Appendix K

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

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, 2008: Quality-Assurance Data and Comparison to Water-Quality Standards

By Dwight Q. Tanner, Heather M. Bragg, and Matthew W. Johnston

Open-File Report 2008–1357

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Conversion Factors and Datum

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

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

Total Dissolved Gas and Water Temperature in the Lower Columbia River, Oregon and Washington, 2008: Quality-Assurance Data and Comparison to Water-Quality Standards

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Significant Findings

When water is released through the spillways of dams, air is entrained in the water, increasing the downstream concentration of dissolved gases. Excess dissolved-gas concentrations can have adverse effects on freshwater aquatic life. The U.S. Geological Survey (USGS), in cooperation with the U.S. Army Corps of Engineers, collected dissolved-gas and water-temperature data at eight monitoring stations on the lower Columbia River in Oregon and Washington in 2008. Significant findings from the data include:

- During the spill season of April through August 2008, hourly values of total-dissolved-gas (TDG) concentration were occasionally larger than 115-percent saturation for the forebay stations (John Day navigation lock, The Dalles forebay, Bonneville forebay, and Camas). Hourly values of TDG concentration were occasionally larger than 120-percent saturation for tailwater stations (John Day tailwater, The Dalles tailwater, and Cascade Island).
- From late July to September 2008, water temperatures were greater than 20°C (degrees Celsius) at seven stations on the lower Columbia River. According to the State of Oregon temperature standard, the 7-day average maximum temperature of the lower Columbia River should not exceed 20°C; Washington regulations state that the 1-day maximum should not exceed 20°C as a result of human activities.
- Each of the in situ field checks of TDG sensors with a secondary standard was within ± (plus or minus) 1-percent saturation after 3 to 4 weeks of deployment in the river. All field checks of barometric pressure were within ±2.0 millimeters of mercury of a secondary standard, and water-temperature field checks were all within ±0.2°C.
- For the eight monitoring stations in water year 2008, an average of 99.6 percent of the TDG data were received in real time by the USGS satellite downlink and were within 1-percent saturation of the expected value on the basis of calibration data, replicate quality-control measurements in the river, and comparison to ambient river conditions at adjacent stations. Data received from the individual stations ranged from 98.8 to 100.0 percent complete.

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 fill 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, increasing the concentration of dissolved gases (known as total dissolved gas [TDG]) downstream of the spillways. TDG conditions greater than 110-percent saturation can cause gas-bubble trauma in fish and adversely affect other aquatic organisms (U.S. Environmental Protection Agency, 1986).

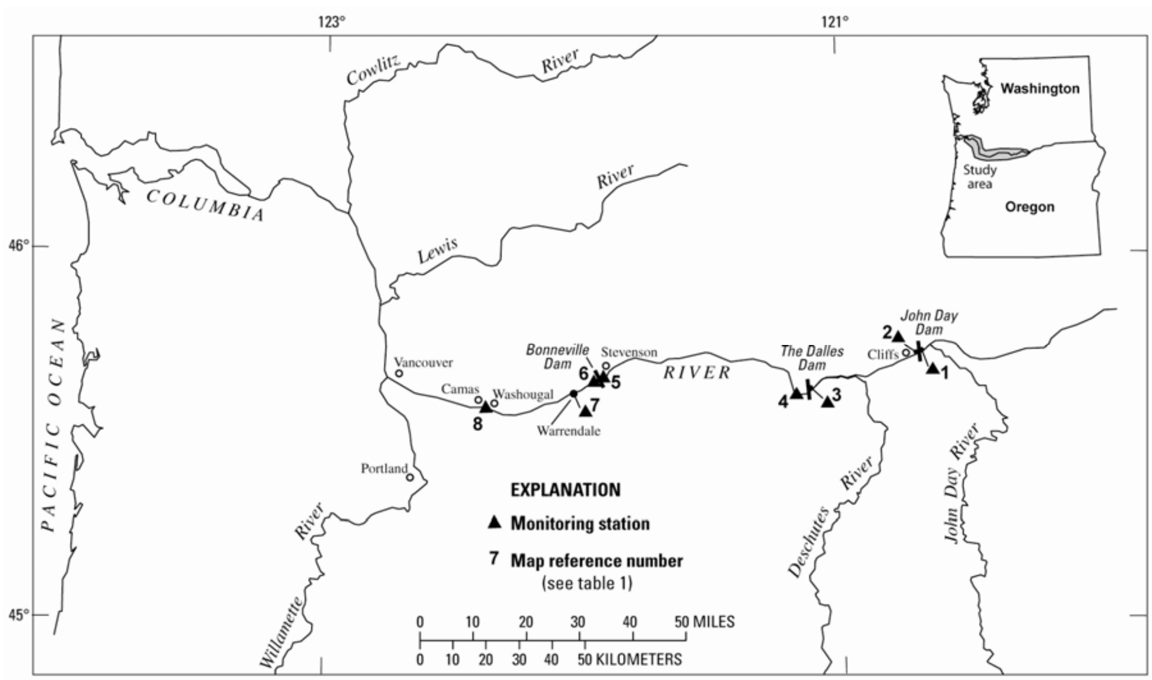

Figure 1. Location of total-dissolved-gas monitoring stations, lower Columbia River, Oregon and Washington, water year 2008.

The USACE regulates spill and streamflow to minimize the production of excess TDG downstream of its dams, but also with the goal of providing for fish passage with spilled water (rather than passage through the turbines). Consequently, the States of Oregon and Washington issue variances to the TDG water-quality standards during the spring and summer. To monitor compliance with these variances, the USACE oversees the collection of real-time TDG and water-temperature data upstream and downstream of Columbia River Basin dams in a network of monitoring stations. Data from the lower Columbia River monitoring stations are available within about 1 hour of current time.

Background

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 survival in the lower Columbia River. The 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. Current and historical TDG and water-temperature data can be accessed at http://oregon.usgs.gov/projs_dir/pn307.tdg/ (accessed October 31, 2008). Nine reports, which were published for water years 1996 and 2000–2007, contain TDG data, quality-assurance data, and descriptions of the 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).

To assure data quality for managing and modeling TDG in the lower Columbia River, hourly data for 2008 were reviewed relative to laboratory and field measurements made during instrument calibrations and daily intersite comparisons. A small fraction of the TDG data was deleted because the data were not of suitable quality. The hourly data were stored in a USGS database and in a USACE database (http://www.nwd-wc.usace.army.mil/tmt/wcd/tdg/months.html, accessed October 31, 2008). The USACE database also includes hourly discharge and spill data.

Purpose and Scope

TDG monitoring in the lower Columbia River provides the USACE with (1) real-time data for managing streamflow and spill at its project dams, (2) reviewed TDG data to evaluate conditions relative to water-quality standards, and (3) data for modeling the effect of various management alternatives of streamflow and spill on TDG levels.

This report describes the TDG data and related quality-assurance data from eight monitoring stations 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 2008 (October 1, 2007, through September 30, 2008) include hourly measurements of TDG pressure, barometric pressure, water temperature, and probe depth. Five of the stations (John Day navigation lock, The Dalles forebay, Bonneville forebay, Cascade Island, and Camas) were operated from February or March to September 2008, which is the usual time of spill from the dams. John Day tailwater and The Dalles tailwater were operated year-round and Warrendale was operated year-round except for May to mid-September, when station operation was stopped at the request of the USACE.

Table 1. Total-dissolved-gas monitoring stations, lower Columbia River, Oregon and Washington, water year 2008

[Map 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 is referenced to NAD 27.]

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 2008
1	JDY	215.7	454314120413701	Columbia River at John Day navigation lock, Washington (John Day navigation lock)	45° 43’ 14”	120° 41’ 37”	10/01/07–10/04/07 and 03/19/08–09/16/08
2	JHAW	214.7	454249120423500	Columbia River, right bank, near Cliffs, Washington (John Day tailwater)	45° 42’ 49”	120° 42’ 35”	Year-round
3	TDA	192.6	453712121071200	Columbia River at The Dalles Dam forebay, Washington (The Dalles forebay)	45° 37’ 12”	121° 07’ 12”	10/01/07–10/05/07 and 03/19/08–09/16/08
4	TDDO	188.9	14105700	Columbia River at The Dalles, Oregon (The Dalles tailwater)	45° 36’ 27”	121° 10’ 20”	Year-round
5	BON	146.1	453845121562000	Columbia River at Bonneville Dam forebay, Washington (Bonneville forebay)	45° 38’ 45”	121° 56’ 20”	02/27/08–09/17/08
6	CCIW	145.9	453845121564001	Columbia River at Cascade Island, Washington (Cascade Island)	45° 38’ 45”	121° 56’ 40”	10/01/07–10/05/07 and 02/27/08–09/30/08
7	WRNO	140.4	453630122021400	Columbia River, left bank, near Dodson, Oregon (Warrendale)	45° 36’ 30”	122° 02’ 14”	10/01/07–05/01/08 and 09/17/08–09/30/08
8	CWMW	121.7	453439122223900	Columbia River, right bank, at Washougal, Washington (Camas)	45° 34’ 39”	122° 22’ 39”	02/27/08–09/23/08

Methods of Data Collection

Methods of data collection for TDG, barometric pressure, and water temperature are described in detail in Tanner and Johnston (2001). A summary of these methods follows:

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

The eight fixed-station monitors were calibrated every 3 weeks, except from October 2007 through March 2008, when they were calibrated at 4-week intervals. At the beginning of the monitoring season in February or March, a new TDG membrane was installed on each Hydrolab. The field calibration procedure was as follows: A Hydrolab (which was calibrated several days before the field trip and used as a secondary standard) was deployed alongside of the field Hydrolab for a period of up to 1 hour to obtain check measurements of TDG and water temperature prior to removing the field Hydrolab (which had been deployed for 3 or 4 weeks). The field Hydrolab was then replaced with another Hydrolab that had been calibrated recently at the laboratory and the secondary standard used again to check TDG and temperature measured by the newly deployed Hydrolab in the river. The equilibration process for the newly placed Hydrolab usually lasted about 1 hour. The electronic barometer at the fixed station was calibrated using a portable barometer (Suunto, Escape 203) that had been recently calibrated at the National Weather Service facility in Portland.

During each field calibration, the minimum compensation depth was calculated to determine whether the Hydrolab was positioned at an appropriate depth to measure TDG. This minimum compensation depth, which was calculated according to Colt (1984, p. 104), is the depth above which de-gassing will occur due to decreased hydrostatic pressure. To measure TDG accurately, the Hydrolabs were positioned at a depth below the calculated minimum compensation depth whenever possible.

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

Summary of Total-Dissolved-Gas Data Completeness and Quality

A summary of USGS TDG data completeness and quality for water year 2008 is shown in table 2. (The USACE satellite downlink was a parallel system, so the amount and quality of data received by the USACE were almost identical). Data in table 2 were based on the total amount of hourly TDG data that could have been collected during the monitoring season. Any hour without TDG pressure data or barometric pressure data was counted as an hour of missing data for TDG in percent saturation, which is calculated as TDG pressure divided by the barometric pressure (both in mm Hg) multiplied by 100. The fourth column in table 2 shows the percentages of data that were received in real time and passed quality-assurance checks. TDG data were considered to meet quality-assurance standards if they were within ± (plus or minus) 1 percent saturation of the expected value, based on calibration data, replicate quality-control measurements in the river, and daily comparisons to ambient river conditions at adjacent stations. At each station, at least 98.8 percent of the data were received in real time by the USGS downlink and met quality-control checks, with an overall average of 99.6 percent (table 2).

Table 2. Total-dissolved-gas data completeness and quality, lower Columbia River, Oregon and Washington, water year 2008.

[Results are based on values in USGS database; TDG, total dissolved gas]

Abbreviated station name	Planned monitoring in hours	Number of missing or deleted hourly values	Percentage of real-time TDG data passing quality assurance
John Day navigation lock (JDY)	4,427	15	99.7
John Day tailwater (JHAW)	8,784	103	98.8
The Dalles forebay (TDA)	4,450	3	99.9
The Dalles tailwater (TDDO)	8,784	2	100.0
Bonneville forebay (BON)	4,873	1	100.0
Cascade Island (CCIW)	5,305	30	99.4
Warrendale (WRNO)	5,449	18	99.7
Camas (CWMW)	5,010	15	99.7
TOTAL	47,082	187	99.6

Table 3 lists the major portions of data that were either missing from the database (for example, when data telemetry failed) or data that were later deleted from the database because they did not meet quality-assurance standards. Table 3 includes temperature data, whereas table 2 has only TDG data. The John Day tailwater station had the most missing or deleted data. TDG data were lost at that station from August 22 until August 25 due to a torn membrane. These data could not be recovered. A torn membrane was also the cause of missing data at Cascade Island on August 13–14. However, duplicate data were able to be recovered from the data logger, because there is a dual sensor system at this station. At Camas, there were several episodes in May and June of missing data, probably due to ships docking overnight and blocking the DCP transmitting antenna. At the Warrendale station, real-time data were lost January 26–27, probably due to ice affecting the DCP antenna. These datasets from Camas and Warrendale were both recovered from the data logger in the field and restored to the databases. If the recovered data from Cascade Island, Camas, and Warrendale were included in the fourth column of table 2, the percentage of TDG data passing quality assurance would be 100 percent for those stations.

Table 3. Major portions of missing or deleted data, lower Columbia River, Oregon and Washington, water year 2008.

[USACE station identifier: JDY, John Day navigation lock; JHAW, John Day tailwater; CCIW, Cascade Island; WRNO, Warrendale; CWMW, Camas. Parameter abbreviation: TDG, total dissolved gas; BP, barometric pressure; WT, water temperature; DCP, data-collection platform]

Date and Time	USACE station identifier	Parameter	Reason / Notes
8/19/08 01:00 through 8/20/08 12:00	JDY	BP	Short circuit in DCP; data not recovered
8/22/08 14:00 through 8/25/08 12:00	JHAW	TDG	Torn membrane; data not recovered
8/13/08 07:00 through 8/14/08 09:00	CCIW	TDG	Torn membrane; data recovered from backup sensor
1/26/08 17:00 through 1/27/08 09:00	WRNO	TDG, BP, WT	Transmission antenna covered by ice; data recovered
5/3–5/4/08 6/15–6/16/08 6/22–6/23/08	CWMW	TDG, BP, WT	For 5 hours each of these weekends, the transmission antenna was blocked by a ship at dock; data recovered

Quality-Assurance Data

Data collection for TDG, barometric pressure, and water temperature involves several quality-assurance procedures, including calibration of instruments in the field and in the laboratory, daily checks of the data, and data review and archive. These methods are explained in detail in Tanner and Johnston (2001), and the results of the quality-assurance data for water year 2008 are presented in this section.

After field deployment for 3 or 4 weeks, the TDG sensors were calibrated in the laboratory. First, the instrument was tested, with the membrane in place, for response to increased pressure and to supersaturation conditions. The membrane was then removed from the sensor and allowed to dry for approximately 24 hours. Before replacing the membrane, the TDG sensor was examined independently. The calibration test procedure compared 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 above barometric pressure (approximately 113-percent, 126-percent, and 139-percent saturation, respectively). The accuracy of the TDG sensors was calculated by computing the difference between the expected reading and the TDG sensor reading (expected minus actual) for each of the four test conditions and dividing by the barometric pressure. All sensor readings were within 0.6-percent saturation (fig. 2). Of the 93 laboratory checks that were performed, only 4 indicated that a sensor needed recalibrating because the difference between the expected reading and the sensor reading exceeded 2 mm Hg. The largest difference between expected versus actual TDG pressure was 4 mm Hg.

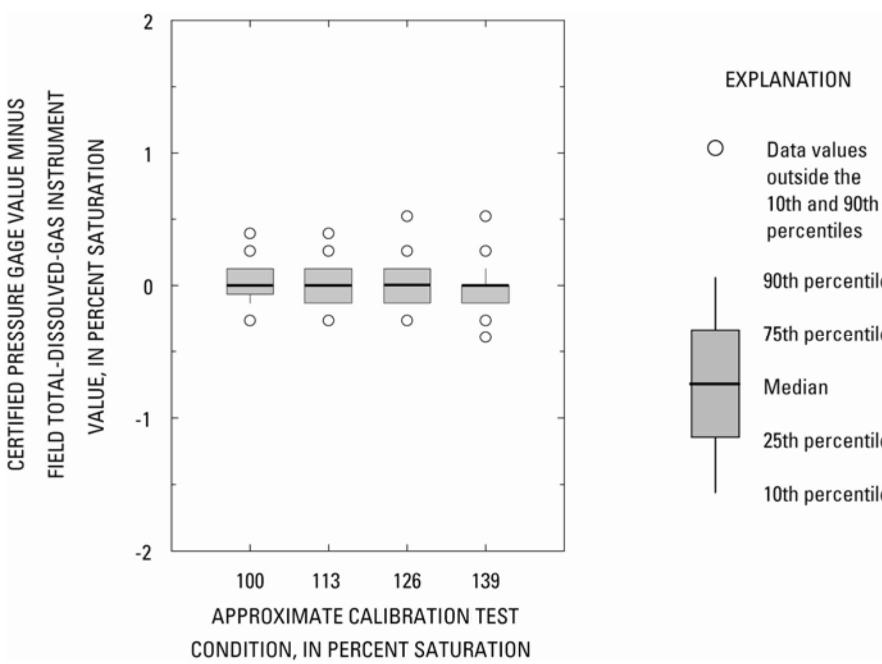

Figure 2. Accuracy of total-dissolved-gas sensors after 3 or 4 weeks of field deployment at eight monitoring stations in the lower Columbia River, Oregon and Washington, water year 2008 (number of comparison values = 93).

The differences in barometric pressure, water temperature, and TDG between the secondary standard instruments and the fixed-station monitors after field deployment were measured and recorded as part of the 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 independent instruments. For water temperature and TDG, the measurements were made in situ with the secondary standard (a recently calibrated Hydrolab) positioned alongside the field Hydrolab in the river. A digital barometer, calibrated every 6 to 8 weeks, served as the secondary standard for barometric pressure. Figures 3, 4, and 5 illustrate the distribution of quality-assurance data for each of the three parameters from all eight stations.

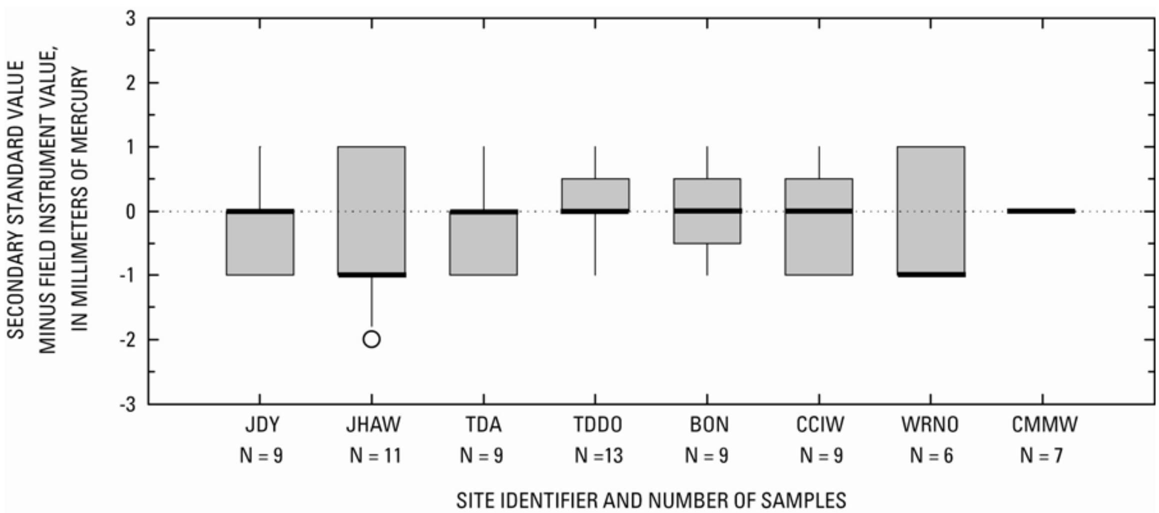

Figure 3. Difference between the secondary standard and the field barometers after 3 or 4 weeks of field deployment at eight stations in the lower Columbia River, Oregon and Washington, water year 2008.

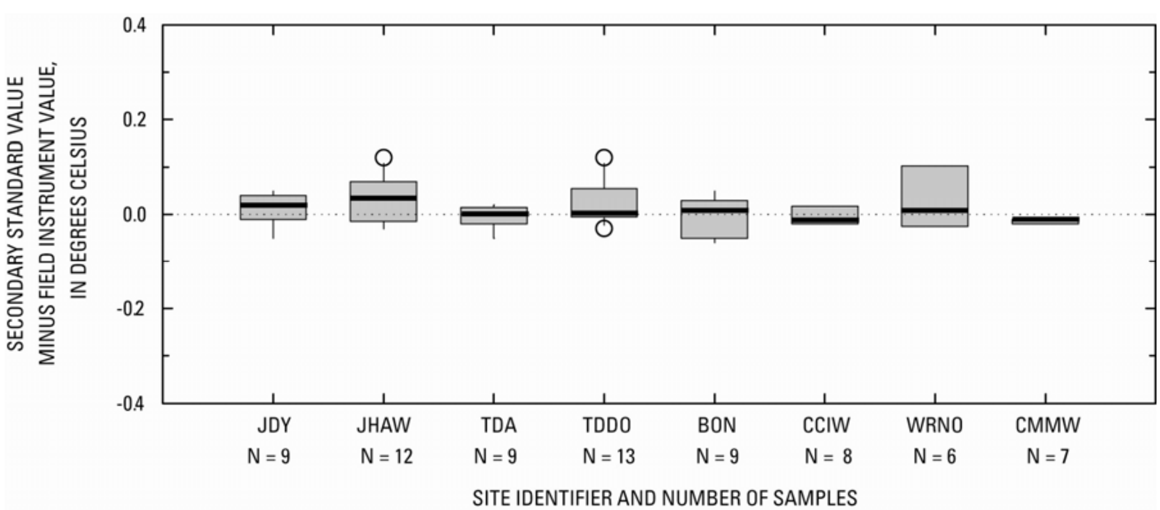

Figure 4. Difference between the secondary standard and the field temperature instruments after 3 or 4 weeks of field deployment at eight stations in the lower Columbia River, Oregon and Washington, water year 2008.

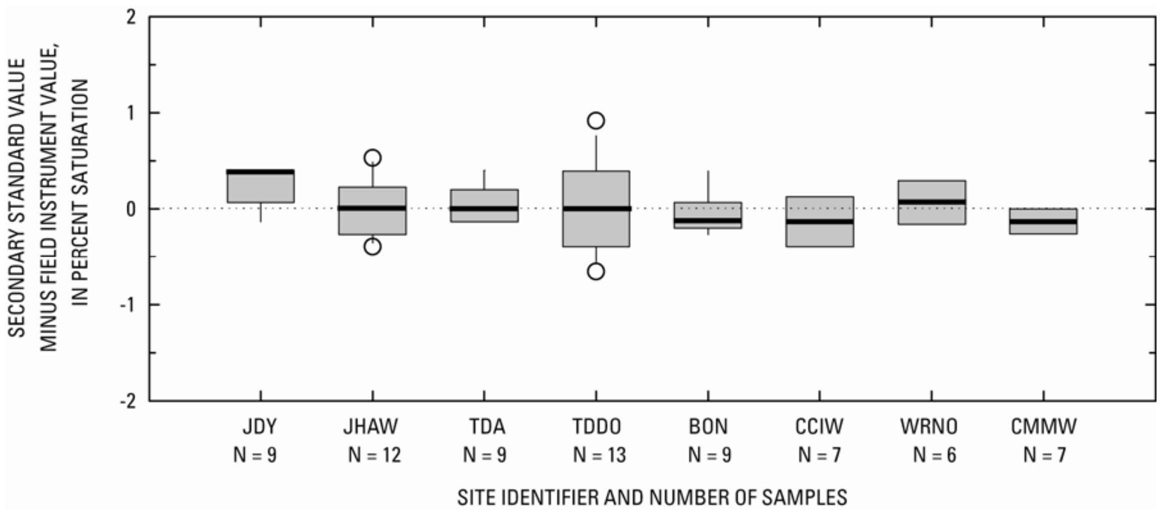

Figure 5. Difference between the secondary standard and the field total-dissolved-gas instruments after 3 or 4 weeks of field deployment at eight stations in the lower Columbia River, Oregon and Washington, water year 2008.

The comparisons of the digital and field barometers are shown in figure 3. All field values were within 2 mm Hg of standard values. The secondary standard temperature sensor and field temperature sensor results are presented in figure 4. All differences were within 0.2°C (degrees Celsius), with most falling within 0.1°C.

Differences between the secondary standard and field TDG sensors were calculated following equilibration of the secondary standard unit to site conditions before removing the field unit. The side-by-side equilibrium was considered complete when the TDG values for each sensor remained constant for 4 to 5 minutes after a minimum of 30 minutes.

All data demonstrate less than 1.0-percent saturation difference between the two TDG sensors (fig. 5). The two greatest differences were +0.9 percent saturation (November 29, 2007) and –0.6 percent saturation (April 30, 2008) at The Dalles tailwater. Both field instruments passed post-deployment calibration tests and performed well for the rest of the field season. More equilibration time of the secondary standard instrument likely would have resulted in a lesser difference between the instruments in both instances.

Effects of Spill on Total Dissolved Gas

Spill from each dam increased the level of TDG. Spill data in this report are from the USACE Website (http://www.nwd-wc.usace.army.mil/tmt/wcd/tdg/months.html). Nighttime spill from John Day Dam occurred April 10–April 21; spill was then continuous until it ceased on August 31 (fig. 6*A*). Spill from The Dalles Dam (fig. 7*A*) and from Bonneville Dam (fig. 8) was continuous during April 10–August 31. Both Cascade Island and Warrendale are downstream of Bonneville Dam (fig. 1), but Cascade Island was the only tailwater station with TDG levels commonly larger than 120 percent (fig. 9*A*). The monitoring station at Warrendale had a planned shutdown during May 1–September 17.

The relation between spill and TDG was nearly linear for data from John Day Dam (fig. 6*B*) and The Dalles Dam (fig. 7*B*). Increases of spill greater than 150,000 ft^3/s from Bonneville Dam did not lead to significant increases in TDG at Cascade Island (fig. 9*B*).

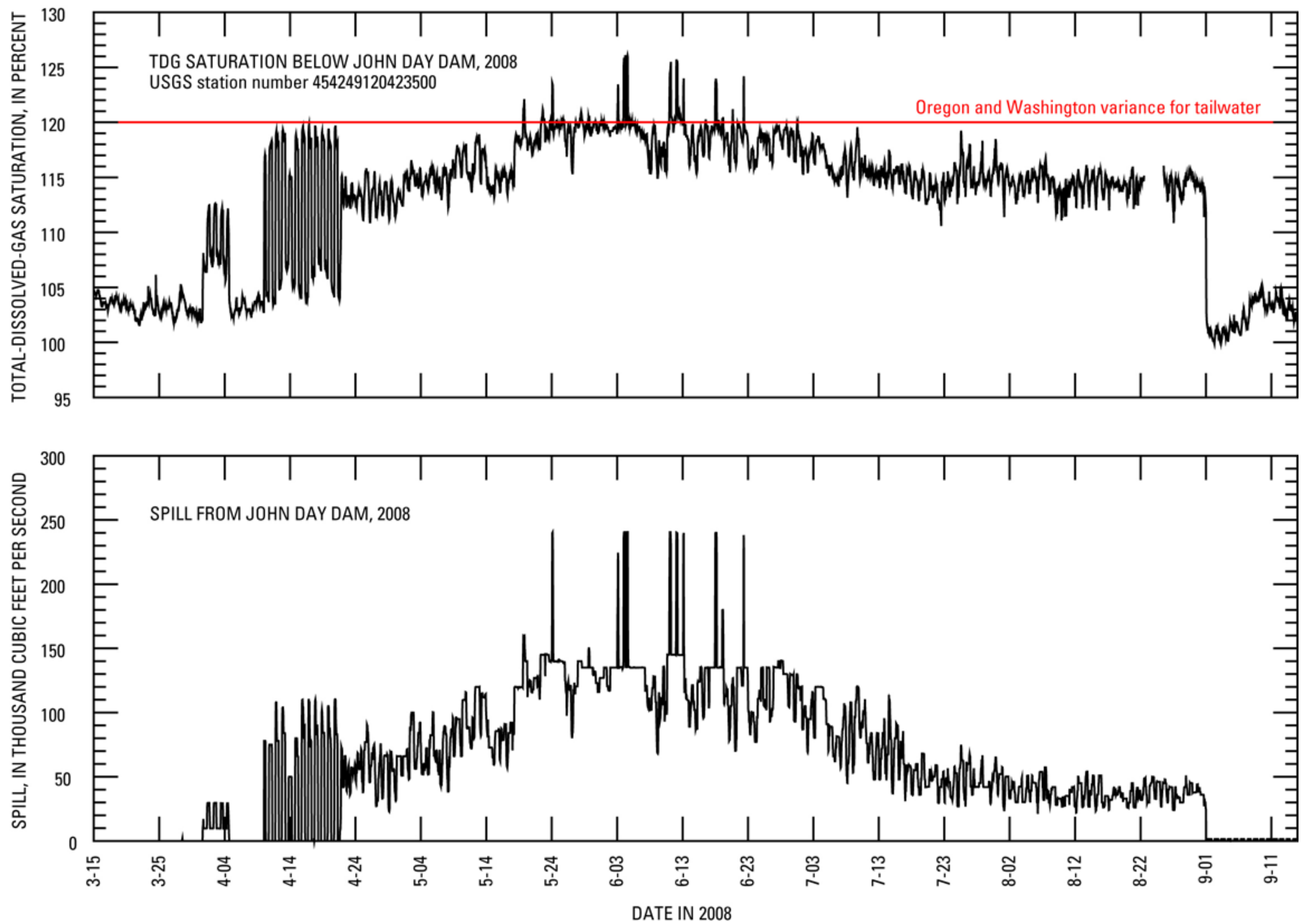

Figure 6*A*. Total-dissolved-gas saturation downstream of John Day Dam and spill from John Day Dam, lower Columbia River, Oregon and Washington, March 15 through September 15, 2008. Date format = M–DD.

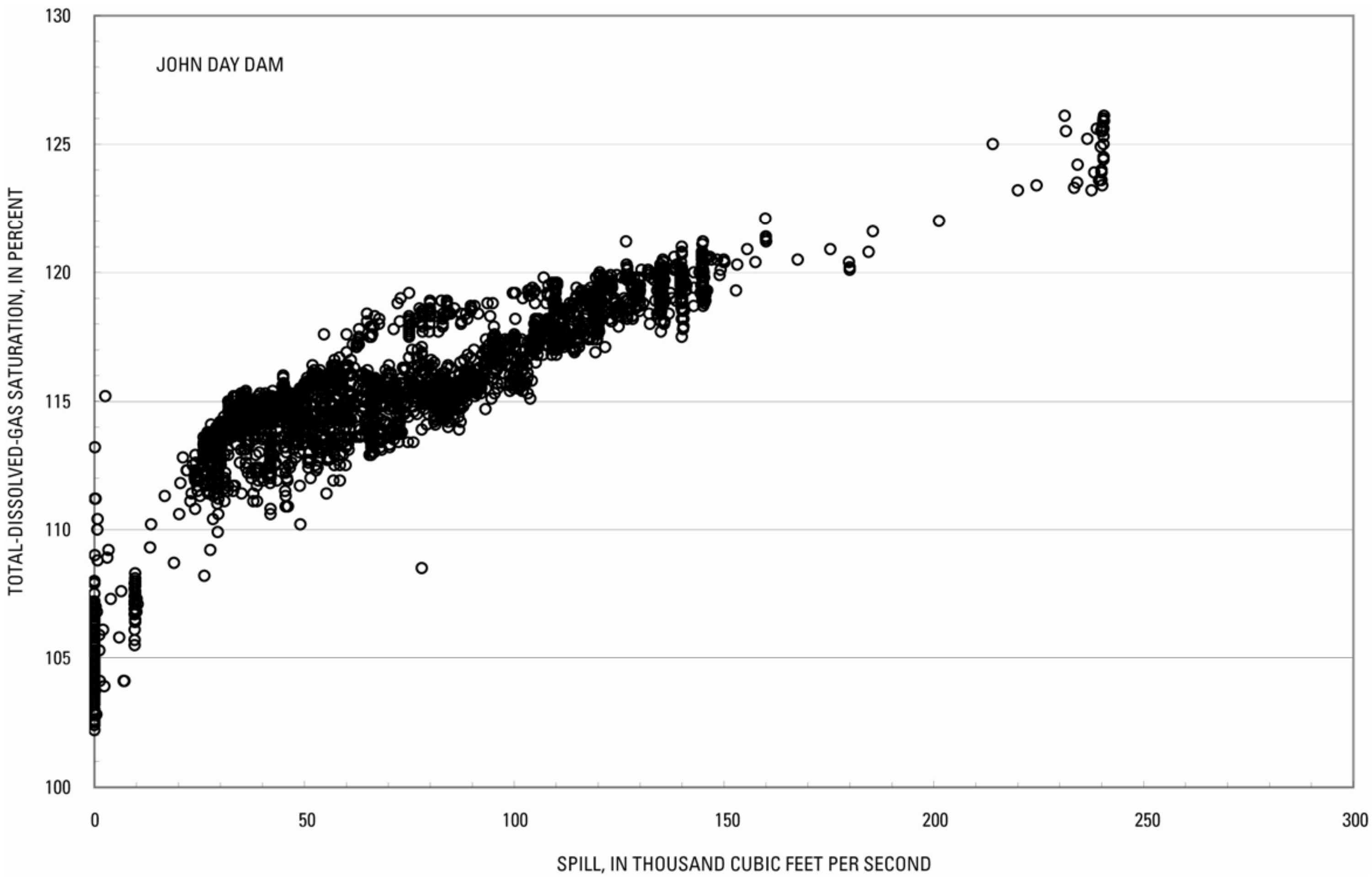

Figure 6*B*. Relation of total-dissolved-gas saturation downstream of John Day Dam and spill from John Day Dam, lower Columbia River, Oregon and Washington, April 1 through August 31, 2008.

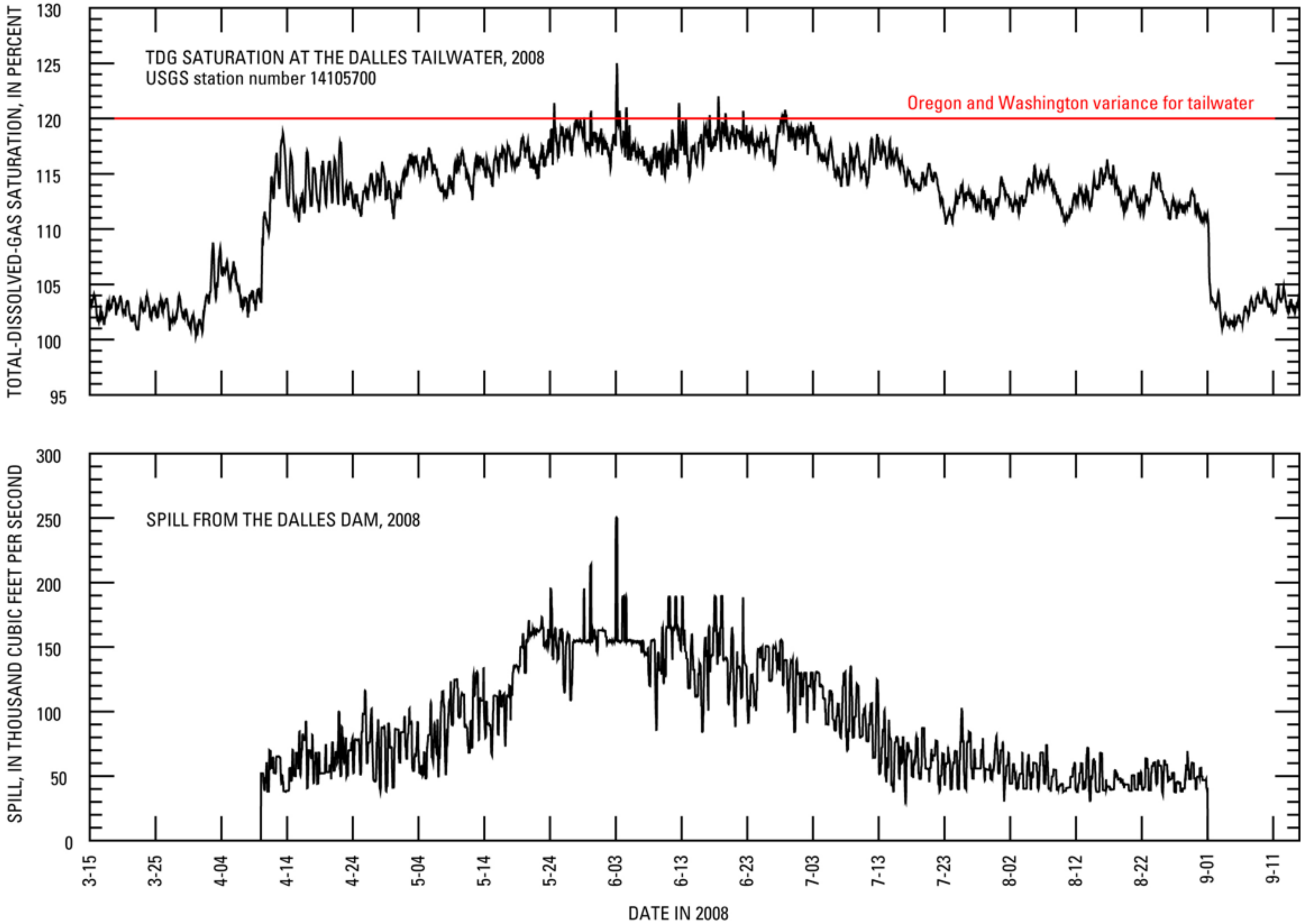

Figure 7*A*. Total-dissolved-gas saturation downstream of The Dalles Dam and spill from The Dalles Dam, lower Columbia River, Oregon and Washington, March 15 through September 15, 2008. Date format = M-DD.

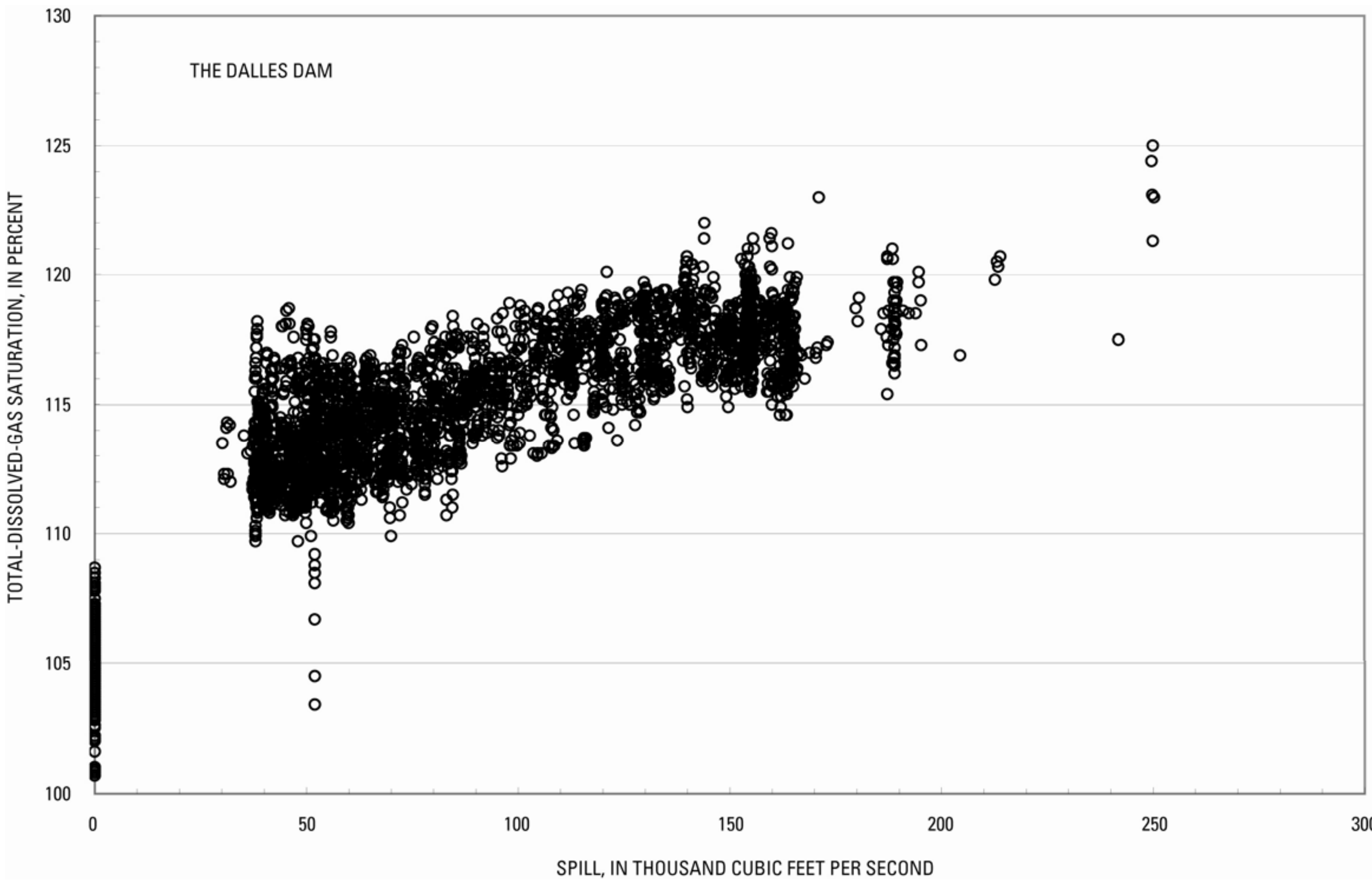

Figure 7*B*. Relation of total-dissolved-gas saturation downstream of The Dalles Dam and spill from The Dalles Dam, lower Columbia River, Oregon and Washington, April 1 through August 31, 2008

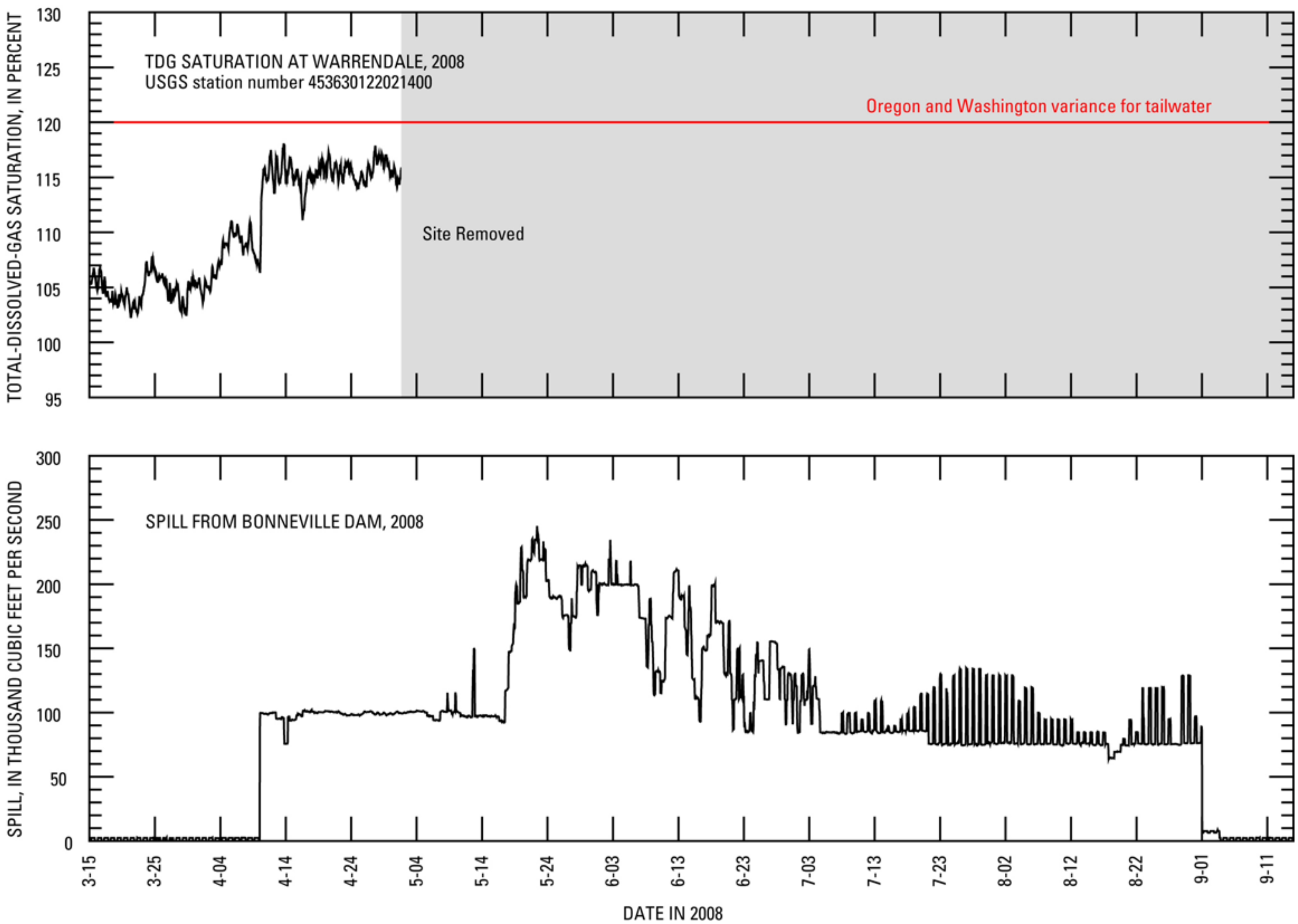

Figure 8. Total-dissolved-gas saturation downstream of Bonneville Dam at Warrendale and spill from Bonneville Dam, lower Columbia River, Oregon and Washington, March 15 through September 15, 2008. Date format = M–DD.

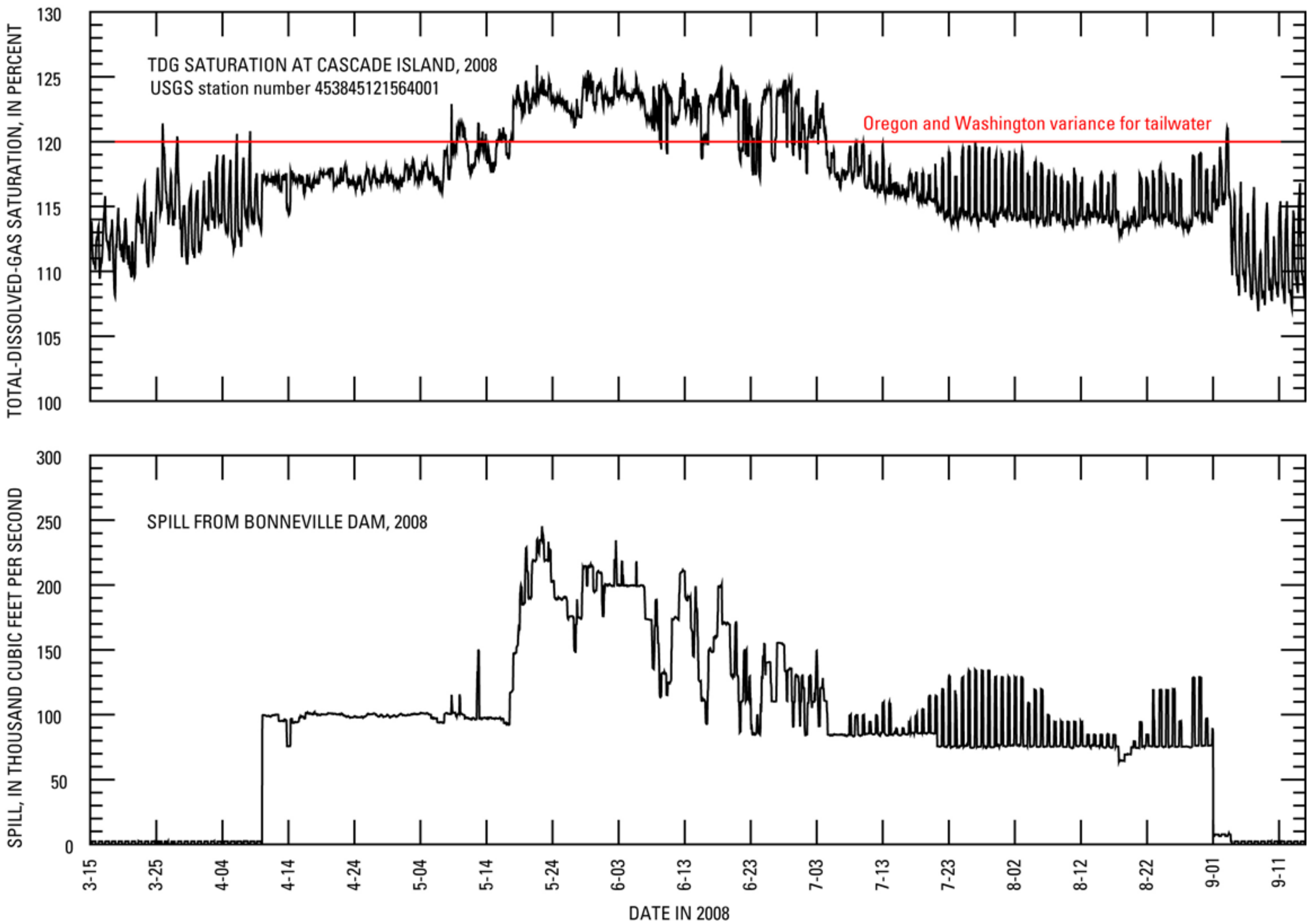

Figure 9*A*. Total-dissolved-gas saturation downstream of Bonneville Dam at Cascade Island and spill from Bonneville Dam, lower Columbia River, Oregon and Washington, March 15 through September 15, 2008. Date format = M–DD.

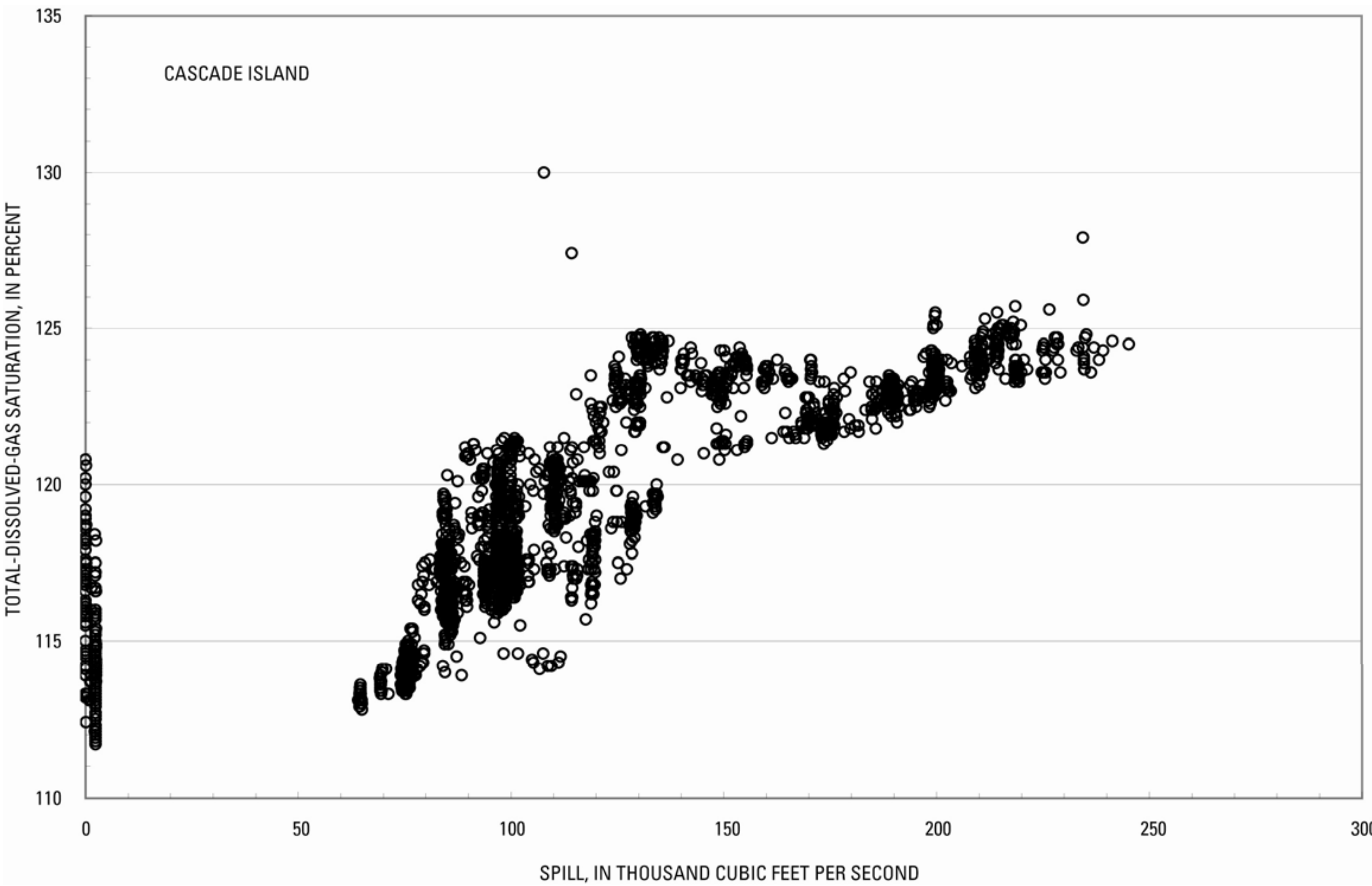

Figure 9*B*. Relation of total-dissolved-gas saturation downstream of Bonneville Dam at Cascade Island and spill from Bonneville Dam, lower Columbia River, Oregon and Washington, April 1 through August 31, 2008

The forebay stations—John Day navigation lock (fig. 10), The Dalles forebay (fig. 11), Bonneville forebay (fig. 12), and Camas (fig. 13)—are each located immediately upstream of a dam, except for Camas, which is located 24.4 mi downstream of Bonneville Dam. As a result, the forebay stations were expected to have lower levels of total dissolved gas than the tailwater stations. TDG levels at John Day forebay, The Dalles Dam forebay, and Bonneville forebay were occasionally larger than 115-percent saturation due to spill from upstream dams. At Camas, (fig. 13), TDG saturation was greater than 115 percent on numerous occasions from April to August. Some of the daily increases in TDG at Camas may have been due to the production of oxygen by aquatic plants (photosynthesis) and to temperature increases caused by daytime heating (Tanner and Bragg, 2001).

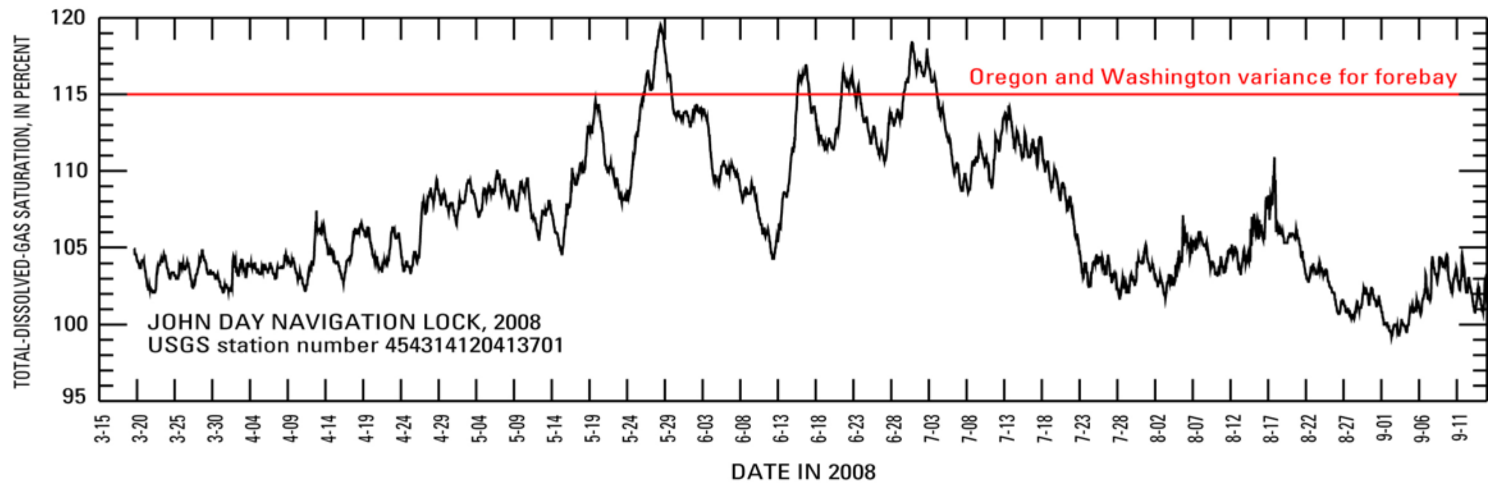

Figure 10. Total-dissolved-gas saturation upstream of John Day Dam, lower Columbia River, Oregon and Washington, March 15 through September 15, 2008. Date format = M–DD.

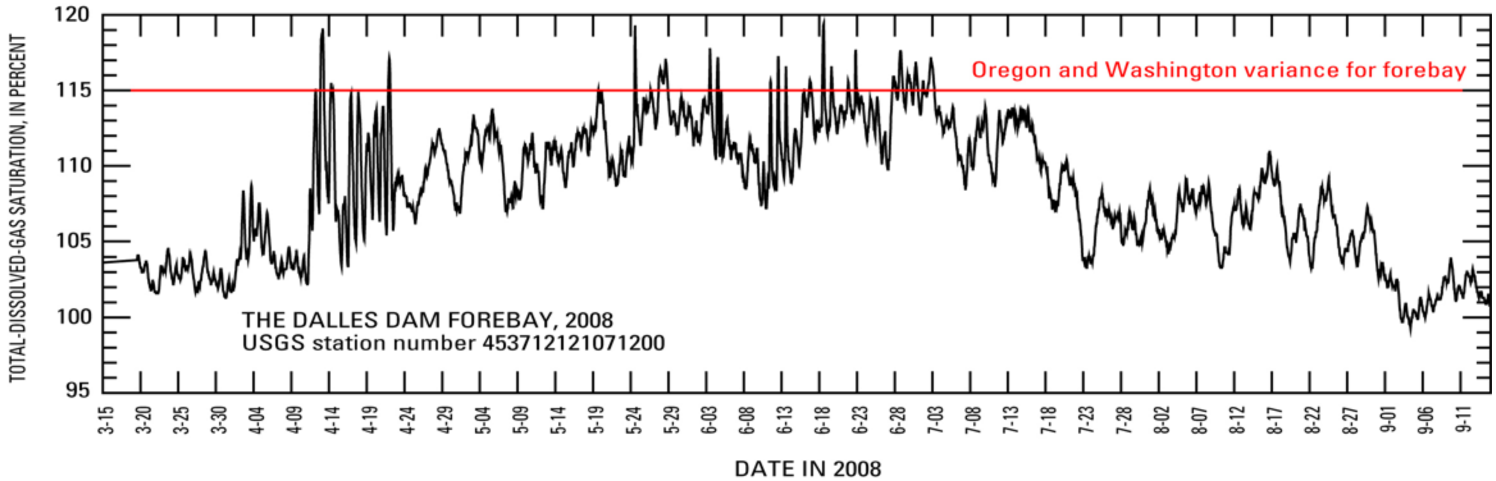

Figure 11. Total-dissolved-gas saturation upstream of The Dalles Dam, lower Columbia River, Oregon and Washington, March 15 through September 15, 2008. Date format = M–DD.

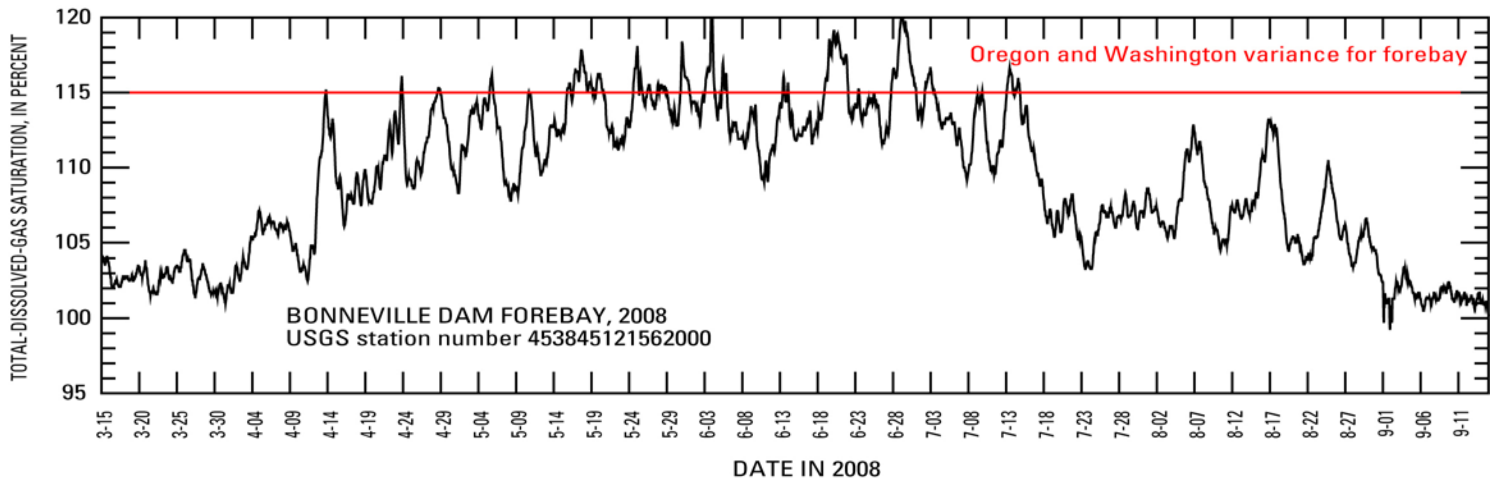

Figure 12. Total-dissolved-gas saturation upstream of Bonneville Dam, lower Columbia River, Oregon and Washington, March 15 through September 15, 2008. Date format = M-DD

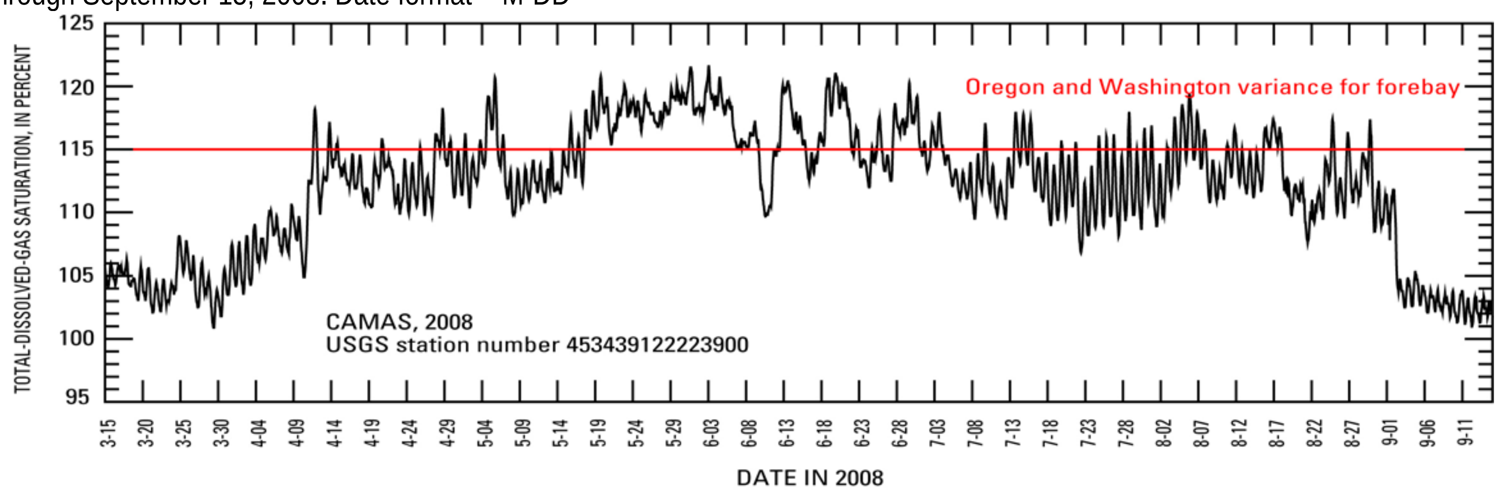

Figure 13. Total-dissolved-gas saturation at Camas, lower Columbia River, Oregon and Washington, March 15 through September 15, 2008. Date format = M–DD.

Comparison of Total Dissolved Gas and Temperature to Standards

In 2008, variances or waivers were granted to the water-quality standard for TDG of 110-percent saturation. These variances were established to allow spill for fish passage at dams on the Columbia River. The State of Oregon granted a 2-year variance for 2008 and 2009 (State of Oregon, 2007). The State of Washington provided for fish passage in its water-quality standards consistent with approved gas-abatement plans through February 2010 (State of Washington, 2006a). From April 1 through August 31, 2008, the USACE was granted variances allowing TDG to reach 115-percent saturation at forebay stations (John Day navigation lock, The Dalles forebay, Bonneville forebay, and Camas) and 120 percent at tailwater stations, directly downstream of dams (John Day tailwater, The Dalles tailwater, Cascade Island, and Warrendale). The 115- and 120-percent variances were exceeded if the average of the highest 12 hourly values in 1 day (1:00 a.m. to midnight) was larger than the numerical standard. A separate variance of 125 percent was in place for all stations for the highest 2-hour average (Oregon Environmental Quality Commission, written commun., 2007), or the highest 1-hour average (State of Washington, 2006a). Although the Camas station is not located at the forebay of a dam, it is 24.4 mi downstream of Bonneville Dam and is regulated as a forebay station.

The discussion in this report will deal only with the hourly TDG values and how they compare to the numerical value of the variances. The distribution of hourly TDG values for the spill season (April 1 through August 31, 2008) is shown in figure 14. The applicable variance is shown with the data for each station. Data from the forebay stations show an increase in the median TDG (from JDY to TDA to BON to CWMW), which probably reflects the river's inability to de-gas downstream of each dam before another dam is encountered to again cause an increase in TDG.

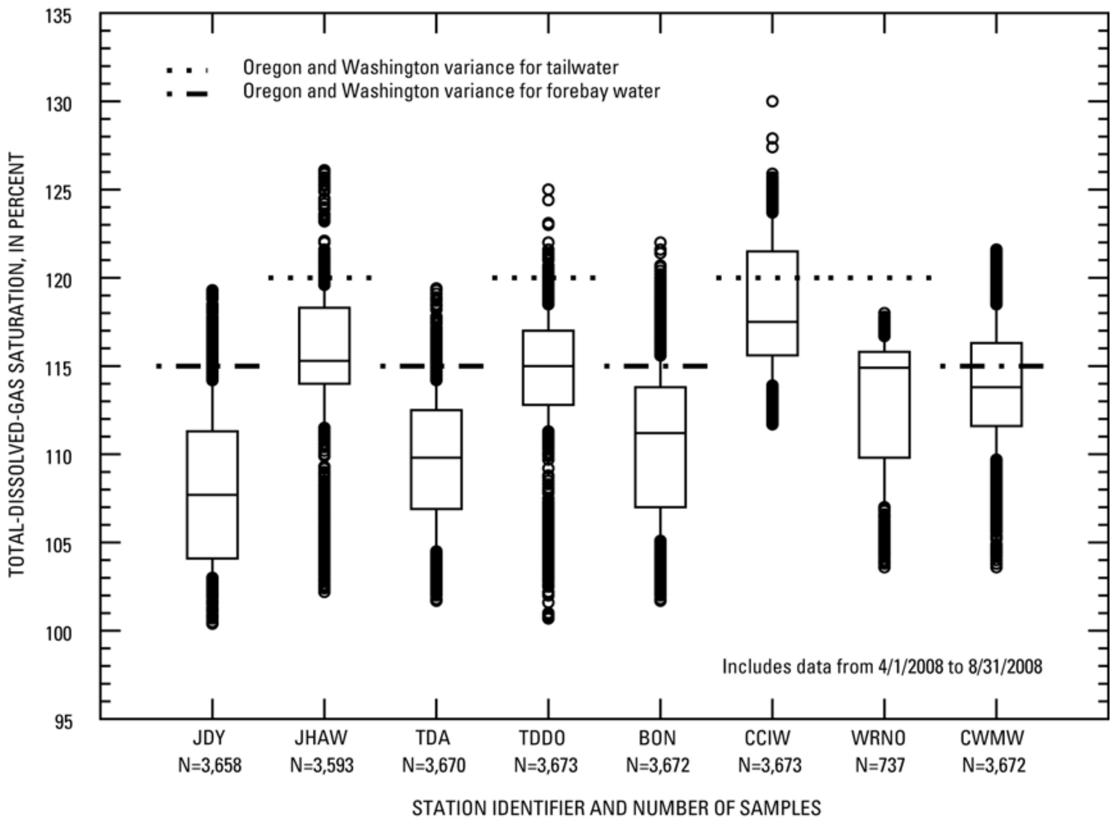

Figure 14. Distributions of hourly total-dissolved-gas data and Oregon and Washington water-quality variances, lower Columbia River, Oregon and Washington, April 1, 2008, through August 31, 2008. See table 1 for explanation of station identifiers.

Except for Cascade Island, which is the closest tailwater station downstream of a dam (0.2 mi downstream), 90 percent or more of the hourly TDG data were less than the variances. In contrast, none of the hourly TDG values exceeded the variance at Warrendale, which is 5.7 mi downstream of Bonneville Dam. At Camas, more than 25 percent of the hourly values exceeded 115-percent saturation.

Water-temperature standards that apply to the lower Columbia River are complex and depend on the effects of human activities and the locations of salmonid rearing, spawning, and egg incubation areas. According to the State of Oregon water-temperature standard, the 7-day-average maximum temperature of the lower Columbia River should not exceed 20°C (Oregon Department of Environmental Quality, 2008). Washington State regulations state that the water temperature in the Columbia River shall not exceed a 1-day maximum of 20.0°C due to human activities (State of Washington, 2006b).

As with the TDG data, this report deals only with the hourly values for water temperature. Water temperatures upstream and downstream of John Day Dam (fig. 15), The Dalles Dam (fig. 16), and Bonneville Dam (fig. 17), and at Camas (fig. 18) were larger than 20.0°C from late July until September. Water temperatures at the forebay stations were approximately equal to the temperatures at the tailwater stations, indicating the sensors were place in well-mixed conditions in the forebays. At the Camas station (fig. 18), there was a distinct daily temperature cycle, with an amplitude of about 1°C, the minimum occurring at about 09:00 hours and the maximum at about 19:00 hours.

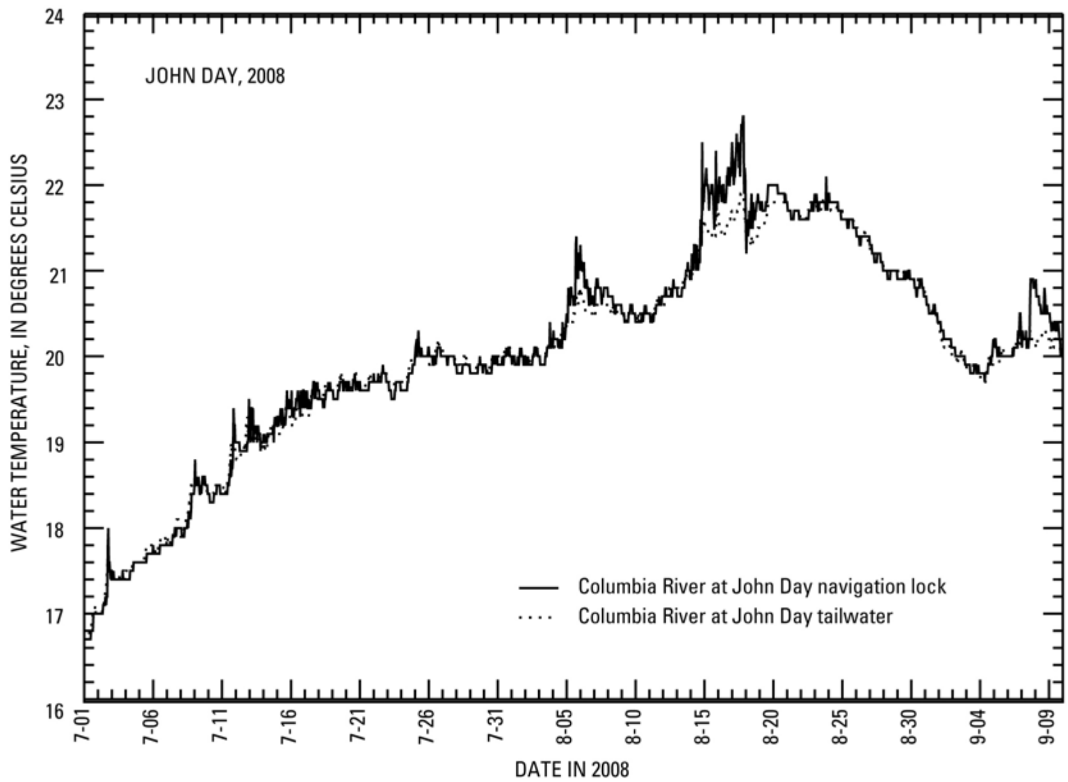

Figure 15. Water temperature upstream and downstream of John Day Dam, lower Columbia River, Oregon and Washington, summer 2008. Date format = M–DD.

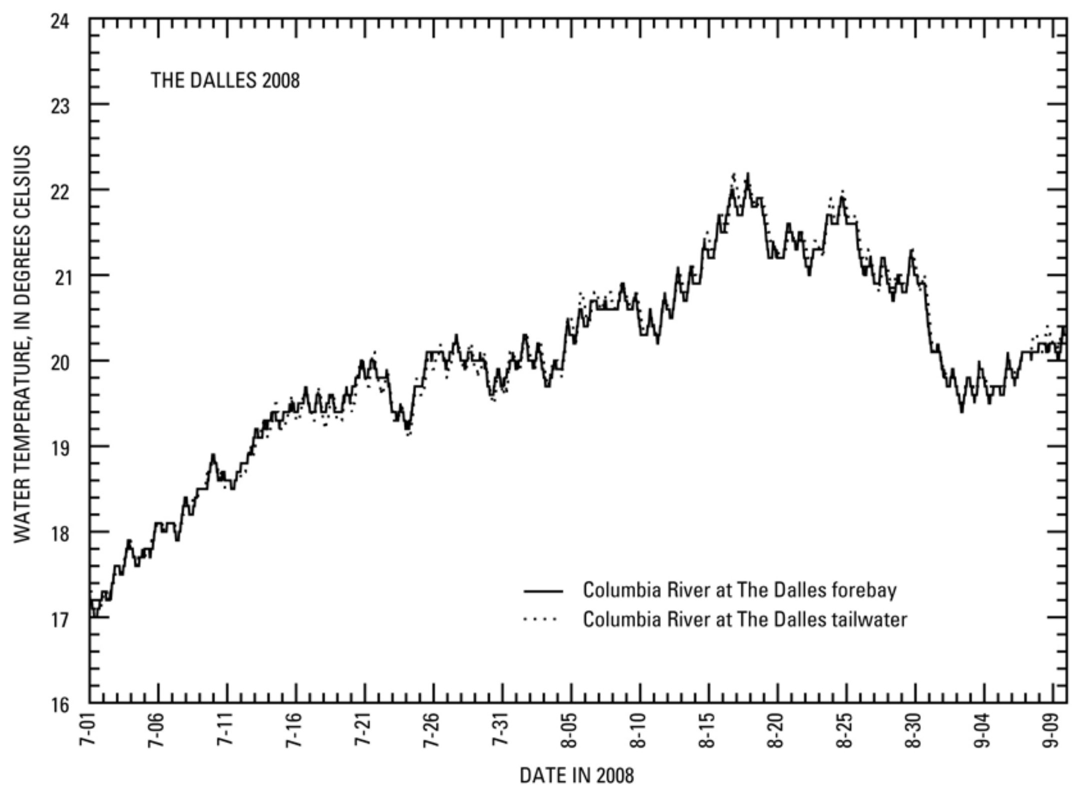

Figure 16. Water temperature upstream and downstream of The Dalles Dam, lower Columbia River, Oregon and Washington, summer 2008. Date format = M–DD.

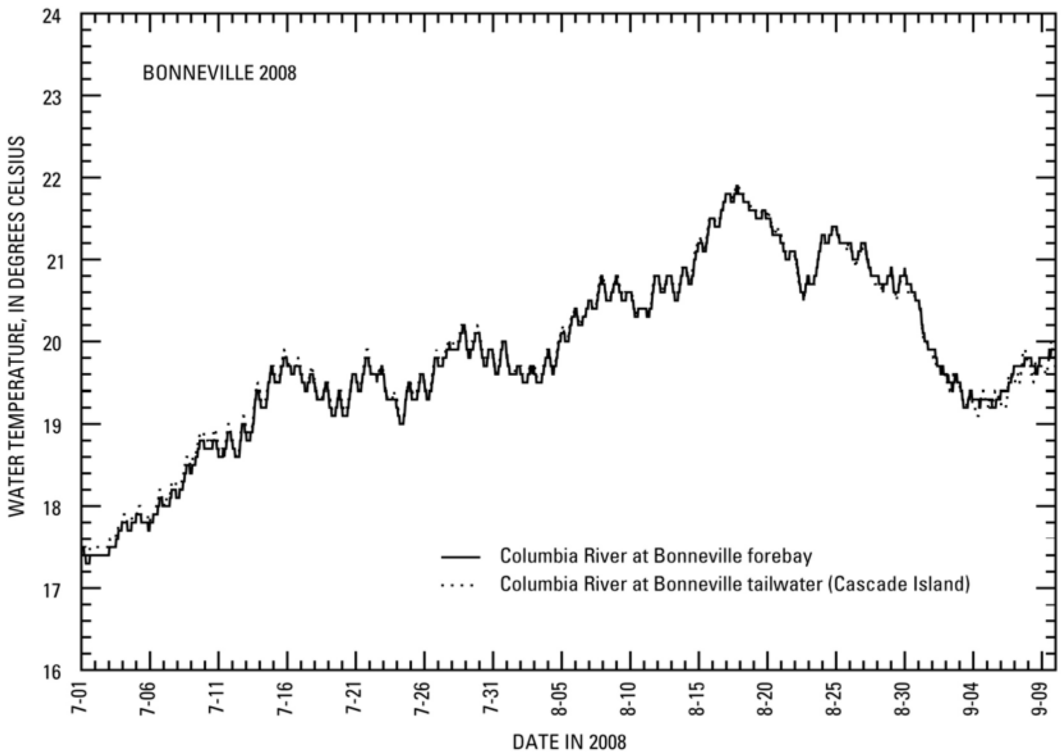

Figure 17. Water temperature upstream and downstream of Bonneville Dam, lower Columbia River, Oregon and Washington, summer 2008. Date format = M–DD.

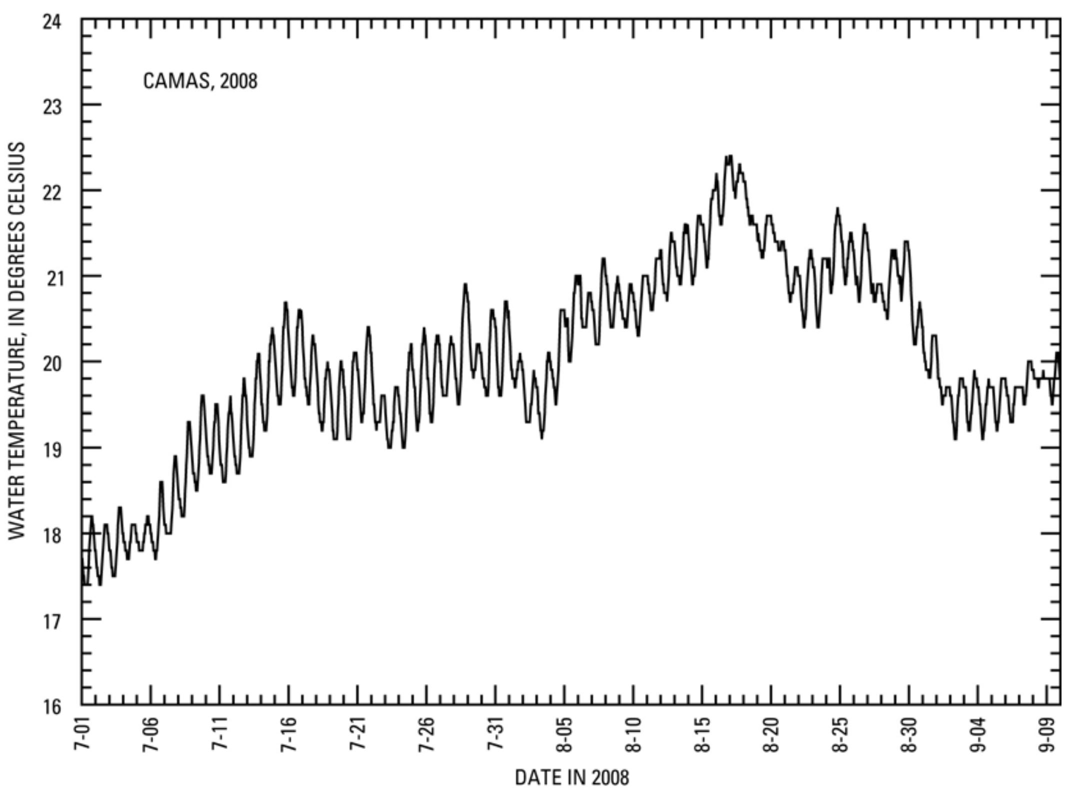

Figure 18. Water temperature at Camas, lower Columbia River, Oregon and Washington, summer 2008. Date format = M–DD.

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