US Army Corps of Engineers®

Northwestern Division

2015 TOTAL DISSOLVED GAS REPORT

Spill at John Day Dam

Columbia Basin Water Management Division
Reservoir Control Center
Water Quality Unit

December 2015

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COLUMBIA RIVER BASIN

December 2015

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

2015 TOTAL DISSOLVED GAS REPORT
COLUMBIA RIVER BASIN

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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
CRT	Columbia River Treaty
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
MOP	minimum operating pool
NOAA Fisheries	National Oceanic and Atmospheric Administration, Fisheries
NWRFC	Northwest River Forecast Center
ODEQ	Oregon Department of Environmental Quality
PUD	Public Utility District
QA	quality assurance
QC	quality control
RCC	Reservoir Control Center
Reclamation	United States Bureau of Reclamation
RPA	Reasonable and Prudent Alternative (from the Biological Opinion)
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
VARQ	Variable Q, a variable flow associated with Libby flood control
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.

2014 Supplemental BiOp[1]**:** The current governing Biological Opinion for the Federal Columbia River Power System. It recommends a comprehensive series of actions to avoid jeopardizing 13 Endangered Species Act (ESA)-listed salmon and steelhead species throughout their life cycle and adverse modification of designated critical habitat.

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

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

Gas Cap: Voluntary spill for fish passage up to the applicable state TDG criteria.

HEC-ResSim: The USACE Hydrologic Engineering Center's Reservoir System Simulation model is an operational hydrologic model of a river system used for flood control studies, planning studies, and daily streamflow forecasting.

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

[1] The 2014 Supplemental BiOp considered the Action Agencies' 2014-2018 Implementation Plan (2014-2018 IP) and the 2013 Comprehensive Evaluation and also incorporates both the 2008 NOAA BiOp and the 2010 Supplemental BiOp. References to the 2014 Supplemental BiOp also include, as appropriate, references to prior BiOps.

Involuntary Spill: Involuntary spill is driven largely by hydrologic capacity at each dam; the quantity of water that exceeds the capacity of a dam to either temporarily store the water upstream of the dam or pass the water through its turbines. In these circumstances, water must be released through the spillway. Involuntary spill occurs due to either **Lack of Load** or **Lack of Turbine**, but can also occur as a result of the management of reservoirs for flood risk[2], scheduled or unscheduled turbine unit outages or transmission outages of various durations, passing debris, or any other operational and/or maintenance activities required to manage dam facilities for safety and authorized project uses.

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

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

maintaining reserves primarily occurs at Grand Coulee, Chief Joseph, The Dalles, John Day, Bonneville, and occasionally McNary dams.

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

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

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.

Spill cap: The estimated spill rate to achieve the appropriate level of spill to meet the applicable state water quality standards (WQS), generally 115 percent in the forebay or 120 percent in the tailwater, or to meet target levels of TDG identified in the Spill Priority List. The maximum project spill level that meets but does not exceed the gas cap is referred to as the spill cap.

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.

TDG Instance: An instance 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 agency 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.

Part 1 Program Description

1.0 Introduction

This report describes the U.S. Army Corps of Engineers' (Corps) Columbia River Basin spill and water quality monitoring program for 2015 and addresses the Corps' reporting responsibilities related to the Oregon Department of Environmental Quality (ODEQ) Total Dissolved Gas (TDG) modification, the 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.

This report provides information requested by ODEQ and WDOE including weather, flow and runoff conditions for the spill season, information regarding project operations, data from the physical and biological monitoring programs, description and results of any biological or physical studies of spillway structures and prototype fish passage devices, and progress on implementing measures contained in the lower Columbia and Snake rivers TDG TMDL documents. This report also includes documentation on the performance of the TDG monitoring system.

The following is a list of the appendices included in this report, which is available on the website: http://www.nwd-wc.usace.army.mil/tmt/wqnew/tdg_and_temp/2015

- Appendix A - General overview of the monitoring system with information on the fixed monitoring stations (FMS), updated in 2015.
- Appendix B - TDG Monitoring Plan for 2015-2018.
- Appendix C - Fish Operations Plan (FOP) for 2015 spill season.
- Appendix D - 2015 monthly FOP implementation reports for the fish passage season. This appendix contains graphs of flow, spill and high 12-hour percent TDG average along with spill variance tables. The 2015 FOP Implementation Reports are also posted electronically on the TMT website at http://www.nwd-wc.usace.army.mil/tmt/documents/FOP_Implementation_Reports/
- Appendix E - Summary of TDG instance types when TDG levels exceed state water quality standards (WQS).
- Appendix F - TDG TMDL implementation summary providing an overview of the status of the Corps' TDG TMDL activities.
- Appendix G - Walla Walla District report on the Quality Assurance/Quality Control (QA/QC) review for TDG and temperature monitoring gauges at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, and McNary dams.
- Appendix H - Portland District report on the QA/QC review for TDG and temperature monitoring gauges at John Day, The Dalles, Bonneville, and the Warrendale and Camas/Washougal sites.
- Appendix I - Seattle District report on the QA/QC review for TDG and temperature monitoring gauges at Chief Joseph Dam.
- Appendix J - Gas Bubble Trauma (GBT) Monitoring and Data Reporting by the Fish Passage Center.

1.1 Clean Water Act and Endangered Species Act

1.1.1 General

TDG and water temperature are the primary water quality parameters monitored by the Corps in the mainstem Columbia and Snake rivers in the states of Oregon and Washington. TDG is influenced by water management operations at the dams (e.g., water released over the dam spillways, releases through the powerhouses and other facilities, and forebay and tailwater water surface elevations), as well as environmental factors including ambient temperatures and wind conditions. Part 3 of this report provides a discussion of the Corps' monitoring program for temperature and TDG.

1.1.2 Corps' 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 Digest of Water Resources Policies and Authorities**, Engineering Pamphlet 1165-2-1, Section 18-3.b, page 18-5 dated July 30, 1999, which states:

> Although water quality legislation does not require permits for discharges from reservoirs, downstream water quality standards should be met whenever possible. When releases are found to be incompatible with state standards they should be studied to establish an appropriate course of action for upgrading release quality, for the opportunity to improve water quality in support of ecosystem restoration, or for otherwise meeting their potential to best serve downstream needs. Any physical or operational modification to a project (for purposes other than water quality) shall not degrade water quality in the reservoir or project discharges.

In 2008, 19 flow deflectors were installed at Chief Joseph Dam to reduce TDG production when spill is necessary. During testing and in actual operations, the spillway flow deflectors have successfully reduced TDG levels associated with spillway releases when inflow TDG levels approach approximately 120 percent. In addition, for lower TDG levels, Chief Joseph Dam can spill a significant amount of water without increasing downstream TDG levels. The Corps' spill management policy utilizes the spillway flow deflectors at Chief Joseph Dam as an effective means for moderating system TDG levels under involuntary spill conditions.

1.1.3 Endangered Species Act FCRPS Biological Opinions

1.1.3.1 Background

During the 1990s, Snake and Columbia River salmonids were listed under the Endangered Species Act (ESA). Through ESA consultations, the Corps implemented a variety of operational and structural measures that were called for in biological opinions to improve the survival of listed salmonids. The 2014 Supplemental BiOp calls for the Corps to provide spill for juvenile fish migration in the FCRPS. The Action Agencies annually develop a Fish Operations Plan (FOP) that provides detailed information on the

implementation of the BiOp spill operations for fish passage. For this reporting period, the Corps was implementing the 2014 Supplemental BiOp and the 2000 U.S. Fish and Wildlife Service (USFWS) BiOp.

1.1.3.2 USFWS and NOAA Fisheries BiOps

USFWS 2000 BiOp
According to the FCRPS 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.

NOAA Fisheries 2014 FCRPS BiOp
The 2014 Supplemental BiOp RPAs include operations that have an effect on water quality: RPA Actions 4, 15, 26, 29 and 32. For the 2015 fish passage season, the Federal agencies operated the FCRPS in accordance with the 2015 FOP, which is provided in Appendix C.

The FCRPS BiOps may be found at the following website:
http://www.salmonrecovery.gov/BiologicalOpinions/FCRPSBiOp.aspx

1.1.4 TDG Standards

The following are the applicable TDG WQS as currently approved by the states of Oregon and Washington.

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 percent 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 percent 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 modification[3] from the Oregon Department of Environmental Quality 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 percent 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. Two operational conditions have been selected from the TDG modification list and are highlighted for the purposes of this report:

(iii) Spill must be reduced when the average TDG concentration of the 12 highest hourly measurements per calendar day exceeds 120 percent 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 percent 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.

[3] At the request of the Oregon Department of Environmental Quality, the term "waiver" will now be referred to as "TDG modification".

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 percent as measured in the forebays of the next downstream dams and must not exceed an average of 120 percent as measured in the tailraces of each dam (these averages are measured as an average of the twelve highest consecutive hourly readings in any one day, relative to atmospheric pressure); and
- A maximum TDG one hour average of 125 percent must not be exceeded during spillage for fish passage.

On March 24, 2015, the Corps coordinated with WDOE on an extension of the June 30, 2010, Washington criteria adjustment, which went into effect immediately and applied through July 31, 2015. The Corps submitted its updated TDG Gas Abatement Plan by July 31, 2015 for WDOE consideration of the subsequent criteria adjustment.

1.1.5 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. Appendix F provides the status of the Corps' TDG TMDL implementation activities.

1.1.6 Operating Guidelines

The Corps' Reservoir Control Center (RCC) Water Quality Unit 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 2014 Supplemental BiOp and applicable state water quality standards (WQS), to the extent practicable.

WDOE's method of calculating percent saturation TDG is "an average of the twelve highest consecutive hourly readings in any one day." For the remainder of this report, this method is referred to as the "WDOE method." ODEQ applies the state WQS to the tailwater gauges (below the dams in Oregon: McNary, John Day, The Dalles and Bonneville) using the average of the 12 highest hourly readings in a given day. For the remainder of this report, this method is referred to as the "ODEQ method." Part 5 of this report provides detailed information on the TDG instances using the ODEQ and WDOE methods.

The Corps' four projects on the lower Columbia River share the state border. Whichever calculation method (WDOE and ODEQ) is the more stringent (restrictive) for the projects that are in both states (i.e. McNary, John Day, The Dalles, and Bonneville dams) is the one that is applied. The resulting daily averages are shown for both states in the web report: http://www.nwd-wc.usace.army.mil/ftppub/water_quality/12hr/.

This website contains two tailwater TDG values at the four lower projects with both states' values computed. The applicable (more stringent) TDG value is shown in black text (red text if a TDG instance occurred), and the other less stringent value has strikethrough and grey text.[4]

[4] Oregon specified these conventions in an internal management directive, "The Use of Significant Figures and Rounding Conventions in Water Quality Permitting" from 2013. http://www.deq.state.or.us/wq/pubs/imds/SigFigsIMD.pdf ; From the Oregon guidance document, Oregon DEQ would typically use 3 significant digits. When rounding calculated values to 3 significant digits if the digit that is being dropped is a 5 rounding the preceding digit up. Thus the total dissolved gas calculated level of 120.5 % would be reported as "121 %TDG", 3 significant digits and the 5 being dropped and the last digit rounding upward. Washington specified its conventions in a memo, "Clarification of WAC 201A-200(1)(f)(ii), Measuring Total Dissolved Gas (TDG) During Fish Spill on the Columbia and Snake Rivers" from 2008. http://www.nwd-wc.usace.army.mil/ftppub/water_quality/12hr/wa/WA_TDG_Calculation.pdf; From the Washington memo, it states, "Round 12 hour average to nearest whole number." Therefore, TDG would be reported as 111% or 112% per either states requirements, not 111.4% or 111.5% and TDG instances would be calculated accordingly.

Part 2 Program Operating Conditions

2.1 Water Year Runoff Conditions

The following provides an overview of the water year runoff and reservoir operations, including a description of the weather, water supply, and reservoir operations.

2.1.1 Weather [5]

In 2015, the region's weather was warmer and drier than normal. August of 2014 through September of 2015 Basin-wide temperatures varied widely and were above normal (1.9ºF/3.4ºC).

The Columbia River Basin Water Year (WY) 2015 (over the 12-month period, October 2014 – September 2015) was below average in precipitation affecting Columbia River flows and below average in the region affecting Snake River flows as shown in Table 1. The accumulative precipitation as reported by the Northwest River Forecast Center (NWRFC) for WY 2015 was 93 percent of average (1981 to 2010) in the Columbia River above Grand Coulee Dam, 82 percent of normal in the Snake River above Ice Harbor Dam, and 84 percent of normal in the Columbia River above The Dalles Dam.

TABLE 1
WY 2015 Columbia River Basin Percent Precipitation

Location	Columbia River above Grand Coulee	Snake River above Ice Harbor	Columbia River above The Dalles
October 2014	118%	60%	98%
November 2014	150%	111%	119%
December 2014	81%	112%	92%
January 2015	80%	53%	64%
February 2015	111%	80%	92%
March 2015	131%	52%	86%
April 2015	55%	53%	51%
May 2015	63%	129%	97%
June 2015	59%	32%	44%
July 2015	67%	128%	83%
August 2015	78%	56%	64%
September 2015	108%	116%	101%
Oct - Sept Average	**93%**	**82%**	**84%**

Note: Basin Precipitation as percentage of the 1981-2010 period

The 2014-2015 WY was characterized by very warm temperatures, starting in October and continuing through the summer of 2015. Although below average precipitation across the

[5] Take from the 2014-2015 Annual Report of the Columbia River Treaty, Canada and United States Entities (2014-2015 Annual Treaty Report). http://www.nwd-wc.usace.army.mil/PB/PEB_08/docEntities.htm

basin was recorded, the very warm winter caused an unusual amount of winter precipitation, which in the northern half of the basin was above normal rainfall rather than snow. This led to near record high flows in February, followed by unusually high March flows, an earlier snowmelt, and near record low flows over the summer months.

By late February, the very warm temperatures (with several locations having their warmest February on record) had depleted regional snowpack. This was accompanied by above average precipitation, which mostly fell as rain in all but the northernmost parts of the basin, and prematurely melted the existing snowpack across the U.S. basins and the Canadian Kootenay Basin.

In mid-April, the jet stream began to split around the region to the north and south as a late-developing El Niño took hold over the tropical Pacific. That, in combination with unusually warm waters off the Pacific Northwest coast, led to an unusually hot and dry spring and early summer. Between May 1 and July 20, there were only about six days with below average temperatures for the date with all others either near or above average. Four significant heat waves were noted across the region from mid-June through early August, with the worst being an 11-day stretch from June 26 through July 5 when temperatures remained 14°F/8°C above average across the basin, and high temperatures in many valleys exceeded 95°F/35°C for a full week. An equally intense heat wave was noted from July 30 through August 1. These long stretches of heat exacerbated already meager runoff by increasing evapotranspiration. The combination of low flows and hot temperatures resulted in low flows and very warm river water temperatures, even in headwater locations and on both regulated and unregulated streams.

2.1.2 Water Supply

The NWRFC April 1, 2015 forecast of January through July runoff for the Columbia River above The Dalles Dam was 96.0 Maf; however, the actual observed runoff volume was 83.7 Maf. This value is low compared to the historical average (1981-2010) January-July runoff volume of 101.4 Maf. The April-August runoff at The Dalles suffered even more due to the lack of snowpack and totaled 58.4 Maf, or 67 percent of the 30 year average (1981 – 2010). Since 1960, WY 2015 ranks the third driest out of 55 years of record in total April-August runoff as measured at The Dalles. Runoff in the Snake River Basin was also dry with the observed April-July runoff at Lower Granite totaling 10.6 Maf, or 53 percent of the 30 year average. The April-July period is considered the most representative runoff period for the lower Snake River and the April-August period is considered the most representative for the lower Columbia River.

Table 2 provides WY 2015 average monthly unregulated streamflow and the percentage of the 1981-2010 average monthly flows for the Columbia River at Grand Coulee and The Dalles dams. Unregulated flows provide a general perspective on the water supply for that month or year from rainfall or snowmelt. The average monthly unregulated flow at The Dalles Dam during the spring runoff was highest in May, with daily flows peaking on June 4, 2015, at 354 kcfs, well below the median historic runoff peak of near 500 kcfs[6].

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

TABLE 2
Columbia River Flow in WY 2015[7]

Time Period	At Grand Coulee		At The Dalles	
	Unregulated Flow (kcfs)	% of Average	Unregulated Flow (kcfs)	% of Average
October 2014	51	112	79	96
November 2014	63	134	107	113
December 2014	58	146	116	128
January 2015	50	125	117	119
February 2015	94	237	204	177
March 2015	116	193	194	131
April 2015	113	97	193	83
May 2015	201	80	298	72
June 2015	205	72	266	61
July 2015	100	56	123	52
August 2015	67	72	85	68
September 2015	65	120	88	101
Oct - Sept Average	**100**	**95%**	**157**	**86%**

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

2.1.3 Reservoir Operation

The following overview of reservoir operations includes a description of flood control, streamflow, operations, and 7Q10 flows.

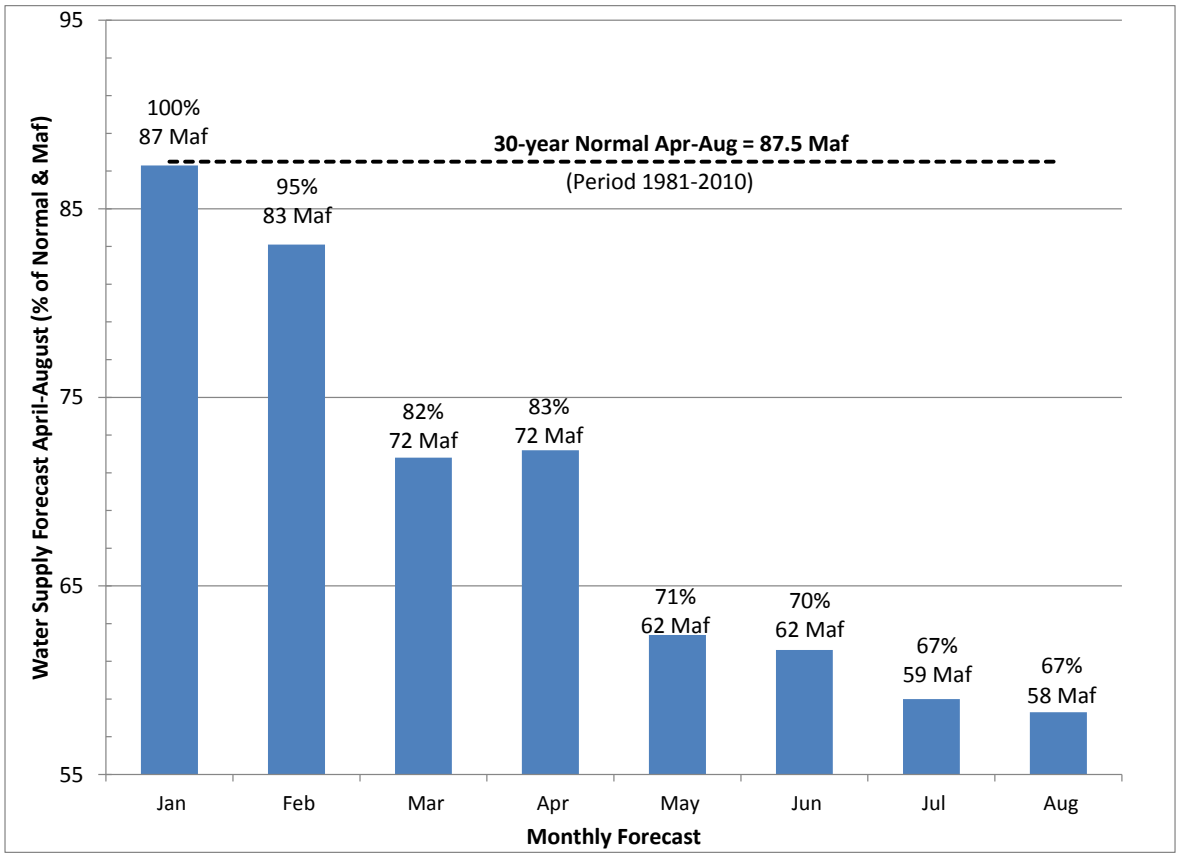
2.1.3.1 General

The WY 2015 began with Grand Coulee Dam storage at 94.2 percent full. Projected water supply forecasts for The Dalles peaked in January then decreased continually through August as shown in Figure 1. Because of the warm winter temperatures causing winter precipitation to fall as rain instead of snow, the shape of the runoff at Bonneville Dam resulted in two main peaks in February and March. As Figure 2 shows, the highest flows at Bonneville Dam during the April through August period occurred on April 4 with flows of 232 kcfs then declined continually after that.

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[8] were not met at Priest Rapids, which was 135 kcfs, McNary Dam, which was 220 kcfs, or Lower Granite Dam, which was 85 kcfs. The summer seasonal flow objectives were not met at McNary Dam, which was 200 kcfs or Lower Granite Dam, which was 50 kcfs.

FIGURE 1
2015 Water Supply April-August Forecast at The Dalles

[7] From 2015 Annual Treaty Report.
[8] The spring and summer flow objectives are defined in the 2015 Water Management Plan.



2.1.3.2 Flood Control

After January 2015, the NWRFC 2015 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 FCRPS dams were operated to their specified flood control 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, and U.S. Fish and Wildlife Service's 2000 BiOp, and NOAA Fisheries' 2014 Supplemental BiOp for operation and maintenance of the FCRPS. The unregulated peak flow, based on the Corps' system regulation model (HEC-ResSim) at The Dalles Dam, was estimated at 354 kcfs on June 4, 2015, and a regulated peak flow for April through July was 222.5 kcfs and occurred on April 2, 2015, as measured at The Dalles, Oregon.

2.1.3.3 Total River Flow

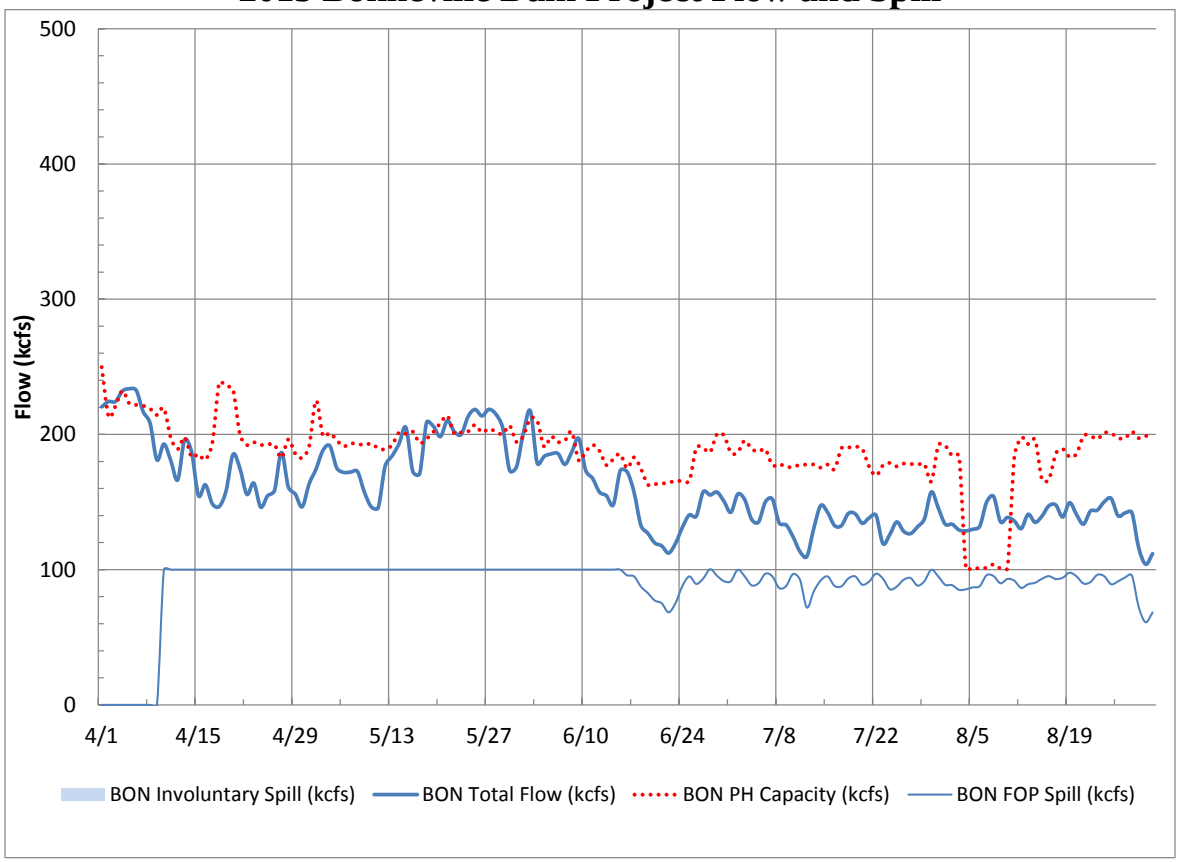
Daily average observed streamflows were below average in 2015 due to the below average runoff volume (as seen at The Dalles). This resulted in below average flows at the FCRPS projects as illustrated at two locations: Bonneville for the lower Columbia, and Ice Harbor for the lower Snake River.

Daily average total river flow on the lower Columbia River, as measured at Bonneville Dam, from April 1 through August 31, ranged from 104 kcfs to 234 kcfs, averaging 161

kcfs (Figure 2). The daily average flow peaked on April 5, 2015. Total river flows began to recede gradually in early April and continued a steady recession until the end of August when flows reached 104 kcfs.

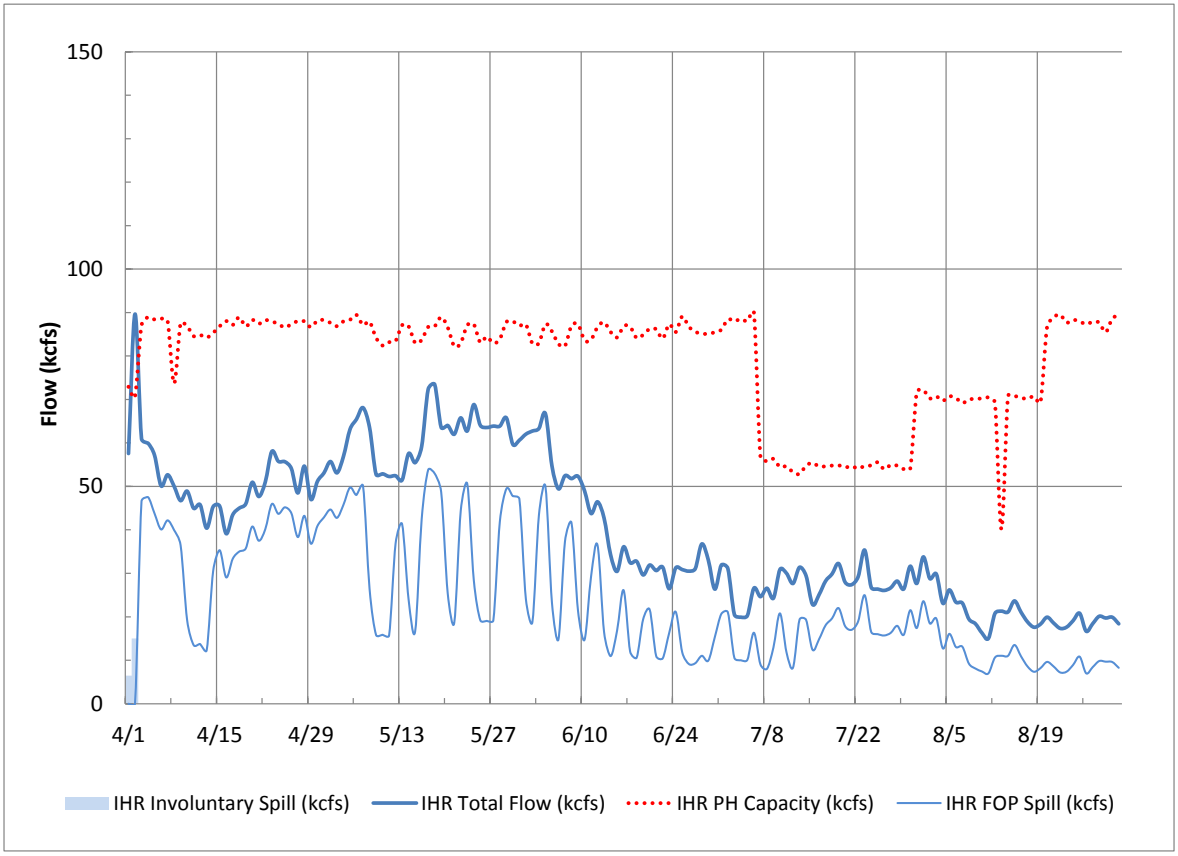
On the lower Snake River as measured at Ice Harbor Dam, daily average total river flow from April 1 through August 31 ranged from 15 kcfs to 90 kcfs, averaging 40 kcfs (Figure 3). Daily average flow peaked on April 2. Flows began to recede after the April peak with a gradual recession ending the month of August at about 15 kcfs.

FIGURE 2
2015 Bonneville Dam Project Flow and Spill



Note: Daily powerhouse capacities provided by BPA Duty Schedulers

FIGURE 3
2015 Ice Harbor Dam Project Flow and Spill



Note: Daily powerhouse capacities provided by BPA Duty Schedulers

2.1.3.4 7Q10 Flow

When flows exceed the 7Q10 criteria (the average peak annual flow for seven consecutive days that has a recurrence interval of ten years), the ODEQ and WDOE TDG criteria do not apply. The 7Q10 flow criteria and the respective daily average flows for the Corps' Columbia River Basin dams are shown on Table 3. In 2015, river flows did not exceed the 7Q10 flow criteria.

TABLE 3
Dates When 7Q10 Flows Were Exceeded in 2015

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	**214**	**214**	**214**	**214**	**447**	**454**	**461**	**467**
4/1/2015	60	60	64	64	230	227	221	239
4/2/2015	62	49	54	58	194	195	192	220
4/3/2015	69	80	84	90	243	235	219	224
4/4/2015	60	57	59	61	225	225	217	224
4/5/2015	56	55	57	60	225	224	223	232
4/6/2015	54	53	51	57	228	221	216	234
4/7/2015	51	48	49	50	217	213	208	233
4/8/2015	50	47	51	53	197	212	208	217
4/9/2015	48	48	49	50	191	195	193	208
4/10/2015	46	43	45	47	173	178	175	181
4/11/2015	47	45	47	49	188	179	167	193
4/12/2015	45	44	44	45	180	173	154	181
4/13/2015	45	42	45	46	172	177	165	166
4/14/2015	43	40	41	40	192	199	185	196
4/15/2015	43	42	44	45	183	173	161	187
4/16/2015	44	41	44	45	155	153	137	155
4/17/2015	41	38	39	39	156	159	150	163
4/18/2015	43	41	41	43	149	146	130	149
4/19/2015	45	42	44	45	152	146	132	147
4/20/2015	43	43	44	46	153	153	138	158
4/21/2015	47	47	49	51	163	167	154	185
4/22/2015	47	44	45	48	161	159	148	175
4/23/2015	51	49	51	51	162	159	142	156
4/24/2015	56	55	57	58	167	169	154	164
4/25/2015	54	52	54	56	160	158	143	146
4/26/2015	56	55	55	56	157	151	139	155
4/27/2015	54	53	53	54	159	156	141	159
4/28/2015	50	45	47	49	168	180	167	187
4/29/2015	50	51	53	55	166	160	147	161
4/30/2015	48	45	47	47	146	150	136	156
5/1/2015	51	50	52	51	129	135	120	147
5/2/2015	53	50	51	53	179	165	150	163
5/3/2015	54	54	55	56	180	185	167	174
5/4/2015	55	52	53	53	179	177	164	188
5/5/2015	56	53	55	57	190	185	164	192
5/6/2015	63	62	62	63	171	165	148	175
5/7/2015	67	65	65	66	172	170	158	172
5/8/2015	66	64	65	68	180	172	158	172
5/9/2015	65	63	64	64	162	169	153	173
Total Days	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Part 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 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 percent TDG criteria. The Corps monitors and tracks instances when TDG and temperature 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 42 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. Two 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 2015-2018 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 2015-2018 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. The TDG Monitoring Plan summarizes what to measure, how and when to take the measurements, and how to analyze and interpret the resulting data. The 2015-2018 TDG Monitoring Plan is provided as Appendix B of this report.

3.3 Changes in the FMS

The John Day Dam tailwater (JHAW) and Anatone (ANQW) TDG gauges needed repairs in 2015 and a discussion of those repairs are as follows:

The John Day Dam tailwater TDG gauge appeared to have percent TDG levels drifting low, so a reference pipe sensor was installed alongside the field-deployed instrument from August 19 through September 14 to obtain comparison measurements. Comparison of the TDG

values confirmed that the JHAW gauge was inaccurate and drifting downward. Therefore, on October 1, 2015 the reference pipe was designated as the primary deployment pipe and the field instrument was transferred to it for data collection.

The Anatone deployment pipe on the Snake River was rebuilt twice during the 2015 water year. The first repair occurred during December 2014. The pipe was pulled out of the water and it was then discovered that the rope inside the pipe had become tangled. It was repaired and worked well until August 2015, when a piece of wood entered the pipe, became wedged against an eye bolt that the rope goes through, and the sonde could consequently not be moved. The eye bolt was replaced with a stainless steel bar, new rope was installed, and the pipe was re-anchored in the same location as the December repair.

3.4 Malfunctioning Gauge Occurrences

During 2015, there were nineteen occurrences affecting 116 gauge days where six FMS gauges malfunctioned due to various reasons as shown in Table E-6 (Appendix E). This is the highest number since records began in 2006 and far exceeds any previous record. The next highest number of occurrences (8) was in 2009 when flows on the lower Columbia River in July and August were similarly low as 2015. The following describes the 2015 occurrences:

- Three occurrences at Lower Granite forebay gauge resulted in missing data on June 9-10 and August 26-28 due to a DPS/DCP transmission error and a bad communication cable, respectively. There was a defective sonde on June 24-30 that resulted in erroneously high values and this data was deleted.
- Two occurrences at Little Goose tailwater gauge resulted in low percent TDG (drifting downward) and elevated percent TDG due to a bio fouled membrane and a defective membrane, respectively. Therefore, the data for July 23-August 10 and August 20 was deleted.
- Three occurrences at Lower Monumental tailwater gauge resulted in elevated percent TDG, missing data, and erroneously low percent TDG due to punctured membranes, a bad communication cable, and crayfish in the cap, respectively. As a result the data for June 23-24 August 7-8 and August 30-31 was deleted.
- One occurrence at Ice Harbor tailwater gauge resulted in erroneously low percent TDG due to defective sonde. As a result, the data for July 28 was deleted.
- Two occurrences at McNary tailwater gauge resulted in elevated percent TDG and erroneously low percent TDG due to a punctured membrane and flow obstructions respectively. Therefore data from May 4-7 and August 10-11 was deleted.
- Eight occurrences at John Day tailwater gauge resulted in low percent TDG (drifting downward) due to unknown causes, possibly algae or bio fouling. The low percent TDG data changed very slowly and thus it was not readily recognized that a problem existed. Data was deleted for April 27-30; May 8-13; May 16-19; June 13-29; July 10-21; July 29-August 10; August 16-19 and August 21-31.

From the historical perspective, TDG readings drifting downward is unusual and not typically seen. Therefore, gauge data was verified when it drifted significantly downward and, in some cases, the data was accurate despite the drift downward. The very warm water temperatures and low flow conditions in 2015 resulted in circumstances contributing

to gauges drifting downward. Two gauges that malfunctioned by drifting downward: John Day tailwater water and Little Goose tailwater. Possible causes are: 1) fouling from dirt and debris; 2) little understood biological processes that reduce the oxygen and TDG levels in the river when the water becomes quite warm and shallow; 3) algae growth; 4) the accumulation of a bacterial biofilm; and 5) limited circulation due to some little understood hydraulics near the sonde.

Malfunctioning gauge TDG instances are noted as a Type 2a instance in Appendix E, Tables E-2, E-3A, and E-3B. Table E-2 (Appendix E) is based on raw data and is populated during real-time operations. Tables E-4 through E-5 (Appendix E) are based on revised data and do not include the malfunctioning gauge data since these tables provide statistical information on hourly TDG levels.

3.5 QA/QC on FMS

The 2014 Supplemental BiOp, RPA Action 15, calls for "real-time monitoring and reporting of TDG and temperatures measured at fixed monitoring sites." The Corps' districts operate the FMSs according to the 2015-2018 TDG Monitoring Plan and prepare annual performance reports for the FMS operation. The 2015 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 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 received averaged 97.2 percent for the 15 monitoring sites in 2015 (nine seasonal and six year-round).
- The TDG data received from the individual sites ranged from 92.9 percent to 100.0 percent complete. 45.6 percent of the invalid/missing data was due to low TDG readings, primarily at the Little Goose tailwater (LGSW), Clearwater River near Peck (PEKI), Lower Monumental tailwater (LMNW), and McNary tailwater (MCPW) stations. The second and third most frequent causes of anomalous/missing data were defective membranes and cable failures accounting for 20.0 and 11.5 percent, respectively.
- The TDG sensors from the 15 seasonal and annual FMSs were removed from the field and calibrated in the laboratory every 3 weeks between April 2015 and August 2015. From September 2014 through March 2015, the six annual FMSs 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 -0.12 mmHg, -0.15 mmHg, and -0.05^{o}C, respectively. The sensor post-deployment check revealed mean ambient pressure, ambient pressure plus 100 mmHg, and temperature differences of 0.10 mmHg, -0.21 mmHg, and -0.04°C, respectively.

- The median for the 171 in-situ field checks of TDG sensors with the replacement probe were within ±1 percent after the deployment period.
- The calculated median for the 175 field checks for barometric pressure was 0.00 mm Hg. 174 of the individual values were within ±0.2 mm Hg of a secondary standard.
- The calculated median for the water temperature field checks was 0.00ºC. Station medians ranged from -0.05ºC to 0.05ºC. 174 of the 175 individual assessments were within ±0.2ºC.
- The Anatone (ANQW) deployment pipe was cleaned with compressed air to remove built-up sediment during May. The purpose of this repair was to replace a tangled deployment rope and move the pipe alignment farther upstream to its original location.

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

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:

- All but 1 of the 85 TDG sensor laboratory checks that were performed after field deployment were within ±0.5 percent saturation of a primary standard.
- Data received from the eight individual monitoring sites ranged from 71.9 percent (at the John Day Tailwater gauge) to 99.9 percent complete. See Table 2 of Appendix H for individual gauge data completeness information. Table 3 of Appendix H provides the causes for missing data.
- All quality-assurance values exceed the criteria established by the TDG Monitoring Plan. Criteria for data completeness (95 percent) were met at seven of the eight monitoring stations. Deleted data at the John Day tailwater station resulted in data completeness below criteria.
- After 3-4 weeks of deployment in the river, 79 of 89 TDG sensor field checks were within ±1.0 percent saturation of a secondary standard. Nine of the field checks greater than ±1.0 percent saturation occurred at the John Day tailwater station and resulted in periods of deleted TDG data at the station.
- The TDG sensors were removed from the monitoring stations and calibrated every 3 weeks, except from September 2014 through March 2015, when they were calibrated at 4 week intervals.
- All 90 barometric pressure field checks were within ±1 mm Hg of a primary standard, and all 90 water-temperature field checks were within ±0.2°C of a secondary standard.

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

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 99.0 percent at the tailwater station (CHQW) to 99.8 percent at the forebay station (CHJ). Missing data were largely due to DCP malfunctions and programming problems.
- For TDG data, at the tailwater station (CHQW) a total of 5 hours were rejected due to slow probe response time after recalibration, while at the forebay station (CHJ) a total of 6 hours were rejected due to slow probe response time after recalibration. No temperature data were rejected at stations CHJ and CHQW.
- Laboratory calibration data were good and within 0.1°C for temperature and 1 percent saturation for TDG. Field calibration data were good and generally within 2 mm Hg of the secondary standard barometer, 0.1ºC of the secondary standard thermometer, and 2 percent saturation of the secondary standard TDG instrument.
- A total of 26 out of 26 (100 percent) 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 25 out of 26 (96 percent) in-situ field checks of barometric pressure were within ±2 mm Hg of a secondary standard, and 26 out of 26 (100 percent) 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 I.

Part 4 Fish Passage Spill Program

4.1 Spill

Operation of the FCRPS to meet multiple authorized purposes can result in instances of percent TDG exceeding the 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 Operation Plans

The 2014 Supplemental BiOp calls for the Corps to provide spill for juvenile fish migration in the FCRPS. The Corps, in coordination with other Action Agencies and NOAA Fisheries, annually develops a Fish Operation Plan (FOP) that provides detailed information on the implementation of the BiOp spill and transport operations at the four lower Snake River and four lower Columbia River dams. The FOP was developed in

collaboration with regional sovereigns and is consistent with spill operations specified for juvenile fish passage in the 2014 Supplemental BiOp.

At some Corps' projects, the amount of fish passage spill is a specified level, and, at others, the Corps is to spill up to the applicable state TDG criteria -- referred to as the "gas cap." The maximum project spill level that meets but does not exceed the gas cap is referred to as the spill cap. The 2015 FOP, provided in Appendix C, describes specific fish operations implemented this year and are summarized in Table 4.

TABLE 4
2015 FOP Spill Operations

Project	Planning Dates	Time	Spill Amount (Not to Exceed the Spill Cap)
Lower Granite	April 3 - June 20	24 hours per day	20 kcfs
Lower Granite	June 21-August 31	24 hours per day	18 kcfs
Little Goose	April 3 - August 31	24 hours per day	30% of project outflow or to the spill cap, whichever is less
Little Goose	During flows < 32 kcfs	24 hours per day	Constant spill of 7-11 kcfs (dependent on the total outflow)
Lower Monumental	April 3 - June 20	24 hours per day	Spill cap
Lower Monumental	June 21-August 31	24 hours per day	17 kcfs
Ice Harbor	April 3 - April 28	0500-1800	45 kcfs during the day
Ice Harbor	April 3 - April 28	1800-0500	Spill cap at night
Ice Harbor	April 28 - July 13	24 hours per day	Alternating between 2-day blocks of 30% of project outflow vs. 45 kcfs during the day/spill cap at night
Ice Harbor	July 13 - August 31	0500-1800	45 kcfs during the day
Ice Harbor	July 13 - August 31	1800-0500	Spill cap at night
McNary	April 10 - June 15	24 hours per day	40% of project outflow or to the spill cap, whichever is less
McNary	June 16-August 31	24 hours per day	50% of project outflow or to the spill cap, whichever is less
John Day	April 10 - April 27	24 hours per day	30% of project outflow or to the spill cap, whichever is less
John Day	April 27 - July 20	24 hours per day	Alternate between 2-day blocks of 30% vs. 40% of project outflow
John Day	July 21 - August 31	24 hours per day	30% of project outflow or to the spill cap, whichever is less
John Day	April 10 - August 31	24 hours per day	Minimum spill is 25% of project outflow
The Dalles	April 10 - August 31	24 hours per day	40% of project outflow or to the spill cap, whichever is less
Bonneville	April 10 - June 16	24 hours per day	100 kcfs or to the spill cap, whichever is less
Bonneville	June 16 - August 31	24 hours per day	Alternating between 2-day blocks of 95 kcfs vs. 85 kcfs during the day/121 kcfs at night
Bonneville	April 10 - August 31	24 hours per day	Minimum spill is 50 kcfs

4.1.2 Fish Passage Spill

Fish-passage spill, also referred to as voluntary spill, occurs for the benefit of juvenile fish migration in accordance with the operative biological opinions. The 2015 FOP established spill levels for juvenile fish passage at the four lower Snake and four lower Columbia River dams during the juvenile fish migration season. The fish passage spill called for in the 2015 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. With elevated total river flows from early February through the first week of April, continuous involuntary spill began on March 29 at McNary (see Part 4.1.5 for more details). Tracking TDG instances for this report starts on April 1.

The amount of fish passage spill for the 2015 spill season at each dam is shown in weekly graphs that show the flow, FOP spill, and percent TDG for April through August are

included in the monthly FOP implementation reports (Appendix D) which can be found at: http://www.nwd-wc.usace.army.mil/tmt/wqnew/tdg_and_temp/2015/.

4.1.3 BiOp Performance Standard Test Operations

Under the 2014 Supplemental BiOp, juvenile dam passage performance standards were established based on dam passage survival through all passage routes, with a benchmark of 96 percent average dam passage survival for migrating spring fish (yearling Chinook and steelhead) and 93 percent for migrating summer fish (subyearling fall Chinook). Juvenile passage improvements that include surface passage structures (e.g., spillway weirs and sluiceways) have been completed at all eight federal dams on the lower Columbia and lower Snake rivers in order to reduce passage times at dams and improve passage survival through the hydrosystem. In 2015, the Corps did not conduct juvenile dam passage performance standard testing at any FCRPS projects. A summary of performance standard testing results to date may be found in the FCRPS BiOp annual progress report that may be found on the following website.
https://www.salmonrecovery.gov/BiologicalOpinions/FCRPSBiOp/ProgressReports.aspx

4.1.4 Long Term Turbine Outages

Unit outages can affect the spill volume at the dams by causing additional involuntary spill. Table 5 summarizes the long term unit outages during the 2015 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 29 long term outages during the Fish Passage Season. There were five long term (greater than one month) unit outages on the lower Snake River, six on the lower Columbia River, and eighteen on the middle Columbia River.

TABLE 5
2015 Long Term Outages

Project	Unit	Start Date	Finish Date	Reason
Lower Granite	4	7/6/15	8/28/15	6 Yr Overhaul / Cavitation Repair
Little Goose	2	7/13/15	8/13/15	Digital Governor Installation
Lower Monumental	1	2/26/15	1/12/17	Annual, remove cyclinder
Ice Harbor	3	7/6/15	8/27/15	Bus section outage to clean disconnects and insulators
Ice Harbor	4	7/6/15	8/27/15	Bus section outage to clean disconnects and insulators
McNary	12	2/8/15	10/9/15	Forced - Thrust bearing overheat
John Day	3	2/6/14	9/30/15	Forced out with ground, awaiting contract award
John Day	5	3/30/15	5/21/15	Digital Governor Installation
John Day	9	3/17/15	6/6/15	5 Yr Overhaul
John Day	10	5/11/15	6/25/15	Digital Governor Installation
The Dalles	7	5/4/15	6/25/15	5 Yr Overhaul
Chief Joseph	8	7/6/15	8/21/15	Annual / Digital Governor Replacement / Thrust Cooler Replacement
Chief Joseph	15	9/29/14	6/5/15	Turbine Replacement / Quad Services
Chief Joseph	16	3/2/15	10/8/15	Turbine Replacement / Quad Services
Chief Joseph	21	7/7/15	10/30/15	Transformer bushing replacement
Chief Joseph	22	7/7/15	10/30/15	Transformer bushing replacement
Chief Joseph	23	7/7/15	10/30/15	Transformer bushing replacement
Chief Joseph	24	7/7/15	10/30/15	Transformer bushing replacement
Chief Joseph	25	7/7/15	10/30/15	Transformer bushing replacement
Chief Joseph	26	7/7/15	10/30/15	Transformer bushing replacement
Chief Joseph	27	7/7/15	10/30/15	Transformer bushing replacement
Grand Coulee	5	3/10/15	7/8/15	Quinn maintenance and Bypass Valve Replacement
Grand Coulee	9	9/5/14	6/19/15	5 Yr Overhaul /SF-6 Breaker Annual /PSS install
Grand Coulee	10	3/9/13	6/5/15	Forced - line 3 trip, transformer fault
Grand Coulee	11	2/6/14	6/19/15	Forced - line 3 trip, transformer fault
Grand Coulee	13	6/18/15	12/30/15	Quinn maintenance / TRs / WECC Testing /Relay Install
Grand Coulee	14	4/5/15	6/19/15	Forced, transformer leak
Grand Coulee	21	3/23/15	5/30/15	K21A Transformer Cooler Replacement
Grand Coulee	24	3/5/13	10/22/15	Overhaul Transformer/fixed wheel gate testing
TOTAL OUTAGES = 29				

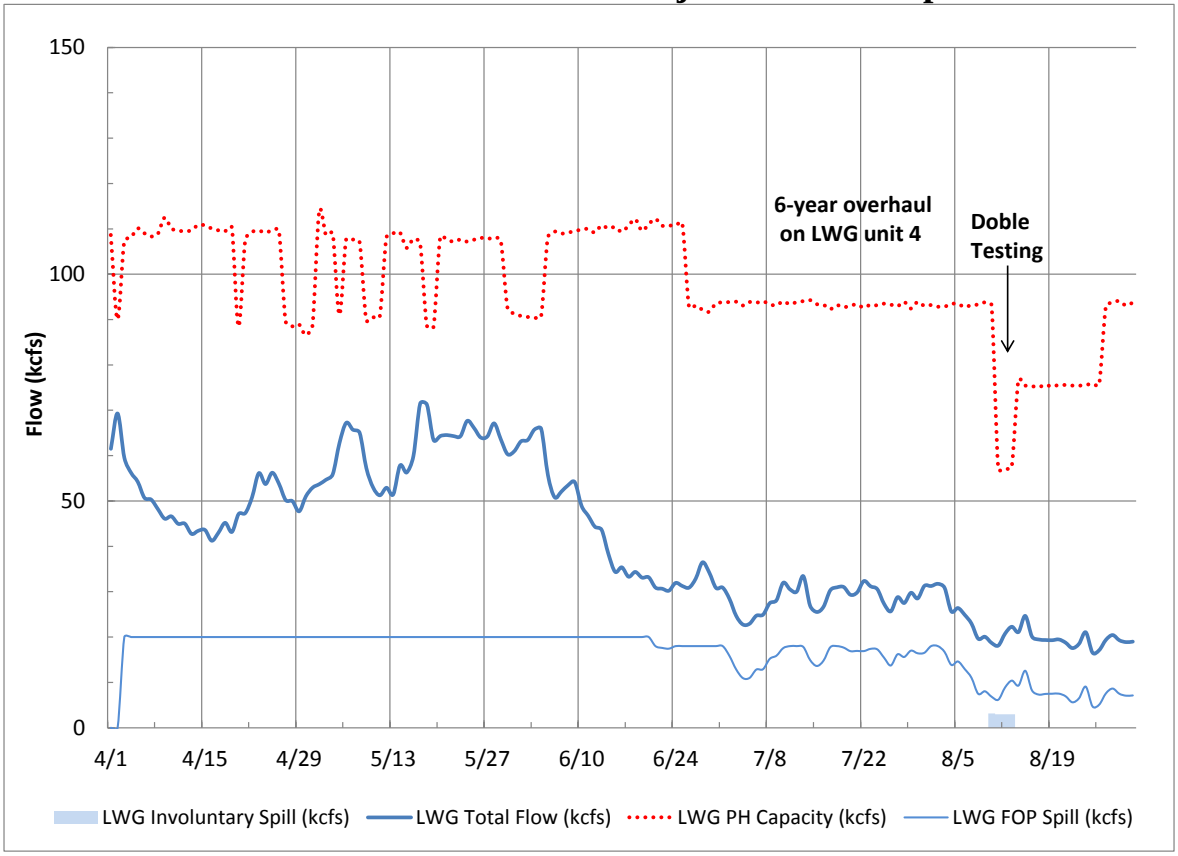
4.1.5 Involuntary Spill

Due to lack of turbine availability, lack of load, and other hydraulic conditions, involuntary spill occurred for one day or more at three of the lower Columbia River and four lower Snake River dams.

Involuntary spill occurred on March 29 at McNary Dam and continued for12 days. The other lower Columbia and lower Snake River dams began involuntary spill from March 30 to as late as August 10. There was no involuntary spill at Bonneville Dam as was shown above in Figure 2. The Dalles Dam had involuntary spill for four days from March 31 to April 3. John Day Dam had involuntary spill for five days from March 30 to April 3.

On the lower Snake River, involuntary spill occurred at Ice Harbor Dam for two days from April 1 to April 2. Lower Granite Dam had involuntary spill for four days from August 10 to August 13 (Figure 4) as a result of doble testing. Little Goose Dam had involuntary spill for one day on April 2 due to unit outages. Lower Monumental Dam had involuntary spill for one day on July 25 due to doble testing.

FIGURE 4
2015 Lower Granite Dam Project Flow and Spill



Note: Daily powerhouse capacities provided by BPA Duty Schedulers

Part 5 Instances of TDG Exceeding WQS

The 2015 water year was characterized by very low flows on the lower Columbia and Snake rivers. Total river flows on the lower Columbia River as measured at Bonneville Dam remained below 235 kcfs for all of the April through August period Total river flows on the lower Snake River as measured at Lower Granite Dam remained below 73 kcfs for all of the April through August period. Because of these low flows and very little involuntary spill, the TDG instances were primarily due to two factors: 1) malfunctioning gauges, and 2) the Corps balancing TDG production with spill for fish passage at Lower Monumental Dam to meet juvenile dam passage survival performance standards.

Part 5 discusses the TDG instances in 2015.

5.1 TDG Instance Calculation Methods

Calculations and reporting in Part 5 are consistent with the Corps' Operating Guidelines described above in Part 1.1.6.

5.2 TDG Instances

5.2.1 115 percent and 120 percent TDG Instances

Table 6 provides a summary of TDG instances for the 2015 spill season for the lower Columbia and lower Snake projects. There were a total of 167 TDG instances in 2015 (Table 6 and Table E-2, Appendix E).

The majority (69 percent) of the TDG instances was malfunctioning gauges which caused six of the 16 gauges to have TDG instances in the April through August period. As shown on Table E-6, in Appendix E, the malfunctioning gauge events were caused by several factors such as communication cables breaking; ruptured membranes and unknown causes, possibly algae or bio fouling. Part 3.4 discusses the factors that caused the gauges to drift downward.

The second greatest cause of TDG instances in 2015 was a result of managing TDG production and achieving the juvenile dam passage survival performance standards at Lower Monumental Dam as specified in the 2014 Supplemental BiOp. The unique reservoir configuration combined with environmental conditions downstream of Lower Monumental Dam often results in very little degassing of the water spilled at this project once the water reaches the Ice Harbor Dam forebay. As a result, providing fish passage spill to achieve performance standards at Lower Monumental Dam while not exceeding the 115 percent TDG limit in the Ice Harbor Dam forebay is challenging and often results in TDG levels that exceed 115 percent TDG. Consequently, maintaining performance standard spill for fish passage is prioritized over managing to 115 percent in the Ice Harbor Dam forebay. The TDG instances related to this approach for benefitting juvenile fish migration occurred only at the Ice Harbor forebay gauge.

TABLE 6
2015 Spill Seasons
Number of TDG Instances Exceeding WQS
ODEQ/WDOE Combined Calculation Method

Fixed Monitoring Stations	2015 Quantity	2014 Quantity	Two-Year Avg Quantity	Applicable Standard
Lower Granite Forebay	12	0	6	WA
Lower Granite Tailwater	0	5	3	WA
Little Goose Forebay	1	13	7	WA
Little Goose Tailwater	20	0	10	WA
Lower Monumental Forebay	0	23	12	WA
Lower Monumental Tailwater	7	4	6	WA
Ice Harbor Forebay	44	41	43	WA
Ice Harbor Tailwater	1	3	2	WA
McNary Forebay	0	17	9	WA
McNary Tailwater	6	14	10	WA/OR
John Day Forebay	0	10	5	WA
John Day Tailwater	71	19	45	WA/OR
The Dalles Forebay	0	11	6	WA
The Dalles Tailwater	0	5	3	WA/OR
Bonneville Forebay	5	32	19	WA
Bonneville Tailwater	0	21	11	WA/OR
Total Number of TDG Instances	**167**	**218**	**193**	

Notes: *Does not include days when 7Q10 flows were exceeded (see Table 8). ** Instances are counted if the calculated values exceed either the Oregon or Washington state standards, but the exceedance is only counted as 1 day.

5.2.3 Instances of TDG Exceeding the 125 percent WQS

During the 2015 spill season, there were ten instances of hourly TDG readings exceeding the Washington one-hour standard of 125 percent TDG, Table E-4 (Appendix E). These ten instances occurred at Lower Monumental tailwater on April 5 and is believed to be a change in the spill pattern from 0800 to 1730 hours in order for divers to work in the water while water was spilled over the spillway. During these hours, the generation dropped to minimum generation while the spill remained at the spill cap, which resulted in spilling 70 percent of the river. With this high percentage of spill, and the change in spill pattern, it is thought that the high TDG levels generated from the spill may have flowed near the gauge, resulting in these high readings. USGS and district staff investigated the issue and determined the gauge was functioning correctly.

5.2.4 TDG Instances in Oregon

Oregon requested the following additional information in Table 7 identifying TDG instances that occurred at the dams covered by the Oregon TDG modification. In 2015,

there were 77 TDG instances which exceeded the 120 percent TDG standard in the reservoir tailwater. All 77 TDG instances were due to malfunctioning gauges. Six TDG instances occurred at McNary tailwater and were due to flow obstructions and a ruptured membrane. The other 71 TDG instances were due to gauge data drifting downward at John Day tailwater. The TDG instances are approximately 13 percent of 612 possible gauge days (4 gauges x 153 days), from April 1 through August 31.

TABLE 7
2015 Spill Season
Number of TDG Instances Exceeding Oregon WQS

Fixed Monitoring Stations	April 1 - August 31 120% TDG Instances	April 1 - August 31 125% TDG Instances	7Q10 Flow Days	Instances between April 1- April 10
McNary Tailwater	6	0	0	0
John Day Tailwater	71	0	0	0
The Dalles Tailwater	0	0	0	0
Bonneville Tailwater	0	0	0	0
Total Number of Exceedances for Oregon	**77**	**0**	**0**	**0**

5.2.5 7Q10 Flows Days

During 2015, flows on the mid-Columbia, lower Columbia and lower Snake rivers were so low that there were zero days when the 7Q10 flow criteria was exceeded (See Table 3 and 8).

TABLE 8
Number of Days
When 7Q10 Flows Were Exceeded In 2015

Fixed Monitoring Stations	Number of 7Q10 Days
Lower Granite Forebay	0
Lower Granite Tailwater	0
Little Goose Forebay	0
Little Goose Tailwater	0
Lower Monumental Forebay	0
Lower Monumental Tailwater	0
Ice Harbor Forebay	0
Ice Harbor Tailwater	0
McNary Forebay	0
McNary Tailwater	0
John Day Forebay	0
John Day Tailwater	0
The Dalles Forebay	0
The Dalles Tailwater	0
Bonneville Forebay	0
Bonneville Tailwater	0
Camas/Washougal	0
Total Number of 7Q10 Days	**0**

5.2.6 Comparison of Annual TDG Instances

Table 9 provides daily TDG instances above the WQS. In 2015, instances numbered less than in 2014 (167 days as compared to 218 days). This low number is attributed to the low flows, 53 percent of normal April-July runoff at Lower Granite, and 67 percent of normal April-August at The Dalles Dam. In previous annual TDG reports, the total number of TDG instances that occurred in the current year were compared with the previous years, but was reset in 2014 because of the changes to the state TDG standards and the TDG management approach for attaining juvenile fish passage performance standards at Lower Monumental.

TABLE 9
2015 Annual Comparison of
TDG Instances Exceeding WQS

Year	Days in Spill Season[1]	Number of Days of Instances	Percent of Days Exceeding TDG Standard (%)	Percent of Days Consistent With TDG Standard (%)	Percent of Normal Runoff at TDA[2]	Percent of Normal Runoff at LWG[3]
2015	2448	167	7	93	67	53
2014	2448	218	9	91	108	99
Average	**2448**	**193**	**8**	**92**	**88**	**76**
[1] Days in Spill Season based on number of gages (16) x days in spill season (153): April 1 - August 31.						
[2] The Dalles Apr-Aug Observed Runoff (1981-2010) = 87.5 Maf						
[3] Lower Granite Apr-July Observed Runoff (1981-2010) = 19.9 Maf						

5.2.7 Types of Daily TDG Instances

Beginning in 2003, Oregon and the Technical Management Team (TMT) requested the Corps track the causes of TDG instances where the percent TDG exceeded the WQS. Table E-1 (Appendix E) provides a listing of the six causes or TDG instance types. The Corps tracked the daily TDG instance types for the forebay and tailwater of each of the Corps' FCRPS dams during the 2015 spill season. Each type of TDG instance represents conditions that cause daily average percent TDG to exceed the WQS. The 2015 tracking results are summarized in Table 10. Daily details by dam can be found in Appendix E. The daily TDG instance type designation given for each occurrence is based on the Corps' determination of causation.

During the 2015 spill season, there were a total of 167 instances out of 2,448 gauge-days in which the TDG levels were above the TDG criteria. Certain types of TDG instances, such as Types 1 and 2a, associated with high flows and malfunctioning gauges respectively, may occur every year and are a normal part of reservoir operations. Efforts continue to reduce daily instances when possible.

TABLE 10
2014 - 2015 Spill Seasons
Types and Numbers of TDG Instances

2015	2014	TYPE	DEFINITION
0	140	**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.
0	0	**1a**	Planned and unplanned outages of hydro power equipment including generation unit, intertie line, or powerhouse outages.
0	5	**2**	TDG exceedances due to the operation or mechanical failure of non-generating equipment.
116	22	**2a**	Malfunctioning FMS gauge, resulting in fewer TDG or temperature measurements when setting TDG spill caps.
8	51	**3**	TDG exceedances due to uncertainties when using best professional judgment, SYSTDG model and forecasts.
43	N/A	**3a**	TDG instances due to balancing TDG production with spill for fish passage to meet juvenile dam passage survival performance standards at Lower Monumental Dam.
167	**218**	**Totals**	

5.2.8 Recurring High TDG Instances

There were three locations that had a high number of TDG instances during the 2015 spill season: John Day tailwater, Ice Harbor forebay, and Little Goose tailwater. The following is a discussion about each of these high TDG instance gauges.

5.2.8.1 John Day Tailwater

The John Day tailwater gauge had a total of 71 TDG instances (see Table 6) during the 2015 spill season which is the highest amount among the FCRPS TDG gauges and 43% of the total number of instances that occurred in 2015. John Day tailwater gauge had only 19 TDG instances in 2014 so a high number of TDG instances in 2015 is unusual. As indicated on Table E-3A (Appendix E), the 71 TDG instances were all classified as Type 2a instances which shows that malfunctioning gauge issues were significant at John Day tailwater during 2015. John Day tailwater gauge data drifted downward resulting in low percent TDG. The exact cause is not known, but could be possibly algae or bio fouling as discussed in Part 3.4 and 5.2.1.

5.2.8.2 Ice Harbor Forebay

The Ice Harbor forebay gauge had a total of 44 TDG instances (see Table 6) during the 2015 spill season. As indicated on Table E-3A (Appendix E), the 44 TDG instances were classified as 43 Type 3a instances and 1 Type 3. The majority of TDG instances being classified as Type 3a indicates that the Lower Monumental spill management operations resulted in many TDG instances and was the predominant factor causing the TDG instances at this gauge in 2015.

5.2.8.3 Little Goose Tailwater

The Little Goose tailwater had 20 TDG instances (See Table 6) during the 2015 spill season. As indicated on Table E-3A (Appendix E), all 20 TDG instances were classified as Type 2a which indicate that malfunctioning gauge issues were significant at Little Goose tailwater during 2015.

Part 6 Gas Bubble Trauma Monitoring

6.1 Biological Monitoring Highlights

The Fish Passage Center compiles a report of GBT monitoring results collected in 2015 (included as Appendix J). The following is a summary of biological monitoring results.

The monitoring of juvenile salmonids in 2015 for GBT was conducted at upper Columbia, mid-Columbia, lower Columbia, and Snake River sites. Fish were collected and examined for signs of GBT at Rock Island Dam on the upper Columbia River, and at Bonneville and McNary dams on the lower Columbia River. The lower Snake River monitoring sites included Lower Granite Dam, Little Goose Dam, and Lower Monumental Dam.

Sampling occurred two days per week at the Columbia River sites and one day a week at each of the Snake River sites during 2015 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. The proportion of each species sampled (limited to Chinook and steelhead) was dependent upon their prevalence at the time of sampling. A daily sample size of 100 fish is necessary to assure that the sample observation accurately represents the population incidence of signs of gas bubble trauma.

Yearling Chinook and steelhead were sampled through the spring at all the sampling sites. Once subyearling Chinook predominated in the smolt collections, the program shifted from sampling yearling Chinook and steelhead to sampling subyearling Chinook through the end of August, unless an adequate sample could not be collected. In 2015, sampling at some sites was terminated prior to the end of August as a result of high temperatures in the Snake and middle Columbia rivers.

Examinations of fish were conducted using variable magnification (6x to 40x) dissecting scopes. The eyes and unpaired fins of specimens were examined for the presence of bubbles. The bubbles present in the fins were quantified using a ranking system based on the percent area of the fins covered with bubbles as shown in Table J-1 (Appendix J).

The action criteria for GBT is established as 15 percent of fish showing any signs of GBT, or 5 percent of fish sampled showing signs of fin GBT greater than or equal to rank 3. Neither of these two action criteria was met in 2015.[9]

[9] From 2009-2012, reports received from the FPC inadvertently specified "rank 1" rather than "rank 3" as the metric to be used to determine the action criteria for GBT. The FPC discovered this error in 2013; therefore,

In 2015, a total of 10,577 juvenile salmonids were examined for GBT at Lower Granite; Little Goose; Lower Monumental; McNary; Bonneville and Rock Island dams between April and August as shown in Table J-2 (Appendix J). Fin signs of GBT were found in 20 (or 0.19% percent) of the total fish sampled at all sites as shown in Table J-3 (Appendix J). The fish that were examined and determined to have fin signs of GBT, 19 were rank 1 where less than 5 percent of a fin area was covered with bubbles, and one was rank 2 where 6 percent to 25 percent a fin area was covered with bubbles. This single rank 2 fish was encountered at Little Goose Dam. No signs of rank 3 or 4 were seen in 2015. Table J-4 (Appendix J) compares the 2015 estimates of the overall percentage of fish with signs of GBT to past years' estimates. The overall annual incidence of GBT in 2015 was in the lower range among the past 19 years.

this report reflects the correction and that "rank 3" was used to determine the action criteria for GBT. Also see memo, FPC 151-13, dated December 20, 2013.