2022 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 2023

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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

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The appendices to this report are available on the internet:
http://pweb.crohms.org/tmt/wqnew/tdg_and_temp/2022/

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
CRSO EIS	Columbia River System Operations Environmental Impact Statement
ESA	Endangered Species Act
FCOP	Flood Control Operating Plan
FMS	fixed monitoring station
FOP	Fish Operations Plan
GBT	gas bubble trauma
HEC-ResSim	Hydrologic Engineering Center's Reservoir System Simulation model
kcfs	thousand cubic feet per second
kaf	thousand acre-feet
Maf	million acre-feet
NMFS	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
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).

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.

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 2020 NOAA Fisheries Columbia River System Biological Opinion (2020 BiOp), 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.

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 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.

[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.

(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.

2020 BiOps: The governing NMFS and USFWS Biological Opinions for the Columbia River System.

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 when a generating unit cannot be in operation because of maintenance or repairs.

Program Description

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 from April through August and is consistent with operations outlined in the Record of Decision for the Columbia River System Operations Environmental Impact Statement (CRSO EIS ROD) dated September 28, 2020, CRSO Final EIS, 2020 National Marine Fisheries Service (NMFS) Columbia River System and U.S. Fish and Wildlife Service Biological Opinions (2020 BiOps)[2], the Extensions of the 2008 Columbia Basin Fish Accords (Accord Extensions)[3], the Corps' requirements under the Endangered Species Act (ESA), and the ongoing communications with the relevant wildlife agencies to ensure consistency with the ESA. Spill operations are detailed in the 2022 Fish Passage Plan (FOP), which also incorporates measures agreed to in the Term Sheet for Stay of Preliminary Injunction Motion and Summary Judgment Schedule (referred to as the 2022 Agreement) for the *NWF et al. v. NMFS et al.* (3:01-cv-00640-SI) litigation as extended in the August 2022 Motion to Stay the Litigation.[4]

This report describes the Corps' Columbia River Basin spill and water quality monitoring program for 2022 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 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

[2] The Corps, in coordination with the other Action Agencies, and NMFS, employs the Regional Implementation Oversight Group (RIOG) and technical teams including the Technical Management Team (TMT) and Fish Passage Operations & Maintenance (FPOM) coordination group, to coordinate with state, tribal and other federal experts for recommendations for implementing operations consistent with the 2020 BiOps.

[3] The 2020 Amendment to and 2018 Extension of the 2008 Columbia Basin Fish Accords are available at https://www.salmonrecovery.gov/Partners/FishAccords.aspx

[4] 2022 Agreement: https://pweb.crohms.org/tmt/JointMotion_TermSheet_CourtOrder_OCT2021.pdf. Those operations were extended to August 31, 2023 as part of a recent motion to extend the litigation stay.

monitoring system that is required in the Terms and Conditions outlined in the 2020 BiOps.

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.[5,6] WDOE WQS allows 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:

[5] 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.

[6] 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. 340-041-104(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:
   i. 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 B 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 2022, 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

Water Supply

While water year (WY) 2022 was once again a warmer and somewhat drier year relative to the 30-year long term average, favorable snowpack building in April and May supported above average late spring and summer volume runoff throughout the Columbia Basin. For the first time since the 2017 WY, the basin experienced both a significant cold snap (end of December 2022) and a significant heat wave (end of July 2022) -- both of which occurred after periods of wet weather and unusually high streamflows. The late spring was particularly notable as it was one of the coldest and wettest April-May periods in several decades and was followed by a pair of late season atmospheric rivers that produced the heaviest June rains since the flood of 2012, triggering a system flood emergency declaration for the Columbia River Basin.

Unregulated flows provide a general perspective on the water supply from rainfall or snowmelt for that month or year. Table 1 provides WY 2022 average monthly unregulated streamflow and the percentage of the 1991-2020 average monthly flows for the Snake River at Lower Granite and Columbia River at The Dalles. April-August runoff volume, measured at Lower Granite and The Dalles were 97 and 108 percent, respectively. The average monthly unregulated flow was greatest in June.

Table 1: Snake and Columbia River average unregulated flows in WY 2022[7]

	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, 2021	17	79	73	88
November, 2021	23	91	117	123
December, 2021	24	86	108	118
January, 2022	22	71	82	84
February, 2022	21	54	75	65
March, 2022	48	86	149	98
April, 2022	43	54	144	59
May, 2022	104	87	342	77
June, 2022	140	146	632	146
July, 2022	35	102	329	143
August, 2022	17	88	138	117
September, 2022	15	82	74	103
2022 WY Average	**42**	**90**	**189**	**103**
Apr-Aug Average	**68**	**97**	**316**	**108**

[7] From National Weather Service Runoff Processor. Note: Unregulated Flows exclude the effects of regulation provided by storage reservoirs. Runoff average period: 1991-2020.

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 April and May, but above average from June through August (Figure 1).

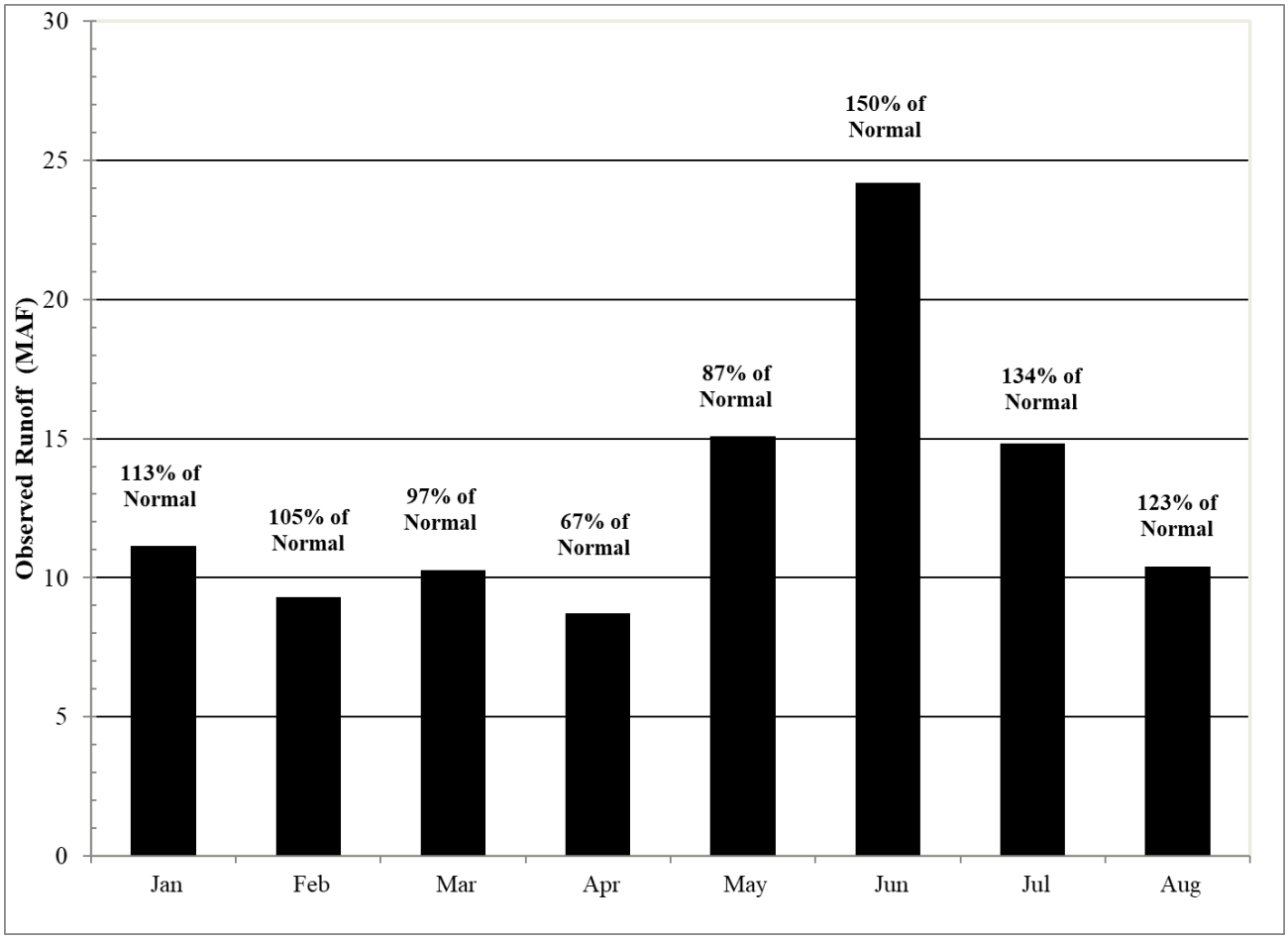

Figure 1: Observed monthly runoff at The Dalles

On the lower Columbia River as measured at Bonneville Dam, daily average total river flow from April 1 through August 31 ranged from 121 to 450 kcfs, averaging 245 kcfs and peaking June 13. A hydrograph for Bonneville Dam representing spill, generation, and miscellaneous flows (summing to total project flow in kcfs) is shown in Figure 2.

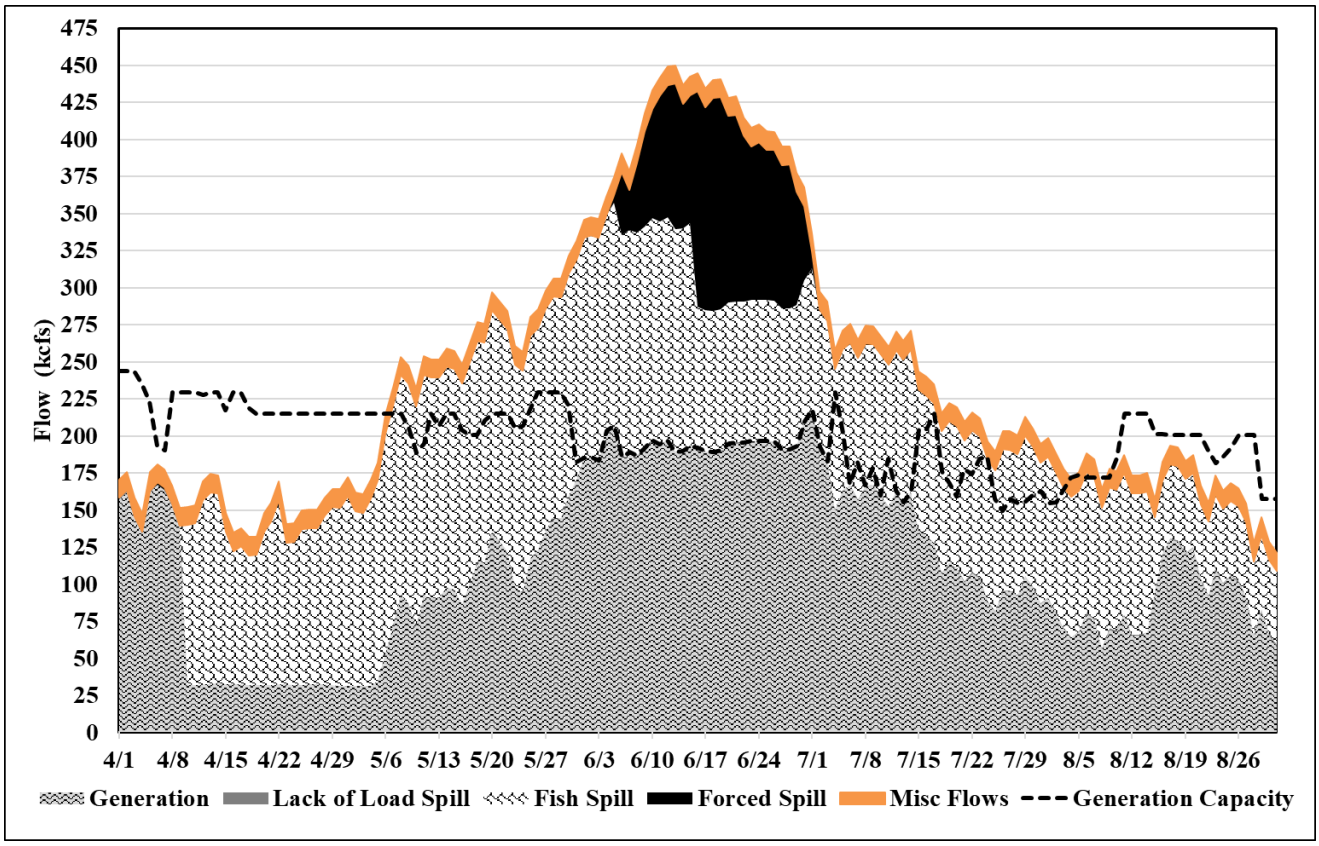

Figure 2: 2022 Bonneville daily project generation flow and spill.

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 to 211 kcfs, averaging 67 kcfs and peaking June 12 (Figure 3). Hydrographs for the remaining lower Snake and Columbia projects are shown in Appendix C.

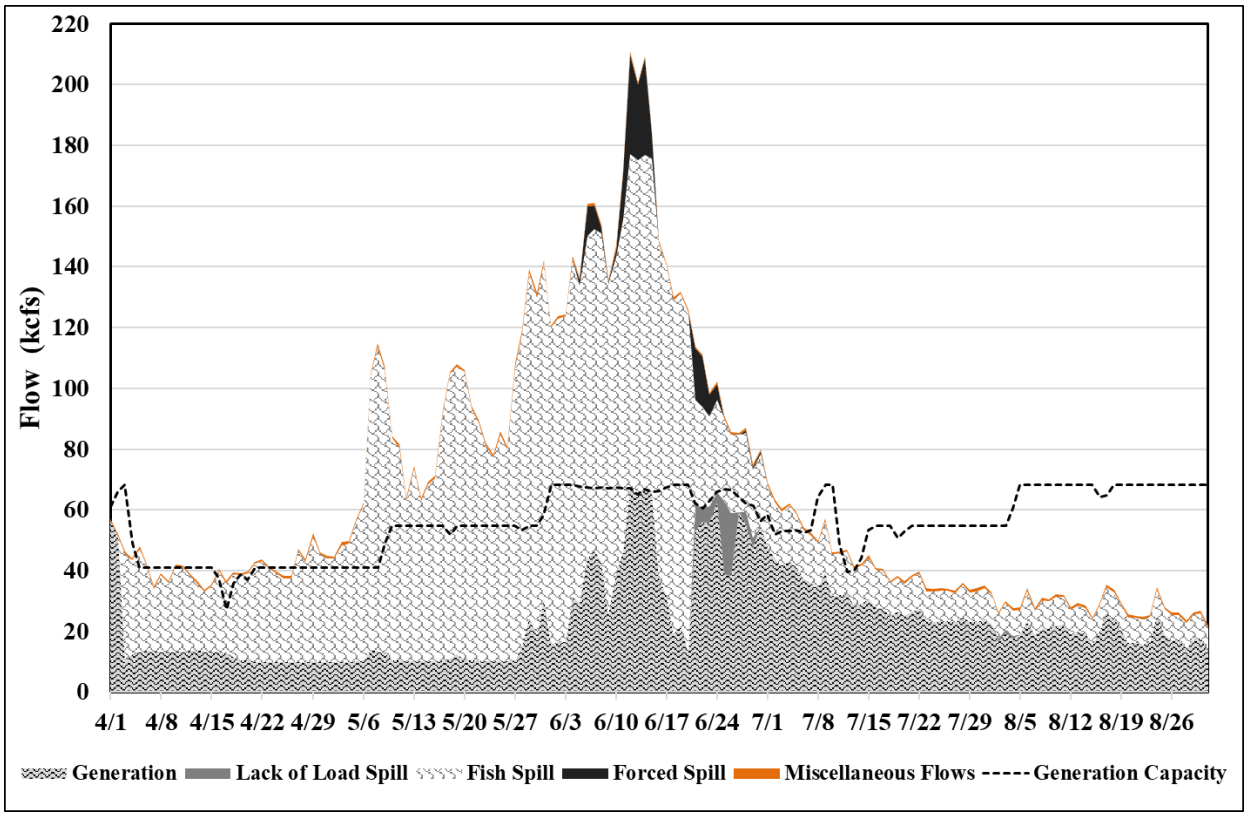

Figure 3: Ice Harbor daily project generation flow and spill.

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 regulated peak outflow during the freshet from The Dalles Dam was 429.0 kcfs on 12 June 2022, and the unregulated peak flow was 686.9 kcfs on 15 June 2022 (based on the Corps' ResSim program output).

Observed Flows above 7Q10

Per the state WQS, TDG exceedances are not tracked during 7Q10 high flow periods. The 7Q10 flow criteria and a relevant subset of daily average flows for the Corps' Snake and Columbia River dams are shown on Table 2.

Table 2: 7Q10 criteria and peak observed flows in WY 2022

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**
5/31/2022	136	129	134	143	314	312	299	331
6/1/2022	126	120	124	122	326	335	323	346
6/2/2022	124	118	122	124	298	336	328	348
6/3/2022	132	125	126	124	314	346	324	346
6/4/2022	143	133	139	143	346	354	337	361
6/5/2022	150	140	141	137	354	375	354	375
6/6/2022	159	155	158	161	369	384	367	391
6/7/2022	159	154	158	162	369	374	357	378
6/8/2022	151	143	150	155	395	403	387	397
6/9/2022	145	139	141	137	392	424	403	418
6/10/2022	153	146	147	149	413	430	414	433
6/11/2022	179	169	169	172	428	433	415	442
6/12/2022	202	202	204	211	467	443	429	449
6/13/2022	205	195	197	201	426	447	429	450
6/14/2022	205	204	206	210	421	433	425	437
6/15/2022	180	174	182	184	440	437	424	442
6/16/2022	151	143	150	149	437	435	421	445
6/17/2022	136	130	136	142	437	437	425	434
6/18/2022	130	125	130	131	418	436	420	440
6/19/2022	131	125	127	132	413	434	421	441
6/20/2022	121	116	121	126	419	435	413	428
6/21/2022	119	115	114	114	403	430	413	429
6/22/2022	108	106	110	112	399	414	391	415
6/23/2022	102	98	97	99	388	412	388	408
6/24/2022	102	99	100	102	392	407	384	410
6/25/2022	92	88	88	91	400	407	383	405
6/26/2022	88	85	86	86	395	403	386	405
6/27/2022	82	80	82	86	396	402	382	395
Total Days Above 7Q10 Level	**3**	**2**	**3**	**3**	**4**	**1**	**0**	**0**

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 TDG 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 2020 BiOp, section 2.17.4.1(D), calls for the monitoring of TDG, specifically:

"The Action Agencies shall monitor TDG (including Grand Coulee, Chief Joseph, and Dworshak Dams, and the lower Snake and lower Columbia River dams) and associated biological impacts in the lower Snake and Columbia rivers in coordination with the mid-Columbia Public Utility Districts. This program will be developed in coordination with NMFS and relevant agencies or partners, and documented in the Water Quality Plan when periodically updated. A TDG monitoring plan will specify monitoring locations, sampling

methodologies, calibration and maintenance of monitoring equipment, QA/QC, data collection and reporting, and archival storage in the Corps' online database. "

The Corps' districts operate the FMSs according to the TDG Monitoring Plan and prepare annual performance reports for the FMS operation. The 2022 reports are included as Appendices E, F, and G. Highlights from these reports are provided below.

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:

- Data completeness for TDG data received was 99.7 percent at the forebay station (CHJ) and 99.1 percent at the tailwater station (CHQW). Data completeness for temperature data received was 100 percent at station CHJ and 98.9 percent at station CHQW. Missing TDG and temperature data at both stations were largely due to DCP malfunctions and programming problems.
- For TDG data, a total of 6 hours were rejected at the forebay station (CHJ) and 7 hours at the tailwater station (CHQW) due to slow probe response time after recalibration. No temperature data was rejected at station CHJ with only 1 hour rejected a station CHQW.
- Laboratory calibration data were good and within 0.1°C for temperature and 2 percent saturation for TDG. Field calibration data were good and generally within 1mm Hg of the secondary standard barometer, 0.2°C 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 24 out of 24 (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 22 out of 24 (92%) in-situ field checks of barometric pressure were within ±2 mm Hg of a secondary standard, and 21 out of 24 (88%) water temperature field checks were all within ±0.2°C.
- Total dissolved gas at Chief Joseph forebay station (CHJ) exceeded 110 percent from mid-June to mid-August, with a maximum value of about 119 percent. Tailwater TDG was greater than 110 percent from late-May to mid-August, with a maximum tailwater TDG of about 124 percent during a spill of 90 kcfs. In general, tailwater TDG saturations were greater than forebay saturations during periods of moderate and high spill.
- Water temperatures at the Chief Joseph Dam forebay (CHJ) and tailwater (CHQW) were greater than 16°C from about mid-July through the end of September. Forebay and tailwater temperatures were greater than 18°C from mid-August through the end of September.

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

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:

- Data completeness for the combined BP, TDG, and temperature data received averaged 98.6 percent for the 14 monitoring sites used in 2022.
- The TDG data received from the individual sites ranged from 85.7 percent to 100.0 percent complete. Sixty percent of all invalid TDG data was due to measurements that were considered too low, primarily at the Lower Monumental forebay (LMNA), Anatone (ANQW), Lower Granite tailwater (LGNW) and Little Goose tailwater (LGSW) stations. The second most frequent cause of missing information was a defective TDG sonde at LGSW that accounted for 13 percent of the total amount of unacceptable TDG data.
- The TDG sensors from the 14 FMS stations were removed from the field and calibrated in the laboratory every three weeks from April 2022 through August 2022. From September 2021 through March 2022, 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 -0.43 mmHg, -0.54 mmHg, and 0.05 °C, respectively. The sensor post-deployment check revealed mean ambient pressure, ambient pressure plus 100 mmHg, and temperature differences of 0.44 mmHg, -0.64 mmHg, and 0.03 °C, respectively.
- The calculated median values for the 166 *in-situ* field checks with the replacement probes were:
    - TDG; 0.0 percent with minimum and maximum station medians of -0.3 and 0.0 percent, respectively.
    - 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 -0.07 ºC to 0.03 ºC.
- Station repairs and maintenance were also completed during the 2022 water year:
    - The Pasco station (PAQW) was relocated back to the shore from the floating platform due to a build-up of woody debris during high flow in June that caused it to flip over on its side. The station is scheduled to be rebuilt prior to the start of the 2023 spill season.
    - Damage to the LGNW station during high flows in June necessitated temporary sonde deployment in the river using a tethered cage. The station is scheduled to be rebuilt prior to the start of the 2023 spill season.
    - Sediment build-up at four of the deployment pipes was removed 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:

- Data received in real-time from the seven individual monitoring sites ranged from 88.5 percent (at Cascade Island, CCIW) to > 99.9 percent complete.
- Criteria for real-time data completeness (95 percent) were met at all monitoring stations, except Bonneville forebay (BON) (91.9 percent) and CCIW (88.5 percent). At BON, the barometric pressure sensor drifted from July 2-15, 2022. The data were later corrected, resulting in final data completeness of 99.8 percent. At CCIW, the telemetered sonde was replaced with an internal logging sonde from June 7-22, 2022, in anticipation of high flow. Excluding that period, data completeness was 98.1 percent at the site.
- After approximately three to four weeks of deployment in the river, 64 of 66 TDG sensor field checks were within ±1.0 percent saturation of a secondary standard sensor. Both field checks that failed the guideline were due to ruptured TDG membranes.
- One of 66 barometric pressure field checks was greater than ±1 mmHg of a primary standard, ranging from +15.7 to -0.9 mmHg. The difference of +15.7 mmHg was due to a malfunctioning barometer at Bonneville forebay that drifted for several weeks before it was replaced. The erroneous data was later corrected.
- All 65 water-temperature field checks were within ±0.2 °C of a secondary standard, ranging from -0.04 to + 0.05 °C.
- All 66 TDG sensor laboratory checks that were performed after field deployment were within ±0.3 percent saturation of a primary standard at ambient air pressure and at ambient air pressure plus 300 mmHg.
- During each scheduled site visit, the TDG sensors were field checked, removed and replaced with recently calibrated sensors, and brought to the lab for calibration checks. The three year-round tailwater sites were visited monthly from October 2022 through March 2022. The seasonal sites were installed in March 29-31, 2022 and all seven sites were visited every three to four weeks April 2022 through September 2022.

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

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 2022 FOP (https://pweb.crohms.org/tmt/documents/fpp/2022/final/FPP22_AppE.pdf) provides detailed information on 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. 2022 target spill operations for spring and summer are summarized in Table 3 and Table 4, respectively.

Table 3: Summary of 2022 spring target spill levels at lower Snake River (April 3 – June 20) and lower Columbia River (April 10 – June 15) projects.

PROJECT	SPRING SPILL DATES	SPRING SPILL OPERATION
Lower Granite [A, C]	April 3 until adult criteria met (no later than April 24)	24 hours/day: 125% Gas Cap
	Adult criteria met (no later than April 24) – June 20	16 hours/day: 125% Gas Cap 8 hours/day: 20 kcfs Performance Standard
Little Goose [B, C]	April 3 – June 20	16 hours/day: 125% Gas Cap 8 hours/day: 30% Performance Standard
Lower Monumental [A, C]	April 3 until adult criteria met (no later than April 24)	24 hours/day: 125% Gas Cap
	Adult criteria met (no later than April 24) – June 20	16 hours/day: 125% Gas Cap 8 hours/day: 30 kcfs Performance Standard
Ice Harbor	April 3 – June 20	24 hours/day: 125% Gas Cap
McNary	April 10 – June 15	24 hours/day: 125% Gas Cap
John Day [D]	April 10 – June 15	16 hours/day: 125% Gas Cap 8 hours/day: 32% Performance Standard
The Dalles [E]	April 10 – June 15	24 hours/day: 40% Performance Standard
Bonneville [F]	April 10 – June 15	24 hours/day: 125% Gas Cap

A. Lower Granite and Lower Monumental Adult Criteria – Within 1 business day of when the earliest of the following conditions occurs: (1) a cumulative total of 25 adult spring Chinook salmon (not including jacks) pass Lower Monumental Dam; or (2) a cumulative total of 50 adult spring Chinook salmon (not including jacks) pass Ice Harbor Dam; or (3) April 24, 2022, the Corps will implement performance standard spill for 8 consecutive AM hours, 0400–1200, to target hours of peak adult passage. If lack of load conditions preclude the implementation of performance standard spill during the targeted AM period, performance standard spill will begin as soon as practicable during AM hours and continue for up to 8 consecutive hours.

B. Little Goose Adult Criteria – Within 1 business day of a cumulative total of 25 adult spring Chinook salmon (not including jacks) passing Lower Monumental Dam, the Corps will implement performance standard spill at Little Goose Dam for 8 consecutive AM hours (April 3–15 starting at 0500 hours; April

16–June 20 starting at 0400 hours) to target hours of peak adult passage. If lack of load conditions preclude the implementation of performance standard spill during the targeted periods, performance standard spill will begin as soon as practicable during AM hours and continue for up to 8 consecutive hours.

C. During periods of high river flow that exceeds powerhouse hydraulic capacity, implementing performance standard spill for 8 consecutive hours as described in Footnotes A and B may result in storing additional inflow in the forebay above MOP. If it is necessary to pond water to achieve the 8-hour block of performance standard spill during high inflow, water stored above MOP should be drafted out over the remaining hours by increasing spill to pass inflow from 1200-1600 hours, then increasing spill as necessary from 1600-0400 to draft the pool back to MOP. If it is forecasted that the drafting spill will result in exceeding 130% TDG in the tailrace, all 16 hours will be used to return the pool to MOP.

D. John Day Dam – The 8 hours/day of performance standard spill may occur with some flexibility, in either a single 8-hour block or two separate blocks per calendar day. Performance standard spill will not be implemented between 2200-0300 hours.

E. The Dalles Dam –TDG in The Dalles tailrace may fluctuate up to 125% prior to reducing spill at upstream projects or reducing spill at The Dalles below 40%. Maintain 40% spill for 24 hours at The Dalles and reduce John Day spill below the 125% TDG spill cap as needed for TDG management.

F. Bonneville Dam – Spill for fish passage should not exceed 150 kcfs due to erosion concerns.

Table 4: Summary of 2022 summer target spill levels at lower Snake River (June 21-August 31) and lower Columbia River (June 16-August 31) projects

PROJECT	SUMMER SPILL[A] (June 21/16 – August 14) (24 hrs/day)	SUMMER SPILL[A] (August 15 – August 31) (24 hrs/day)
Lower Granite [B]	18 kcfs	SW flow (as river flow allows)
Little Goose [B, C]	30%	SW flow or 9 kcfs spill
Lower Monumental [B, D]	17 kcfs	SW flow or 8 kcfs spill
Ice Harbor [B, E]	30%	SW flow or 9 kcfs spill
McNary	57%	20 kcfs
John Day	35%	20 kcfs
The Dalles	40%	30%
Bonneville	95 kcfs	50 kcfs

A. 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.
B. 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.

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 (https://pweb.crohms.org/tmt/documents/FOP_Implementation_Reports/Older/).

The daily flow, FOP spill, and generation rates for April through August are further summarized in Tables C-3 through C-10 of Appendix C. The flow, generation, actual and

FOP fish passage spill for the 2022 spill season at each dam is graphed for the entire April through August spill season and included in Appendix C as Figures C-1 through C-8.

In addition to spring and summer spill for juvenile fish, surface spill was provided for adult steelhead passage at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, and McNary dams from October 1 to November 15, 2021, March 1 to March 30, 2022, and September 1 to September 30, 2022.

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 2022 fish passage season. Not all outages result in spill or elevated TDG levels.

Table 5: 2022 long-term outages

Project	Units	Start Date	End Date	Reason
Grand Coulee	07	9/2/2020	6/3/2022	Forced out of service due to possible stator ground
Grand Coulee	04	12/20/2022	6/7/2022	Forced out of service due to urgent brush maintenance
Grand Coulee	19	1/31/2022	7/1/2022	Triennial maintenance
Grand Coulee	15	2/7/2022	7/15/2022	Sexennial maintenance
Grand Coulee	14	6/5/2022	9/30/2022	Sexennial maintenance, SF-6 Breaker Annual
Grand Coulee	22	7/4/2022	9/16/2022	Panel work
Chief Joseph	09	4/7/2022	9/1/2022	Thermal derate (100% derate)
Chief Joseph	20	10/1/2022	12/30/2022	Stator ground fault failure
Chief Joseph	01	4/18/2022	5/18/2022	Annual maintenance
Chief Joseph	23	4/25/2022	5/26/2022	High lift pump replacement
Dworshak	N/A	N/A	N/A	N/A
Lower Granite	N/A	N/A	N/A	N/A
Little Goose	05	10/23/2019	1/20/2023	Forced out of service due to excessive turbine guide runout
Little Goose	05, 06	4/18/2022	12/23/2022	Powerhouse roof repair
Lower Monumental	05	6/13/2022	7/28/2022	Unit 5 overhaul/cavitation Repair
Ice Harbor	03	10/31/2019	12/30/2022	Turbine replacement
McNary	07	10/4/2022	7/13/2022	9-year overhaul
McNary	13, 14	1/3/2022	5/4/2022	Line 6 out of service for construction work
John Day	07	10/23/2019	12/31/2025	Forced out of serviced due to CO2 discharge
John Day	03	12/12/2022	7/13/2022	Annual maintenance
John Day	04	2/28/2022	11/2/2023	Turbine rehab
John Day	15	5/13/2022	6/16/2022	Headcover pump discharge failure
John Day	11	7/18/2022	9/29/2022	5-year overhaul
John Day	06	7/22/2022	9/28/2022	Main Shaft Realignment
The Dalles	19, 20	10/31/2019	10/27/2022	Forced out of service due to gassing on T-10
The Dalles	17	3/28/2022	7/29/2022	6-year overhaul and top plate replacement
The Dalles	12	4/12/2022	10/27/2022	Annual maintenance
The Dalles	06	5/31/2022	7/21/2022	6-year overhaul
The Dalles	16	6/27/2022	8/11/2022	Annual maintenance
The Dalles	14	7/18/2022	8/25/2022	6-year overhaul
Bonneville	13	2/18/2022	7/28/2022	Forced out of service due to exciter ground
Bonneville	03	4/4/2022	5/24/2022	5-year overhaul
Bonneville	17	4/18/2022	7/14/2022	4-year overhaul
Bonneville	12	7/5/2022	8/10/2022	Panel upgrade/install
Bonneville	12	7/11/2022	8/10/2022	Annual maintenance
Bonneville	13	7/28/2022	10/27/2022	Forced out of service due to exciter ground

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 2022 spill season for the lower Columbia and lower Snake. There was a total of 234-gauge days in 2022 in which the TDG levels were above the applicable TDG criteria and 64 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. Does not include days when flows are greater than the 7Q10

Fixed Monitoring Stations	Exceedances	Data Quality Events
Lower Granite Forebay (LWG)*	0	2
Lower Granite Tailwater (LGNW)	4	18
Little Goose Forebay (LGSA)*	5	0
Little Goose Tailwater (LGSW)	14	13
Lower Monumental Forebay (LMNA)*	8	23
Lower Monumental Tailwater (LMNW)	13	0
Ice Harbor Forebay (IHRA)*	15	0
Ice Harbor Tailwater (IDSW)	10	0
McNary Forebay (MCNA)*	20	0
McNary Tailwater (MCPW)	23	2
John Day Forebay (JDY)*	17	0
John Day Tailwater (JHAW)	25	1
The Dalles Forebay (TDA)*	16	0
The Dalles Tailwater (TDDO)	22	1
Bonneville Forebay (BON)*	21	0
Bonneville Tailwater (CCIW)	21	4
Total	**234**	**64**

* Evaluated during summer spill only.

Categories of TDG Exceedances

The Corps tracked the daily TDG exceedance types for the forebay and tailwater of each of the Corps' Columbia and Snake River projects during the 2022 spill season. Each type of TDG exceedance represents conditions that cause daily average percent TDG to exceed the applicable WQS. Exceedance tracking results are summarized in Table 7. The daily TDG exceedance type designation given for each occurrence is based on the Corps' determination of causation. The primary contributor of TDG exceedances in 2022 was high river flows leading to forced spill.

Table 7: TDG exceedance type summary

TDG Exceedance Type	Definition	Quantity
Forced Spill Exceedance	TDG WQS exceedance due to spill above the FOP spill level.	**158**
Mechanical Exceedance	TDG WQS exceedance due to the operation or mechanical failure of non-generating equipment.	**1**
Uncertainty Exceedance	TDG WQS exceedance due to uncertainties when using best professional judgment, SYSTDG model and forecasts.	**50**
Transition Exceedance	TDG WQS exceedance due to change in the spill operation and WQS from spring to summer.	**25**

Oregon and Washington maximum two-hour criteria

During the 2022 spill season, there were 60 gauge days when TDG readings exceeded either the Washington two-hour standard of 126% TDG or the Oregon two-hour standard of 127% TDG at the tailwater gauges during the spring (Appendix D). There were 9 gauge 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 WY 2022, 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 2022. 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. WRNO did not exceed the TDG criteria during this period.

Fall and early spring spill for adult steelhead

Per the 2020 Biological Opinion, as well as the operations agreed to 2021 Agreement (as extended in 2022), surface-oriented spill is conducted via the spillway weir, for adult steelhead that overshoot and then migrate back downstream through McNary Dam and the lower Snake River dams from September 1 until November 15 and from March 1 to the

start of spring spill. This operation occurred three times per week on non-consecutive days for four hours each morning. In 2022, there were no exceedances of the 115%/120% WQS during spill for adult steelhead in the tailwaters of the lower Snake River Project or 110% in McNary's tailwater. Previously, the Corps had interpreted Washington's 110% criteria to apply but received clarification that the 115%/120% was the applicable criteria during this operation.[8] Oregon's 110% TDG criterion is the most restrictive criteria at McNary dam.

Gas Bubble Trauma Monitoring

As part of the TDG monitoring program, the NOAA Fisheries 2020 BiOp, section 2.17.4.1(D), specifies that the TDG monitoring program will include:

" …a biological smolt monitoring component to assess GBT symptoms in smolts at selected smolt monitoring locations, especially between April 3 and June 20 when the flexible spring spill operation is being implemented. TDG pressure and percent saturation, water temperature, and barometric pressure must be sampled on at least an hourly basis. This information, and the results of biological monitoring shall be shared with resource agencies on a near real-time basis. This will reduce take by ensuring that incubating eggs and fry or migrating juvenile and adult salmon and steelhead are not exposed to TDG levels higher than anticipated and that the effects of increased exposure to TDG are not more severe for juvenile and adult migrants than expected."

The Fish Passage Center compiles a yearly report of Gas Bubble Trauma (GBT) monitoring results (Appendix H). The monitoring of juvenile salmonids in 2022 for GBT was conducted at five Columbia and Snake River projects as part of the Smolt Monitoring Program. Sampling occurred two days per week at the Columbia River sites and one day a week at each of the Snake River sites during 2022 fish passage spill operations. The goal of the GBT monitoring program is to sample 100 salmonids during each day of sampling at each site, limited to Chinook and steelhead. 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 bubbles. Of the 10,553 juvenile salmonids examined, 84 had signs of GBT between April and August (see Appendix H, Table H-4, Table H-6).

GBT monitoring of native resident non-salmonids (NRN) was conducted by the U.S. Geological Survey in 2022 at four locations in the spring: below Lower Granite, Ice Harbor, McNary, and Bonneville with a goal of collecting 100 samples per sampling day. Fish were collected at each location weekly (4 April to 13 June) during the spring spill period by backpack electrofishing and beach seining. Washington and Oregon state water quality agencies established minimum and target sample sizes for monitoring, but the minimum sample size of 50 fish and target sample size of 100 fish were not met in all weeks at individual projects due to high water flows and resulting low fish collections.

[8] Letter dated October 5, 2022, from Vincent McGowan, P.E. Water Quality Program Manager, Department of Ecology, State of Washington regarding Clarification of Total Dissolved Gas Standards during Fall/Winter Spill Operations.

Collected fish were examined for GBT according to the criteria and protocol established for the regional smolt monitoring program (SMP). Overall, GBT incidence and severity rankings were low and did not exceed the thresholds that would have triggered changes to the spill program.

The GBT incidence rates observed in native nonsalmonids was dependent on the evaluation criteria used. Using only the GBT incidence and ranking criteria used by the SMP resulted in relatively low incidence rates for all species combined at Bonneville (0–1.9%), McNary (0–8.6%), Ice Harbor (0–7.7%), and Lower Granite (0–3.4%). However, if the GBT found in the unpaired fins and eyes (SMP criteria) is combined with GBT observed elsewhere on the fish (e.g., paired fins, head, body), then GBT incidence rates increase to 0–4.9% at Bonneville, 0–13.7% at McNary, 0–10.3% at Ice Harbor, and 0–5.5% at Lower Granite. This illustrates the importance of the criteria used to determine GBT incidence rates in native nonsalmonids https://www.cbfish.org/PiscesPublication.mvc/SearchByTitleDescriptionAuthorOrDate