Appendix H

2014 Portland District TDG Report
Prepared by USGS
(Includes John Day, The Dalles, and Bonneville Dams)

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Prepared in cooperation with the U.S. Army Corps of Engineers

Total Dissolved Gas and Water Temperature in the Lower Columbia River, Oregon and Washington, Water Year 2014

By Heather M. Bragg and Matthew W. Johnston

Open-File Report 2014–1237

U.S. Department of the Interior
U.S. Geological Survey

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SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2014

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Conversion Factors, Datum, and Abbreviations and Acronyms

Conversion Factors

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
mile (mi)	1.609	kilometer (km)
millimeter (mm)	0.03937	inch (in.)
square mile (mi^2)	2.590	square kilometer (km^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows: °F=(1.8×°C)+32.

Datum

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Abbreviations and Acronyms

BON	Bonneville forebay
CCIW	Cascade Island
CWMW	Camas
DCP	Data-collection platform
JDY	John Day navigation lock
JHAW	John Day tailwater
NIST	National Institute of Standards and Technology
RM	River mile
TDA	The Dalles forebay
TDDO	The Dalles tailwater
TDG	Total dissolved gas
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WRNO	Warrendale

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Total Dissolved Gas and Water Temperature in the Lower Columbia River, Oregon and Washington, Water Year 2014

By Heather M. Bragg and Matthew W. Johnston

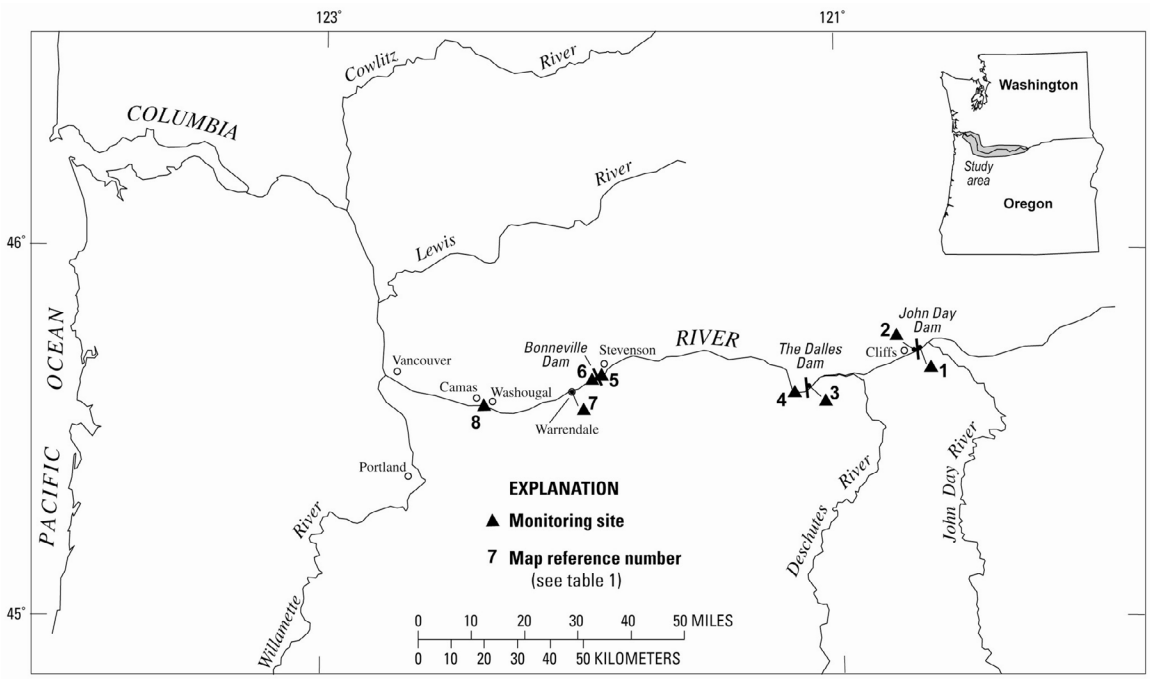
Significant Findings

An analysis of total-dissolved-gas (TDG) and water-temperature data collected at eight fixed monitoring stations on the lower Columbia River in Oregon and Washington in water year 2014 indicated the following:

- All of the 81 TDG sensor laboratory checks that were performed after field deployment were within ±0.5-percent saturation of a primary standard.
- After 3–4 weeks of deployment in the river, 68 of 75 TDG sensor field checks were within ±1.0-percent saturation of a secondary standard. Six of the field checks greater than ±1.0-percent saturation occurred at the John Day tailwater station and three of them resulted in periods of deleted data at the station.
- All 77 barometric pressure field checks were within ±1 millimeter of mercury of a primary standard, and all 74 water-temperature field checks were within ±0.2 degrees Celsius of a secondary standard.
- TDG data were considered complete if received in real time and within 1-percent saturation of the expected value on the basis of calibration data, replicate quality-control measurements, and comparison to river conditions at adjacent stations. For the eight monitoring stations, data completeness ranged from 78.2 to 100 percent.
- All quality-assurance values exceed the criteria established by the U.S. Army Corps of Engineers TDG monitoring plan. Criteria for data completeness (95-percent) were met at six of the eight monitoring stations. Deleted data at the John Day tailwater station and missed transmissions at the Camas station resulted in data completeness below criteria.

Introduction

The U.S. Army Corps of Engineers (USACE) operates several dams in the lower Columbia River Basin in Oregon and Washington (fig. 1), which encompasses 259,000 mi^2 of the Pacific Northwest. These dams are multipurpose structures that fulfill regional needs for flood control, navigation, irrigation, recreation, hydropower production, fish and wildlife habitat, water-quality maintenance, and municipal and industrial water supply. When water is released through the spillways of these dams (instead of being routed through the turbines to generate electricity), ambient air is entrained in the water. This results in an increase in the concentration of dissolved gases (referred to here as "total dissolved gas," or "TDG") in the water downstream of the spillways. Concentrations of TDG greater than 110-percent saturation can cause gas-bubble trauma in fish and adversely affect other aquatic organisms (U.S. Environmental Protection Agency, 1986). The USACE regulates streamflow and spill from its dams on the lower Columbia River to minimize the production of excess TDG downstream of the dams, with the additional goal of providing for fish passage through the spillways (rather than through the turbines).



Base map modified from USGS and other digital data, variable scales. Projection unknown.

Figure 1. Location of U.S. Army Corp of Engineers dams and total-dissolved-gas monitoring stations, lower Columbia River, Oregon and Washington, water year 2014.

Real-time TDG and water-temperature data are vital to the USACE for dam operation and for monitoring compliance with environmental regulations. The data are used by water managers to maintain water-quality conditions that facilitate fish passage and ensure their survival in the lower Columbia River. The U.S. Geological Survey (USGS), in cooperation with the Portland District of the USACE, has collected TDG and related data in the lower Columbia River each year since 1996. The hourly values were stored in the USGS database and in a USACE database (U.S. Army Corps of Engineers, 2014). Those

data are available online within approximately an hour of collection time, and the current and historical TDG and water-temperature data can be accessed at *http://oregon.usgs.gov/projs_dir/pn307.tdg/* (accessed October 27, 2014). The USACE database also includes hourly river discharge and spill data.

Fifteen previous reports, published for water years 1996 and 2000–2013, describe the TDG data, quality-assurance data, and methods of data collection (Tanner and others, 1996; Tanner and Bragg, 2001; Tanner and Johnston, 2001; Tanner and others, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2011, 2012, 2013; and Bragg and Johnston, 2014).

This report presents the TDG data and related quality-assurance data that demonstrate the USACE Portland District compliance with the TDG monitoring plan (U.S. Army Corps of Engineers, 2008). To assure the accuracy and integrity of the data needed for managing and modeling TDG in the lower Columbia River, hourly values were reviewed relative to concurrent field measurements, laboratory sensor calibrations, and intersite comparisons. All deleted or missing data are explained in detail.

Data Collection

Eight monitoring stations were operated on the lower Columbia River, from the navigation lock of the John Day Dam (river mile [RM] 215.7) to Camas, Washington (RM 121.7) (fig. 1, table 1). Data for water year 2014 (October 1, 2013–September 30, 2014) include hourly measurements of TDG pressure, barometric pressure, water temperature, and sensor depth. Five of the stations (John Day navigation lock, The Dalles forebay, Bonneville forebay, and Camas) were operated from March to September 2014, the period that includes the usual time for dam spill operations. The stations John Day tailwater, The Dalles tailwater, and Warrendale were operated year-round. Warrendale and Camas remain part of the monitoring program although TDG data from the stations are no longer part of the USACE spill management program.

Table 1. Total-dissolved-gas monitoring stations, lower Columbia River, Oregon and Washington, water year 2014.

[Map reference number refers to figure 1; USACE, U.S. Army Corps of Engineers; Columbia River mile locations were determined from U.S. Geological Survey (USGS) 7.5-minute topographic maps; stations in this report are referenced by their abbreviated name or USACE station identifier; °, degree; ’, minute; ”, second; latitude and longitude are referenced to the North American Datum of 1927; River mile is distance from the mouth of the Columbia River.]

Map reference number	USACE station identifier	River mile	USGS station number	USGS station name (and abbreviated station name)	Latitude	Longitude	Period of record in water year 2014
1	JDY	215.7	454314120413701	Columbia River at John Day navigation lock, Washington (John Day navigation lock)	45° 43’ 14”	120° 41’ 37”	03/11/14–09/15/14
2	JHAW	214.7	454249120423500	Columbia River, right bank, near Cliffs, Washington (John Day tailwater)	45° 42’ 49”	120° 42’ 35”	10/01/13–09/30/14
3	TDA	192.6	453712121071200	Columbia River at The Dalles Dam forebay, Washington (The Dalles forebay)	45° 37’ 12”	121° 07’ 12”	03/12/14–09/16/14
4	TDDO	188.9	14105700	Columbia River at The Dalles, Oregon (The Dalles tailwater)	45° 36’ 27”	121° 10’ 20”	10/01/13–09/30/14
5	BON	146.1	453845121562000	Columbia River at Bonneville Dam forebay, Washington (Bonneville forebay)	45° 38’ 45”	121° 56’ 20”	03/12/14–09/24/14
6	CCIW	145.9	453845121564001	Columbia River at Cascade Island, Washington (Cascade Island)	45° 38’ 45”	121° 56’ 40”	03/26/14–09/17/14
7	WRNO	140.4	453630122021400	Columbia River, left bank, near Dodson, Oregon (Warrendale)	45° 36’ 30”	122° 02’ 14”	10/01/13–09/30/14
8	CWMW	121.7	453439122223900	Columbia River, right bank, at Washougal, Washington (Camas)	45° 34’ 39”	122° 22’ 39”	03/14/14–09/18/14

Instrumentation at each monitoring station consists of a Hach® Hydrolab water-quality instrument, a Vaisala electronic barometer, a Sutron SatLink2 data-collection platform (DCP), and a power supply. The instruments at each station are powered by a 12-volt battery that is charged by a solar panel or a 120-volt alternating-current line. Measurements are collected, logged, and transmitted every hour. The DCP transmits the four most recent hours of logged data to the Geostationary Operational Environmental Satellite system (Jones and others, 1991). The data are automatically decoded and transferred to the USACE and USGS databases.

Station visits were completed every 4 weeks at the three year-round stations during September 2013 through March 2014, and every 3 weeks during March 2014 to September 2014 at all eight stations. The field calibration procedure was as follows: A reference Hydrolab (which was calibrated before the field trip for use as a secondary standard) was deployed alongside the field-deployed Hydrolab for as long as 1 hour to obtain comparison measurements of TDG and water temperature. The field Hydrolab (which had been deployed for 3 or 4 weeks) was then removed and replaced with another Hydrolab that had been recently calibrated in the laboratory. The newly deployed Hydrolab was allowed to equilibrate and the secondary standard was again used to compare TDG and temperature values. The electronic barometer at the monitoring station was calibrated using a portable barometer (NovaLynx 230-M202) that is calibrated annually to National Institute of Standards and Technology (NIST) standards.

During each field visit, the minimum compensation depth was calculated to determine whether the Hydrolab was positioned at an appropriate depth to obtain an accurate measurement of TDG. This minimum compensation depth, which was calculated according to Colt (1984, p. 104), is the depth above which degassing will occur because of decreased hydrostatic pressure. To measure TDG accurately, the Hydrolabs were positioned, whenever possible, at a depth below the calculated minimum compensation depth.

The Hydrolab that was removed from the field after 3 or 4 weeks of deployment was later calibrated in the laboratory. The integrity of the TDG membrane was tested, and the membrane was removed and air-dried. The TDG sensor (without the membrane attached) was calibrated at 0, 100, 200, and 300 millimeters of mercury (mm Hg) greater than atmospheric pressure to span the expected range of TDG in the river (approximately 100-, 113-, 126-, and 139-percent saturation, respectively). The membrane was then installed on the TDG sensor and retested.

Data Completeness

To assure the accuracy and integrity of the TDG data in the lower Columbia River, hourly values were reviewed relative to concurrent field measurements, laboratory instrument calibrations, and daily intersite comparisons. A summary of the completeness of the TDG percent saturation data is shown in table 2. Data were based on the total number of hourly TDG and barometric pressure data values that could have been collected during the monitoring season. No barometric pressure data were missing when TDG data were available, so data completeness relies on TDG data only. TDG saturation values were considered to meet quality-assurance standards if they were within ±1-percent saturation of the expected value.

Table 2. Completeness and quality of total-dissolved gas data, lower Columbia River, Oregon and Washington, water year 2014.

[TDG, total dissolved gas]

Abbreviated station name	Planned monitoring (hours)	Number of missing or deleted hourly values	Percentage of real-time TDG data passing quality assurance criteria
John Day navigation lock (JDY)	4,510	1	100
John Day tailwater (JHAW)	8,760	1,517	82.7
The Dalles forebay (TDA)	4,511	141	96.9
The Dalles tailwater (TDDO)	8,760	6	99.9
Bonneville forebay (BON)	4,701	1	100
Cascade Island (CCIW)	4,199	4	99.9
Warrendale (WRNO)	8,760	31	99.6
Camas (CWMW)	4,513	985	78.2

Periods for which substantial spans of TDG data were either missing from the database or were later deleted from the database because they did not meet quality-assurance standards, are listed in table 3. Failed instrument communications and datalogger transmissions were the most common causes of missing data, although most of those data was recovered and later entered into the databases. The vast majority of the deleted data was at the John Day tailwater station. Review of the field checks and instream data indicated erroneously low TDG values during three periods: October-November 2013, August 2014, and September 2104. Additional data collection and analysis are ongoing to determine the cause of the low data values.

Table 3. Periods of missing real-time total-dissolved-gas (TDG) data, lower Columbia River, Oregon and Washington, water year 2014.

[USACE (U.S. Army Corps of Engineers); Station identifier: JHAW, John Day tailwater; TDA The Dalles forebay; TDDO, The Dalles tailwater; WRNO, Warrendale; CWMW, Camas]

Date	USACE station identifier	Reason / Note
10/01/13 to 11/08/13 08/07/14 to 08/26/14 09/15/14 to 09/21/14	JHAW	Erroneously low TDG values
05/15/14 to 05/17/14 05/28/14 to 06/02/14	TDA	Failed communication between the water-quality instrument and datalogger
03/12/14	TDDO	Water-quality instrument removed from deployment pipe during maintenance
02/09/14 02/10/14 03/02/14	WRNO	Failed satellite transmissions due to inclement weather
03/31/14 to 04/02/14 06/30/14 to 07/24/14	CWMW	Failed satellite transmissions; data were recovered
07/25/14 to 07/29/14 08/16/14 to 08/25/14	CWMW	Ruptured membrane on TDG sensor
07/29/14 to 07/30/14	CWMW	Datalogger malfunction

Quality-Assurance Data

The collection of accurate data for TDG, barometric pressure, and water temperature involves several quality-assurance procedures, including side-by-side instrument comparisons in the field, sensor calibrations in the laboratory, daily checks of the data, and data review and archiving. The results of the quality-assurance procedures for water year 2014 are presented in this section.

After field deployment for 3 or 4 weeks, the TDG instruments were calibrated in the laboratory. First, the sensor was tested, with the gas-permeable membrane in place, for response to supersaturated conditions. The membrane was then removed from the sensor and allowed to dry for at least 24 hours. Before replacing the membrane, the TDG sensor was examined independently by comparing the reading of the TDG sensor to barometric pressure (100-percent saturation). Using a certified digital pressure gage (primary standard), comparisons were also made at pressures of 100, 200, and 300 mm Hg greater than barometric pressure (approximately 113-, 126-, and 139-percent saturation, respectively). The accuracy of the TDG sensors was calculated as the difference between the primary standard and the TDG sensor reading (expected minus actual) for each of the four test conditions divided by the barometric pressure and multiplied by 100 to obtain a percentage difference. Of the 81 laboratory checks that were performed on instruments after field deployment, all were within ±0.5-percent saturation (fig. 2).

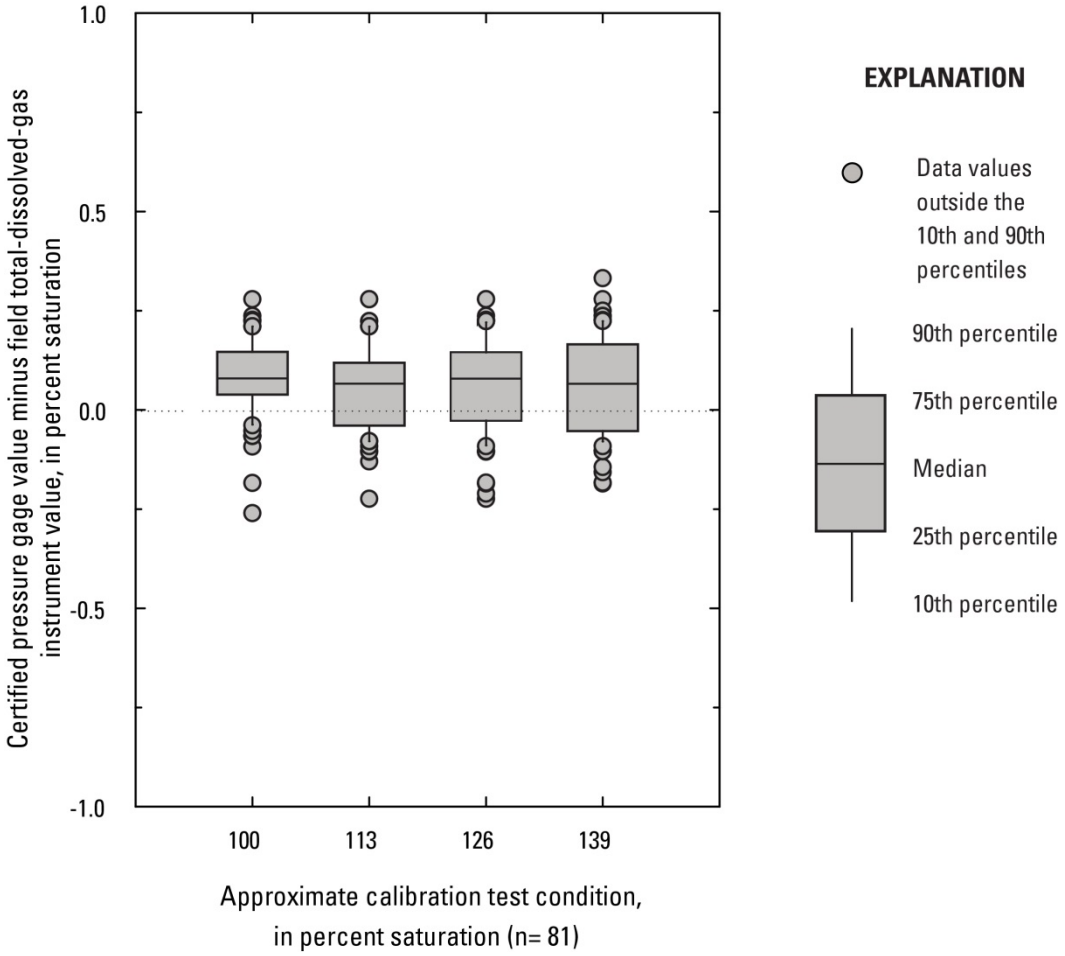


Figure 2. Boxplot showing accuracy of total-dissolved-gas sensors in the laboratory after 3 or 4 weeks of field deployment at eight monitoring stations in the lower Columbia River, Oregon and Washington, water year 2014 (number of comparison values =81).

The differences in barometric pressure, water temperature, and TDG between the secondary standard instruments and the station monitors at the end of their field deployment were measured and recorded as part of every field inspection and calibration procedure. These differences, calculated as the secondary standard values minus the field instrument values, were used to compare and quantify the accuracy and precision between the two instruments. For water temperature and TDG, the measurements were made with the secondary standard (a recently calibrated Hydrolab) positioned alongside the Hydrolab deployed in the river. A digital barometer (NIST certified through April 2015) served as the primary standard for barometric pressure. The distribution of quality-assurance data for each of the three parameters from the eight stations is shown in figures 3, 4, and 5.

Comparisons of the digital barometer and the field barometers are shown in figure 3. All of the field values were within 1 mm Hg of standard values. The secondary standard

temperature sensor and the field temperature sensor results are presented in figure 4. All differences were within 0.2 °C.

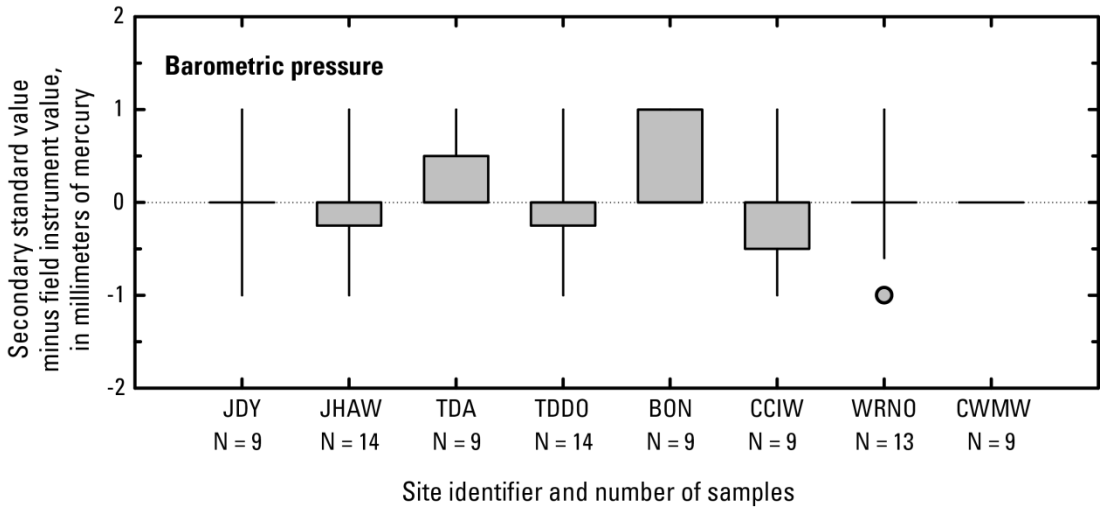


Figure 3. Boxplot showing difference between the secondary standard and the field barometers in the field after 3 or 4 weeks of deployment at eight stations in the lower Columbia River, Oregon and Washington, water year 2014. See figure 2 for explanation of boxplots.

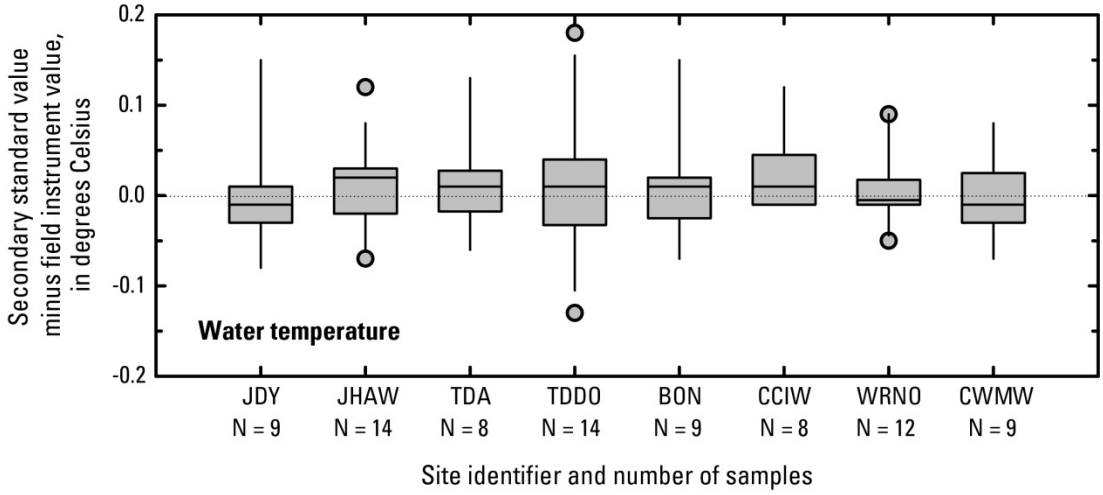


Figure 4. Boxplot showing difference between the secondary standard and the field temperature instruments in the field after 3 or 4 weeks of deployment at eight stations in the lower Columbia River, Oregon and Washington, water year 2014. See figure 2 for explanation of boxplots.

Differences between the secondary standard TDG sensor and the field TDG sensors were calculated following equilibration of the secondary standard instrument to the site conditions before removing the field instrument. The side-by-side equilibrium was considered complete after a minimum of 20 minutes when the TDG values for each sensor remained constant for 3–5 minutes. Excluding the John Day tailwater station, only 1 of the 61 TDG field checks indicated a saturation difference greater than ±1.0 percent (fig. 5). That difference (+2.0 percent) was recorded at Warrendale and was likely the result of an incomplete equilibration of the reference Hydrolab during changing instream condi-

tions. No data were deleted as a result of that field check. Of the 14 field checks at the John Day tailwater station, two were +1-2 percent and four were +2-5 percent. Three of the checks resulted in periods of deleted data (table 3). The three other checks seemed to be the result of incomplete reference Hydrolab equilibrations or changing instream conditions rather than true differences, and no data was deleted.

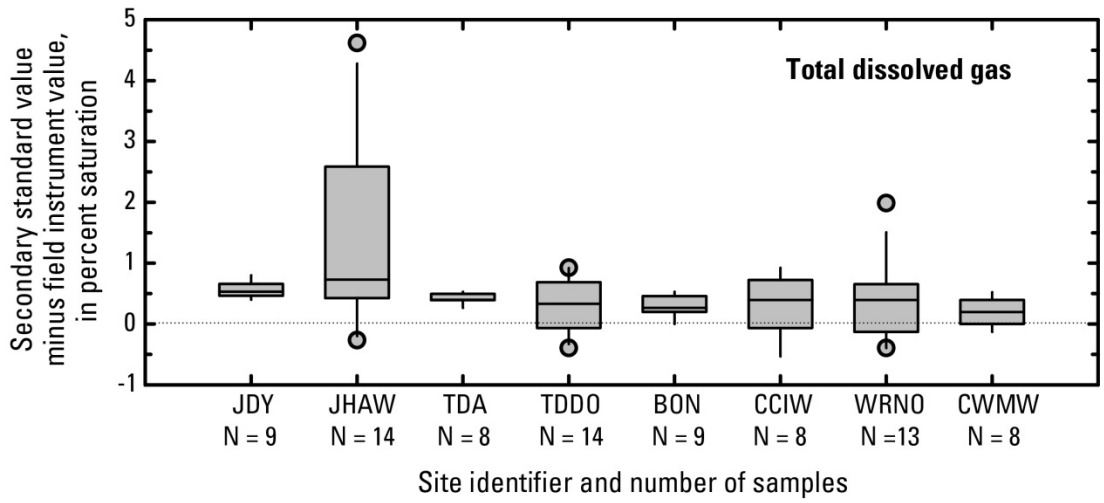


Figure 5. Boxplot showing difference between the secondary standard and the field total-dissolved-gas instruments in the field after 3 or 4 weeks of deployment at eight stations in the lower Columbia River, Oregon and Washington, water year 2014. See figure 2 for explanation of boxplots.

Effects of Spill on Total-Dissolved-Gas Saturation

The relation between spill discharge at the dams and TDG at the corresponding tailwater station or stations are shown for John Day Dam (fig. 6), The Dalles Dam (fig. 7), and Bonneville Dam (fig. 8). For spill between approximately 25,000 and 70,000 ft^3/s, the TDG saturation downstream of John Day Dam remained relatively level or slightly decreasing between 111 percent and 116 percent. For spill greater than 70,000 ft^3/s, the TDG saturation increased steadily with greater spill. At the stations downstream of The Dalles Dam and Bonneville Dam, the TDG saturation values generally increased with greater spill over the entire range of values.

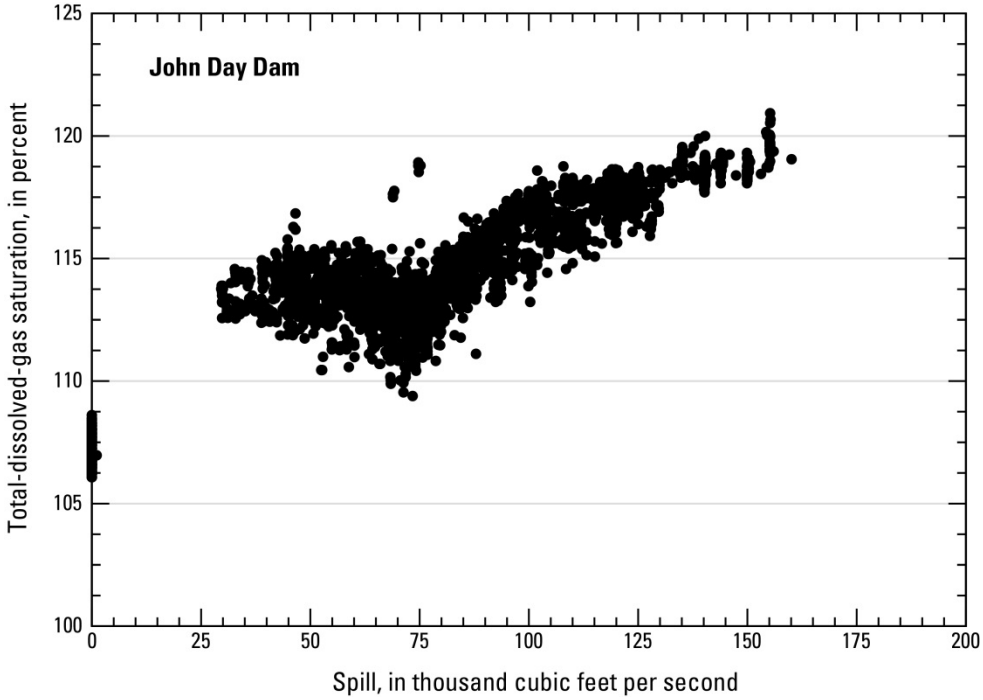


Figure 6. Graph showing relation of total-dissolved-gas saturation downstream of John Day Dam and spill from John Day Dam, lower Columbia River, Oregon and Washington, April 1–August 31, 2014.

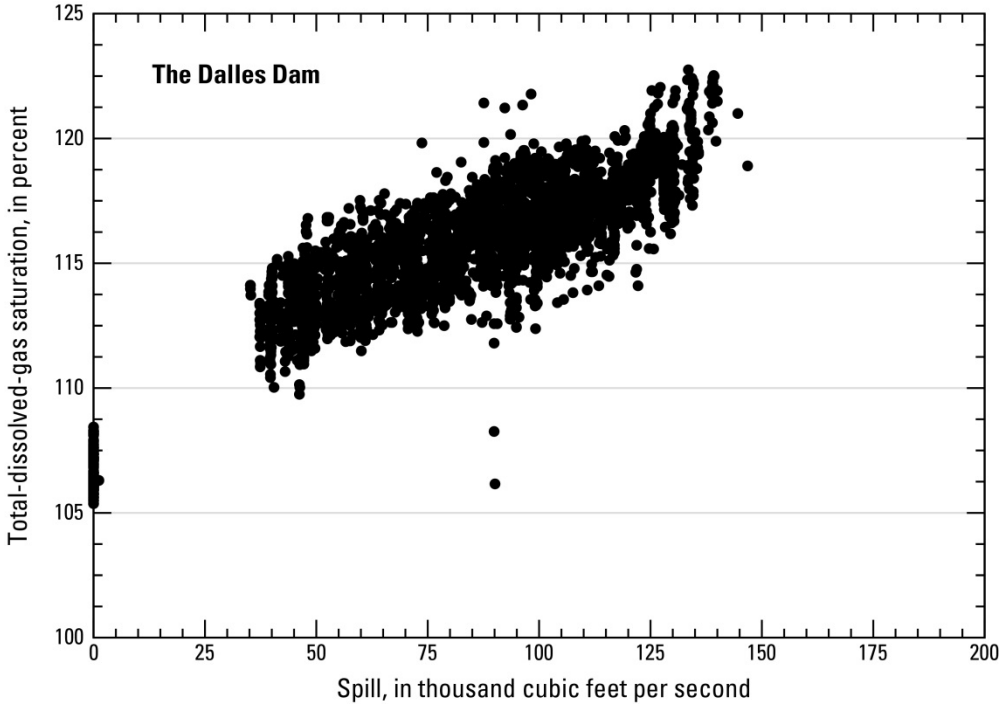


Figure 7. Graph showing relation of total-dissolved-gas saturation downstream of The Dalles Dam and spill from The Dalles Dam, lower Columbia River, Oregon and Washington, April 1–August 31, 2014.

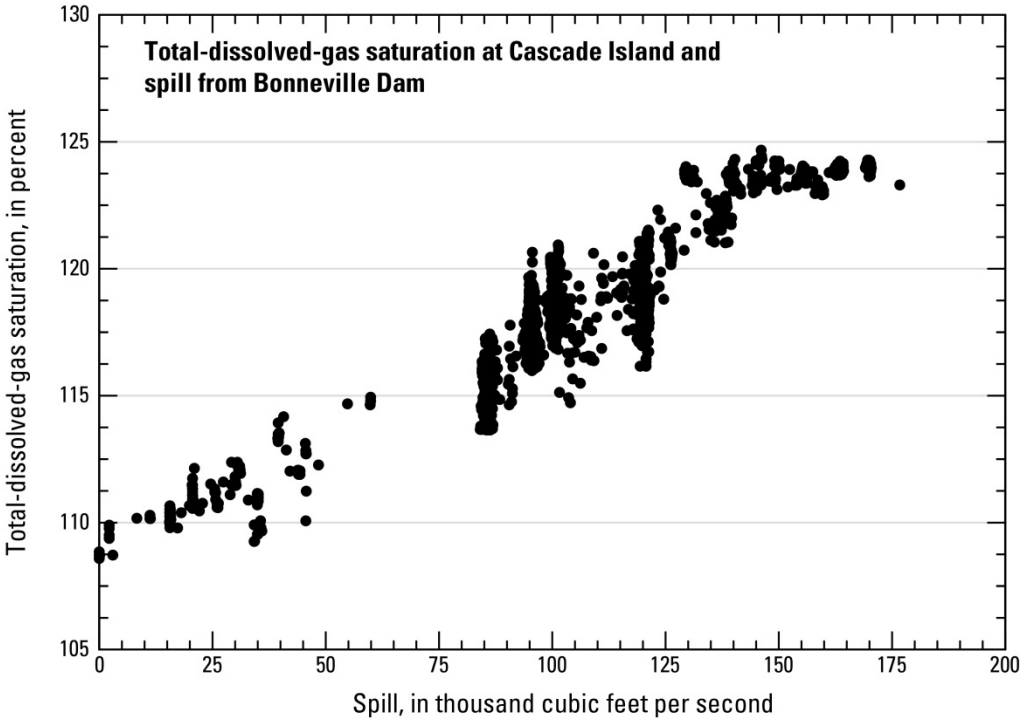


Figure 8. Graph showing relation of total-dissolved-gas saturation downstream of Bonneville Dam at Cascade Island and spill from Bonneville Dam, lower Columbia River, Oregon and Washington, April 1–August 31, 2014

Total-Dissolved-Gas and Water-Temperature Data

The distribution of hourly TDG values for the 2014 spill season (April 1 through August 31, 2014) is shown in figure 9. Time-series plots of the hourly TDG percent saturation and the spill at the closest upstream dam are shown in figures 10 through 17.

The hourly values for water temperature are shown in figures 18–22. Water temperatures at the forebay stations were approximately equal to the temperatures at the tailwater stations, except during short periods at the John Day stations and at the Bonneville forebay and Warrendale stations.

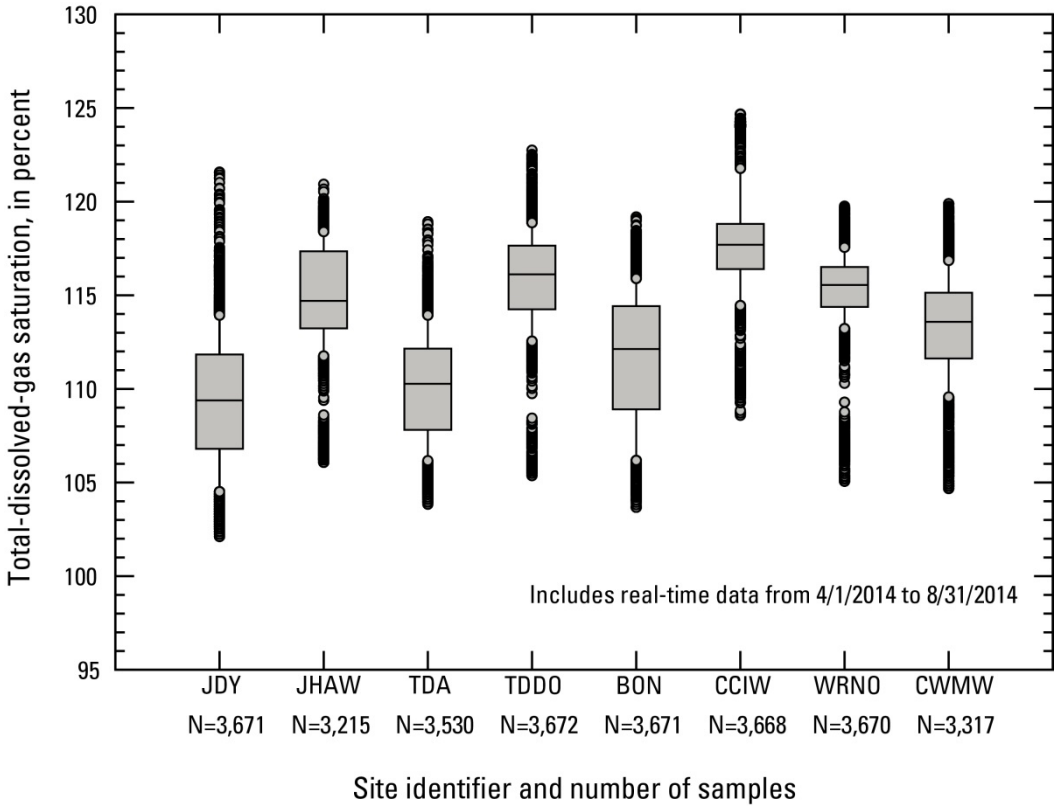


Figure 9. Boxplot showing distributions of hourly total-dissolved-gas data, lower Columbia River, Oregon and Washington, April 1–August 31, 2014. See figure 2 for explanation of boxplots.

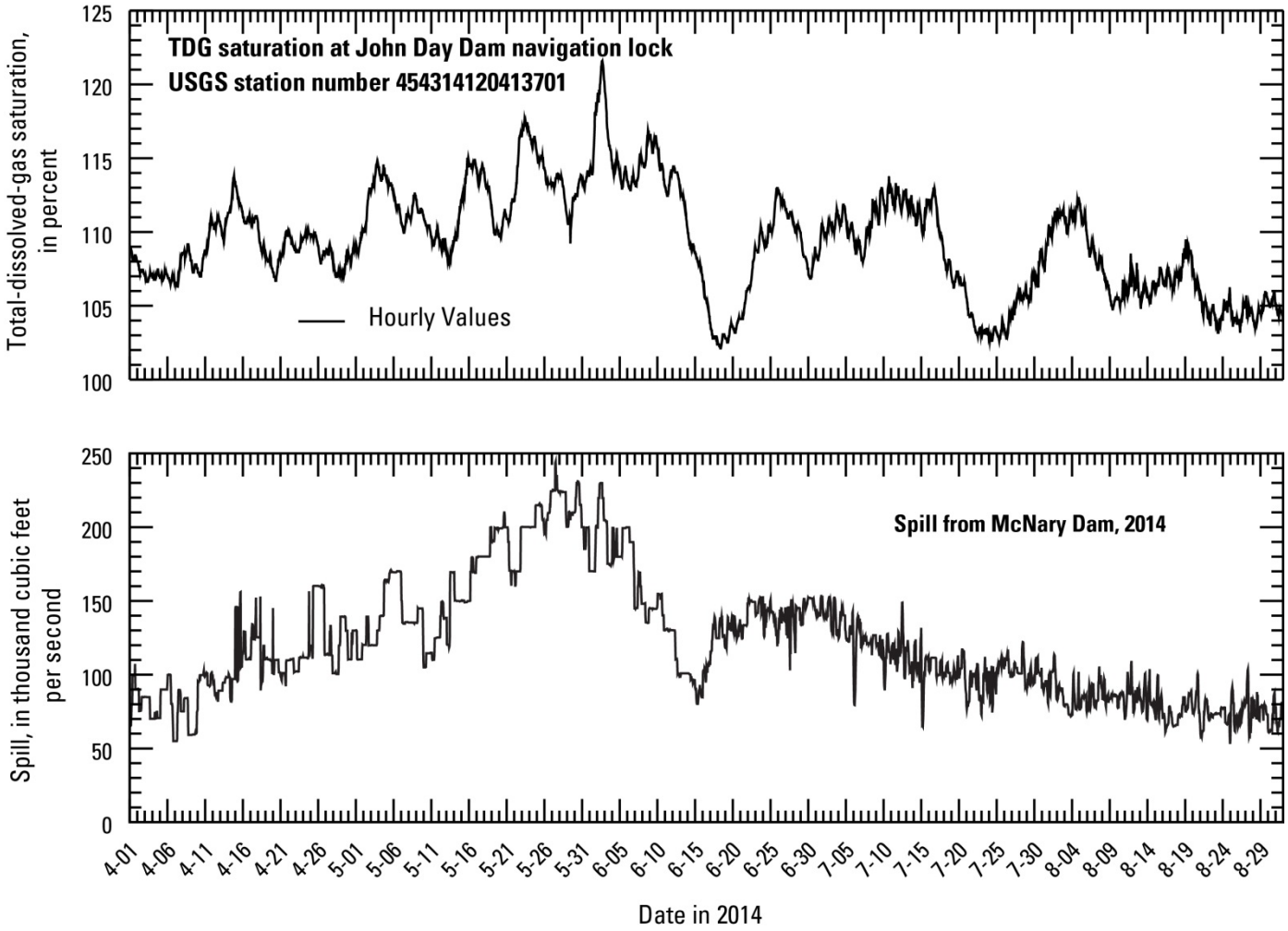


Figure 10. Graphs showing total-dissolved-gas (TDG) saturation at John Day navigation lock and spill from McNary Dam (76 river miles upstream of John Day Dam), lower Columbia River, Oregon and Washington, April 1–August 31, 2014.

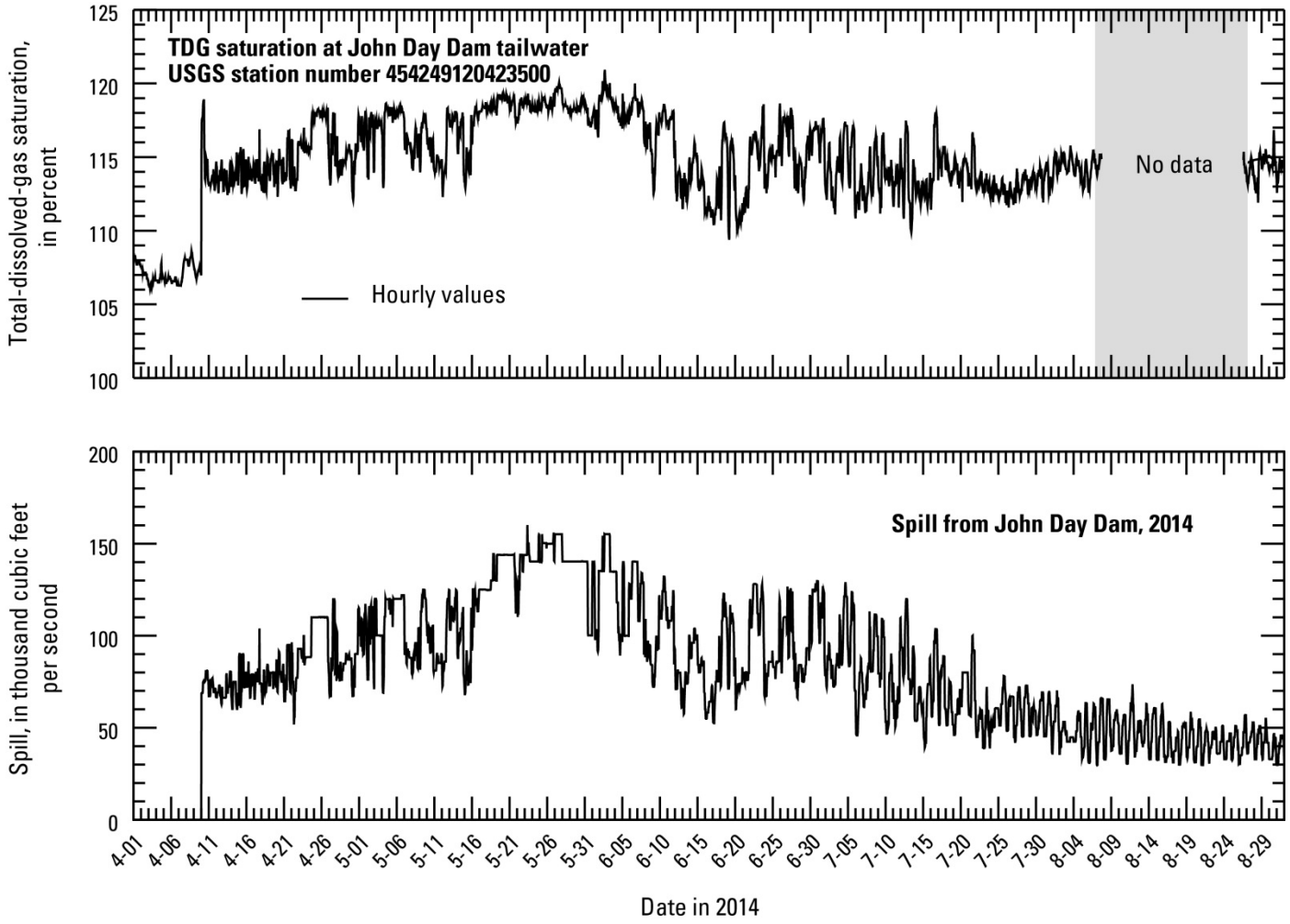


Figure 11. Graphs showing total-dissolved-gas (TDG) saturation at John Day tailwater and spill from John Day Dam, lower Columbia River, Oregon and Washington, April 1–August 31, 2014.

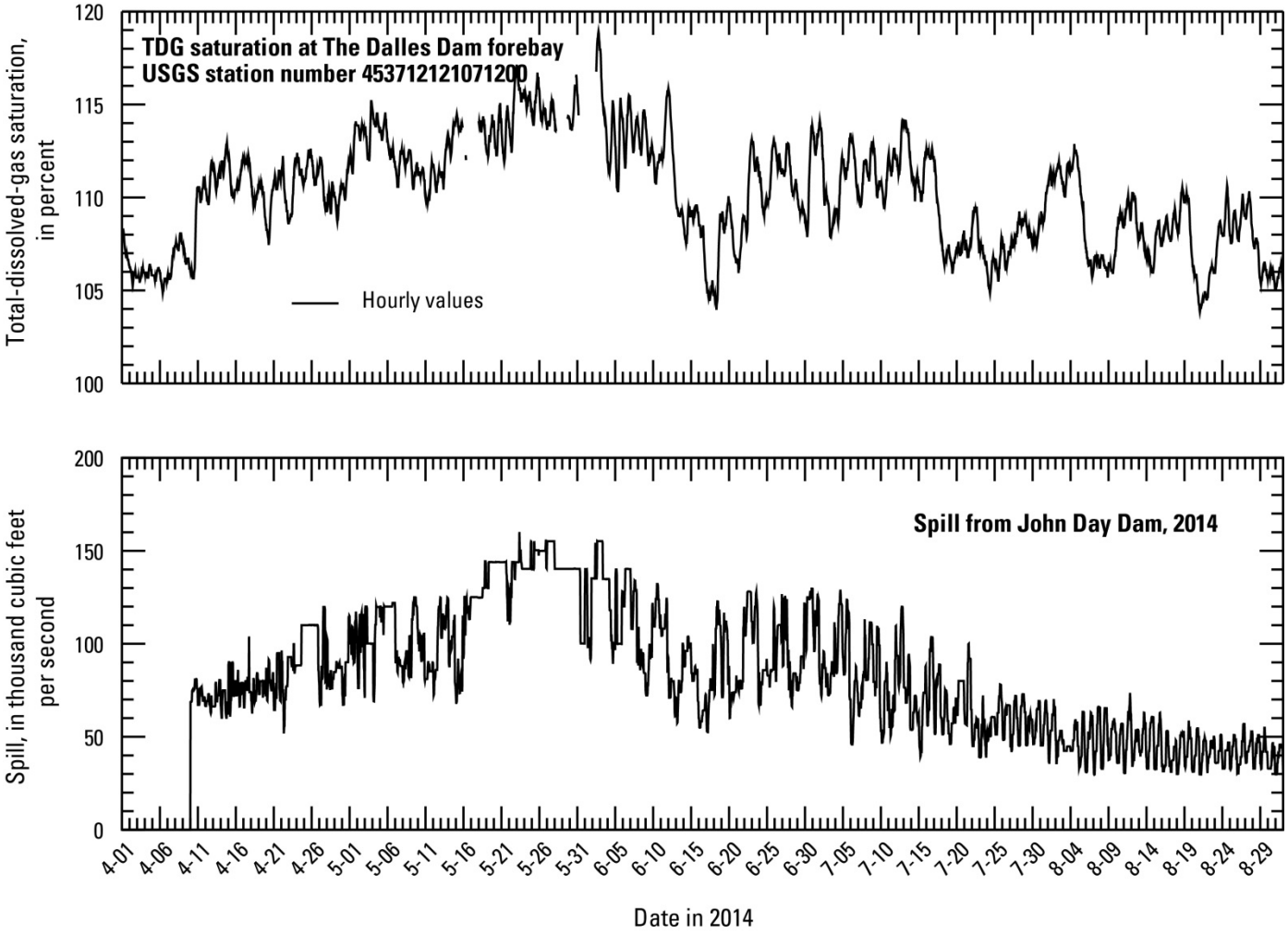


Figure 12. Graphs showing total-dissolved-gas (TDG) saturation at The Dalles forebay and spill from John Day Dam, lower Columbia River, Oregon and Washington, April 1–August 31, 2014.

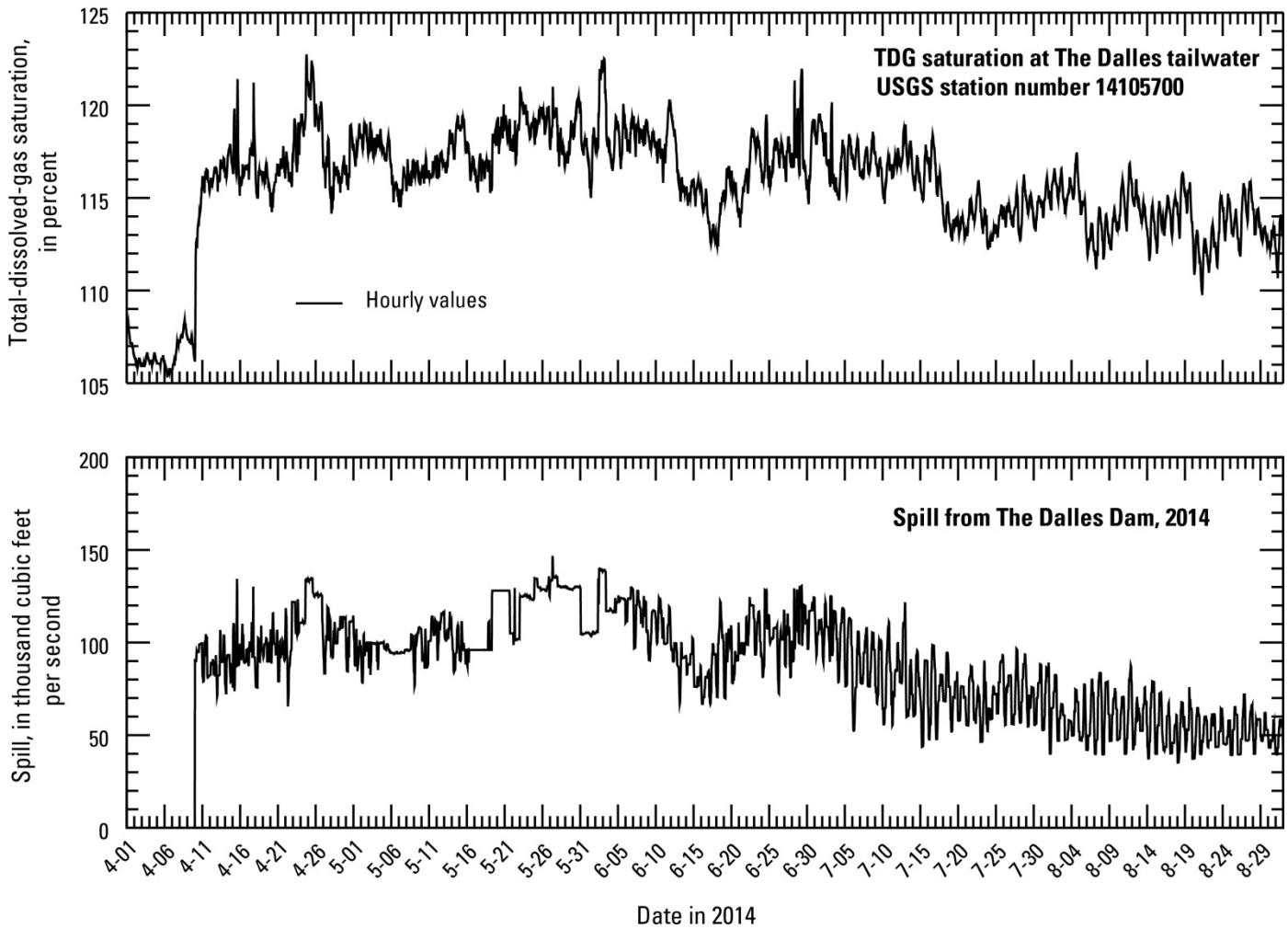


Figure 13. Graphs showing total-dissolved-gas (TDG) saturation at The Dalles tailwater and spill from The Dalles Dam, lower Columbia River, Oregon and Washington, April 1–August 31, 2014.

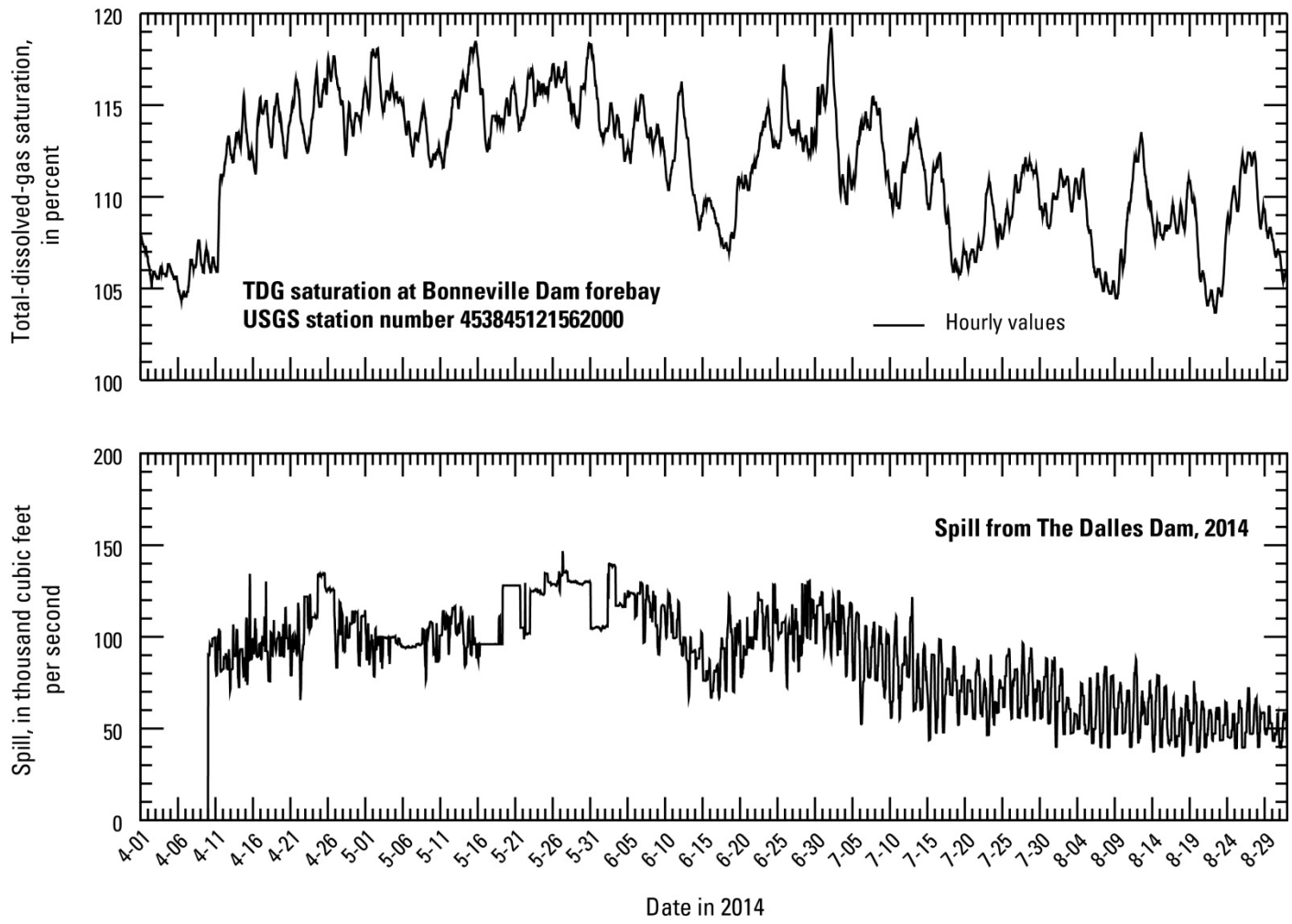


Figure 14. Graphs showing total-dissolved-gas (TDG) saturation at Bonneville forebay and spill from The Dalles Dam, lower Columbia River, Oregon and Washington, April 1–August 31, 2014.

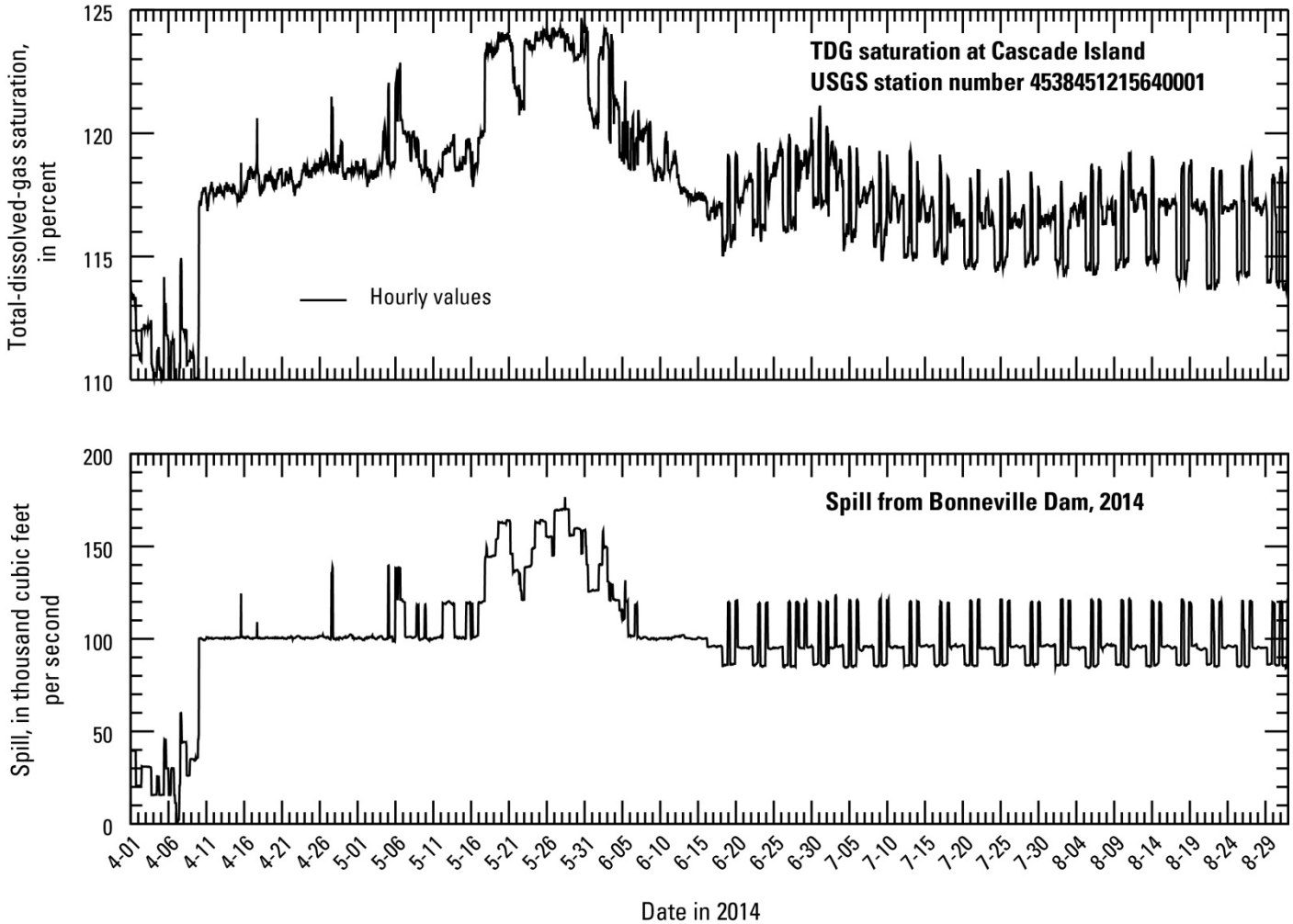


Figure 15. Graphs showing total-dissolved-gas (TDG) saturation at Cascade Island and spill from Bonneville Dam, lower Columbia River, Oregon and Washington, April 1–August 31, 2014.

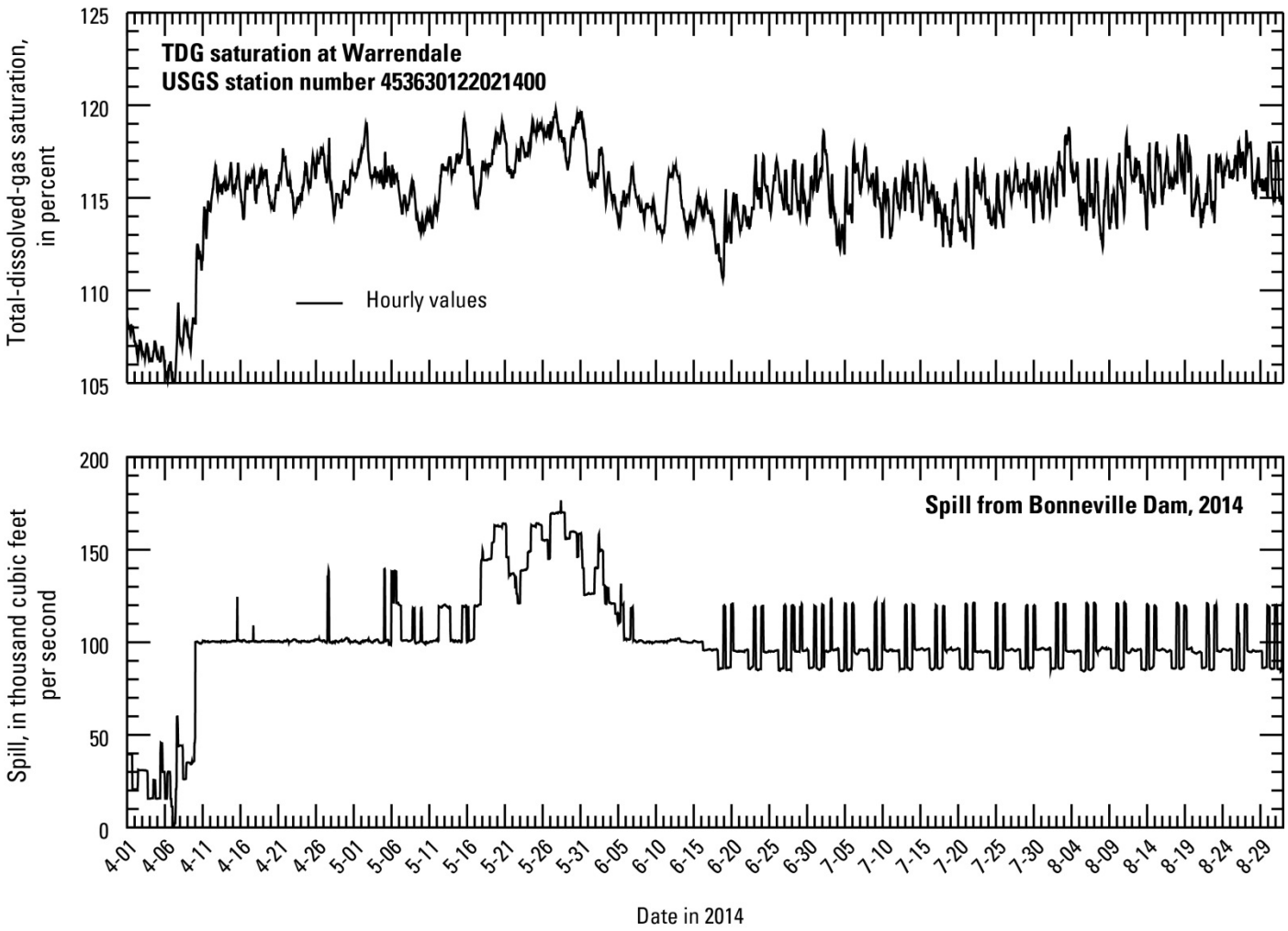


Figure 16. Graphs showing total-dissolved-gas (TDG) saturation at Warrendale and spill from Bonneville Dam, lower Columbia River, Oregon and Washington, April 1–August 31, 2014.

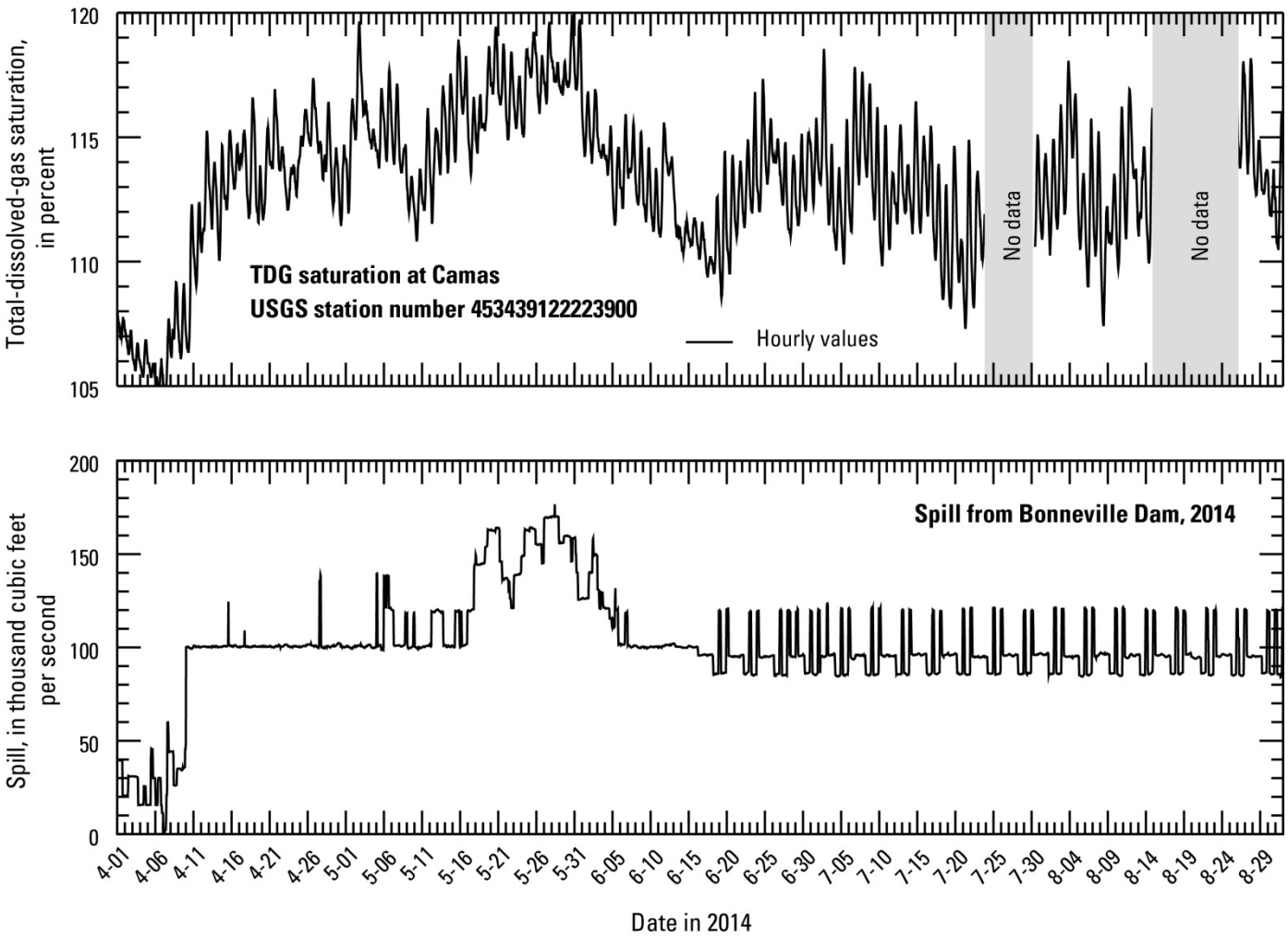


Figure 17. Graphs showing total-dissolved-gas (TDG) saturation at Camas and spill from Bonneville Dam, lower Columbia River, Oregon and Washington, April 1–August 31, 2014.

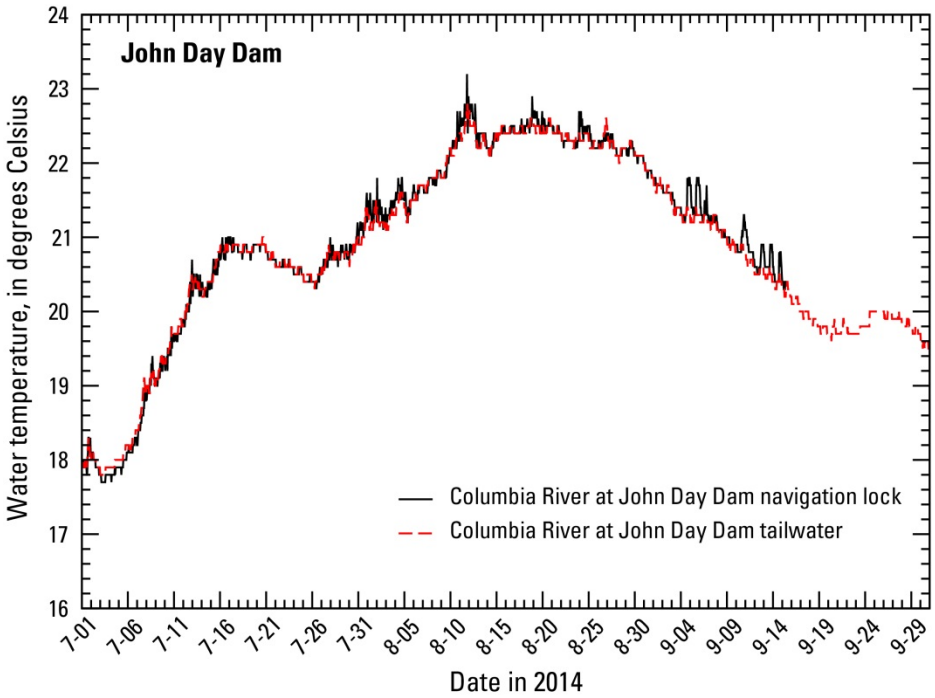


Figure 18. Graph showing hourly water temperature values upstream of John Day Dam and downstream of John Day Dam, lower Columbia River, Oregon and Washington, summer 2014.

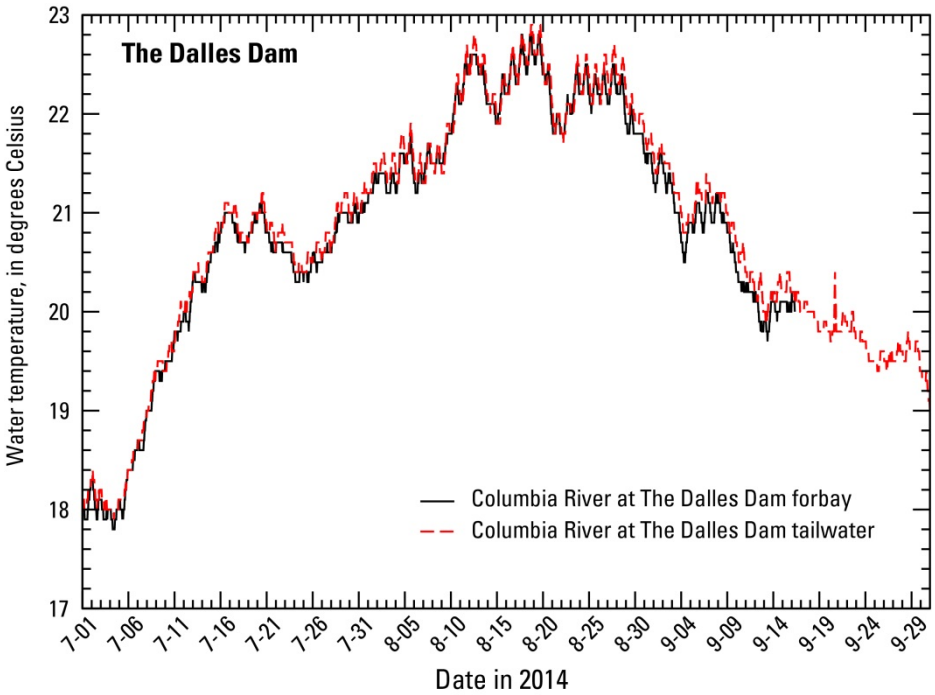


Figure 19. Graph showing hourly water temperature values upstream and downstream of The Dalles Dam, lower Columbia River, Oregon and Washington, summer 2014.

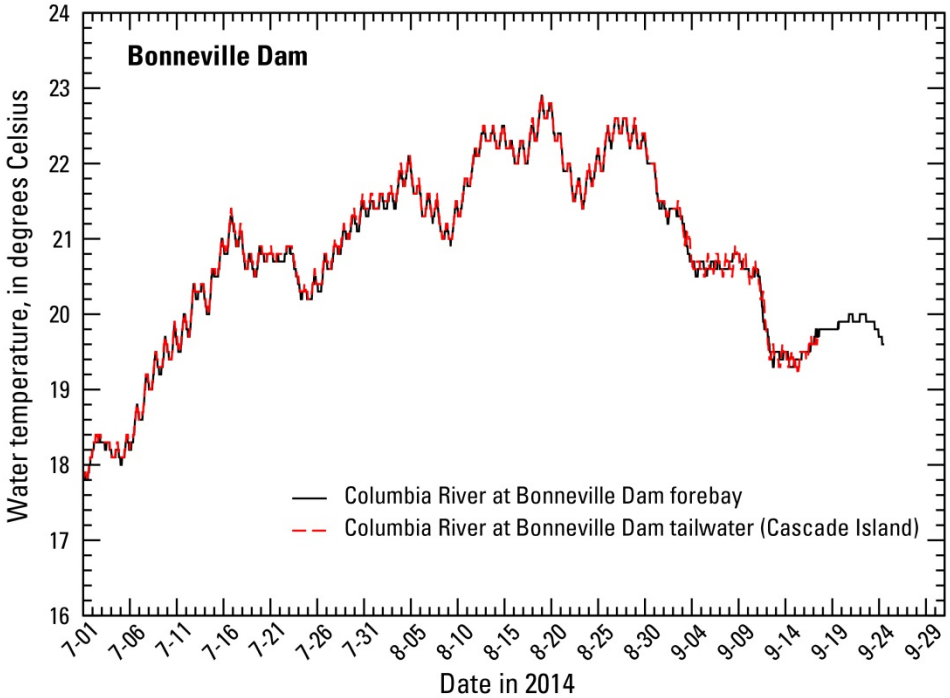


Figure 20. Graph showing hourly water temperature values upstream of Bonneville Dam and downstream of Bonneville Dam at Cascade Island, lower Columbia River, Oregon and Washington, summer 2014.

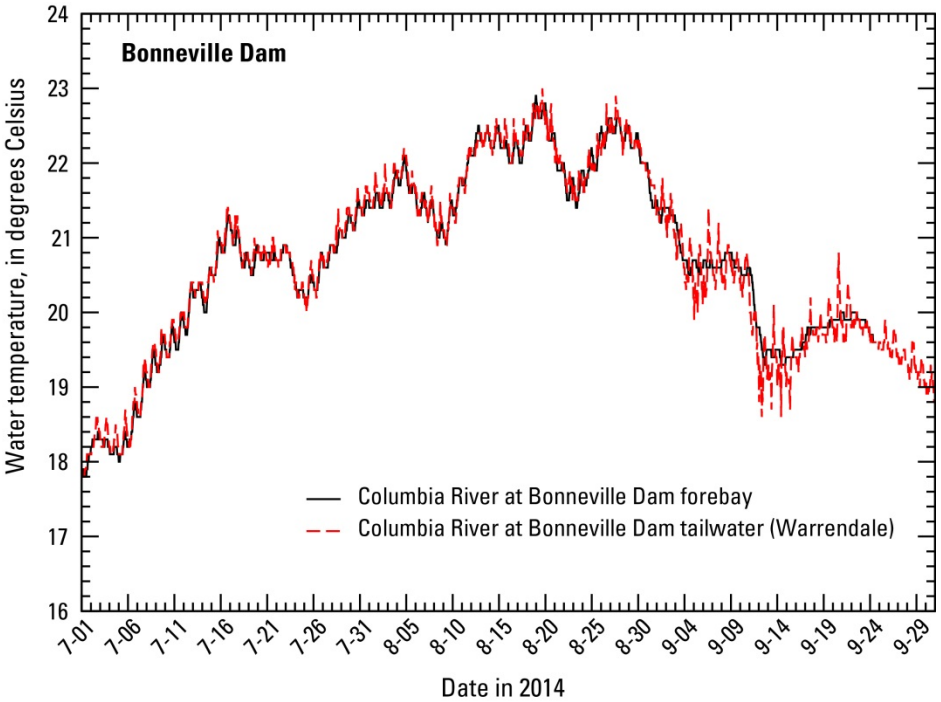


Figure 21. Graph showing hourly water temperature values upstream of Bonneville Dam and downstream of Bonneville Dam at Warrendale, lower Columbia River, Oregon and Washington, summer 2014.

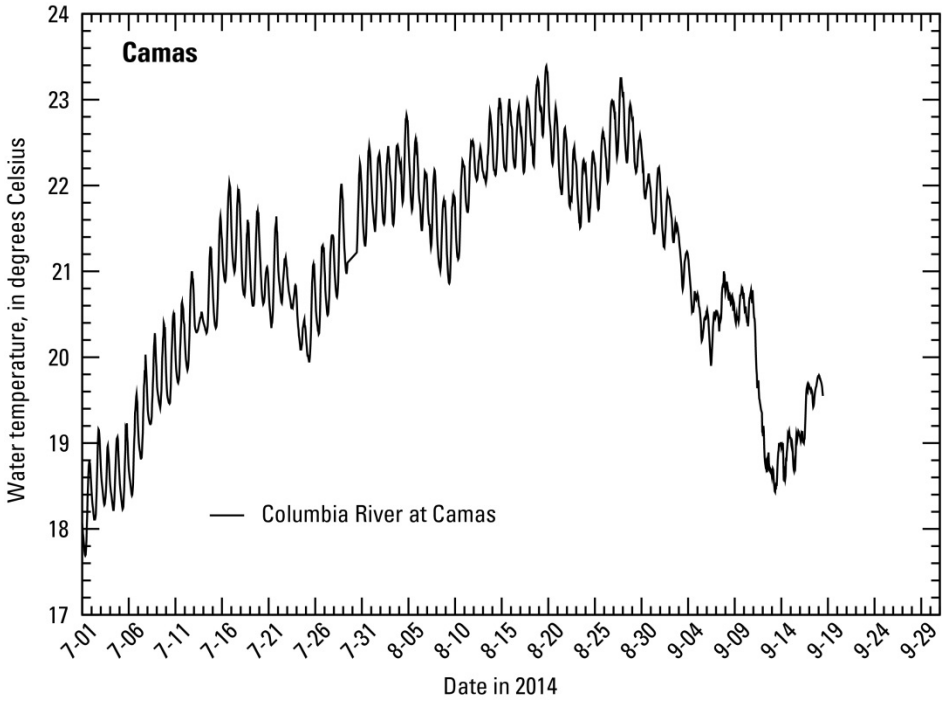


Figure 22. Graph showing hourly water temperature values downstream of Bonneville Dam at Camas, lower Columbia River, Oregon and Washington, summer 2014.

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