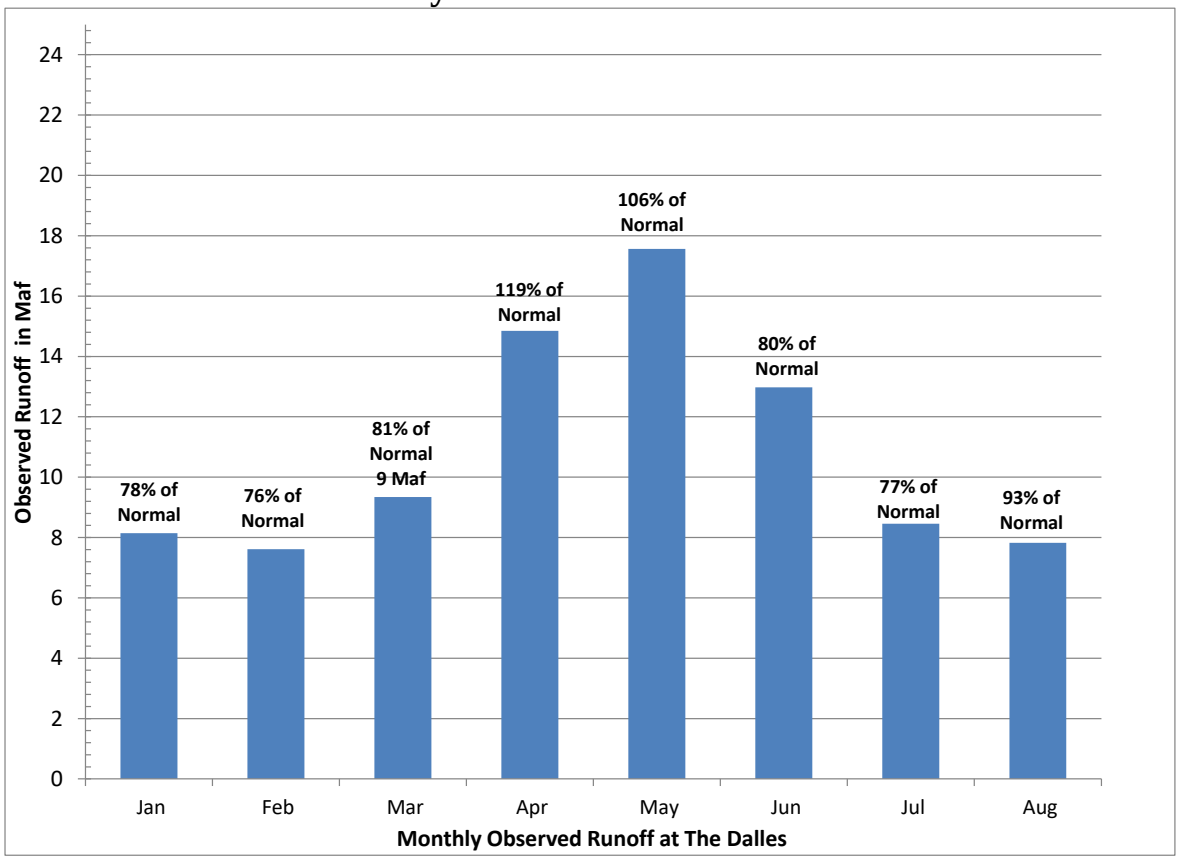
Water Year 2019 began with Grand Coulee Dam within the top six feet of the reservoir with an elevation of 1283.9 ft. The observed runoff at The Dalles was below average in January through March, but rose above average in April and May. The observed runoff at The Dalles then gradually declined through August as shown in Figure 1. The shape of the runoff at Bonneville Dam resulted in four peaks in April through May with daily average flows near 350 kcfs and spill up to 135 kcfs. As Figure 2 shows, the highest observed outflows at Bonneville Dam occurred on April 11, 2019 with flows of 366 kcfs and the other three peaks occurred on April 22 with a flow of 357 kcfs; on May 19 with a flow of 354 kcfs and on June 1 with a flow of 342 kcfs. Flows then declined continually through the summer.

Generally, reservoir operation objectives included: 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 spring seasonal flow objectives[4] were 135 kcfs at

[3] From 2019 National Weather Service Runoff Processor.
[4] The spring and summer flow objectives are defined in the 2019 Water Management Plan.

Priest Rapids, 96 kcfs at Lower Granite and 220 kcfs at McNary dams. The Lower Granite and McNary spring flow objectives were met with flows exceeding 120 kcfs and 253 kcfs, respectively. The Priest Rapids flow objective was not met with flows of 123 kcfs. The summer seasonal flow objectives were 200 kcfs at McNary Dam and 51.2 kcfs at Lower Granite Dam, and these objectives were not met with corresponding flows of 145 and 37 kcfs.

FIGURE 1
2019 Monthly Observed Runoff at The Dalles



2.3.2 Flood Risk Management

The 2019 water supply forecasts were below average across the Columbia River Basin. Inflow forecasts and reservoir regulation modeling were performed weekly throughout the winter and spring. The Columbia River Basin storage projects were operated to their specified flood risk management elevations based on the information available during the season. This included the treaty projects operating to the May 2003 Flood Control Operating Plan (FCOP). The Libby project was operated consistently with the Libby Coordination Agreement, including the Libby Operating Plan, U.S. federal requirements for power, NOAA Fisheries 2019 BiOp and U.S. Fish and Wildlife Service's 2000 BiOp, as supplemented in 2006 for Libby Dam (collectively referred to as the 2000/2006 BiOp). The unregulated peak flow, based on the Corps' system regulation model (HEC-ResSim)

at The Dalles Dam, was estimated at 456 kcfs on May 19, 2019. The regulated peak observed flow at The Dalles was 334 kcfs, which occurred on May 19, 2019.

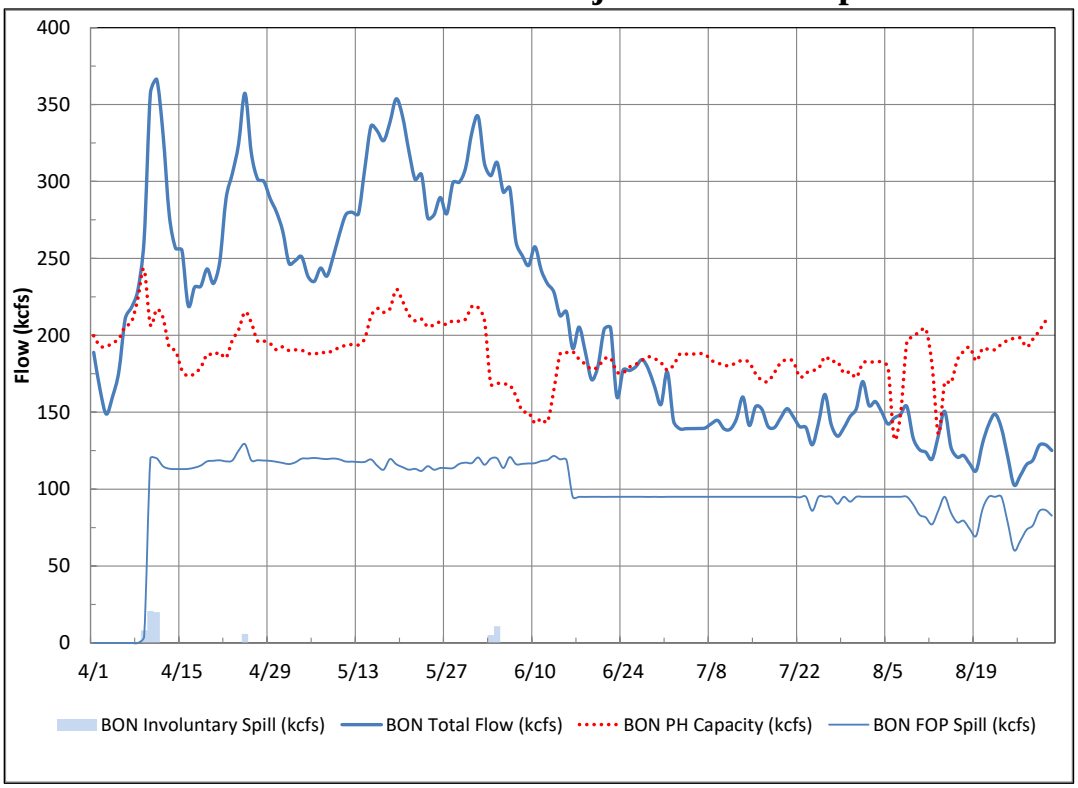
2.3.3 Total River Flow

Daily average observed streamflows were below average in 2019 due to the below average (93% of normal) runoff volume for April through August as measured at The Dalles. This resulted in below average flows at the federal Columbia Basin projects as illustrated at Bonneville Dam. Daily average observed streamflows on the lower Snake River were above average in 2019 due to the above average runoff volumes for April through July (118%) as measured at Ice Harbor Dam.

Daily average total river flow on the lower Columbia River, as measured at Bonneville Dam, from April 1 through August 31, ranged from 103 - 366 kcfs, averaging 186 kcfs (Figure 2). Daily average flow peaked mid-April. Total river flows began to recede gradually in late May and continued a steady recession until the end of August when flows reached 125 kcfs.

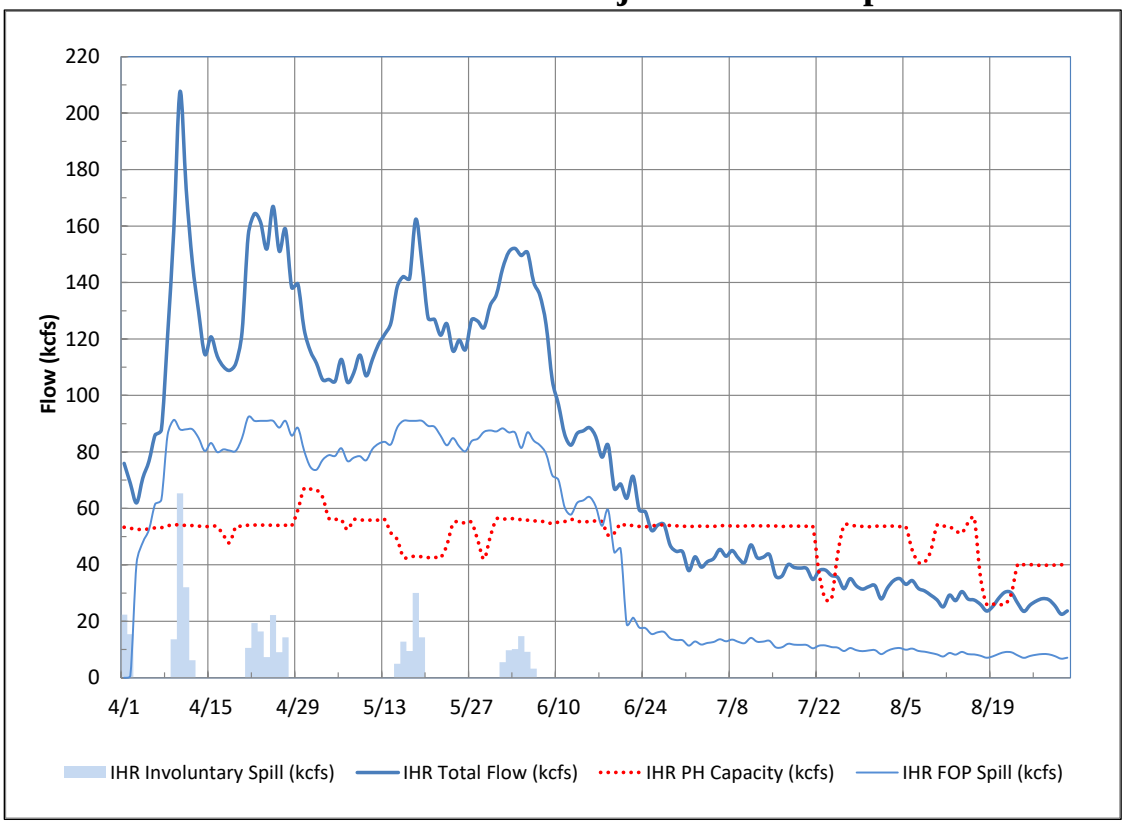
On the lower Snake River as measured at Ice Harbor Dam, daily average total river flow from April 1 through August 31 ranged from 23 - 207 kcfs, averaging 81 kcfs (Figure 3). Daily average flow peaked in mid-May. Total river flows began to recede gradually in late May and continued a steady recession until the end of August when flows reached 24 kcfs.

FIGURE 2
2019 Bonneville Dam Project Flow and Spill



Note: Daily powerhouse capacities provided by BPA Duty Schedulers

FIGURE 3
2019 Ice Harbor Dam Project Flow and Spill



Note: Daily powerhouse capacities provided by BPA Duty Schedulers

2.3.4 Calculation of 2019 7Q10 Flows

Based on the expected return interval of the 7Q10 flows (10 years), the lack of observed exceedances on the Lower Snake River prompted re-calculation of the values for both the Snake and Columbia Rivers using a similar methodology to that outlined in the 2002 Snake River TMDL and Gas Abatement Plan. At Bonneville Dam, the recomputed 7Q10 value was equal to the value previously computed in 2010, however, the 7Q10 values at other Lower Columbia River projects were 2-4 kcfs lower than the values computed previously. A discussion of the methodology and results of the 7Q10 calculation is presented in Appendix K.

2.3.5 2019 Observed Flows above 7Q10

With above average runoff (118% of average) in 2019 on the lower Snake River and the below average runoff (93% of average) in 2019 on the lower Columbia River, daily average flows exceeded the 7Q10 criteria at three lower Snake River projects for one day each– Little Goose, Lower Monumental, and Ice Harbor dams. TDG exceedances are not tracked during 7Q10 high flow periods.

There were no days when daily flows reached the 7Q10 flows on the lower Columbia River. The 7Q10 flow criteria and a relevant subset of daily average flows for the Corps' Snake and Columbia River dams are shown on Table 3.

TABLE 3
7Q10 Criteria and Peak 2019 Observed Flows

Date	LWG Flows (kcfs)	LGS Flows (kcfs)	LMN Flows (kcfs)	IHR Flows (kcfs)	MCN Flows (kcfs)	JDA Flows (kcfs)	TDA Flows (kcfs)	BON Flows (kcfs)
7Q10 Flow Criteria	**196**	**196**	**196**	**197**	**437**	**440**	**446**	**454**
4/3/2019	63	59	60	62	128	129	126	149
4/4/2019	66	68	67	71	141	154	153	160
4/5/2019	74	73	73	77	151	164	164	177
4/6/2019	80	80	80	86	165	188	190	210
4/7/2019	86	84	84	88	174	201	202	218
4/8/2019	120	115	117	121	179	188	194	229
4/9/2019	159	153	154	159	231	226	234	262
4/10/2019	195	197	205	208	306	345	337	357
4/11/2019	165	159	166	173	286	325	324	366
4/12/2019	135	133	136	147	249	294	291	331
4/13/2019	123	121	124	130	216	242	236	278
4/14/2019	115	110	110	115	205	228	228	257
4/15/2019	114	111	114	121	204	235	225	255
4/16/2019	110	108	107	114	208	209	200	219
4/17/2019	106	104	103	110	200	217	202	231
4/18/2019	102	101	102	109	198	214	209	232
4/19/2019	108	107	108	111	221	230	218	243
4/20/2019	126	119	117	122	201	211	202	234
4/21/2019	154	151	149	157	245	252	236	248
4/22/2019	161	157	156	164	264	282	271	289
4/23/2019	158	154	152	161	278	293	286	305
4/24/2019	156	149	147	152	306	324	306	325
4/25/2019	163	163	159	167	322	343	331	357
4/26/2019	157	149	150	151	293	310	288	319
4/27/2019	155	151	150	159	280	285	280	302
4/28/2019	139	133	132	138	277	288	273	300
4/29/2019	136	133	131	140	269	280	266	289
4/30/2019	122	118	118	124	268	268	252	280
Total Days	**0**	**1**	**1**	**1**	**0**	**0**	**0**	**0**

Note: Gray shaded rows represent days where observed daily average flows exceeded 7Q10 flow criteria

3. 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 water quality monitoring data along with dam operating data are reviewed daily as part of the process of setting spill caps to maintain TDG levels within the 110%, 115%, and 120% TDG criteria. 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.

3.1 Fixed Monitoring Stations

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.

3.2 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.

3.3 Changes in or Maintenance of the FMSs

Significant modifications or maintenance issues for the Corps' Fixed Monitoring Equipment in 2019, are listed below.

Anatone: Sediment build-up occurred in the Anatone (ANQW) deployment pipes that resulted in low TDG measurements and/or difficulty retrieving the sonde. Cleaning of the pipe may have altered the position of the end of the pipe. A custom welded and rigged tractor wheel pipe termination anchor was used at this station to secure the end of the pipe in the flow in 2018, which may have shifted due to compressed air causing buoyancy of the pipe. The sonde was eventually moved outside of the deployment pipe in August 2019. Further investigation via pipe cameras and possible repositioning will occur after the spring runoff of 2020.

Lower Monumental Tailwater: The Lower Monumental (LMNW) tailwater station was damaged due to a wildfire which occurred on 31 August 2019. The fire originated from the boat ramp downstream and appeared to be the result of a campfire. This caused 67 hours of data loss as it occurred on a Saturday and could not be immediately repaired. The deployment equipment was destroyed or damaged (deployment box, deployment pipe, deployment rope, and sonde communication cable) and was repaired in November 2019.

Lewiston: The TDG probe is no longer maintained at the Lewiston (LEWI) gage due to rising expenses. The gage is still operated by NWW water quality staff as a temperature station.

3.4 Malfunctioning Gauge Occurrences

During 2019, there were five tailwater gauges that malfunctioned for a period greater than six hours. There were a total of 21 occurrences of FMS gauges malfunctioning as shown in Table E-6 (Appendix D).

The Bonneville tailwater TDG gauge (CCIW) was removed to prevent damage during the forecasted high flows May 17-May 22. In past years, total flow between 450 and 500 kcfs damaged the gauge. Access to the gauge is limited above a tailwater stage of 28.0 feet, which correlates with a flow of approximately 400 kcfs. The forecast on May 16 indicated flows in excess of 420 kcfs the week of May 20, with flows exceeding 380 kcfs on May 18. The Corps and USGS agreed that the real-time instrument should be replaced on May 17 while the gauge was still accessible. When the 10-day flow forecast predicted flows less than 380 kcfs, the USGS replaced the TDG gauge on May 21. Although real-time data were not available for daily spill review, the Corps later received the recorded data for this period after the fact.

On May 15, an error was discovered in the reported air pressure data at The Dalles tailwater gauge (TDDO). A 1.01 multiplier was being applied to the data transmitted from the gauge. This error caused an approximately one percent increase in the calculated percent saturation metrics at TDDO and resulted in 12-hr average TDG exceedances that were not previously reported. Therefore, spill caps for The Dalles spill may have been greater than they would have otherwise been. The multiplier is no longer being applied and all data from 2015 through 2019 have been corrected.

Malfunctioning gauge TDG data quality events are tracked in Appendix D in Tables D-2, and D-5. Tables D-2 through D-4 are based on revised.

3.5 QA/QC on FMS

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 2019 reports are included as Appendices G, H, and I. Highlights from these reports are provided below.

3.5.1 Walla Walla District QA/QC

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:

- Data completeness for the combined barometric pressure, TDG, and temperature data averaged 95.5% for the 14 monitoring sites in 2019 (eight seasonal and six year-round).
- The TDG data received from all the stations ranged from 93.9 to 100.0% complete. The primary cause (31%) of missing/invalid data was due to defective TDG membranes, primarily at the McNary tailwater station (MCPW). The second most frequent cause of missing data was a defective sonde at McNary tailwater, which accounted for 22.0% of the total.
- The TDG sensors from the 14 seasonal and annual FMSs were removed from the field and calibrated in the laboratory every three weeks between April 2019 and August 2019. From September 2018 through March 2019, the six annual FMSs were calibrated at four-week intervals.
- The sensor pre-deployment checks had calculated mean ambient pressure, ambient pressure plus 300 mmHg, and temperature differences of -0.30 mmHg, -0.23 mmHg, and 0.04^{o}C, respectively. The sensor post-deployment check revealed mean ambient pressure, ambient pressure plus 100 mmHg, and temperature differences of -0.38 mmHg, -0.86 mmHg, and 0.02°C, respectively.
- The median for the 157 in-situ field checks of TDG sensors with the replacement probe was 0.0%. Station median values ranged from -0.3% to 0.1%.
- The calculated median for the 157 field checks for barometric pressure was 0.01 mmHg with station medians ranging from -0.10 to 0.20 mmHg.
- The calculated median for the water temperature field checks was -0.1^{o}C. Station medians ranged from -0.7^{o}C to 0.02^{o}C.
- The Lower Monumental Tailwater (LMNW) deployment box and pipe were damaged due to a wildfire and was reconstructed in November 2019.

- The end of the Anatone (ANQW) deployment pipe shifted during clean-out maintenance resulting in lost data hours and repairs.

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

3.5.2 Portland District QA/QC

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:

- Data received in real-time from the eight individual monitoring sites ranged from 94.7% (at Cascade Island) to 100% complete.
- Criteria for data completeness (95%) were met at all monitoring stations, except for CCIW. Equipment was removed at CCIW from May 17 to 21 in anticipation of high flows at the site, accounting for 39% 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, 82 of 90 TDG sensor field checks were within ±1.0 percent saturation of a secondary standard sensor. Four of the field checks that failed the ±1.0 percent saturation guideline were due to ruptured membranes on the TDG sensors. The other four (ranging from -1.5 to +2.5 percent saturation) were due to slow equilibration of the reference sensor and did not appear to be true indications of inaccurate field sensors.
- Five of 89 barometric pressure field checks were greater than ±1 mmHg of a primary standard, ranging from -2.1 to +2.2 mmHg. The offsets within the datalogger or database were adjusted accordingly, and no data were deleted or corrected. All 90 water-temperature field checks were within ±0.2°C of a secondary standard, ranging from -0.13 to +0.06 °C.
- The TDG sensors were removed from the monitoring stations and calibrated every four weeks from October through December 2018. The four-week schedule was interrupted by the federal government shutdown and resulted in 2 six-week intervals between site visits from January to March 2019. The sensors were then field checked and lab calibrated every three weeks from March through September 2019.
- All 93 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 full detailed QA/QC report on the Portland District gauges can be found in Appendix G.

3.5.3 Seattle District QA/QC

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:

- Data completeness for TDG and temperature data received ranged from 99.9% at the Chief Joseph tailwater (CHQW) gauge to 99.8% at the Chief Joseph forebay (CHJ) gauge. Data completeness for temperature data received was 99.9% at station CHJ and 98.7% at station CHQW. Missing TDG and temperature data were largely due to DCP malfunctions and programming problems.
- For TDG data, at the forebay (CHJ) station a total of 4 hours were rejected due to slow probe response time after recalibration. At the tailwater station (CHQW) a total of 4 hour was rejected due to slow probe response time after recalibration. For temperature, 1 hour was rejected at station CHQW due to slow probe response time after recalibration. No temperature data were rejected at stations CHJ.
- Laboratory calibration data were good and within 0.1°C for temperature and 1% saturation for TDG. Field calibration data were good and generally within 1 mmHg of the secondary standard barometer, 0.1ºC of the secondary standard thermometer, and 1% 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% after 2 weeks of deployment in the river.
- A total of 26 out of 27 (96%) in-situ field checks of barometric pressure were within ±2 mmHg of a secondary standard, and 27 out of 27 (100%) water temperature field checks were all within ±0.2°C.

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

4. Fish Passage Spill Program

4.1 Spill

Operation of the federal Columbia River System projects to meet multiple authorized purposes can result in exceedances of percent TDG state water quality standards. Part 4 provides detailed information on the implementation of fish passage spill as well as involuntary spill (e.g., lack of turbine, lack of load, transmission constraints, etc.).

4.1.1 Fish Passage Spill Operations

The Corps developed the 2019 FOP that provides detailed information on the implementation of the 2019-2021 Spill Operation Agreement and 2019 BiOp spill and transport operations at the Corps' four lower Snake River and four lower Columbia River projects.

The amount of fish passage spill 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. The 2019 FOP, provided in Appendix B, describes specific fish operations implemented this year and are summarized in Table 4.

TABLE 4
2019 FOP Spill Operations

Project	Planning Dates	Duration	Spill Amount (Not to Exceed the Spill Cap)
Lower Granite	April 3 - June 20	16 hours/day	120% Gas Cap ±2 kcfs
Lower Granite	April 3 - June 20	8 hours/day	20 kcfs
Lower Granite	June 21 - August 31	24 hours/day	18 kcfs ±2 kcfs
Little Goose	April 3 - June 20	16 hours/day	120% Gas Cap ±2 kcfs
Little Goose	April 3 - June 20	8 hours/day	30% of project outflow or to the spill cap, whichever is less
Little Goose	June 21 - August 31	24 hours/day	30% of project outflow or to the spill cap, whichever is less
Little Goose	During flows < 32 kcfs	24 hours/day	Fixed spill of 7-11 kcfs (dependent on total outflow)
LMN	April 3 - June 20	16 hours/day	120% Gas Cap (Uniform spill pattern)
LMN	April 3 - June 20	8 hours/day	30 kcfs (Uniform spill pattern)
LMN	June 21 - August 31	24 hours/day	To the spill cap up to 17 kcfs ±2 kcfs
Ice Harbor	April 3 - June 20	16 hours/day	120% Gas Cap
Ice Harbor	April 3 - June 20	8 hours/day	30% of project outflow or to the spill cap, whichever is less
Ice Harbor	June 21 - August 31	24 hours/day	30% of project outflow or to the spill cap, whichever is less
Ice Harbor	April 3 - August 31	24 hours/day	Minimum spill with RSW is 8.4 kcfs
McNary	April 10 - June 15	16 hours/day	120% Gas Cap ±2 kcfs
McNary	April 10 - June 15	8 hours/day	48% of project outflow or to the spill cap, whichever is less
McNary	June 16 - August 31	24 hours/day	57% of project outflow or to the spill cap, whichever is less
John Day	April 10 - June 15	16 hours/day	120% Gas Cap ±2 kcfs
John Day	April 10 - June 15	8 hours/day	32% of project outflow or to the spill cap, whichever is less
John Day	June 16 -August 31	24 hours/day	35% of project outflow or to the spill cap, whichever is less
The Dalles	April 10 - June 15	16 hours/day	120% Gas Cap ±3 kcfs
The Dalles	April 10 - June 15	8 hours/day	40% of project outflow or to the spill cap, whichever is less
The Dalles	June 16 - August 31	24 hours/day	To the spill cap or 40% of project outflow
Bonneville	April 10 - June 15	16 hours/day	120% Gas Cap ±3 kcfs
Bonneville	April 10 - June 15	8 hours/day	100 kcfs ±3 kcfs
Bonneville	June 16 – August 31	24 hours/day	To the spill cap up to 95 kcfs ±3 kcfs
Bonneville	April 10 - August 31	24 hours/day	Minimum spill is 50 kcfs
Bonneville	April 10 - August 31	24 hours/day	Maximum spill is 150 kcfs

The 2019 FOP established spill levels for juvenile fish passage at the four lower Snake and four lower Columbia River projects during the juvenile fish migration season. The fish

passage spill called for in the 2019 FOP occurred from April 3 to August 31 at the lower Snake River dams, and from April 10 to August 31 at the lower Columbia River dams.

4.1.2 Fish Passage Spill Rates

The Corps tracks the rate of spill that occurs at the eight fish passage dams as part of the FOP Implementation Report requirements. The amount of fish passage spill is 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 J-3 through J-10 of Appendix J. The amount of flow, generation, actual and FOP fish passage spill for the 2019 spill season at each dam is graphed for the entire April through August spill season and included in Appendix J as Figures J-1 through J-8.

4.1.3 Long Term Turbine Outages

Unit outages can affect the spill rate at the dams by causing additional involuntary spill. Table 5 summarizes the long term unit outages during the 2019 Fish Passage Season and identifies outages outside of the reporting period. Not all outages actually have, or will, result in spill or elevated TDG levels, but are included for informational purposes. There were a total of 32 long term outages during the 2019 Fish Passage Season. There were seven long term (greater than one month) unit outages on the lower Snake River, 14 on the lower Columbia River, and 11 on the middle Columbia River.

TABLE 5
2019 Long Term Outages

Project	Unit	Start Date	End Date	Reason
Grand Coulee	PG8	1/24/2019	ongoing	Forced outage - cause unknown
Grand Coulee	22	2/11/2019	ongoing	Major overhaul
Grand Coulee	PG7	2/26/2019	8/20/2019	Turbine shaft seal indicator repair
Grand Coulee	7	6/3/2019	ongoing	Quin Maintenance, Breaker Annual, WECC Testing
Grand Coulee	5	7/12/2019	8/29/2019	4-year disconnect maintenance
Grand Coulee	16	6/11/2018	ongoing	Quin / TRs / WECC Testing / SF6 Breaker Annual / Disc. / GND Switch
Grand Coulee	10	6/12/2018	6/7/2019	Pilot Exciter Testing, High Beam trouble
Grand Coulee	10	7/29/2019	8/29/2019	Brush Maintenance
Chief Joseph	11	6/3/2019	8/8/2019	Thrust Bearing Cooler Replacement, Turbine Bearing Replacement
Chief Joseph	27	11/8/2018	6/11/2019	Quin Services
Chief Joseph	15	4/15/2019	5/23/2019	Thrust Bearing Cooler Replacement, Annual Maintenance
Little Goose	5	4/21/2017	ongoing	Forced outage - excessive turbine guide runout
Lower Monumental	2	7/15/2019	ongoing	Liner and Blade Seal Replacement, Unit Annual
Lower Monumental	4	7/8/2019	8/29/2019	Annual, VBS Inspection
Lower Monumental	1	5/28/2019	7/11/2019	Digital Governor Installation
Ice Harbor	2	4/29/2016	5/2/2019	Turbine Replacement
Ice Harbor	4	1/28/2019	8/14/2019	Forced outage due to possible oil leak
Ice Harbor	3	5/3/2019	ongoing	Turbine Replacement
McNary	5	5/23/2019	ongoing	Turbine Hub Seal Replacement
McNary	13	6/10/2019	ongoing	HPOIS and Lubrication Oil Change-Out
John Day	5	1/26/2017	ongoing	Turbine Blade Linkage Rehab
John Day	6	7/14/2015	ongoing	Stator Winding Failure
John Day	7	8/4/2017	ongoing	CO2 Discharge
John Day	3	4/15/2019	ongoing	Five-year Overhaul, Servo Seal, Cavitation
The Dalles	5	5/31/2018	8/29/2019	Governor Oil Leak
The Dalles	6	11/19/2018	8/29/2019	Transformer Replacement, Annual
The Dalles	3	4/15/2019	5/23/2019	Annual
The Dalles	4	4/15/2019	5/23/2019	5-year Overhaul
The Dalles	19	10/7/2018	ongoing	Gassing on T10
The Dalles	20	10/7/2018	ongoing	Gassing on T10
Bonneville	6	7/8/2019	8/29/2019	5-year Overhaul
Bonneville	15	3/18/2019	5/16/2019	4-year Overhaul
TOTAL OUTAGES = 32				

4.1.4 Involuntary Spill

January through March 2019 saw periods of involuntary spill at Little Goose and Ice Harbor, with a total of 15 project days of spill.

Involuntary spill on the lower Columbia River began on April 8 prior to the start of FOP spill operations. Involuntary spill ceased on April 10 (Figure 2) for all projects except Bonneville, at which involuntary spill continued intermittently until June 4.

The lower Snake River projects began involuntary spill on April 9 at Lower Granite, Little Goose, and Lower Monumental Dam, and March 19 at Ice Harbor Dam. Involuntary spill due to high flows continued on the lower Snake River projects intermittently until June 7. In July and August, Doble testing resulted in involuntary spill at all lower Snake River projects.

4.2 Total Dissolved Gas Model - SYSTDG

The SYSTDG model was used extensively throughout the 2019 WY and daily in the spring during the period of operations under the 2019-2021 Spill Operation Agreement. Because of the observed high predictive errors seen for certain TDG gauges (LGSA; LGSW and LMNA) in the 2018 statistical analysis, new SYSTDG production equations were developed for all of the fish passage dams. Calibrations for the new equations were weighted to better match 120% TDG levels. This weighted calibration approach resulted in TDG production equations perform better in the spring during high flows than during summer low flows. Because of this global revision of the TDG production equations, the statistical analysis for the spring is particularly important. The following are the highlights of the comparison of the spring (April through June) statistical analysis against the April through August statistical analyses:

- While there were 11 TDG gauges with a standard deviation (SD) of 1.6 or higher in the 2019 April- August statistical analysis, there were none in the 2019 April-June statistical analysis.
- The system-wide SD for the April-June statistical analysis was 1.1% compared to the system-wide SD for the April-August statistical analysis of 1.6%. This 0.5% difference can be attributed to the TDG production equations being well developed for high flows in the spring and less accurate for the low flows in the summer.
- The model results were less precise (system-wide SD of 1.1% in the April-June period) than precision of the TDG target (within 1.0%). Therefore, predicted TDG / spill relationship was at times a more useful model result than a predicted TDG magnitude.

5. TDG Exceedances of the WQS

Exceedance reporting in this section is consistent with the Corps' Operating Guidelines described above in Section 1.

5.1 WQS exceedances and data quality events during fish passage spill

Exceedances of % TDG state WQS in 2019 were primarily due to two factors: 1) flows that result in exceeding powerhouse capacity and involuntary spill, and 2) uncertainty of forecasts and causal factors leading to a spill cap that resulted in greater than predicted TDG, despite compliance with *Procedure for Setting 2019 Spring Spill Caps* (*see* Appendix B). Also, at times, there were problems related to data quality or availability (data quality event) due to malfunctioning FMS gauges, resulting in erroneous or unavailable TDG.

5.1.1 120% (Spring) and 115%/120% (Summer) TDG evaluation

Table 6 provides a summary of TDG exceedances and data quality events during the 2019 spill season for the lower Columbia and lower Snake projects except when flows are greater than the 7Q10. There were a total of 157 gauge days in 2019 in which the TDG

levels were above the applicable TDG criteria and 21 days in which there was a data quality event and TDG could not be evaluated. (See Table 6 and Table D-2, Appendix D).

TABLE 6
Summary of TDG Exceedance and Data Quality Events

Fixed Monitoring Stations	Exceedances	Data Quality Events
Lower Granite Forebay (LWG)	0*	0
Lower Granite Tailwater (LGNW)	13	0
Little Goose Forebay (LGSA)	0*	0
Little Goose Tailwater (LGSW)	20	0
Lower Monumental Forebay (LMNA)	0*	0
Lower Monumental Tailwater (LMNW)	29	1
Ice Harbor Forebay (IHRA)	2*	0
Ice Harbor Tailwater (IDSW)	31	1
McNary Forebay (MCNA)	0*	0
McNary Tailwater (MCPW)	3	7
John Day Forebay (JDY)	2*	0
John Day Tailwater (JHAW)	4	2
The Dalles Forebay (TDA)	1*	0
The Dalles Tailwater (TDDO)	38	10
Bonneville Forebay (BON)	0*	0
Bonneville Tailwater (CCIW)	14	0
Total	**157**	**21**

* Evaluated during summer spill only

5.1.2 Recurring High TDG Exceedances

In 2019, three gauge locations had the highest number of TDG exceedances:

- The Dalles Tailwater gauge (TDDO) had 38 exceedances due to typical model and forecast uncertainties.
- The Lower Monumental Tailwater gauge had 29 exceedances: 19 due to high flow causing involuntary spill, 8 due to model and forecast uncertainties, 2 due to operation or mechanical failure of non-generating equipment.
- The Ice Harbor Tailwater gauge had 31 exceedances: 17 due to high flow causing involuntary spill, 7 due to model and forecast uncertainties, 5 due to generating unit outages causing involuntary spill, 2 due to operation or mechanical failure of non-generating equipment.

5.1.3 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 2019 spill season. Each type of TDG exceedance represents conditions that cause daily average percent TDG to exceed the applicable WQS. The 2019 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	Definition	2019 Quantity
1	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.	71
1a	Planned and unplanned outages of hydro power equipment including generation unit, intertie line, or powerhouse outages.	6
2	TDG exceedances due to the operation or mechanical failure of non-generating equipment.	8
3	TDG exceedances due to uncertainties when using best professional judgment, SYSTDG model and forecasts.	72

Type 1 exceedances may occur every year due to high flows and are a normal part of reservoir operations, though efforts continue to reduce daily TDG exceedances when possible.

The two primary contributors of TDG exceedances in 2019 were involuntary spill from high flows that exceeded the powerhouse capacities at run-of-river projects (Type 1) and uncertainty when using best professional judgment, the SYSTDG model, and forecasts (Type 3). These uncertainties resulted in unpredicted high resultant TDG levels despite compliance with *Procedure for Setting 2019 Spring Spill Caps*. The 2019 spring spill operations to the 120% TDG gas caps at all eight fish passage projects was a new spill operation with large daily spill variations.

5.1.4 Exceedances of TDG in Oregon

TDG exceedances that occurred at the dams covered by the Oregon TDG modification are shown in Table 8. In 2019, there were 59 TDG exceedances which exceeded the 120% TDG standard in the reservoir tailwater. These 59 TDG exceedances are approximately 10% of 612 possible gauge days (4 gauges x 153 days), from April 1 through August 31. There were 38 TDG exceedances at TDDO that were attributed to unpredicted resultant TDG levels despite of using best professional judgment and following the procedures for setting spill caps.

TABLE 8
Number of 120% TDG Exceedances of Oregon WQS

Fixed Monitoring Stations	April 1 - August 31 120% TDG Exceedances	7Q10 Flow Days	Exceedances between April 1- April 10
McNary Tailwater	3	0	0
John Day Tailwater	4	0	0
The Dalles Tailwater	38	0	0
Bonneville Tailwater	14	0	0
Total Number of Exceedances for Oregon	**59**	**0**	**0**

5.1.5 Oregon and Washington 125% Criteria

During the 2019 spill season, there were 16 days when TDG readings exceeding the two-hour standard of 125% TDG, as shown in Table E-4 (Appendix D) for the tailwater gauges. The majority of 125% TDG exceedances occurred on the lower Snake River and were attributed to involuntary spill in April. On the lower Columbia, TDG values above 125% were observed only at The Dalles Tailwater gauge and were due to uncertainties when using best professional judgment, models and forecasts.

5.2 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 WY2019, the TDG exceedances are typically due to involuntary 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, April and September 2019. 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 gauge did not exceed the TDG criteria during this period.
- There were ten days of 110% TDG exceedances at Ice Harbor dam tailwater gauge during March and one in April 2019 due to involuntary spill.

- There were two 110% TDG exceedances in April 2019; one at McNary tailwater and one at John Day tailwater due to involuntary spill.

6. Gas Bubble Trauma Monitoring

The Fish Passage Center compiles a report of Gas Bubble Trauma (GBT) monitoring results collected in 2019 (Appendix I). The monitoring of juvenile salmonids in 2019 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 2019 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 11,328 juvenile salmonids examined, 224 had signs of GBT between April and August of 2019 (see Appendix I, Table I-3).

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 not met at the Snake River or Mid-Columbia River sites but was met once at the Upper Columbia site (RIS) in 2019. The single occurrence at the Rock Island Dam occurred on June 13th. During this occurrences, flows in the Upper Columbia River were below the hydraulic capacities at upstream projects and TDG in the Rocky Reach tailrace had been at or below 116% for several days prior. The criterion of 5% severe GBT was not met in 2019.