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Total Dissolved Gas and Water Temperature in the Lower Columbia River, Oregon and Washington, 2004: Quality-Assurance Data and Comparison to Water-Quality Standards

Scientific Investigations Report 2004-5249

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

Front cover:
Native-American fishing platform on the Columbia River near Cliffs, Washington. In the foreground is the pipe housing the total-dissolved-gas sensor at the John Day tailwater monitoring site.
(Photograph by Heather M. Bragg, U.S.Geological Survey)

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Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

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Conversion Factors and Datum

Multiply	By	To obtain
	Area	
inch (in)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.59	square kilometer (km^2)
cubic feet per second (ft^3/s)	0.028317	cubic meters per second (m^3/s)
inch (in)	2.54	centimeter (cm)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F = (1.8 x °C) + 32

Total Dissolved Gas and Water Temperature in the Lower Columbia River, Oregon and Washington, 2004: 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 total dissolved gas. 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 (USACE), collected total-dissolved-gas (TDG) and water-temperature data at eight sites on the lower Columbia River in 2004. Significant findings from the data include:

- Variances to the Oregon and Washington water-quality standards for total dissolved gas were exceeded on a few days at three of the monitoring sites: Camas, The Dalles forebay, and Bonneville forebay. These exceedances may have been the result of the cumulative effects of supersaturated water moving downstream through the lower Columbia River. Apparently, the levels of TDG did not dissipate rapidly enough downstream from the dams before reaching the next site.
- TDG levels at an experimental monitoring site directly below Bonneville Dam at Cascade Island showed a larger response to spill than the site 5.5 miles farther downstream at Warrendale.
- From mid-July to mid-September, water temperatures were above 20°C (degrees Celsius) at each of the seven lower Columbia River sites. Both the Oregon and Washington water-quality standards contain a numerical standard of 20°C for the lower Columbia River.
- The new location of the forebay monitoring site at John Day navigation lock showed less daily temperature variation than the previous location. The probe at the new site was farther away from the dam and at a greater depth, so it apparently avoided the daily temperature excursions associated with the surface-layer heating at the previous site.
- Most field checks of total-dissolved-gas sensors with a secondary standard were within ±1% saturation. Most of the field checks of barometric pressure were within ±1 mm Hg (millimeter of mercury) of a secondary standard, and water temperature field checks were all within ± 0.1°C.
- For the seven monitoring sites used to regulate spill in water year 2004, an average of 99.0% of the total-dissolved-gas data were received in real time by the USGS satellite downlink and were within 1% saturation of the expected value, based on calibration data, replicate quality-control measurements in the river, and comparison to ambient river conditions at adjacent sites.

Introduction

The USACE operates several dams in the Columbia River Basin, which encompasses 259,000 square miles 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 total dissolved gas (TDG) downstream from the spillways. TDG conditions above 110% saturation have been shown to cause gas-bubble trauma in fish and adversely affect other aquatic organisms (U.S. Environmental Protection Agency, 1986).

The USACE regulates spill and streamflow to minimize the production of excess TDG downstream from its dams, but there is also 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 summer. In order to monitor compliance to these variances, the USACE oversees the collection of near real-time TDG and water-temperature data upstream and downstream from the Columbia River Basin dams in a network of fixed-station monitors. Data from these sites are available within about 4 hours 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 every year, beginning in 1996. Current and historical TDG and water-temperature data can be found on the USGS website at http://oregon.usgs.gov/projs_dir/pn307.tdg/. Five reports that were published for water years 1996, 2000, 2001, 2002, and 2003 contained TDG data, quality-assurance data, and descriptions of the methods of data collection (Tanner and others, 1996; Tanner and Johnston, 2001; Tanner and Bragg, 2001; Tanner and others, 2002; and Tanner and others, 2003).

To provide suitable data for managing and modeling TDG in the lower Columbia River, hourly data for 2004 were reviewed relative to laboratory and field measurements made during instrument calibrations and daily intersite comparisons. A small fraction of the TDG data were deleted because they were not of suitable quality. The hourly data were stored in a USGS data base (Automated Data Processing System —ADAPS); and in a USACE data base (at http://www.nwd-wc.usace.army.mil/tmt/wcd/tdg/months). The USACE data base also includes hourly discharge and spill data.

Purpose and Scope

The purpose of TDG monitoring in the lower Columbia River is to provide the USACE with (1) real-time data for managing streamflow and spill at its project dams and (2) reviewed TDG data to evaluate conditions in relation to water-quality standards and to provide a data base for modeling the effect of various management scenarios of streamflow and spill on TDG levels.

This report describes the TDG data and related quality-assurance data from the lower Columbia River at eight sites from the forebay of the John Day Dam (river mile [RM] 215.7) to Camas, Washington (RM 121.7) (fig. 1, table 1). Data for water year 2004 (October 1, 2003, to September 30, 2004) include hourly measurements of TDG pressure, barometric pressure, water temperature, and probe depth. Five of the sites (John Day navigation lock, John Day tailwater, The Dalles forebay, The Dalles tailwater, and Camas) were operated from February or March to September 2004, which is the usual time of spill from the dams. In 2004, the monitoring site upstream from John Day Dam was relocated to a site near the navigation lock. Two sites (Bonneville forebay and Warrendale) were operated year-round. The site, Columbia River at Cascade Island, was installed temporarily to assess TDG levels directly in the tailwater of Bonneville Dam. Data from Columbia River at Cascade Island were not used for management purposes, and the site operated only periodically in 2004 due to failure of the probe enclosure.

Acknowledgments

The authors acknowledge the aid and funding support of the U.S. Army Corps of Engineers. Our special thanks goes to James L. Britton (USACE) for technical and logistical support of the project. The authors also acknowledge Amy Brooks (USGS) for preparing summaries and analyses of data.

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 fixed station consisted of a Hydrolab water-quality probe, an electronic barometer, a power supply, and a Sutron Model 8200 data-collection platform (DCP). The instruments were powered by a 12-volt battery that was charged by a solar panel and/or a 120-volt alternating-current line. At the beginning of the monitoring season in March, a new TDG membrane was installed on each Hydrolab. Measurements (including probe depth) were made and logged every hour, and every 4 hours the DCP transmitted the most recent logged data to the Geostationary Operational Environmental Satellite (GOES) system (Jones and others, 1991). The data were automatically decoded and transferred to the USACE data base and to the USGS ADAPS data base. At one site, John Day tailwater, two TDG sensors were installed on the same Hydrolab to ensure that data were reliably collected at this important site.

The fixed-station monitors were calibrated every 2 weeks from March to September 2004, and every 3 weeks for the remainder of the year, at which time Warrendale and Bonneville forebay were the only sites in operation. 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 to obtain check measurements of TDG and water temperature prior to removing the field Hydrolab (which had been deployed for 2 or 3 weeks). The field Hydrolab was replaced with one that had been calibrated recently at the Oregon District Laboratory. Then, the secondary standard was used to check TDG and temperature measured by the newly deployed Hydrolab in the river. The electronic barometer at the fixed station was calibrated using a portable barometer that had been recently calibrated at the National Weather Service facility in northeast Portland.

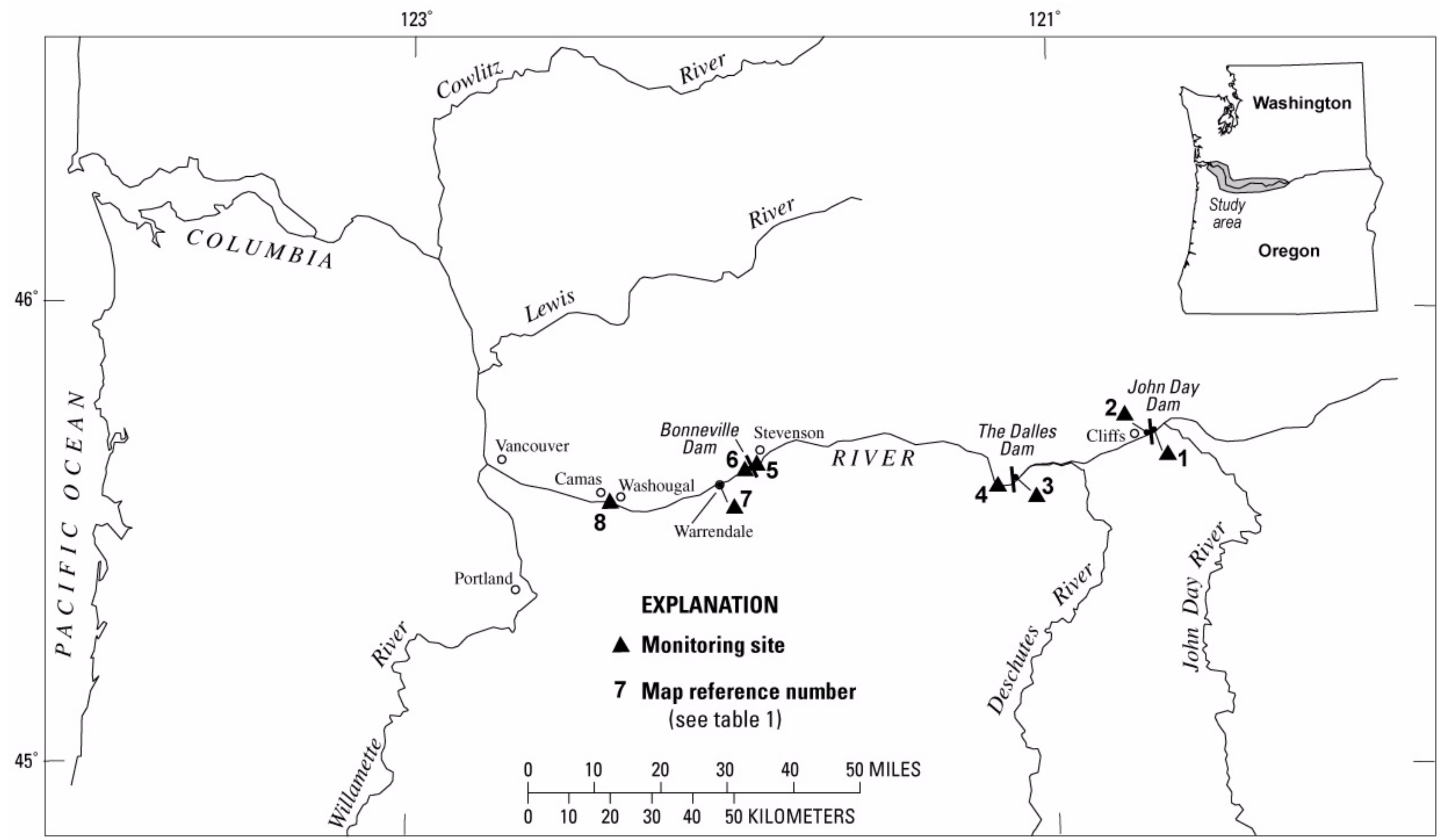

Figure 1. Location of total-dissolved-gas fixed stations, lower Columbia River, Oregon and Washington, water year 2004.

Table 1. Total-dissolved-gas fixed stations, lower Columbia River, Oregon and Washington, water year 2004.

[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 are referenced by their abbreviated name or USACE site identifier in this report, °, degree, ', minute, ", second]

Map reference number	USACE site identifier	Columbia River mile	USGS station number	USGS station name (abbreviated station name)	Latitude	Longitude	Period of record
1	JDY	215.7	454314120413701	Columbia River at John Day navigation lock, Washington (John Day navigation lock)	45°43'14"	120°41'37"	03/25/04-09/28/04
2	JHAW	214.7	454249120423500	Columbia River, right bank, near Cliffs, Washington (John Day tailwater)	45°42'49"	120°42'35"	03/09/04-09/24/04
3	TDA	192.6	453712121071200	Columbia River at The Dalles Dam forebay, Washington (The Dalles forebay)	45°37'12"	121°07'12"	03/09/04-09/29/04
4	TDDO	188.9	14105700	Columbia River at The Dalles, Oregon (The Dalles tailwater)	45°36 27"	121°10'20"	03/10/04-09/29/04
5	BON	146.1	453845121562000	Columbia River at Bonneville Dam forebay, Washington (Bonneville forebay)	45°38'45"	121°56'20"	Year-round
6	CCIW	145.9	453845121564001	Columbia River at Cascade Island, Washington (Cascade Island)	45°38'45"	121°56'40"	Experimental for 2004
7	WRNO	140.4	453630122021400	Columbia River, left bank, near Dodson, Oregon (Warrendale)	45°36'30"	122°02'14"	Year-round
8	CWMW	121.7	453439122223900	Columbia River, right bank, at Washougal, Washington (Camas)	45°34'39"	122°22'39"	02/25/04-09/22/04

The Hydrolab that was brought from the field after 2 to 3 weeks of deployment was then calibrated in the Oregon District Laboratory. The integrity of the TDG membrane was checked, and the TDG sensor was calibrated at 0, 100, 200, and 300 mm Hg above atmospheric pressure to cover the expected range of TDG in the river (approximately 100, 113, 126, and 139% saturation, respectively).

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 degassing will occur, due to decreased hydrostatic pressure. To measure TDG accurately, the Hydrolabs were positioned during each calibration visit at a depth below the calculated minimum compensation depth, wherever possible.

Summary of Total-Dissolved-Gas Data Completeness and Quality

A summary of USGS TDG data completeness and quality for water year 2004 is shown in table 2. (The USACE satellite downlink was a parallel system, so the amount and quality of USACE data were similar). 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, in millimeters of mercury, multiplied by 100%, divided by the barometric pressure, in millimeters of mercury. The fourth column in table 2 shows the percentage of data that was received in real time and passed quality-assurance checks. TDG data were considered to meet quality-assurance standards if they were within ±1% saturation of the expected value, based on calibration data and daily comparisons to ambient river conditions at adjacent sites.

Table 2. Total-dissolved-gas data completeness and quality, lower Columbia River, Oregon and Washington, water year 2004.

[Results are based on the U.S. Geological Survey (USGS) data base; TDG, total dissolved gas]

Station name	Planned monitoring in hours	Number of missing hourly values	Percentage of real-time TDG data passing quality-control checks
John Day navigation lock	4,485	93	97.9
John Day tailwater	4,799	23	99.5
The Dalles forebay	4,887	26	99.5
The Dalles tailwater	4,870	1	100.0
Bonneville forebay	8,784	26	99.7
Warrendale	8,784	78	99.1
Camas	5,038	119	97.6
Average	--	--	99.0

At each station, at least 97.6% of the data was received in real time by the USGS downlink and met quality-control checks, with an overall average of 99.0% (table 2). The site at John Day navigation lock had 93 missing hourly values due mainly to problems in the power supply in April and June. The regulator controlling voltage input to the DCP was faulty, and the increased voltage level caused the DCP to trip the fail-safe software and turn itself off. The site at John Day tailwater had a failure of the probe-suspension system on June 16 and 17, which resulted in 21 hours of data that were not correct because the probe was not at a great enough depth. At The Dalles forebay and at Warrendale, the electronic barometers were randomly and periodically malfunctioning and reporting values for barometric pressure that were too large. The barometer at Warrendale was replaced with a new one in August, and the remainder of the barometers in the lower Columbia River network will be replaced in water year 2005. At Bonneville forebay, there was a problem in the wiring for DCP voltage supply, resulting in 23 hours of lost data on November 2 and 3, 2003. Data loss at the Camas site was due to blockage of the DCP antenna by a large ship March 23 and 24 and to broken TDG membranes in July and August.

Quality-Assurance Data

Data collection for TDG, barometric pressure, and water temperature involved several quality-assurance procedures, including calibration of instruments in the field and in the laboratory, daily checks of the data, and data review for archiving. These methods were explained in detail in Tanner and Johnston (2001), and the results of the quality-assurance program for water year 2004 are presented in this section.

After field deployment for 2 to 3 weeks, the TDG sensors were calibrated in the laboratory. First, the unit was tested, with the membrane in place, for response to increased pressure. 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 first comparing the TDG sensor reading to barometric pressure (0 mm Hg added pressure, or 100% 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%, 126%, and 139% saturation, respectively). The accuracy of the TDG sensors was calculated as the difference between the expected reading and the TDG sensor reading (expected minus actual) for each of the four test conditions multiplied by 100%, and divided by the barometric pressure. As shown in figure 2, all of the sensor readings were within ± 0.5% saturation of the expected value after 2 to 3 weeks of deployment.

The differences in barometric pressure, water temperature, and TDG between the secondary standard instruments and the fixed-station monitors after 2 to 3 weeks of field deployment were measured and recorded as part of the field inspection and calibration procedure. These differences, defined as the secondary standard value minus field instrument value, were used to compare and quantify the 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 portable 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-control data for each of the three parameters from seven field sites.

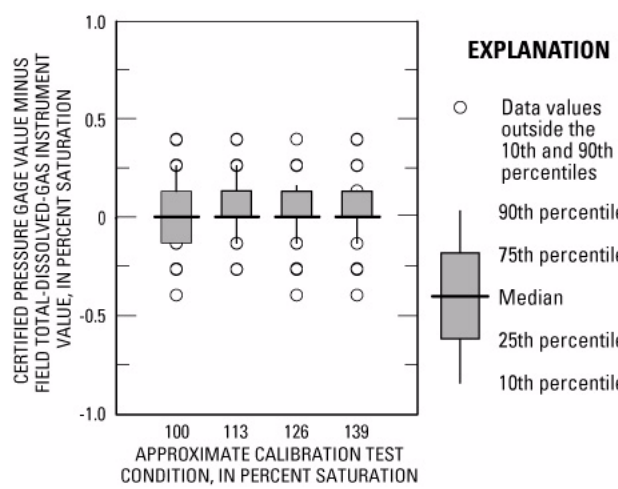

Figure 2. Accuracy of total-dissolved-gas sensors after 2 to 3 weeks of field deployment.

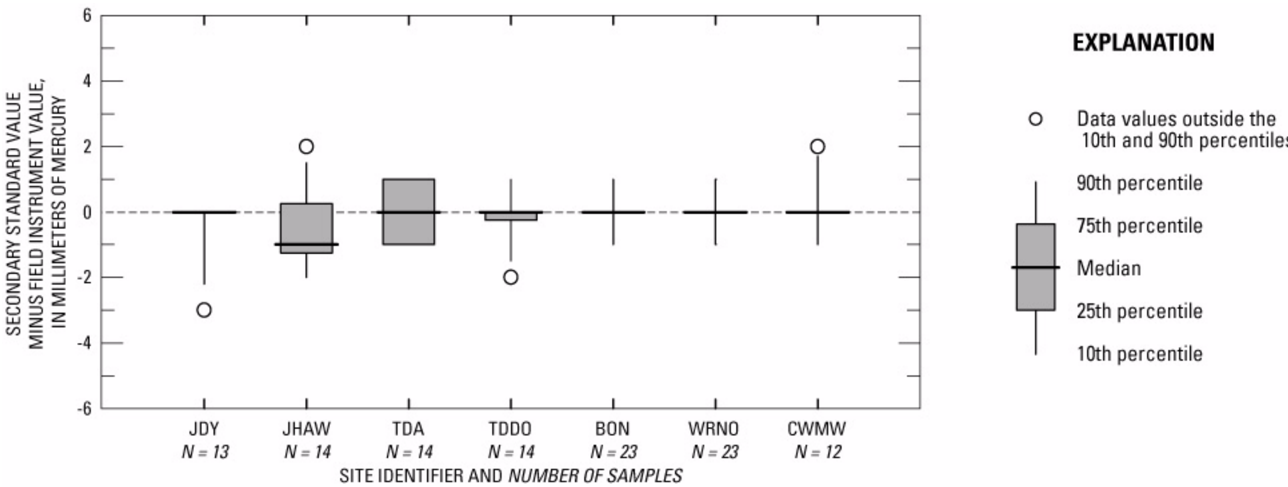

Figure 3. Difference between the secondary standard and the field barometers after 2 to 3 weeks of field deployment.

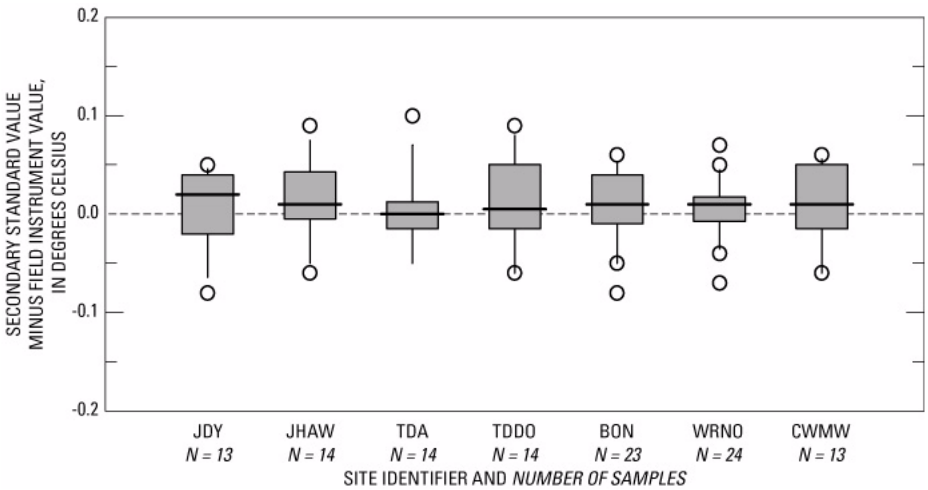

Figure 4. Difference between the secondary standard and the field temperature instruments after 2 to 3 weeks of field deployment.

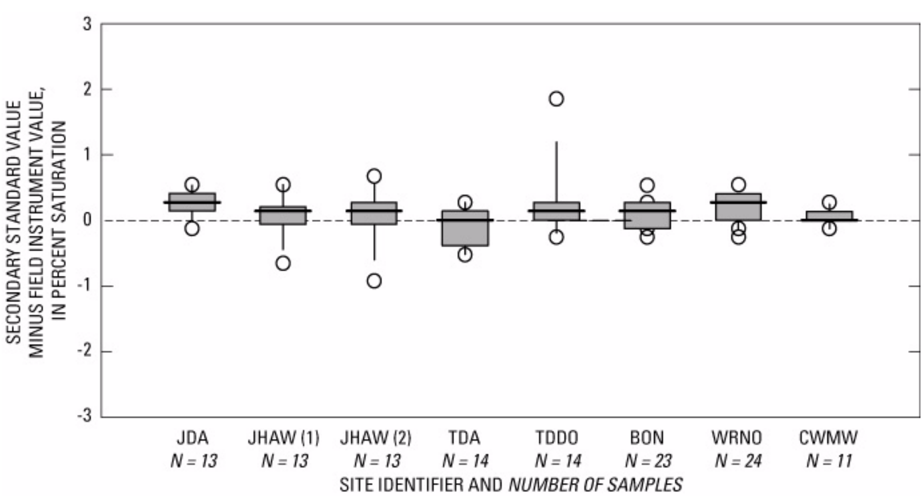

Figure 5. Difference between the secondary standard and the field total-dissolved-gas instruments after 2 to 3 weeks of field deployment.

The comparisons of the portable barometer and the electronic field barometers are shown in figure 3. Most of the field values were within ±1 mm of the standard values, and there was only one difference greater than 2 mm Hg. This difference (-3 mm Hg) was recorded at John Day navigation lock (JDY) shortly before the portable barometer required recalibration. The secondary standard temperature sensor and the field temperature sensor results are presented in figure 4. All of the differences are within 0.1°C.

The differences between the secondary standard TDG sensor and the field TDG sensors were calculated following equilibration of the secondary standard unit to the site conditions before removing the field unit. The side-by-side equilibrium was considered complete after a minimum of 30 minutes when the TDG values for each sensor remained constant for 4 to 5 minutes. As shown in figure 5, most of the differences between the two TDG sensors were within ±1% saturation. One data point (+2% saturation) at The Dalles tailwater site was the result of a malfunctioning TDG sensor that was subsequently removed from use. Two instances of membrane rupture at the Camas site were not included with the plotted data as they do not reflect the performance of the TDG sensors. These ruptures resulted in a total of 108 hours of incorrect TDG data on July 18–19 and August 7–10.

Effects of Spill on Total Dissolved Gas

Spill from each dam increased the level of total dissolved gas downstream. Spill data in this report are from the USACE website (http://www.nwd-wc.usace.army.mil/tmt/wcd/tdg/months). Spill from John Day Dam occurred from April 12 to August 31 (fig. 6). The spill from April 12 to June 20 was usually less than 150,000 ft^3/s (cubic feet per second) and usually occurred only between 7 a.m. and 7 p.m. for fish passage considerations. Figure 6 shows that TDG downstream from John Day Dam increased in response to spill from the dam, with the TDG level usually being less than 120% saturation. From June 21 to August 31, continuous spill from John Day dam varied from about 20,000 ft^3/s to about 70,000 ft^3/s, and the TDG at the John Day tailwater site was always less than 120% saturation.

Spill from The Dalles Dam (fig. 7) was almost continuous at levels generally between 30,000 and 120,000 ft^3/s from April 12 to August 31. TDG levels at The Dalles tailwater site generally ranged from about 111% to 117% saturation during the period of spill.

At Bonneville Dam from April 12 to June 21, the spill generally was 75,000 ft^3/s during the daylight hours and between about 120,000 and 170,000 ft^3/s at night. During that time, the TDG at Warrendale exceeded 120% saturation on 1 day only. On June 21, 2004, the TDG at the Warrendale site peaked at values slightly greater than 120% saturation for several hours (fig. 8). After June 22, Bonneville spills were generally decreased until the spill ended on August 31.

TDG at the experimental site, Columbia River at Cascade Island, showed a response to spill from Bonneville Dam that was different from that at the Warrendale site. The difference in response to spill was most evident from the beginning of the 100,000 ft^3/s spill on April 21 until June 3, when the probe housing (a steel pipe) at Cascade Island broke and the proper probe depth could not be maintained. The Cascade Island site is about 0.2 miles downstream of Bonneville Dam, directly in the spill channel, so the response of TDG to spill (fig. 9) showed a direct correlation, with spill of 75,000 ft^3/s causing about 113–117% TDG saturation, and spill of 160,000 ft^3/s causing an increased TDG saturation up to about 119–121%. The Warrendale site is about 5.5 miles below the Cascade Island site, and is affected by degassing of the river as well as dilution of supersaturated water by powerhouse flows. Examination of the relationship between spill from Bonneville Dam and TDG at Warrendale during the same time period (fig. 10) showed that the response to spill was not clear cut. A spill of 75,000 ft^3/s resulted in TDG of 109–118% saturation, and a spill of 160,000 ft^3/s resulted in a slight increase in TDG, to the range of about 110–119% saturation.

As mentioned above, valid data were available only for part of the season for the Columbia River at Cascade Island. The site was installed on April 6, 2004, and the probe remained positioned in the spill channel at a depth of about 30 to 35 feet until June 3. While trying to retrieve the probe during a routine field calibration on June 3, the probe became lodged part way up the steel pipe housing the probe. It was later discovered that the steel pipe had broken and that several 20-foot sections of the pipe had dropped to the bottom of the river. After June 3, several attempts were made to deploy the probe at a reasonable depth, but it was not possible to do so, and the TDG data after June 3 were determined to be of poor quality. As a result, the TDG data from the Cascade Island site for dates following June 3 were deleted from the public portion of the USGS data base. (The deleted data were retained as raw values in the internal USGS data base.)

The forebay sites, John Day navigation lock, The Dalles forebay, Bonneville forebay, and Camas, were located immediately upstream of a dam, except for Camas, which is located 24.4 miles downstream of Bonneville Dam. As a result, the forebay sites were expected to have lower levels of total dissolved gas. At John Day forebay (fig. 11), TDG was less than 115% saturation for the whole monitoring season. At The Dalles forebay (fig. 12), TDG was periodically above 115% saturation for short periods until June 22, which was the day after spill decreased at John Day Dam (see fig. 6). At Bonneville forebay (fig. 13), TDG was larger than 115% a few times before late June. Finally, at Camas (fig 14), TDG was greater than 115% on several occasions, mainly prior to late June. As documented in the past (Tanner and Bragg, 2001), some of the daily increases in TDG at Camas may be due to the production of oxygen by aquatic plants and to temperature variations.

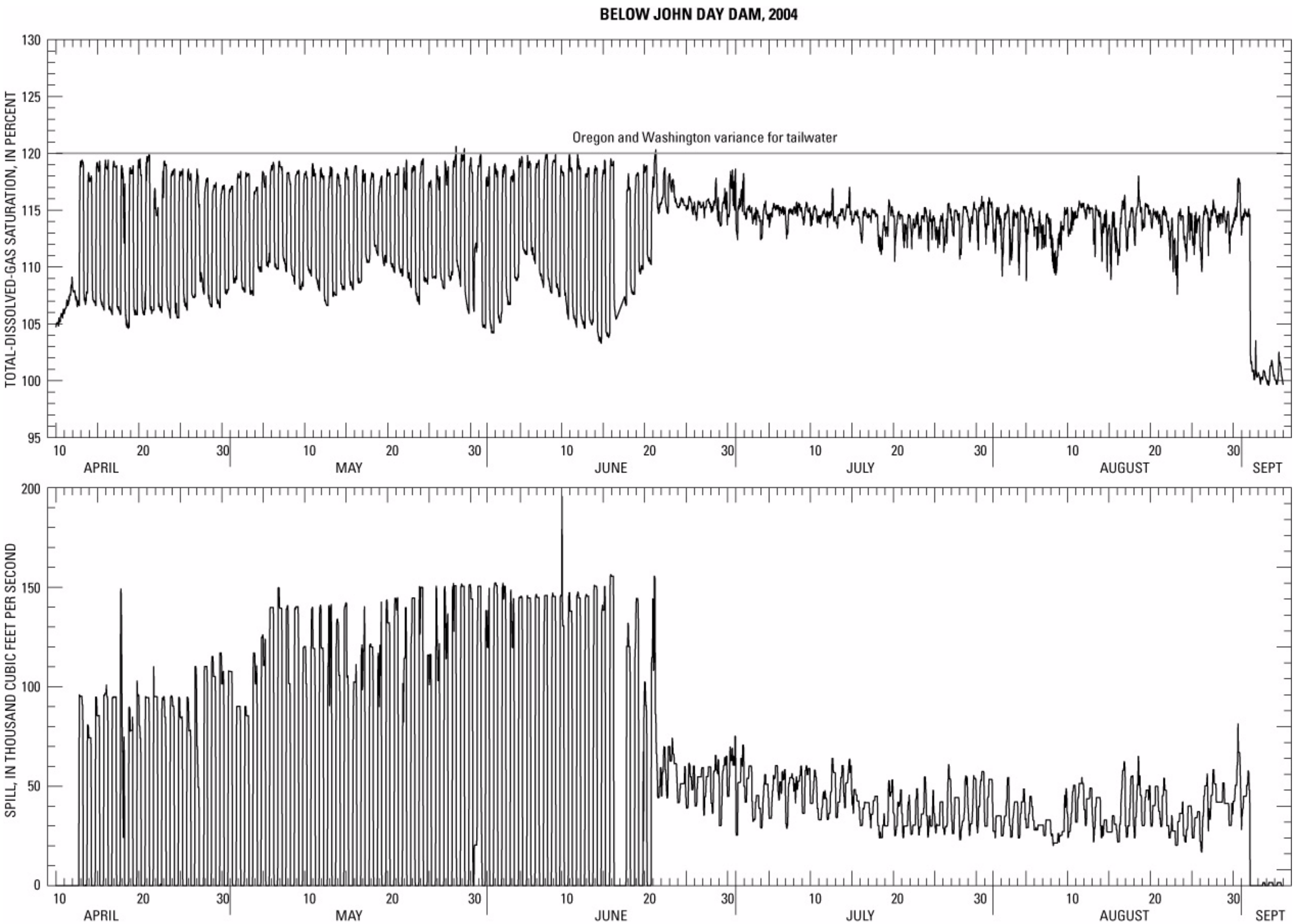

Figure 6. Total dissolved gas downstream of John Day Dam and spill from John Day Dam, April 10 to September 4, 2004.

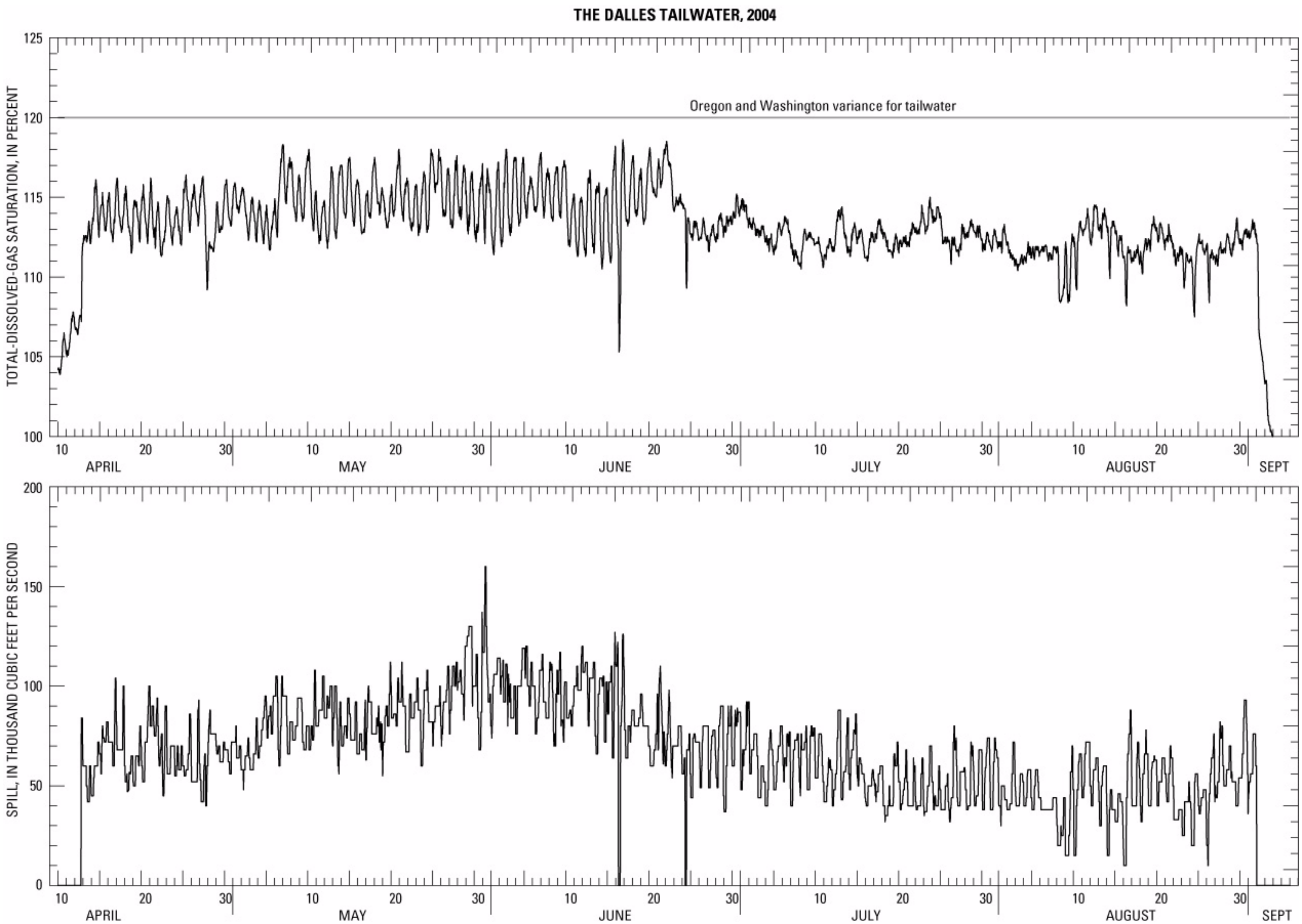

Figure 7. Total dissolved gas downstream of The Dalles Dam and spill from The Dalles Dam, April 10 to September 4, 2004.

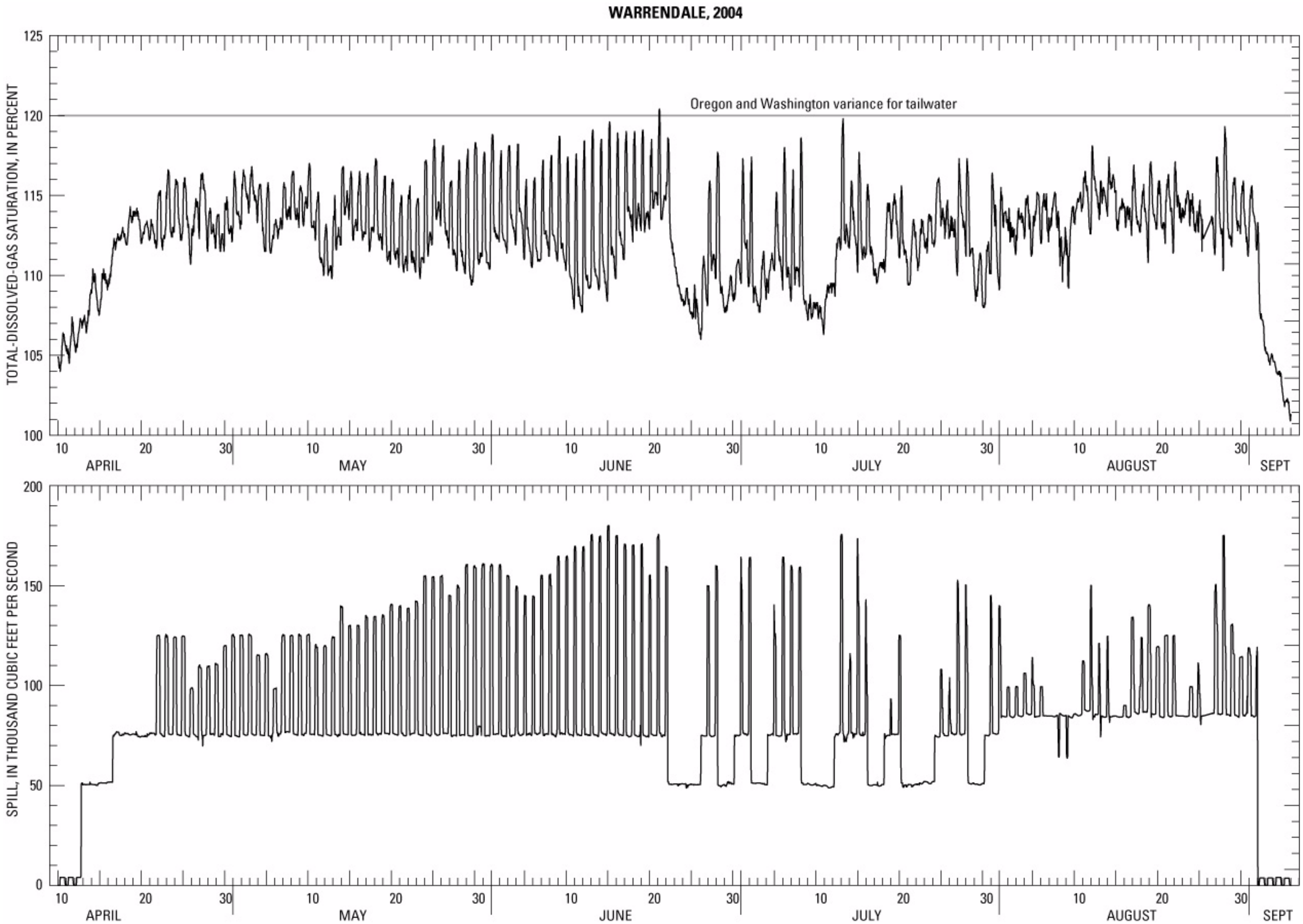

Figure 8. Total dissolved gas downstream of Bonneville Dam at Warrendale and spill from Bonneville Dam, April 10 to September 4, 2004.

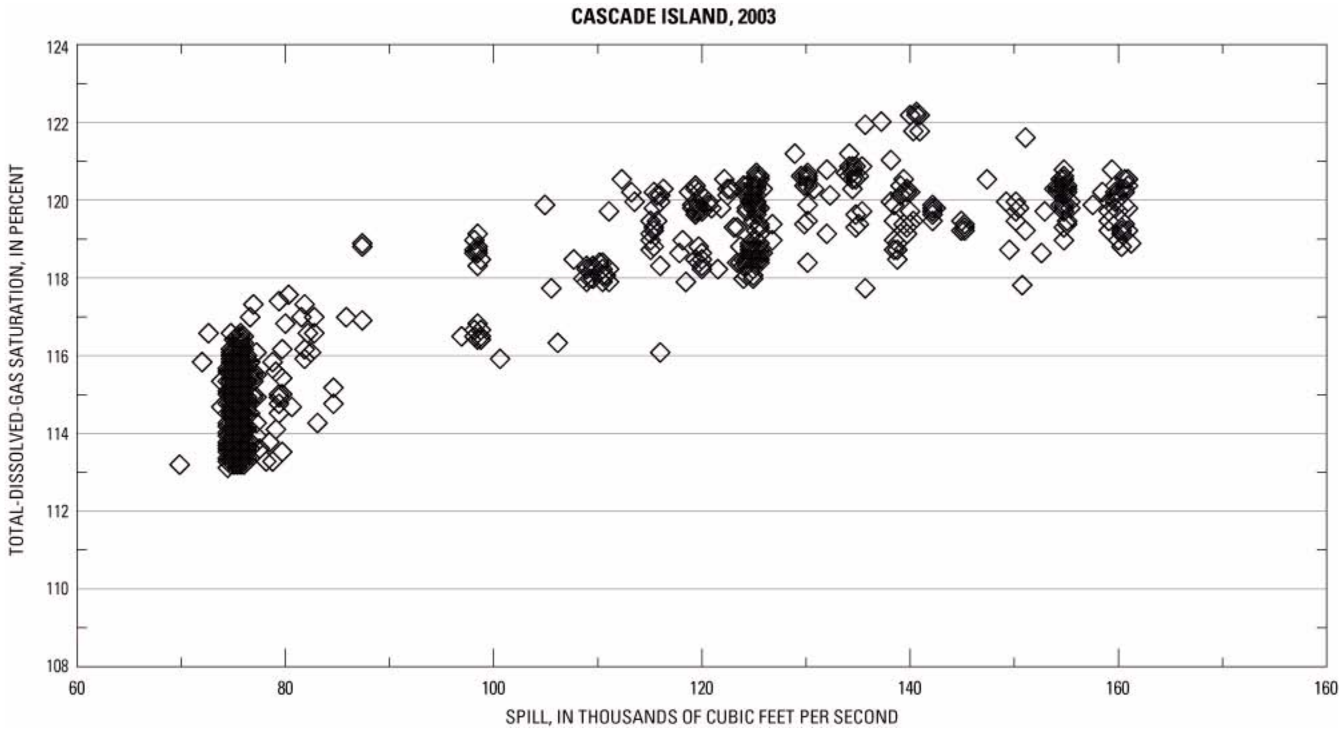

Figure 9. Response of total dissolved gas at Cascade Island to spill from Bonneville Dam, April 21 to June 3, 2004.

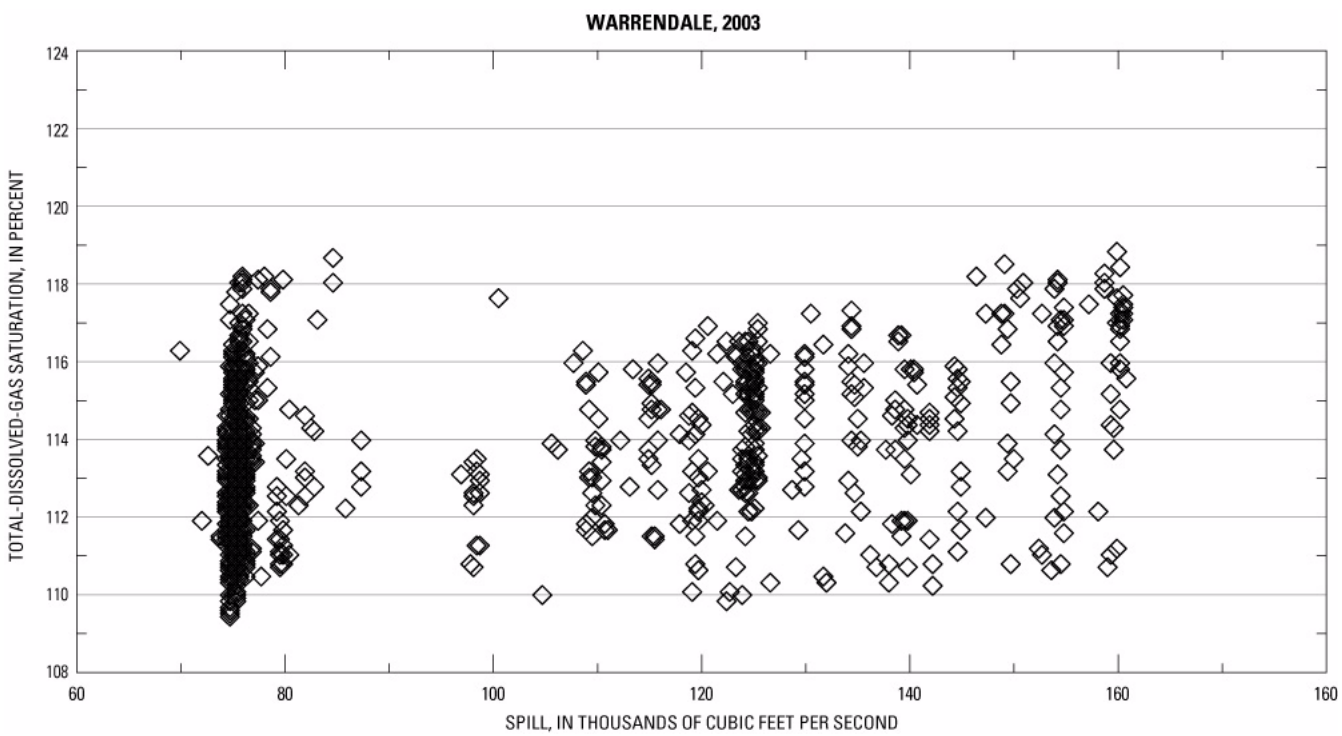

Figure 10. Response of total dissolved gas at Warrendale to spill from Bonneville Dam, April 21 to June 3, 2004.

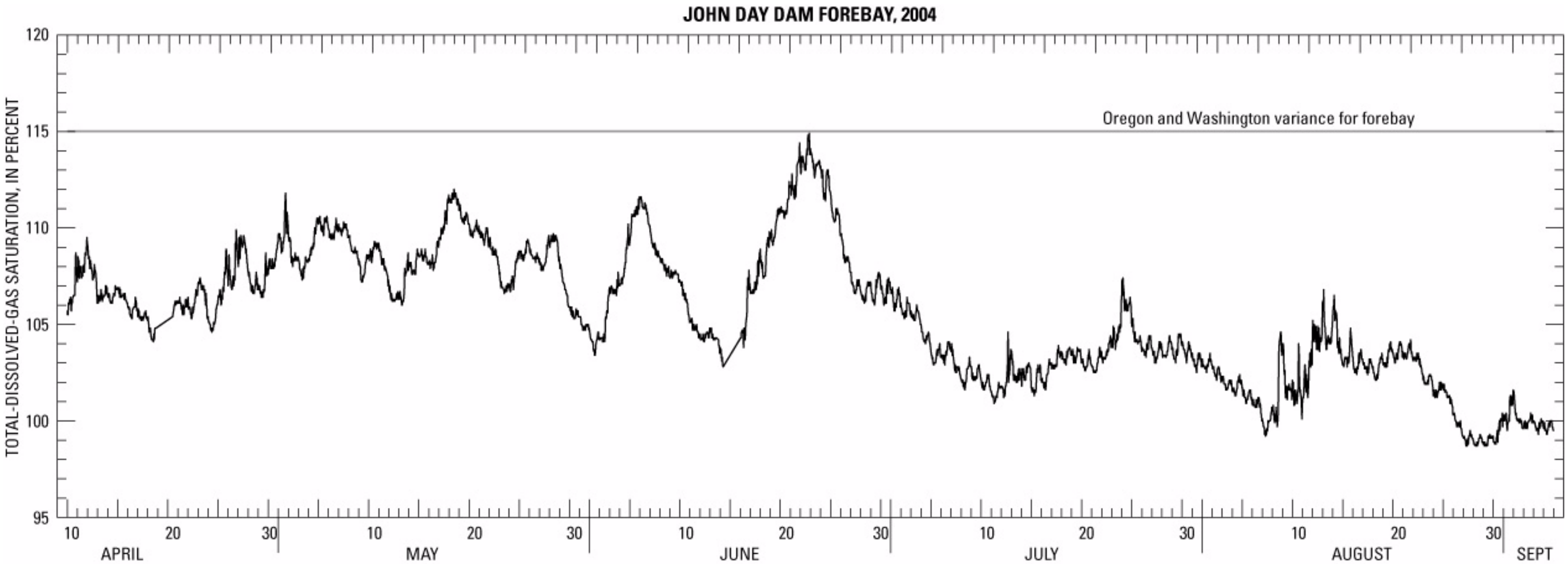

Figure 11. Total dissolved gas upstream of John Day Dam, April 10 to September 4, 2004.

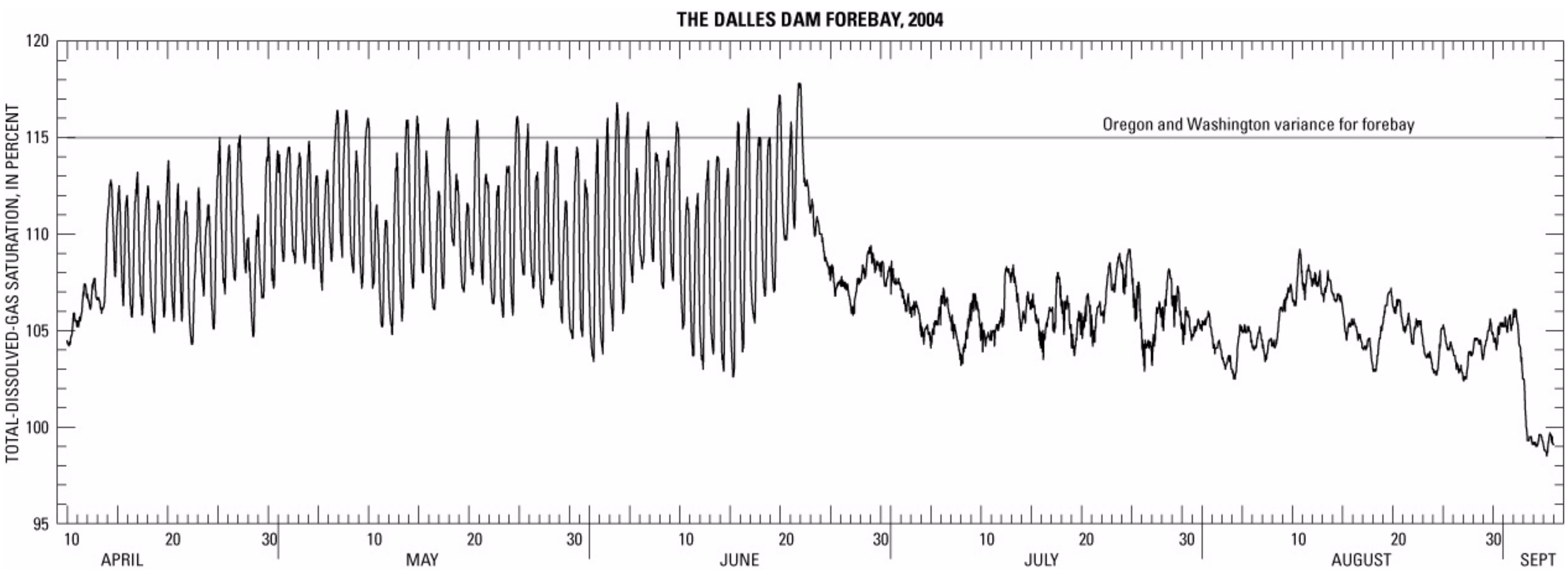

Figure 12. Total dissolved gas upstream of the Dalles Dam, April 10 to September 4, 2004.

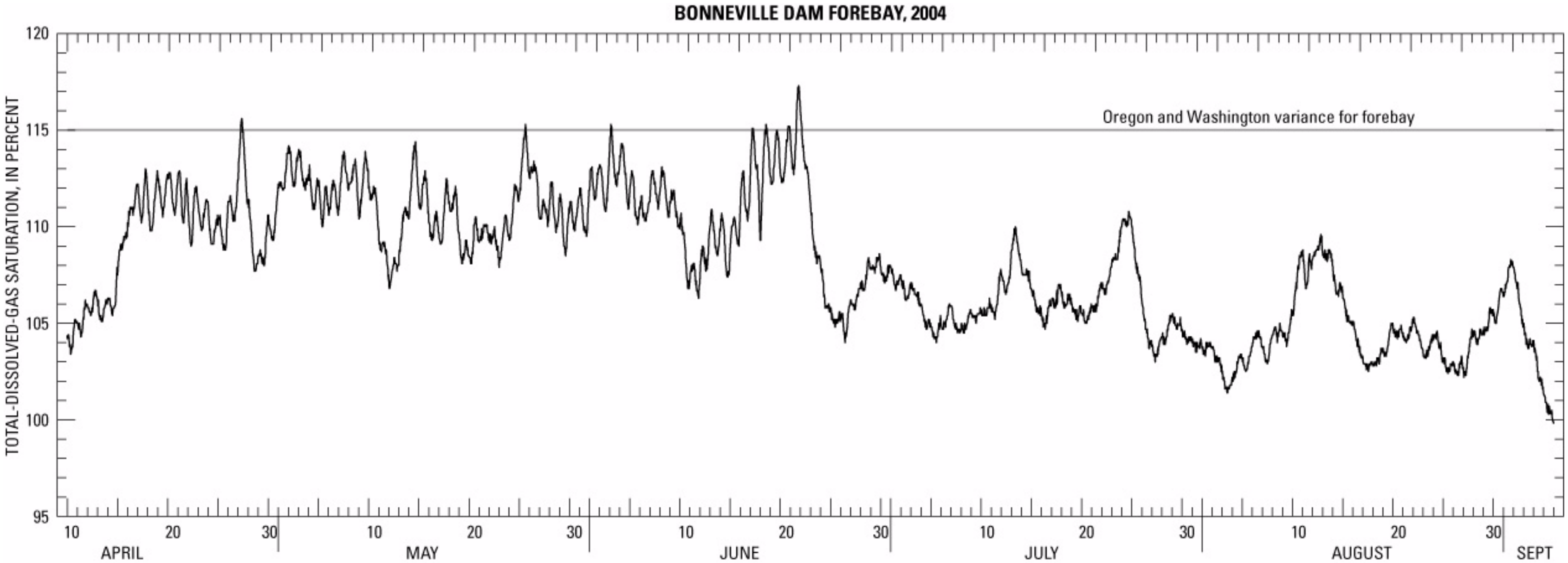

Figure 13. Total dissolved gas upstream of Bonneville Dam, April 10 to September 4, 2004.

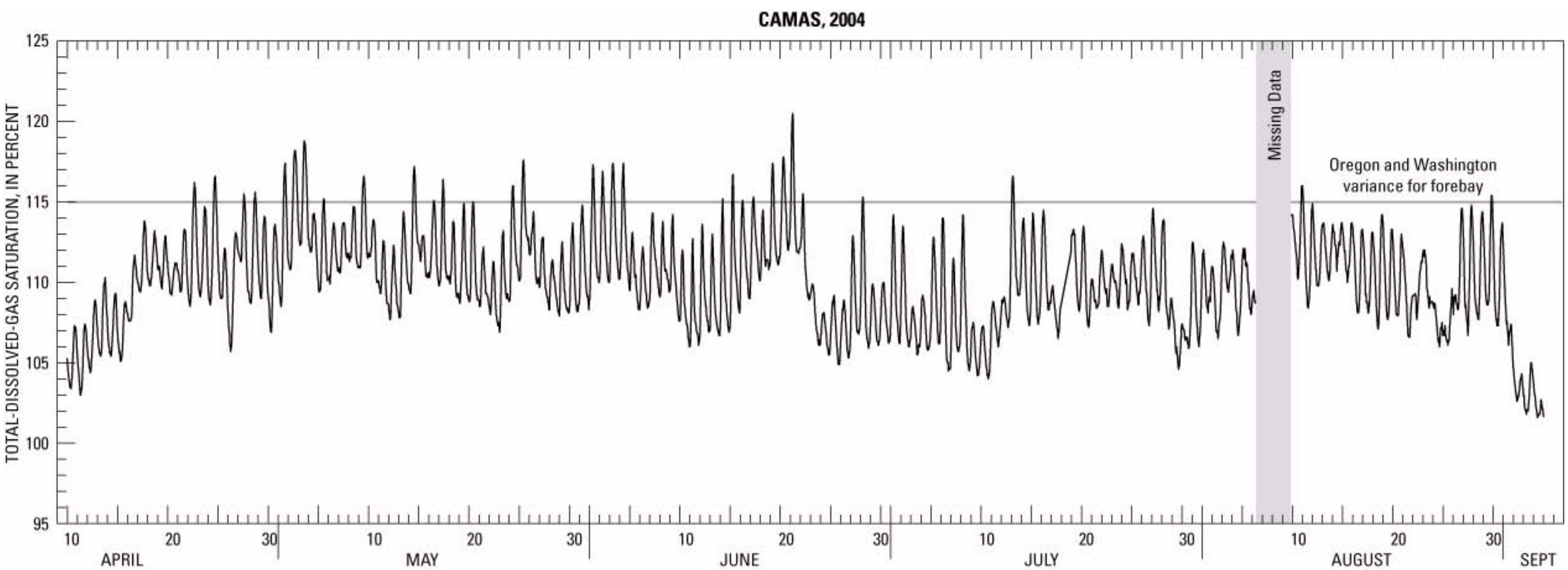

Figure 14. Total dissolved gas at Camas, April 10 to September 4, 2004.

Comparison of Total Dissolved Gas and Temperature to Standards

In 2004, there were variances or exceptions to the water-quality standard for total dissolved gas of 110% saturation. These variances were to allow spill for fish passage at dams on the Columbia River. The State of Oregon granted a multiyear variance, covering 2003 to 2007 (Stephanie Hallock, Oregon Environmental Quality Commission, written commun., 2003). The State of Washington provided for fish passage in its water quality standards consistent with approved gas abatement plans (Washington Administrative Code 173-201A-200(1)(f), http://www.leg.wa.gov/wac/index.cfm?fuseaction=chapterdigest&chapter=173-201A, accessed October 1, 2004). From April 1 to August 31, 2004, the USACE was granted variances of 115% for forebay sites (John Day navigation lock, The Dalles forebay, Bonneville forebay, and Camas) and 120% for tailwater sites directly downstream from dams (John Day tailwater, The Dalles tailwater, and Warrendale). The 115% and 120% variances were exceeded if the average of the highest 12 hourly values in 1 day (1 a.m. to 12 p.m. [midnight]) was larger than the numerical standard. A separate variance of 125% was in place for all sites for the highest 2-hour average (Oregon Environmental Quality Commission, written commun., 2003), or the highest 1-hour average (Washington Department of Ecology, written commun., 2004). Although the Camas site is not located at the forebay of a dam, it is 24.4 miles downstream from Bonneville Dam, and it is regulated as a forebay site.

There was no water-quality variance in place for the site at Cascade Island. This was a new, experimental site with the purpose of collecting data directly in the spillway of Bonneville dam. The USACE did not use total-dissolved-gas data from the Cascade Island site to regulate spill or flow on the Columbia River.

At three of the seven monitoring stations, the Oregon and Washington variance for TDG was exceeded at some time during water year 2004 (table 3). All sites in exceedance of a variance were forebay sites. The site with the most exceedances was Camas, which exceeded the 115% variance six times, followed by The Dalles forebay, which exceeded the 115% variance three times. At Bonneville forebay, the variance of 115% was exceeded one time in 2004.

Table 3. Exceedances of States of Oregon and Washington water-quality variances for total dissolved gas, lower Columbia River, Oregon and Washington, water year 2004.

[Note: Table is based on the U.S. Geological Survey (USGS) data base.]

Station name	Numerical variance for total dissolved gas, in percent saturation	Number of days in exceedance of variance
John Day navigation lock	115	0
John Day tailwater	120	0
The Dalles forebay	115	3
The Dalles tailwater	120	0
Bonneville forebay	115	1
Warrendale	120	0
Camas	115	6

The distribution of TDG values for the spill season (April 12 to August 31, 2004) is shown in figure 15. Even though the median TDG values for the tailwater stations decreased slightly going downstream (from JHAW to TDDO to WRNO), the forebay sites showed a corresponding increase in the median (from JDY to TDA to BON to CWMW). The situation with the forebay sites probably reflects the river's inability to degas to a "baseline" level downstream of each dam, before another dam is encountered to again cause an increase in TDG.

Water temperature standards that apply to the lower Columbia River are complex and depend on the effects of anthropogenic activities and the locations of salmonid rearing, spawning, and egg incubation areas. According to the State of Oregon water-quality standard, the 7-day-average maximum temperature of the lower Columbia River should not exceed 20°C (Oregon Department of Environmental Quality, Temperature Criteria Rules OAR 340-041-0028, modified 05/20/2004, at http://www.deq.state.or.us/wq/wqrules/Div41/OAR340Div41.pdf, accessed October 13, 2004). 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 (Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC, last update July 1, 2003, http://www.ecy.wa.gov/pubs/wac173201a.pdf, accessed October 13, 2004).

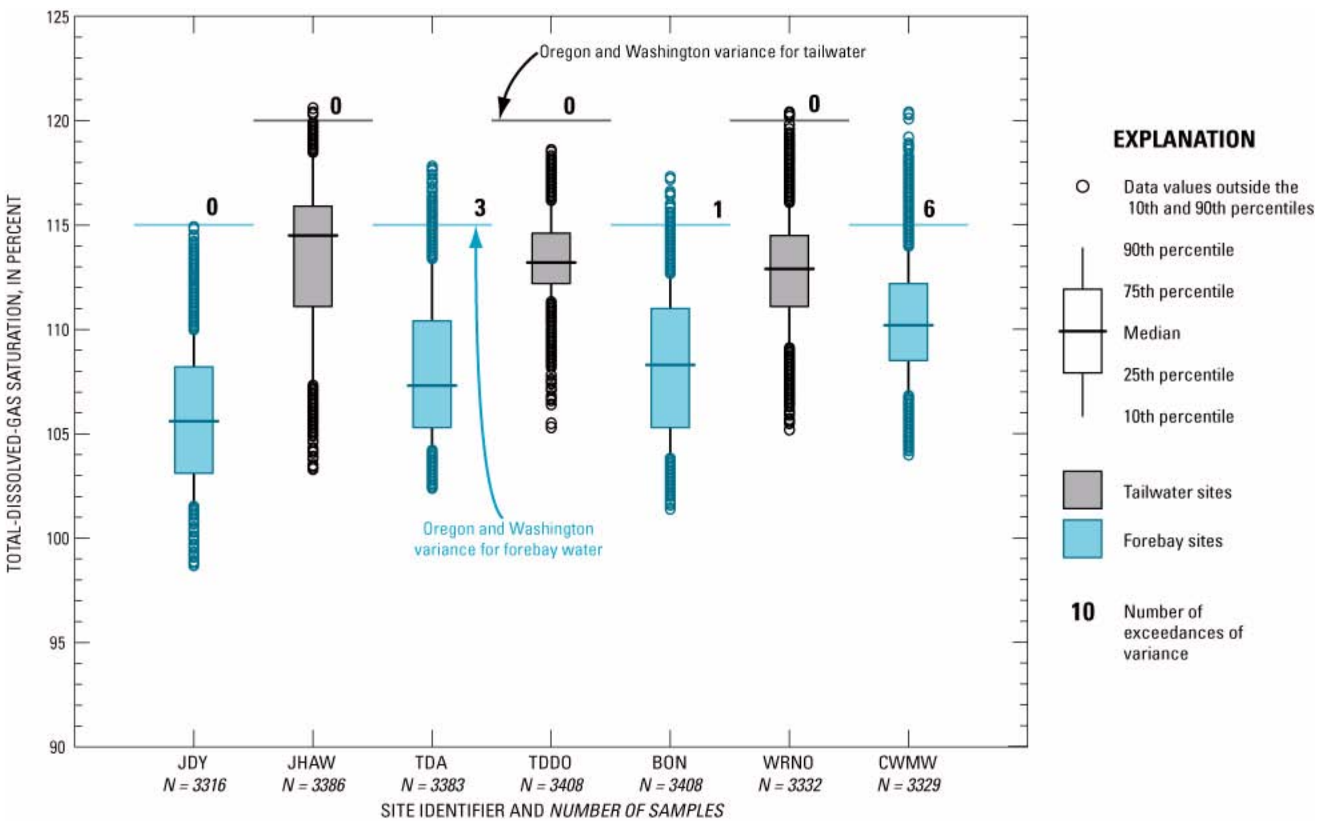

Figure 15. Distributions of hourly total-dissolved-gas data and exceedances of Oregon and Washington water-quality variances, April 12, 2004 to August 31, 2004. (Refer to table 1 for site identifiers.)

Water temperatures upstream and downstream from John Day Dam were equal to or larger than 20.0°C continuously from July 11 to September 14 (fig. 16). The TDG monitoring site at the John Day navigation lock (at river mile 215.7) was new for water year 2004. The site was relocated because the previous site upstream from the John Day Dam, John Day forebay (at river mile 215.6), showed temperature increases caused by heating of the pool's surface. These temperature increases were not representative of the whole river, and contributed to increased TDG levels that also may not have been representative. Examples of these heating events are shown in figure 17, which shows 2003 water temperature data at the old John Day forebay site plotted hour-by-hour against the water temperature at John Day tailwater. The John Day tailwater site probably represented the overall temperature of the river, whereas the John Day forebay site did not, since it was in a pool of stagnant, unmoving water. The data in figure 17, from March 25 to September 15, 2003, show that for many hourly data points, the water above John Day Dam was 1 or 2°C warmer than that of the tailwater.

The new site, at the John Day navigation lock, is about 0.1 mile upstream of the John Day Dam (as contrasted to the old site, which was located directly on the upstream face of the dam). Additionally, the probe at the new site was installed at a depth of about 32 feet, whereas the probe depth at the old site was about 18 feet. These two factors were intended to decrease the influence of surface heating of water near the dam. As the data in figure 18 show, in 2004 at the new site at John Day navigation lock the temperature each hour was very close to the temperature for the same time at the John Day tailwater site.

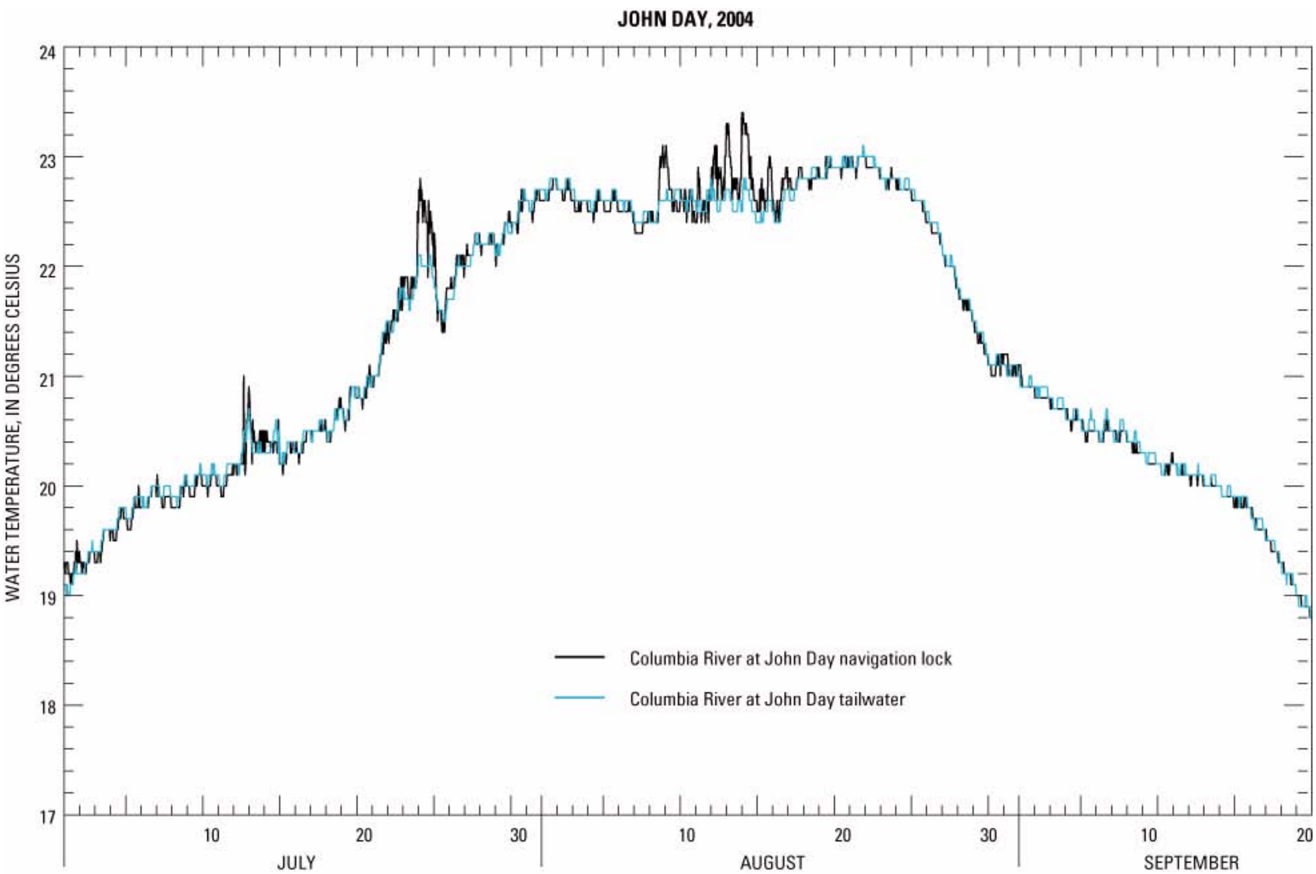

Figure 16. Water temperature upstream and downstream of John Day Dam for summer 2004.

The difference between the two sites was almost always less than 1°C. This indicates that the new site represented the temperature of the river better than the site that was previously upstream of the John Day Dam.

Water temperatures upstream and downstream from The Dalles Dam were equal to or larger than 20.0°C continuously from July 12 to September 12 (fig. 19). The water temperature at The Dalles forebay was approximately equal to the temperature at The Dalles tailwater, indicating well-mixed conditions in the forebay.

Water temperatures upstream and downstream from Bonneville Dam are shown in figure 20. Temperatures at Bonneville forebay were equal to or larger than 20.0°C continuously from July 13 to September 3. The water temperature at Warrendale (the tailwater site) was approximately equal to the temperature at Bonneville forebay, but water temperatures were more variable at Warrendale, sometimes differing from the forebay by as much as 0.4°C.

At the Camas site, the water temperature was 20.0°C or larger continuously from July 13 to September 4 (fig. 21). As in the past, there was a distinct daily cycle to temperature, with an amplitude of about 1°C, a minimum occurring at about 0900 hours, and a maximum at about 1900 hours.

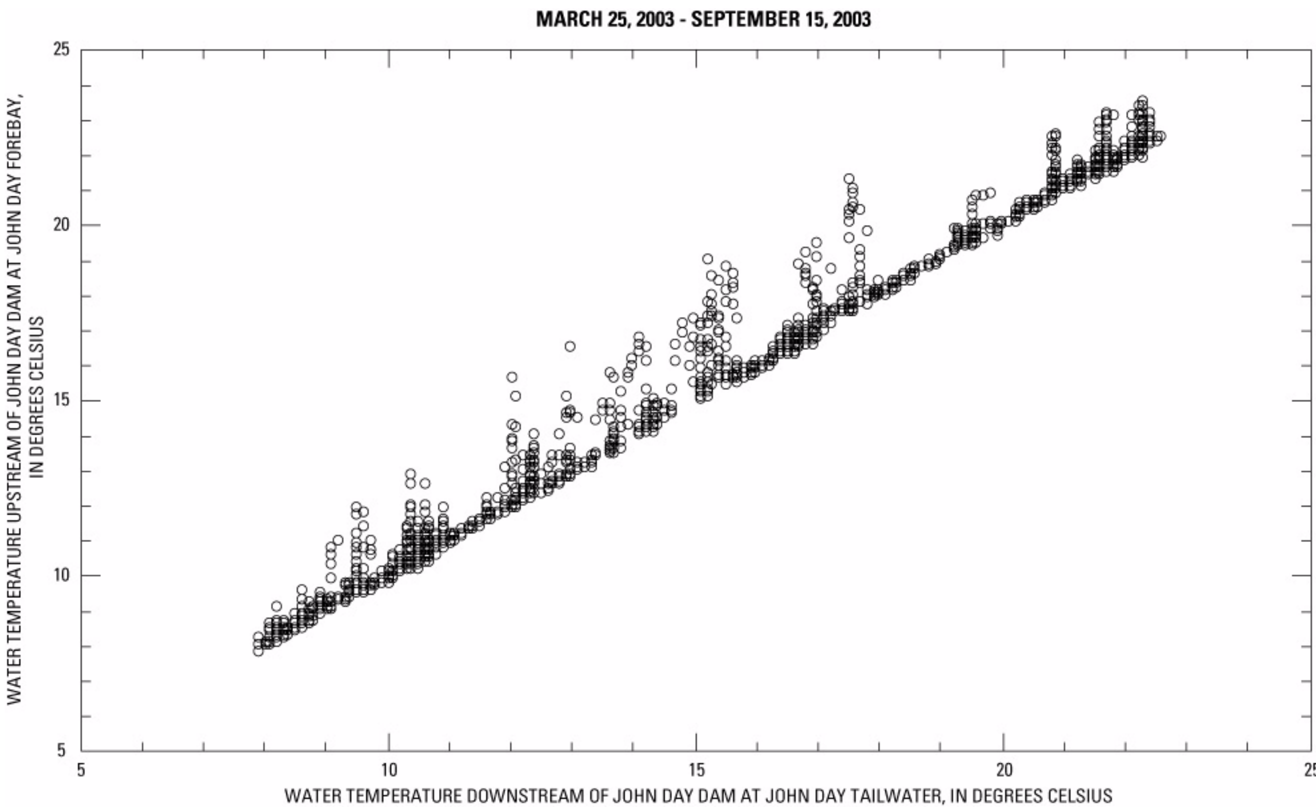

Figure 17. Comparison of hourly water temperature at John Day forebay and John Day tailwater, March 25, 2003 to September 15, 2003.

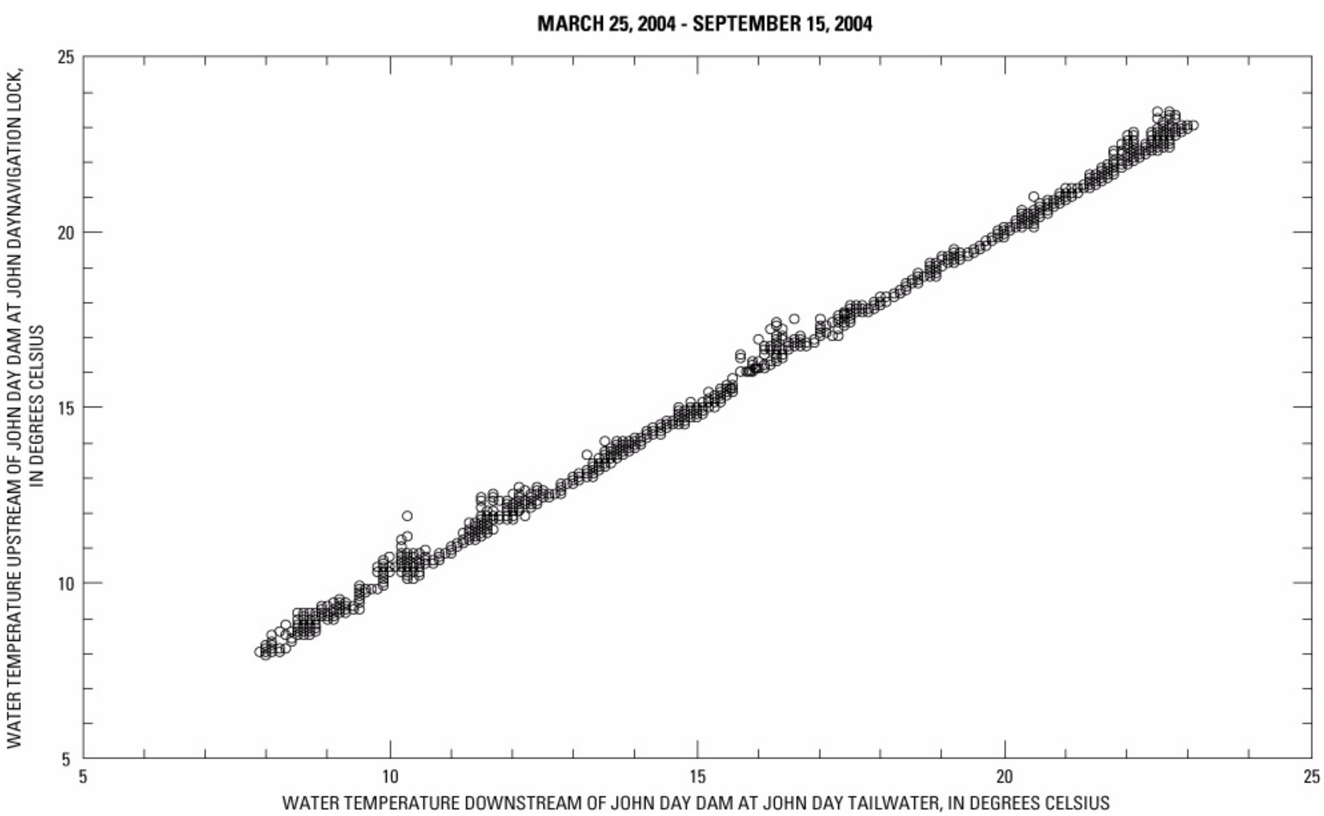

Figure 18. Comparison of hourly water temperature at John Day navigation lock and John Day tailwater, March 25, 2004 to September 15, 2004

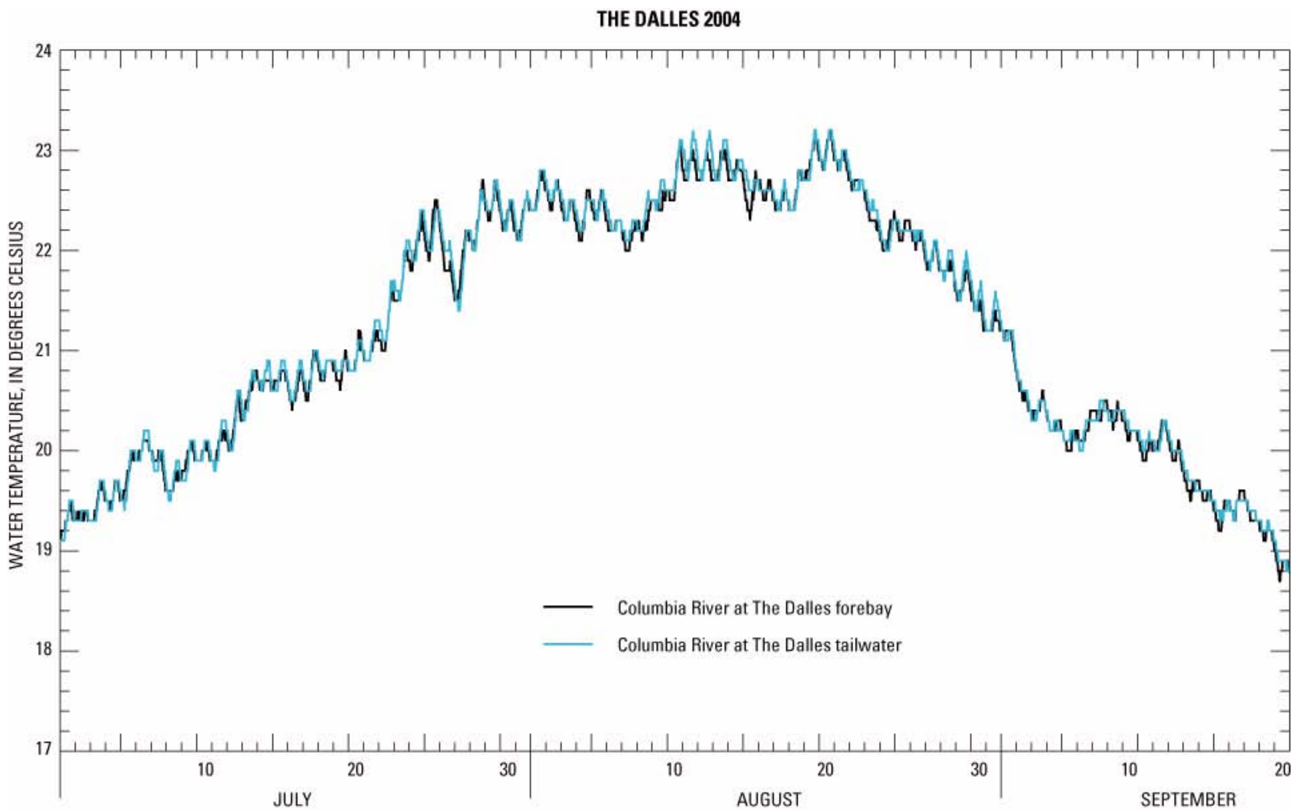

Figure 19. Water temperature upstream and downstream of The Dalles Dam for summer 2004.

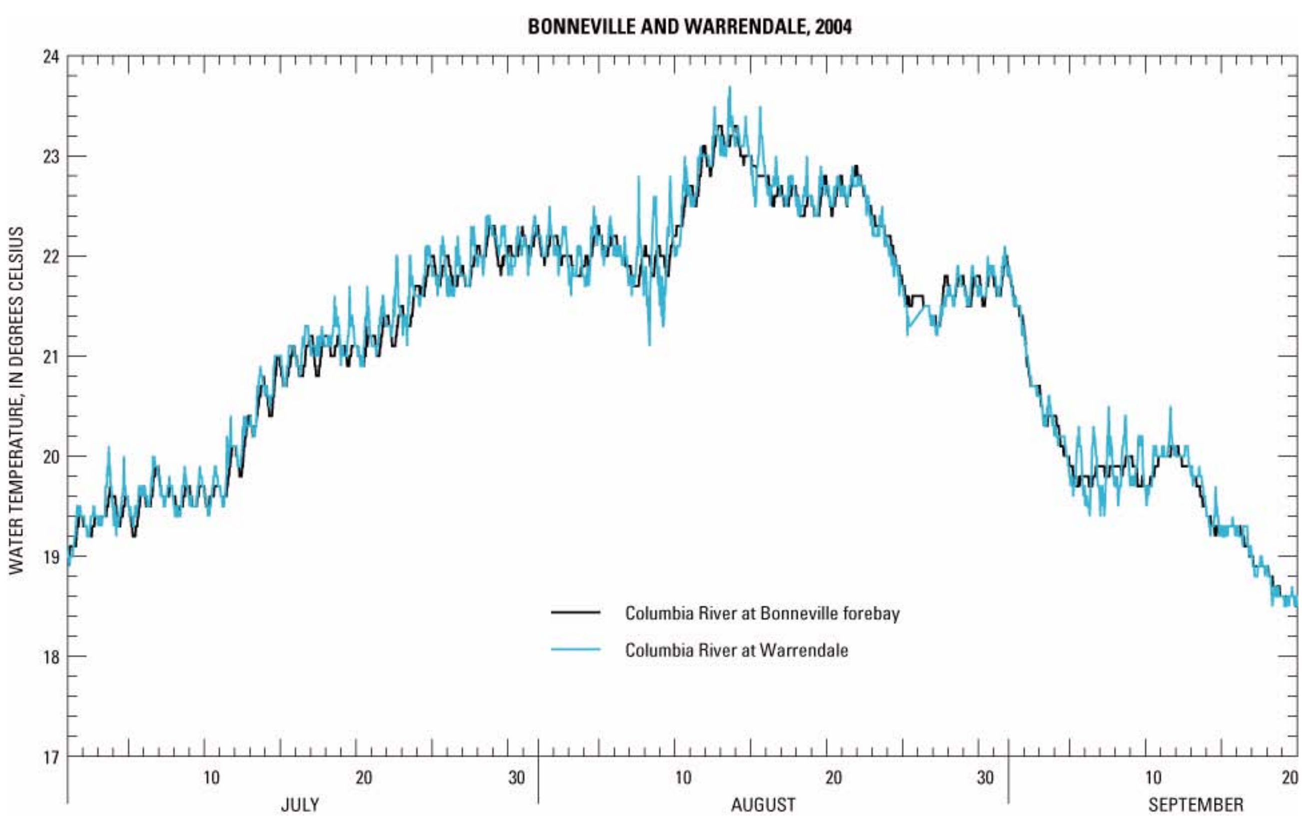

Figure 20. Water temperature upstream and downstream of Bonneville Dam for summer 2004.

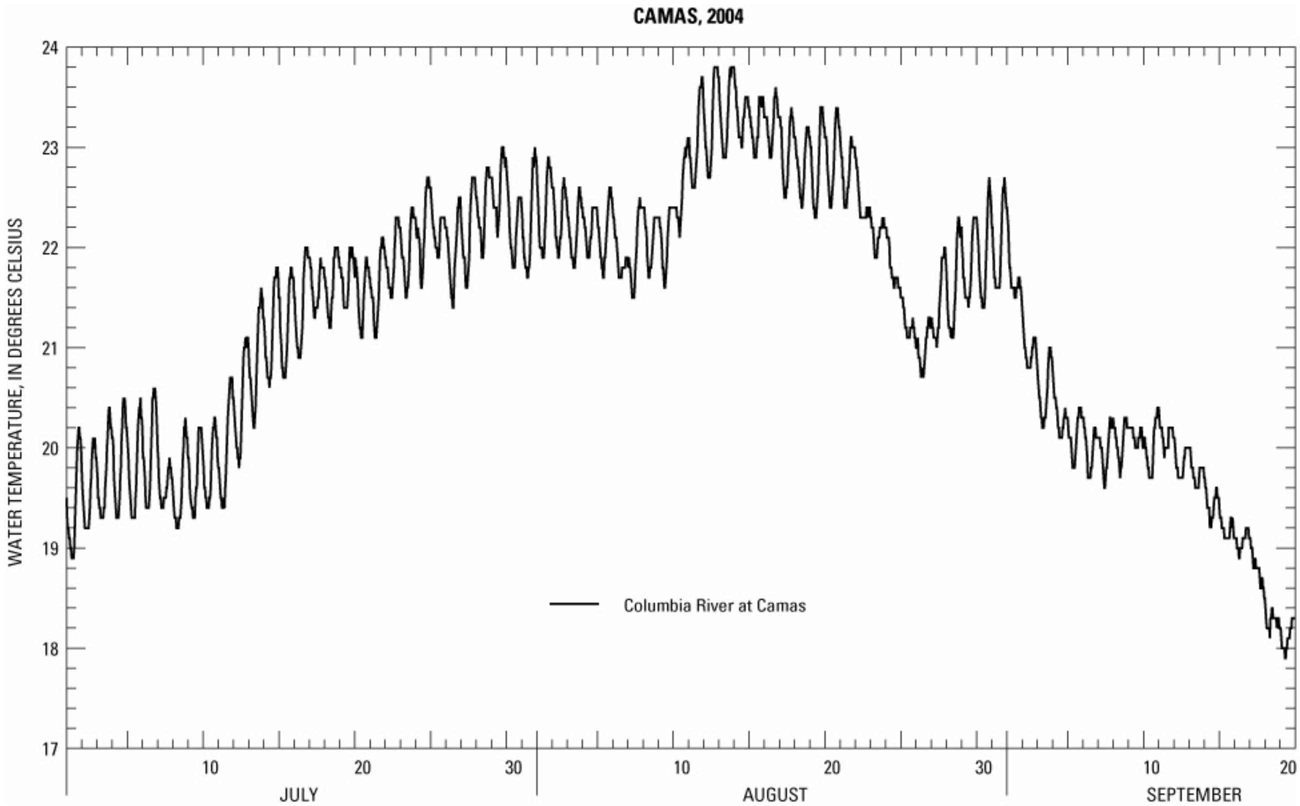

Figure 21. Water temperature at Camas for summer 2004.

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