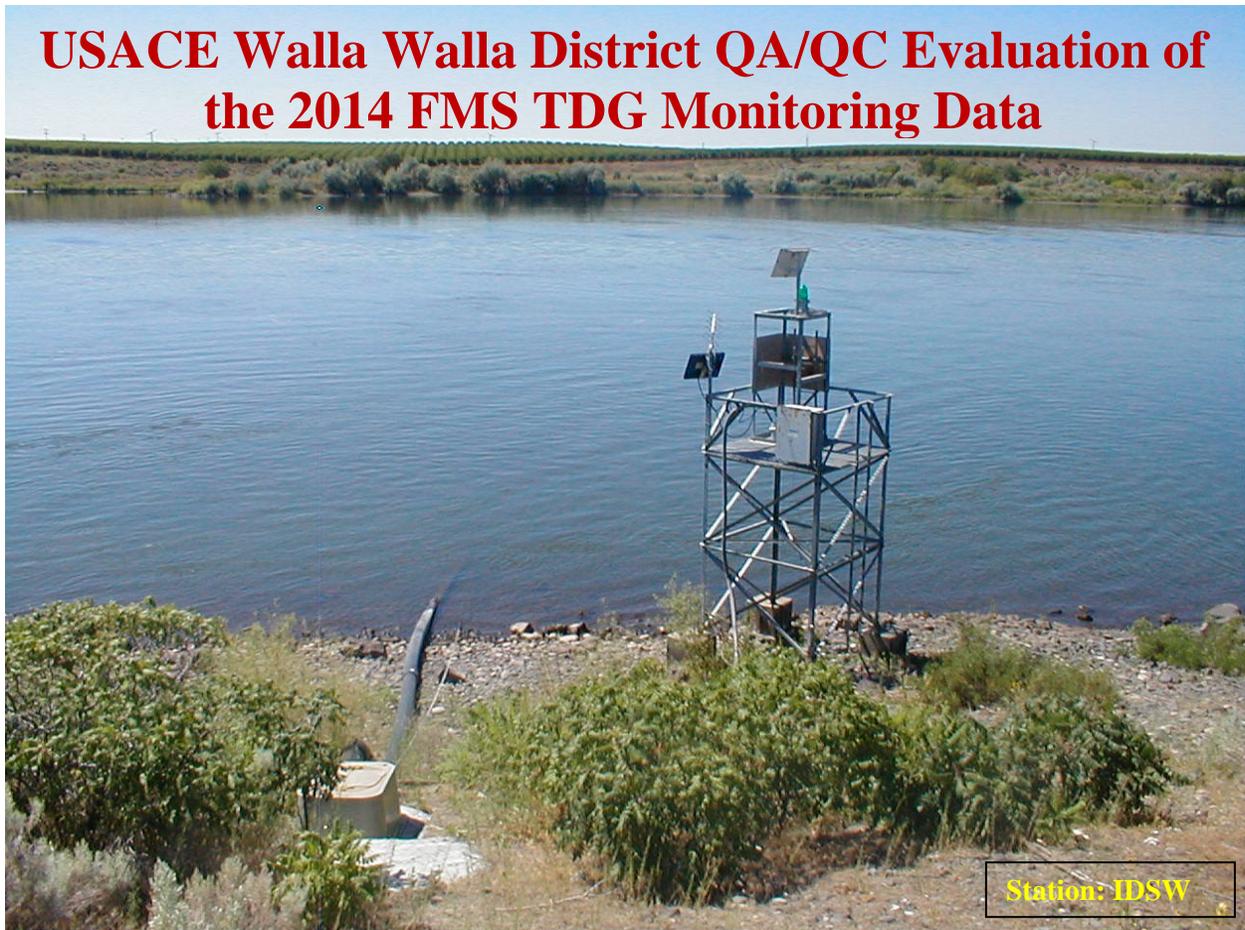


Appendix G

USACE Walla Walla District QA/QC Evaluation of the 2014 FMS TDG Monitoring Data



Includes:

**McNary, Ice Harbor,
Lower Monumental, Little Goose,
Lower Granite, and Dworshak Projects**

USACE Walla Walla District QA/QC Evaluation of the 2014 FMS TDG Monitoring Data

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ABSTRACT

The U.S. Army Corps of Engineers (USACE), Walla Walla District (CENWW), operated fifteen fixed-monitoring system (FMS) stations (nine seasonal and six year round) for total dissolved gas (TDG), barometric pressure (BP), and temperature as part of their 2014 water-quality program. These stations are located on the Columbia, Lower Snake and Clearwater Rivers. This report provides a summary of the 2014 water-year quality assurance/ quality control (QA/QC) evaluation. Highlights include:

- Data completeness for the combined BP, TDG, and temperature data received averaged 98.1 percent for the 15 monitoring sites in 2014 (nine seasonal and six year-round).
- The TDG data received from the individual sites ranged from 89.9 percent to 100.0 percent complete (Table G-7, Appendix G). The Little Goose tailwater (LGSW) FMS gauge had the highest number of unreliable TDG measurements as a result of values that were considered too low. Table G-8 (Appendix G) describes the individual causes for missing and invalid data.
- The TDG sensors from the 15 seasonal and annual FMS were removed from the field and calibrated in the laboratory every 3 weeks between April 2014 and August 2014. From September 2013 through March 2014, the six annual FMS were calibrated at four-week intervals.
- All 168 in-situ field checks of TDG sensors with the replacement probe were within ± 1 percent after the deployment period.
- The calculated median for the 171 field checks for barometric pressure was 0.00 mm Hg. 167 of the individual values were within ± 0.2 mm Hg of a secondary standard. Three outliers occurred at the Lewiston (LEWI) station while one was noted at the McNary tailwater (MCPW) station.
- The calculated median for the water temperature field checks was -0.02 °C. Station medians ranged from -0.08 °C to 0.02 °C. 166 of the 169 individual assessments were within ± 0.2 °C.
- The Pasco (PAQW), Peck (PEKI), Lewiston (LEWI), and Anatone (ANQW) deployment pipes were cleaned with compressed air to remove built-up sediment. The deployment pipe at Dworshak (DWQI) was rebuilt to repair a broken coupling and shorten the pipe to place it in an area of the river with more flow.

1.0 INTRODUCTION

Walla Walla District (CENWW) of the U.S. Army Corps of Engineers (USACE) operates six hydropower projects in the Columbia, Snake, and Clearwater River basins: McNary, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, and Dworshak dams. These six dams are included in the basin-wide fixed-monitoring system (FMS) network. Six of the stations (*i.e.*, the tailwater stations at McNary Dam, Ice Harbor Dam, Lower Monumental Dam, Little Goose Dam, Lower Granite Dam, and Dworshak Dam) are operated throughout the year (Figure G-1; Table G-1). The remaining nine stations record hourly data from 1 April through 31 August, and typically bracket that period.

Three water-quality parameters are monitored at these facilities. One is total dissolved gas (TDG). This parameter is of interest since gas supersaturation results when air is entrained as water flows over the spillways and plunges into the stilling basin where water pressure causes the air to go into solution. The river subsequently becomes shallow beyond the stilling basin and the result is water supersaturated with TDG relative to atmospheric conditions. The U.S. Environmental Protection Agency (USEPA) has established an upper limit of 110 percent TDG for protection of freshwater aquatic life. Greater than 110 percent TDG can cause gas bubble trauma in fish and adversely affect other aquatic organisms. The State of Washington rule adjustment allows the percent TDG to reach 115 percent in the forebays and 120 percent in the tail waters when water is spilled for fish passage. The TDG criteria are not applicable when river discharge is greater than the 7Q10. Washington State TDG standards specify that the maximum TDG measurement cannot exceed 125 percent for one-hour while the Oregon TDG standards limit it to two hours. Two additional parameters that influence the percent TDG are barometric pressure (BP) and water temperature. As such, measurements for these two constituents are also recorded and stored in the database.

Measurements were completed hourly at all stations and transmitted via the Geostationary Operational Environmental Satellite Program (GOES) system to USACE and U.S. Geological Survey (USGS) databases. The Corps Water Management System (CWMS) database at the Northwestern Division (CENWD) office in Portland, Oregon can be accessed at <http://www.nwd-wc.usace.army.mil/report/total.html>. The link to real-time USGS data for Washington is <http://waterdata.usgs.gov/wa/nwis/current/?type=quality>.

2.0 PURPOSE AND SCOPE

The purpose of TDG monitoring is to provide managers, agencies, and interested parties with near real-time data for managing stream flows, spill, and percent TDG downstream from power-producing dams, as well as meeting the legal requirements presented in the 2010/2014 Supplemental Biological Opinion RPA 15. An additional purpose of this report is to show that CENWW complied with the 2010-2014 TDG Monitoring Plan during 2014. Compliance included achieving greater than 95 percent completeness for the entire data set, accomplishing the lab and field calibration using established criteria, and utilizing the primary and secondary standards called for in the plan.

As with any data collection activity, an important component that cannot be overlooked is the quality of the data. Measurement of data quality allows determination of the usefulness and relevance of the data for current and future decision processes. As such, this report:

- Describes the data collection methods.

- Evaluates quality assurance/ quality control (QA/QC) data for the FMS stations at McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite reservoirs. Additionally, this data-collection system provided water quality information for; (a) the Clearwater River downstream of Dworshak Dam and at Peck and Lewiston, (b) the Columbia River near Pasco, and (c) the Snake River near Anatone, Washington (Figure G-1; Table G-1).
 - The QA/QC data includes:
 1. Instrument Data: This data was used to evaluate how an instrument performed as a function of the magnitude and direction that individual sensors deviated over time from their respective laboratory standards. These relationships were determined for each sensor before and after each deployment.
 2. Station Data: These data present comparisons between an in-place instrument that was deployed at a given station for a specified cycle and a newly calibrated QA/QC instrument (field standard). The Sutron[®] barometers at each station were evaluated with a Novalynx[®] hand-held barometer that served as a portable field standard for barometric pressure. Fifteen stations were visited for routine maintenance once every three weeks between 1 April and 31 August. The six year-round stations were maintained once every four weeks for the remainder of the year.

3.0 METHODS

3.1 DATA COLLECTION

The instrumentation at each FMS station consisted of components provided by CENWW and the USGS Kennewick, Washington, office. A 12-volt battery charged by a solar panel powered each station. Forty Hydrolab[®] multi-parameter probes (*i.e.*, MS4A's and MS5's) were utilized. Thirty-one of these units were provided by CENWW and the remaining nine belong to the USGS. Each sonde was deployed 4.1 times, on average, during water year 2014.

3.2 LABORATORY PROCEDURES

The TDG sensor measures the sum of the partial pressures of gaseous compounds dissolved in the water and reports the result in millimeters of mercury (mm Hg). The TDG sensor requires a two-step calibration procedure (*i.e.*, adjustments are made at two points on the calibration curve) that is completed prior to and after deployment. The atmospheric pressure calibration point (Lab BP) is equal to the atmospheric pressure at the time of calibration as measured with a ParoScientific[®] digiquartz barometric pressure standard that is calibrated yearly at the factory. The differences between Lab BP and the pressure measured by the sensor [$\Delta(\text{BP-PT})$] were recorded before and after deployment. The slope of each sensor response was also evaluated to ensure that measurements were interpolated correctly over the full range of expected field values. To accomplish this task, a Heise[™] PTE-1 hand held certified pressure calibrator, calibrated yearly at the factory (primary standard) and an Ashcroft digital test gauge, also calibrated yearly at the factory (primary standard), were used to apply pressure to the TDG sensor. Three hundred millimeters of mercury were added to Lab BP during the pre-deployment check and the differences between Lab BP+300 and the sensors' response were recorded as $\Delta[(\text{BP}+300)\text{-PT}]$. Similar tests were completed post-deployment when 100 mm Hg was added to Lab BP, and the

resulting differences were recorded as $\Delta[(BP+100)-PT]$. Pre-deployment pressure tests were made without a membrane installed. Post-deployment tests were made with a dry membrane in place.

Each sonde also includes a sensor for reporting water temperature in degrees Celsius ($^{\circ}\text{C}$). Sensor thermometers are factory calibrated and cannot be adjusted. However, temperature sensor performance was evaluated pre- and post-deployment by comparing instrument readings to two Barnant Model 600 digital thermistors. Both of these instruments were checked quarterly against a National Institute of Standards and Technology (NIST) mercury thermometer standard.

3.3 FIELD PROCEDURES

The differences in barometric pressure, water temperature, and TDG between a secondary standard instrument (*i.e.*, replacement sensor) and the fixed-station monitors after three or four 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 the field instrument value, were used to compare and quantify the precision between two independent instruments. The Sutron[®] barometers were checked using a Novalynx[®] M2 Series hand-held digital barometer that is calibrated yearly at the factory. The water temperature and TDG comparisons were made *in situ* with the secondary standard (*i.e.*, a recently calibrated Hydrolab[®]) positioned alongside the field Hydrolab[®].

3.4 DEFINING INVALID AND MISSING DATA VALUES

The provisional real-time data were examined daily during the workweek by CENWW and/or USGS employees. Missing values and those that appeared to be outside the expected range were flagged. If a reasonable explanation (*e.g.*, routine maintenance, DCP failure, or defective membrane) could be attributed to the incident, then the data point, or points, was not included in the final data set used for this analysis. Outlying data points that could not be attributed to a specific cause were retained.

4.0 RESULTS AND DISCUSSION

4.1 INVENTORY-WIDE SENSOR QA/QC PERFORMANCE

4.1.1 Pre-deployment

The pre-deployment evaluation of the sensors consisted of 156 individual checks for barometric pressure (Table G-2). The evaluation of the pressure sensors to the standard revealed a calculated mean of -0.11 mm Hg, and a range of -1.0 to 0.9 mm Hg (Table G-2; Figure G-3). Three hundred millimeters of mercury was added to the TDG sensor in the laboratory using the laboratory barometer as the baseline standard. The difference between the barometer with 300 mm Hg of pressure and the instrument was compared against the expected value. The sensor pressure differences ranged from -0.1 percent to 0.1 percent and the calculated mean and median values were both -0.01 percent (Figure G-4; Tables G-2 and G-3).

The dissimilarities between the NIST-traceable thermometer and the sensor thermistors were also quite small. The calculated average and median values for all the instruments were 0.02 $^{\circ}\text{C}$ and 0.03 $^{\circ}\text{C}$, respectively. These calculated values were based on 156 measurements where the minimum and maximum differences for individual sensors ranged from -0.21 $^{\circ}\text{C}$ to 0.12 $^{\circ}\text{C}$

(Tables G-2 and G-3; Figure G-5). The instrument manufacturer's specification is ± 0.20 °C for all instruments within a sample pool.

4.1.2 Post-deployment

The evaluation of the post-deployment QA/QC data also displayed favorable results. A total of 153 data points were used for the evaluation. The differences between the laboratory barometric pressure and that recorded by the sensors ranged from -4.4 mm Hg to 1.2 mm Hg, with a mean of -0.06 mm Hg (Tables G-2 and G-4; Figure G-3). The results of the post calibration checks using barometric pressure +100 mm Hg showed a calculated mean of -0.01 percent, and a range of -0.6 to 0.1 percent (Table G-2; Figure G-4).

There were 153 post deployment checks available for temperature evaluation. Temperature post calibration checks resulted in a calculated mean of 0.01 °C with a range between -0.21 °C and 0.12 °C (Tables G-2 and G-4; Figure G-5).

4.2 SYSTEM-WIDE STATION QA/QC PERFORMANCE

The analysis of the station QA/QC data showed that the in-place barometric air pressure, TDG pressure, and temperature instruments performed well when compared to the secondary standards (Figures G-6 through G-8). A total of 171 readings were used to calculate the mean and median values for barometric pressure (Table G-5). The median of all the differences calculated between the station barometers and the secondary standards was 0.00 mm Hg (Table G-5; Figure G-6). All of the station calculated medians were within -0.1 to 0.1 mm Hg (Table G-6). The defective barometer at LEWI that caused individual extreme values was replaced at the end of April 2014. The published accuracy of the barometers is ± 0.7 mm Hg.

A total of 168 readings were used to calculate the mean and median values for TDG instrument pressure (Table G-5). The overall median for the percent TDG differences between the in-place and replacement sensors was -0.1 percent saturation (Table G-5; Figure G-7). Individual median station values ranged from -0.3 percent saturation to 0.3 percent saturation (Table G-6).

A total of 169 readings were used to calculate the temperature differences between the in-place and replacement sondes (Table G-5). The calculated mean and median temperature differentials for the field data were -0.01 °C and -0.02 °C, respectively (Table G-5; Figure G-8). The median values for individual stations ranged from -0.08 to 0.02 °C (Table G-6). The manufacturer's specification for the temperature sensor is ± 0.20 °C.

4.3 FMS DATA COMPLETENESS AND STATION STATISTICS

Percent completeness for the real-time TDG, barometric pressure, and temperature data were 98.5, 99.8, and 99.8 percent, respectively (Table G-7). The most frequent reason attributed to missing or anomalous in the real-time data set was low TDG pressure (1.12 percent of the combined station performance, which is equivalent to 59.8 percent of all missing and invalid data shown in the last column of Table G-8). Thirteen of the fifteen stations exceeded the required 95 percent criterion for data completeness for all parameters. The exceptions were Little Goose tailwater (LGSW) and Pasco (PAQW) where the TDG data were 93.2, and 89.9 percent complete, respectively, due to hourly values that were rejected as a result of being too low (Table G-8).

4.3.1 Barometric Pressure

Barometric pressure data was 100 percent complete at eleven of the fifteen FMS stations (Table G-7). Three of the remaining eight stations were more than 99 percent complete. The Dworshak station (DWQI) had the lowest completeness at 97.0 percent due to DCP failure. Cable failure was the next most common cause of omitted data, totaling 48 hours (Tables G-8 and G-9).

4.3.2 Total Dissolved Gas

The TDG data from the fifteen stations averaged 98.5 percent complete (Table G-7). The McNary forebay (MCNA), Ice Harbor tailwater (IDSW), Lower Monumental forebay (LMNA), Little Goose forebay (LGSA), and lower Granite forebay (LWG) stations were all 100 percent complete. The two stations that experienced the greatest amount of data loss were Little Goose tailwater (LGSW) and Pasco (PAQW) where the final data set statistics were 93.2, and 89.9 percent complete, respectively (Table G-7). Low TDG pressures accounted for the majority of the data losses at those stations (Table G-8 and G-10).

4.3.3 Temperature

The temperature data from the fifteen FMS stations averaged 99.8 percent complete. Seven stations (McNary forebay [MCNA], Ice Harbor tailwater [IDSW], Lower Monumental forebay [LMNA], Little Goose forebay [LGSA], Lower Granite forebay [LWG], Lewiston [LEWI], and Peck [PEKI]) attained 100 percent completeness (Table G-7). Seven of the remaining eight stations were all greater than 99 percent complete, with Dworshak (DWQI) at 95.3 percent. Cable and DCP failures were the primary reasons for not achieving 100 percent completeness (Table G-8 and G-11).

4.4 DEPLOYMENT PIPE CLEAN-OUT

Sediment build-up occurred in the deployment pipes at Anatone, Peck, Lewiston, and Pasco that resulted in low TDG measurements and/or difficulty retrieving the sonde. The Pasco station on the Columbia River was cleaned on 11 March, followed by Peck and Lewiston on the Clearwater River on 12 March. The Snake River Anatone station was cleaned with compressed air on 29 July.

4.5 DWORSHAK DEPLOYMENT PIPE REPAIR

The Dworshak tailwater (DWQI) FMS station is located on the North Fork of the Clearwater River along the left bank directly adjacent to the Dworshak National Fish Hatchery's water intake pump house near Ahsahka, Idaho. The deployment pipe is made of 8-inch diameter SDR 17 black high density polyethylene (HDPE) pipe and was retrofitted with a screen to prevent muskrat access in 2012.

During the latter part of March when project releases reached 20 kcfs, the deployment pipe disconnected at one of the couplings (Figure G-9). A task order with Resource Management Group, Inc. was developed and the pipe was rebuilt during 12-13 June. The pipe was also shortened by approximately 30-ft at that time to position it in a section of the stream where there was greater flow when the project operates at the low range of discharges. The back-up

deployment pipe located along the shore next to the fish hatchery water intake was used while the main pipe was out of service.

4.5 PECK STATION

A car accident that occurred on 27 March demolished the USGS station structure (Figure G-10). A subsequent investigation by Corps personnel indicated that the TDG related equipment was not significantly damaged. The flexible conduit that connects the NEMA enclosure to the irrigation box was scheduled to be replaced before the accident and completed on 22 May.

5.0 SUMMARY

Hourly TDG, temperature, and barometric data recorded during the 2014 water year at fifteen FMS stations were evaluated. Six tailwater sites were maintained throughout the year and nine additional locations were added for the 1 April through 31 August fish spill season. The combined data from all stations exceeded the 95 percent criterion.

The USGS Kennewick field office performed routine station maintenance, completed emergency repairs, and operated the DCPs under a cooperative agreement with Walla Walla District. The preventative maintenance schedule provided for calibration and routine maintenance at three week intervals during the fish spill season and once every four weeks during the rest of the year. Station performance was hampered primarily by low TDG values, DCP malfunctions, cable failures, defective membranes, and inspections

The pre-deployment QA/QC checks showed a mean difference of -0.11 mm Hg when the TDG sensors were compared to barometric pressure and -0.01 percent when 300 mm Hg of pressure was added. The calculated means for the post-deployment evaluations were -0.06 mm Hg and -0.01 percent when the TDG sensors were compared to barometric pressure and barometric pressure plus 100 mm Hg, respectively. The calculated mean temperature difference was 0.02 °C for pre-deployment and 0.01 °C for post-calibration.

The 40 instruments used to perform this year's monitoring met the manufacturers' specifications. Field checks during routine maintenance demonstrated that the air barometric pressure, percent TDG, and temperature averaged 0.04 mm Hg, 0.0 percent, and -0.01 °C, respectively, when compared to the secondary standards.

The deployment pipes at Peck and Lewiston on the Clearwater River, Pasco on the Columbia River, and Anatone on the Snake River were purged of sediment build-up to remedy issues related to low TDG measurements and instrument retrieval.

Repairs were also completed at two FMS stations during the 2014 water year. The Dworshak (DWQI) deployment pipe was shortened and re-coupled where it was detached, and a length of flex conduit was replaced at the Peck (PEKI) station.

FIGURES

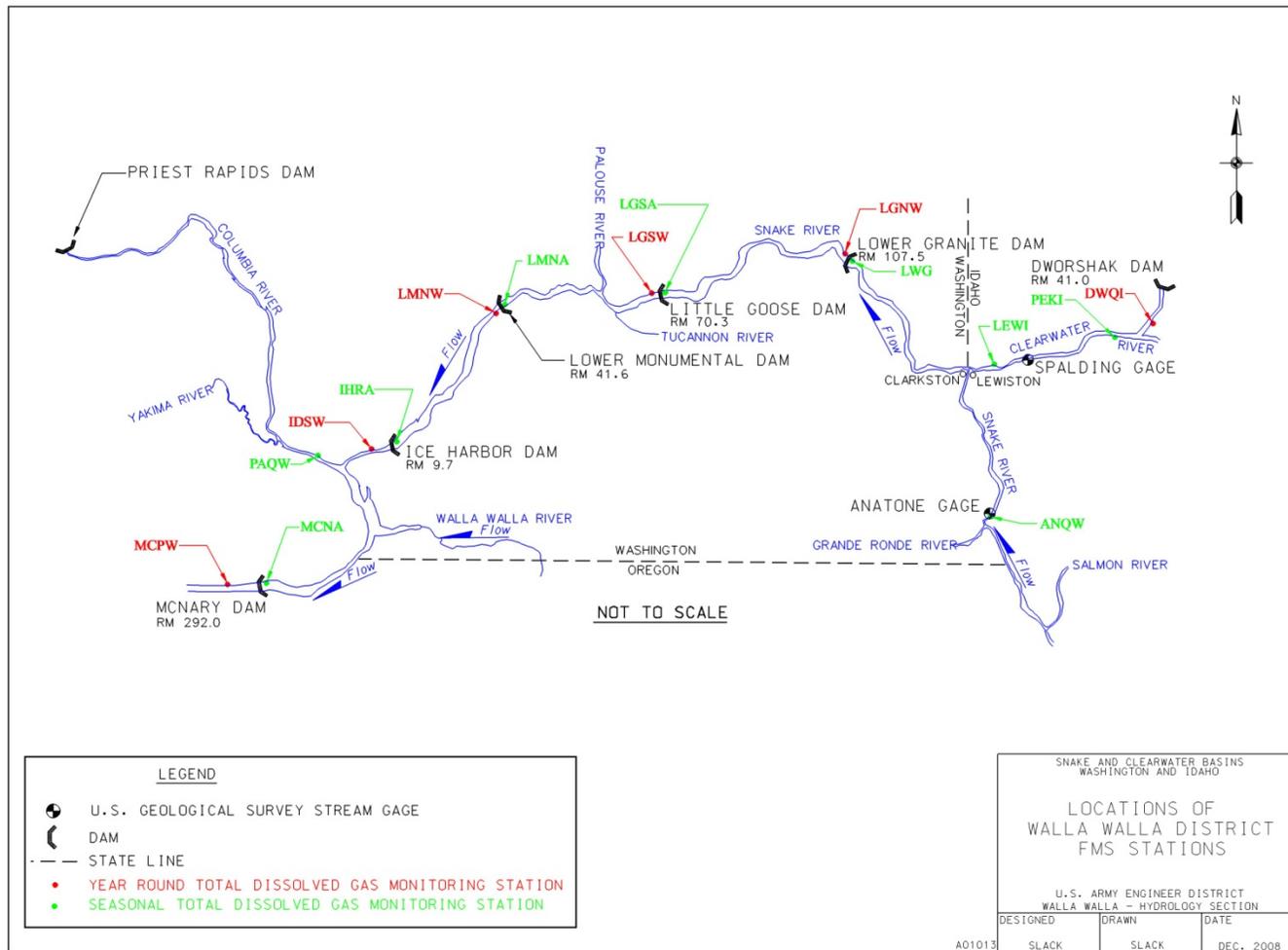


Figure G-1. Locations of Walla Walla District’s FMS stations.

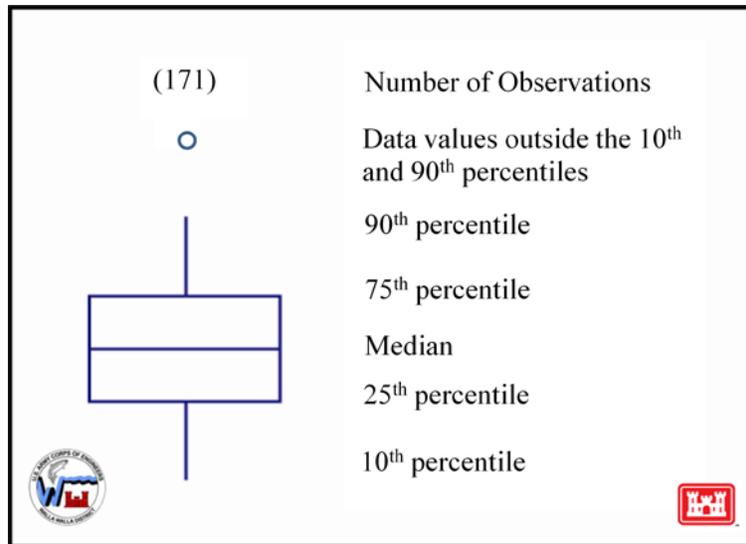


Figure G-2. Explanation key for the box plot information.

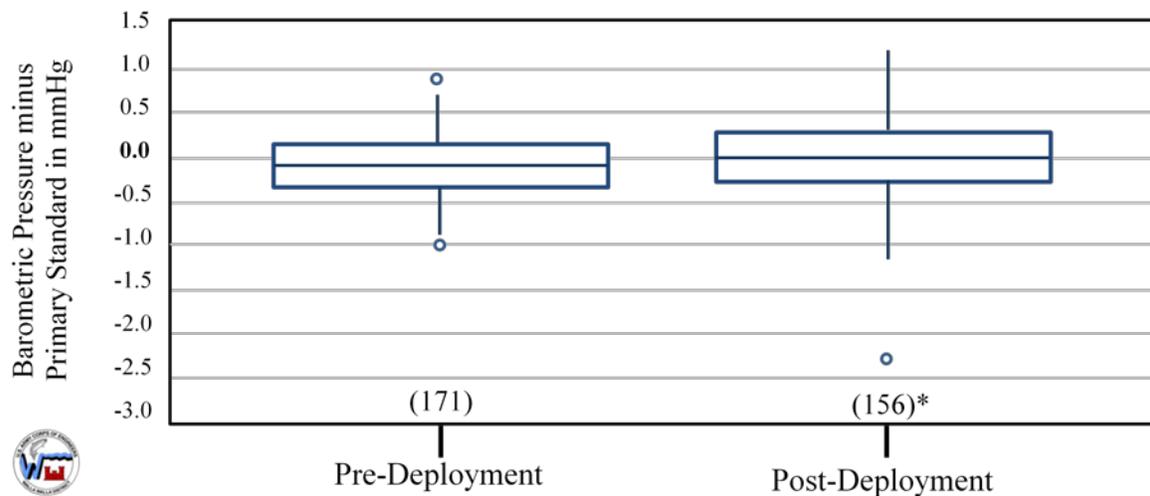


Figure G-3. Summary box plots of the pre-and post-deployment check of the barometric pressure versus the primary standard during the 2014 monitoring season.

Note:

* N was equal to 158 but there were two outliers greater than -5.0 due to malfunctioning barometers.

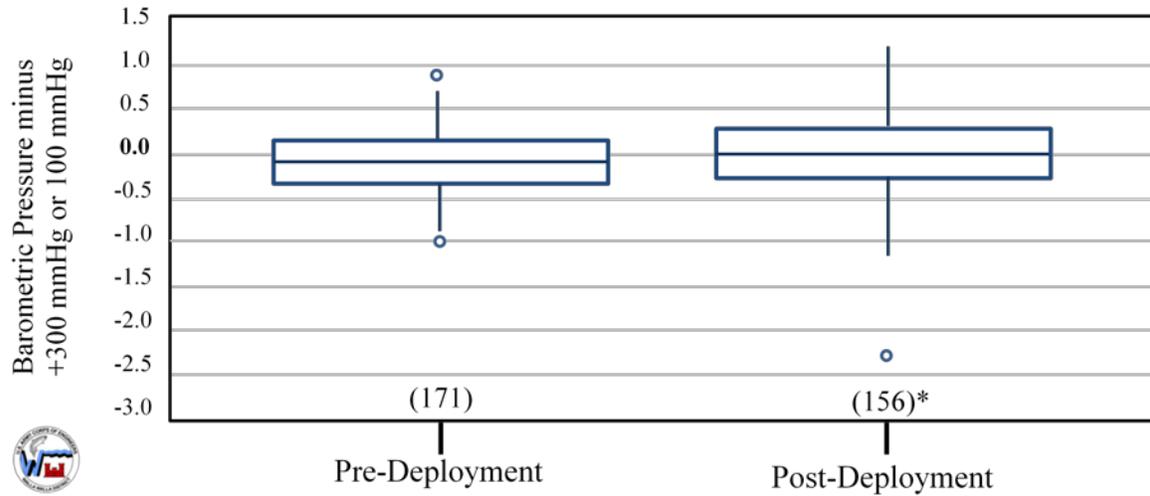


Figure G-4. Summary box plots of the pre-and post-deployment check of the Hydrolab[®] TDG sensors with the addition of 100 and 300 mmHg during the 2014 monitoring season.

Note:

* N was equal to 158 but there were two outliers greater than -5.0 due to malfunctioning barometers.

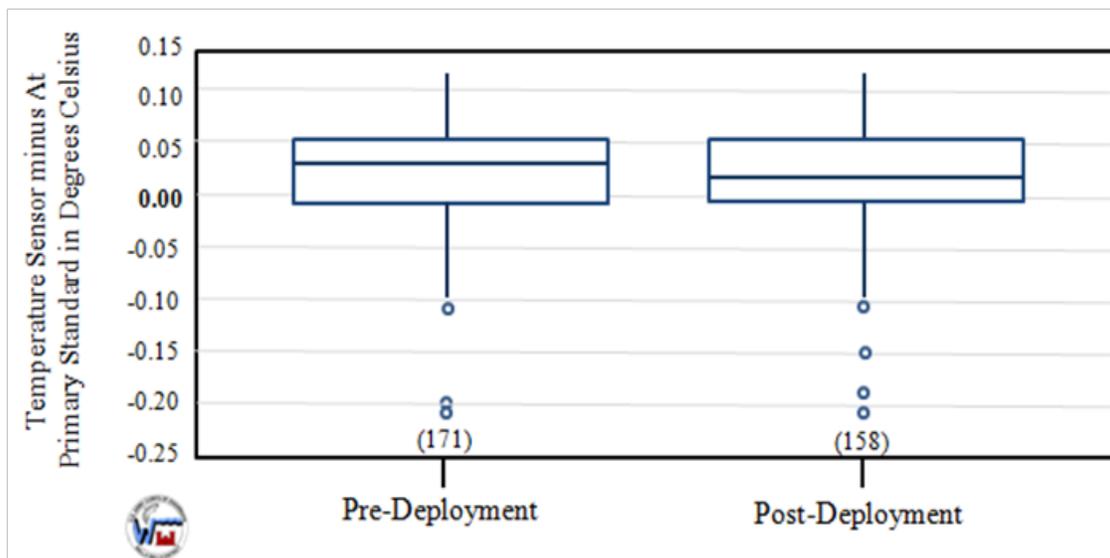


Figure G-5. Summary box plots of the pre- and post-deployment check of the Hydrolab[®] temperature sensors during the 2014 monitoring season.

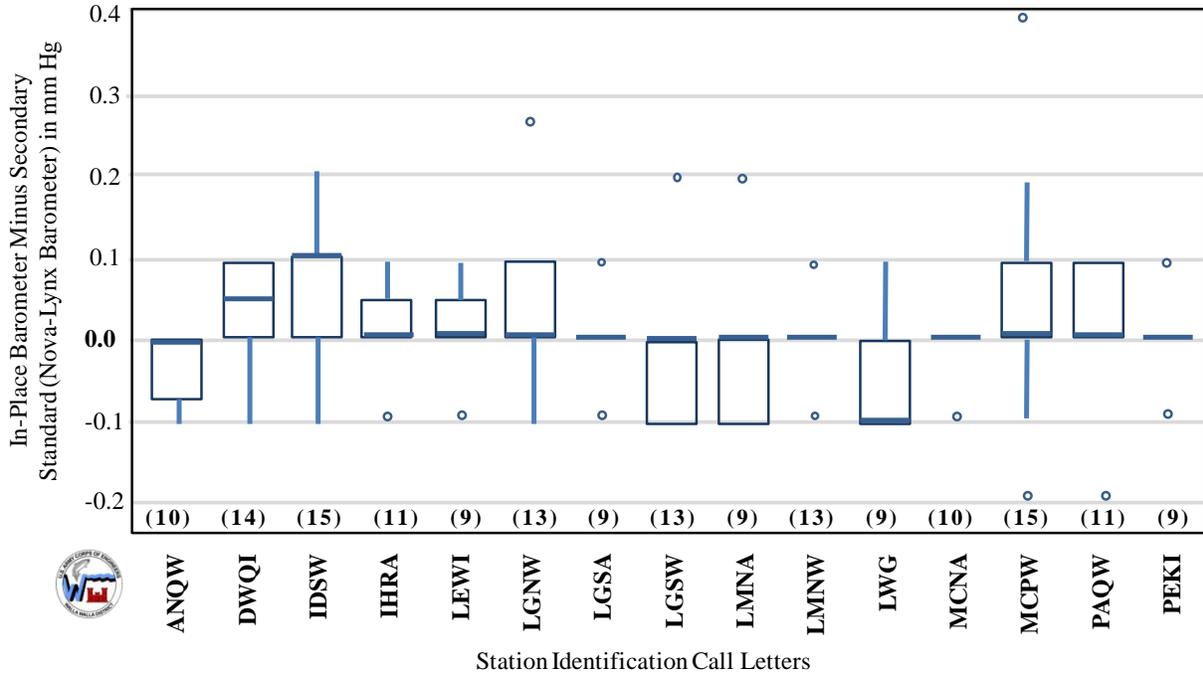


Figure G-6. Box plots of the field barometric pressure sensors check in mm Hg by site during the 2014 monitoring season.

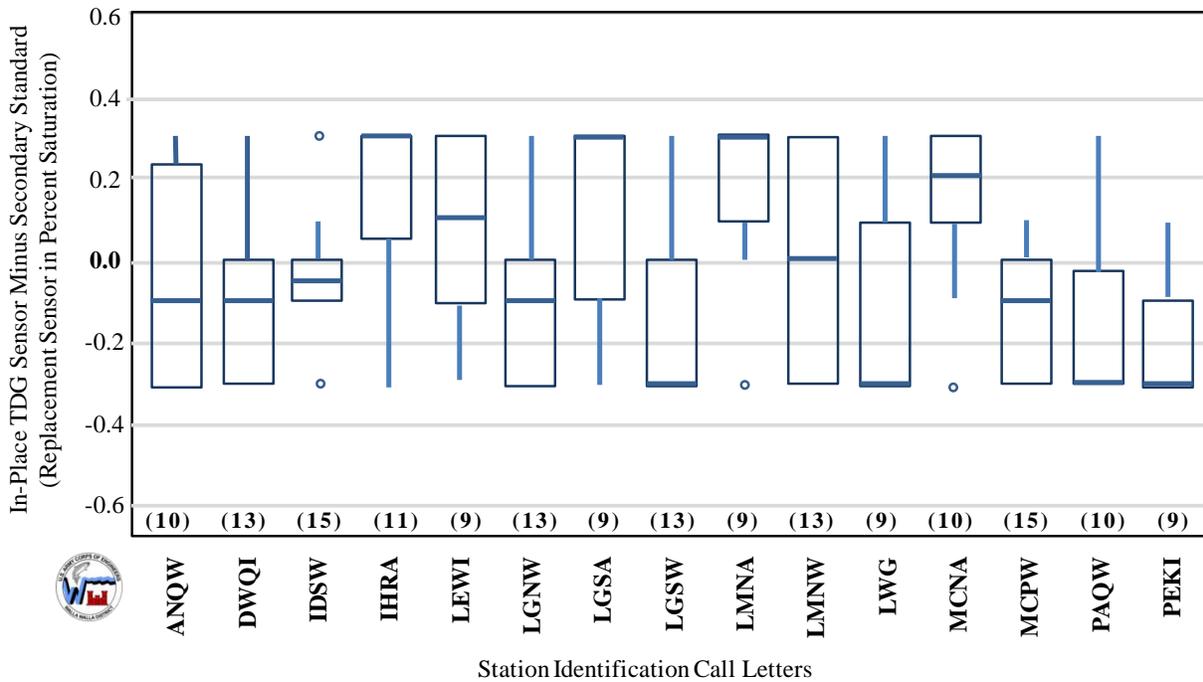


Figure G-7. Box plots of the field total dissolved gas sensor check versus secondary standard in percent saturation by site during the 2014 monitoring season.

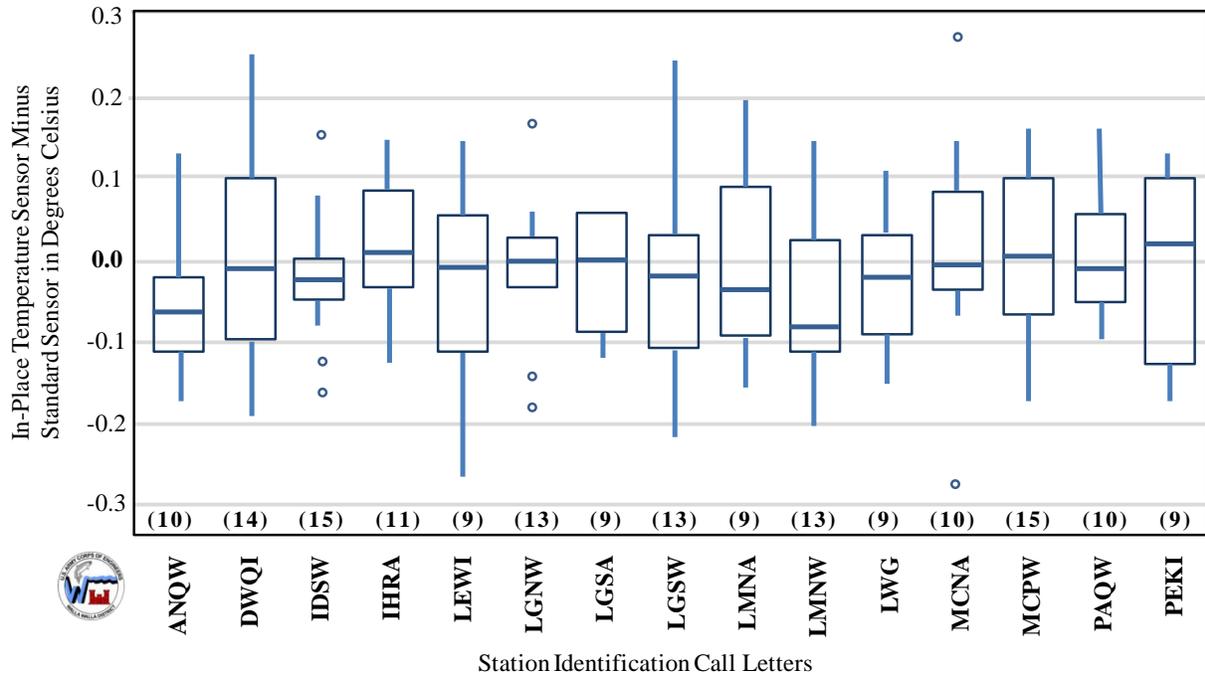


Figure G-8. Box plots of the field temperature sensors check verses secondary standard in degrees Celsius by site during the 2014 monitoring season.



Figure G-9. Disconnected deployment pipe at the Dworshak (DWQI) fixed-monitoring station.



Figure G-10. Damage to USGS Peck gauging station resulting from car accident – PEKI monitoring equipment is between collapsed building and river.

TABLES

Table G-1. CENWW FMS station identification and location information.

Station Number	Station Name	Station ID	Latitude (NAD 83)	Longitude (NAD 83)	Elevation (NGVD 29)	River Mile	DCP ID	XMIT Time
12514400	Columbia River at Pasco, WA	PAQW	46 13 26.2851 N	119 06 57.3388 W	345	329.1	17D6E32C	0:27:10
13334300	Snake River Near Anatone, WA	ANQW	46 05 50.7579 N	116 58 41.2382 W	807	167.5	17D63544	0:16:10
13341000	N.F. Clearwater River at Dworshak Hatchery, ID	DWQI	46 30 11.6464 N	116 19 16.4090 W	1,150	0.5	17D600DE	0:13:10
13341050	Clearwater River Near Peck, ID	PEKI	46 30 00.9396 N	116 23 32.4163 W	930	37.4	17D613A8	0:14:10
13343000	Clearwater River Near Lewiston, ID	LEWI	46 25 52.0867 N	116 56 43.9589 W	750	5.0	17D62632	0:15:10
13343590	Lower Granite Dam Forebay, WA	LWG	46 39 34.1727 N	117 25 34.8564 W	738	107.5	17D643D4	0:17:10
13343595	Lower Granite Dam Tailwater, WA	LGNW	46 39 58.0726 N	117 26 19.2595 W	645	106.7	17D650A2	0:18:10
13343855	Little Goose Dam Forebay, WA	LGSA	46 34 58.3188 N	118 01 32.9831 W	638	70.3	17D66538	0:19:10
13343860	Little Goose Dam Tailwater, WA	LGSW	46 35 00.5280 N	118 02 37.4186 W	560	69.6	17D6764E	0:20:10
13352595	Lower Monumental Dam Forebay, WA	LMNA	46 33 44.6559 N	118 32 08.3477 W	540	41.6	17D686CA	0:21:10
13352600	Lower Monumental Dam Tailwater, WA	LMNW	46 33 04.5051 N	118 32 58.9500 W	445	40.4	17D695BC	0:22:10
13352950	Ice Harbor Dam Forebay, WA	IHRA	46 15 05.2792 N	118 52 43.0096 W	440	10.0	17D6A026	0:23:10
13353010	Ice Harbor Dam Tailwater, WA	IDSW	46 14 27.5868 N	118 57 13.7130 W	340	6.1	17D6B350	0:24:10
14019220	McNary Dam Forebay, WA	MCNA	45 56 28.9200 N	119 17 35.4400 W	340	292.0	17D6D6B6	0:26:10
14019240	McNary Dam Tailwater, WA	MCPW	45 56 02.7775 N	119 19 35.4628 W	240	290.7	17D5F754	0:12:10

Table G-2. Summary of the laboratory results evaluating the overall differences between laboratory standards and the sensors pre- and post-deployment during the 2014 water year.

Deployment	Statistic	Δ (BP) (mm Hg)	Δ [(BP+300)-PT] (%)	Δ [(BP+100)-PT] (%)	Δ T (°C)
Pre	Number	156	156	----	156
	Minimum	-1.00	-0.10	----	-0.21
	25 percentile	-0.30	-0.03	----	-0.01
	Median	-0.10	-0.01	----	0.03
	75 percentile	0.10	0.01	----	0.05
	Maximum	0.90	0.10	----	0.12
	Mean	-0.11	-0.01	----	0.02
Post	Number	153	----	153	153
	Minimum	-4.40	----	-0.60	-0.21
	25 percentile	-0.35	----	-0.05	-0.01
	Median	0.00	----	0.00	0.02
	75 percentile	0.30	----	0.04	0.05
	Maximum	1.20	----	0.10	0.12
	Mean	-0.06	----	-0.01	0.01

Table G-3. Pre-deployment quality assurance data for the individual sensors utilized at the FMS stations during the 2014 water year.

Sensor ID	<u>Δ (PT – BP)</u>			<u>Δ [(BP+300) – PT]</u>			<u>Δ (Water Temperature)</u>		
	# Obs	Range (mm Hg)	Median (mm Hg)	# Obs	Range (mm Hg)	Median (mm Hg)	# Obs	Range (°C)	Median (°C)
26	2	-0.5 to 0.2	-0.15	2	-0.5 to 0.2	-0.15	2	0.00 to 0.03	0.01
27	8	-0.7 to 0.3	-0.05	8	-0.7 to 0.3	-0.05	8	-0.11 to -0.07	0.01
29	6	-0.4 to 0.9	0.0	6	-0.4 to 0.9	0.00	6	-0.07 to 0.06	-0.05
32	6	-0.8 to 0.2	-0.25	6	-0.8 to 0.2	-0.25	6	0.03 to 0.06	0.05
33	6	-0.3 to 0.5	0.05	6	-0.3 to 0.5	0.05	6	-0.21 to 0.05	0.03
34	6	-0.3 to 0.0	-0.20	6	-0.3 to 0.0	-0.20	6	-0.20 to -0.04	0.06
35	4	-0.3 to 0.2	0.00	4	-0.3 to 0.2	0.00	4	0.01 to 0.03	0.02
36	9	-0.7 to 0.2	-0.10	9	-0.7 to 0.2	-0.10	9	-0.02 to 0.05	0.03
37	7	-0.2 to 0.4	0.10	7	-0.2 to 0.4	0.10	7	0.00 to 0.06	0.03
39	9	-0.7 to 0.4	-0.30	9	-0.7 to 0.4	-0.30	9	-0.03 to 0.05	0.03
40	7	-0.2 to 0.3	0.10	7	-0.2 to 0.3	0.10	7	-0.05 to -0.06	0.05
41	8	-0.6 to 0.4	0.05	8	-0.6 to 0.4	0.05	8	-0.03 to 0.01	-0.01
42	3	-0.1 to 0.1	0.00	3	-0.1 to 0.1	0.00	3	-0.01 to 0.03	0.00
43	5	-0.8 to 0.1	-0.40	5	-0.8 to 0.1	-0.40	5	-0.02 to 0.02	0.00
44	2	-0.2 to 0.6	0.20	2	-0.2 to 0.6	0.20	2	0.07 to 0.10	0.08
45	3	-0.8 to 0.0	-0.30	3	-0.8 to 0.0	-0.30	3	0.04 to 0.12	0.10
46	3	-0.8 to -0.6	-0.60	3	-0.8 to -0.6	-0.60	3	0.04 to 0.11	0.07
47	3	-0.6 to 0.1	-0.20	3	-0.6 to 0.1	-0.20	3	0.09 to 0.12	0.11
48	2	0.0 to 0.1	0.10	2	0.0 to 0.1	0.10	2	0.07 to 0.08	0.07
49	2	-0.3 to 0.0	-0.15	2	-0.3 to 0.0	-0.15	2	0.05 to 0.08	0.07
51	1	-0.5 to -0.5	-0.50	1	-0.5 to -0.4	-0.45	1	0.08 to 0.09	0.08
52	2	-0.1 to 0.1	0.00	2	-0.1 to 0.1	0.00	2	0.10 to 0.11	0.11
53	2	-1.0 to 0.2	-0.40	3	-1.0 to 0.2	-0.40	3	0.06 to 0.07	0.07
54	3	-0.1 to 0.3	0.00	3	-0.1 to 0.3	0.00	3	-0.04 to 0.08	0.07
55	3	-0.9 to -0.1	-0.80	3	-0.9 to -0.1	-0.80	3	0.03 to 0.05	0.05
56	2	0.1 to 0.3	0.20	2	0.1 to 0.3	0.20	2	0.06 to 0.08	0.07
57	3	0.2 to 0.4	0.30	3	0.2 to 0.4	0.30	3	0.08 to 0.09	0.09
58	2	-0.6 to -0.2	-0.40	2	-0.6 to -0.2	-0.40	2	0.02 to 0.08	0.05
59	3	0.1 to 0.5	0.10	3	0.1 to 0.5	0.10	3	0.01 to 0.03	0.03
60	3	-0.1 to 0.5	0.00	3	-0.1 to 0.5	0.00	3	0.07 to 0.08	0.08
61	3	-0.6 to -0.2	-0.20	3	-0.6 to -0.2	-0.20	3	0.05 to 0.07	0.05
USGS 1	7	-0.5 to 0.2	-0.10	7	-0.5 to 0.2	-0.10	7	-0.01 to 0.04	0.01
USGS 2	5	-0.6 to -0.1	-0.20	5	-0.6 to -0.1	-0.20	5	-0.06 to -0.01	-0.05
USGS 3	5	0.1 to 0.4	0.20	5	-0.9 to 0.4	0.20	5	0.02 to 0.04	0.03
USGS 4	7	-0.4 to 0.4	0.10	7	-0.4 to 0.4	0.10	7	0.03 to 0.07	0.04
USGS 5	7	-0.7 to 0.2	-0.10	7	-0.7 to 0.2	-0.10	7	-0.02 to 0.04	0.01
USGS 6	2	0.0 to 0.1	0.05	2	0.0 to 0.1	0.05	2	-0.07 to -0.03	-0.05
USGS 7	3	-0.3 to 0.1	-0.10	3	-0.3 to 0.1	-0.10	3	-0.05 to -0.03	-0.03
USGS 8	2	-0.9 to 0.2	-0.35	2	-0.9 to 0.2	-0.35	2	-0.02 to 0.02	0.00
USGS 9	4	-0.6 to -0.1	-0.40	4	-0.6 to -0.1	-0.40	4	-0.03 to -0.01	-0.01

Table G-4. Post-deployment quality assurance data for the individual sensors utilized at the FMS stations during the 2014 water year.

Sensor ID	<u>Δ (BP – PT)</u>			<u>Δ [(BP+100) – PT]</u>			<u>Δ (Water Temperature)</u>		
	# Obs	Range (mm Hg)	Median (mm Hg)	# Obs	Range (mm Hg)	Median (mm Hg)	# Obs	Range (°C)	Median (°C)
26	1	-0.2 to -0.2	-0.20	1	-1.2 to -1.2	-1.20	1	0.00 to 0.00	-0.00
27	7	-0.4 to 0.7	0.20	7	-0.4 to 0.7	0.20	7	-0.11 to -0.07	-0.09
29	6	-0.3 to 1.2	0.25	6	-0.3 to 1.0	0.20	6	-0.06 to -0.03	-0.05
32	5	-0.5 to 0.5	-0.20	5	-0.5 to 0.5	-0.20	5	0.02 to 0.08	0.05
33	4	-0.5 to 0.1	0.00	4	-0.5 to 0.1	0.00	4	-0.15 to 0.05	0.03
34	6	-0.2 to 0.8	0.05	6	-0.2 to 0.8	0.05	6	-0.21 to 0.05	0.04
35	5	-4.4 to 0.2	0.00	5	-4.4 to 0.2	0.00	5	-0.01 to 0.05	0.04
36	8	-0.7 to 0.2	-0.10	8	-0.7 to 0.2	-0.10	8	-0.04 to 0.04	0.01
37	7	-0.9 to 0.6	0.00	7	-0.9 to 0.6	0.00	7	-0.04 to 0.03	0.01
39	9	-0.6 to 0.5	0.10	9	-0.6 to 0.5	-0.10	9	-0.03 to 0.03	0.00
40	7	-0.7 to 0.7	0.00	7	-0.7 to 0.7	0.001	7	0.04 to 0.06	0.04
41	8	-1.0 to 0.3	-0.35	8	-0.8 to 0.3	-0.20	8	-0.04 to 0.01	-0.01
42	3	-0.3 to 0.6	0.55	3	-0.3 to 0.6	0.50	3	0.01 to 0.02	0.02
43	4	-0.8 to -1.0	-0.03	4	-0.8 to -0.1	-0.3	4	-0.01 to 0.01	0.00
44	1	0.0 to 0.0	0.00	1	0.0 to 0.0	0.00	1	0.06 to 0.06	0.06
45	3	-0.7 to -0.6	-0.70	3	-0.7 to -0.6	-0.70	3	0.05 to 0.06	0.06
46	3	-0.1 to 0.0	0.00	3	-1.0 to 0.0	-0.10	3	0.07 to 0.08	0.08
47	3	-1.2 to 0.1	-0.40	3	-1.2 to 0.1	-0.40	3	0.09 to 0.10	0.09
48	3	-0.7 to 0.6	-0.50	3	-0.7 to 0.6	-0.50	3	0.06 to 0.08	0.08
49	2	-0.7 to 0.2	-0.25	2	-0.7 to 0.2	-0.30	2	0.06 to 0.07	0.06
51	1	-0.4 to -0.4	-0.40	1	-0.4 to -0.4	-0.40	1	0.10 to 0.10	0.10
52	2	-0.5 to 1.1	-1.00	2	-0.5 to 0.1	-0.20	2	0.09 to 0.12	0.11
53	2	-0.6 to 0.1	-0.25	2	-0.6 to 0.1	-0.25	2	0.06 to 0.07	0.06
54	3	0.2 to 0.8	0.30	3	-0.7 to 0.8	0.20	3	0.03 to 0.06	0.05
55	3	-0.6 to -0.1	-0.50	3	-0.6 to -0.1	-0.50	3	0.05 to 0.07	0.06
56	2	-2.3 to 0.4	-0.95	2	-1.3 to 0.4	-0.45	2	0.07 to 0.07	0.07
57	3	-0.4 to 0.1	-0.20	3	-0.4 to 0.1	-0.20	3	0.08 to 0.09	0.08
58	1	-4.3 to -4.3	-4.30	1	-4.3 to -4.3	-4.30	1	0.06 to 0.06	0.06
59	2	0.4 to 0.6	0.50	2	0.4 to 0.6	0.50	2	0.03 to 0.03	0.03
60	1	0.1 to 0.1	0.10	1	0.1 to 0.1	0.10	1	0.08 to 0.08	0.08
61	2	-0.7 to 0.4	-0.15	2	-0.7 to 0.4	-0.15	2	0.05 to 0.05	0.05
USGS 1	7	-0.1 to 0.2	0.20	7	-0.1 to 0.2	0.36	7	-0.03 to 0.02	0.01
USGS 2	5	-0.7 to 0.5	-0.02	5	-0.7 to 0.5	-0.02	5	-0.10 to 0.00	-0.06
USGS 3	5	-0.2 to 0.3	0.00	5	-0.2 to 0.3	0.00	5	-0.02 to 0.02	0.01
USGS 4	6	0.0 to 0.4	0.15	6	0.0 to 0.4	0.15	6	0.01 to 0.03	0.03
USGS 5	7	-0.4 to 0.6	0.30	7	-0.4 to 0.6	0.30	7	-0.06 to 0.04	0.01
USGS 6	2	-0.3 to 0.3	0.00	2	0.3 to -0.3	0.00	2	-0.11 to 0.00	-0.05
USGS 7	3	0.4 to 0.7	0.60	3	0.4 to 0.7	0.60	3	-0.03 to -0.03	-0.03
USGS 8	2	-0.5 to -0.3	-0.40	2	-0.5 to -0.3	-0.40	2	-0.01 to 0.00	-0.01
USGS 9	4	0.2 to 0.5	0.35	4	0.2 to 0.5	0.40	4	-0.06 to -0.01	-0.03

Table G-5. Summary of the field results for the differences between the in-place and replacement sensors during 2014 water year.

Statistic	ΔBP^1 (mm Hg)	ΔTDG^2 (% sat)	ΔT^2 (°C)
Number	171	168	169
Minimum	-3.10	-0.8	-0.26
Maximum	4.40	0.3	0.27
Mean	0.04	0.0	-0.01
Median	0.00	-0.1	-0.02

Footnotes:

¹ Field – laboratory sensor

² Replacement – In-place sensor

Table G-6. Summary of the field results for the differences between the in-place and replacement sensors by station during 2014 water year.

Station ID	<u>Δ Barometric Air Pressure</u>			<u>Δ Total Dissolved Gas</u>					<u>Δ Water Temperature</u>		
	# Obs	Range (mm Hg)	Median (mm Hg)	# Obs	Range (mm Hg)	Median (mm Hg)	Range (% Sat)	Median (% Sat)	# Obs	Range (°C)	Median (°C)
MCPW	15	-0.2 to 0.4	0.00	15	-2 to 1	-1.0	-0.3 to 0.1	-0.1	15	--0.17 to 0.15	0.00
MCNA	10	-0.1 to 0.0	0.00	10	-2 to 2	1.5	-0.3 to 0.3	0.2	10	-0.26 to 0.27	-0.01
PAQW	11	-0.2 to 0.1	0.00	10	-2 to 2	-2.0	-0.3 to 0.3	-0.3	10	-0.10 to 0.15	-0.02
IDSW	15	-0.1 to 0.2	0.10	15	-6 to 2	-1.0	-0.8 to 0.3	-0.1	15	-0.17 to 0.17	-0.02
IHRA	11	-0.1 to 0.1	0.00	11	-2 to 2	2.0	-0.3 to 0.3	0.3	11	-0.13 to 0.15	0.01
LMNW	13	-0.1 to 0.1	0.00	13	-2 to 2	0.0	-0.3 to 0.3	0.0	13	-0.20 to 0.16	-0.08
LMNA	9	-0.1 to 0.2	0.00	9	-2 to 2	2.0	-0.3 to 0.3	0.3	9	-0.16 to 0.19	-0.03
LGSW	13	-0.2 to 0.2	0.00	13	-2 to 2	-2.0	-0.3 to 0.3	-0.3	13	-0.22 to 0.23	-0.02
LGSA	9	-0.1 to 0.1	0.00	9	-2 to 2	2.0	-0.3 to 0.3	0.3	9	-0.12 to 0.06	0.00
LGNW	13	-0.1 to 0.1	0.00	13	-2 to 2	-1.0	-0.3 to 0.3	-0.1	13	-0.19 to 0.16	0.00
LWG	9	-0.1 to 0.1	-0.10	9	-2 to 2	-2.0	-0.3 to 0.3	-0.3	9	-0.16 to 0.11	-0.03
ANQW	10	-0.1 to 0.0	0.00	10	-2 to 2	-1.0	-0.3 to 0.3	-0.1	10	-0.17 to 0.12	-0.07
LEWI	10	-3.1 to 4.4	0.00	9	-2 to 2	1.0	-0.3 to 0.3	0.1	9	-0.26 to 0.14	-0.01
PEKI	9	-0.1 to 0.1	0.00	9	-2 to 1	-2.0	-0.3 to 0.1	-0.3	9	-0.17 to 0.12	0.02
DWQI	14	-0.1 to 0.1	0.05	13	-2 to 2	-1.0	-0.3 to 0.3	-0.1	14	-0.19 to 0.23	-0.01

Table G-7. Database completeness with the number and percent of all missing or invalid barometric pressure, total dissolved gas, and temperature points for each FMS station during the 2014 water year.

Station ID	Monitoring Period	<u>Barometric Pressure</u>		<u>Total Dissolved Gas</u>		<u>Temperature</u>	
		Number Missing/ Anomalous	Percent Complete	Number Missing/ Anomalous	Percent Complete	Number Missing/ Anomalous	Percent Complete
MCPW	1 Oct – 30 Sep	48	99.5	47	99.5	48	99.5
MCNA	1 Apr – 31 Aug	0	100.0	0	100.0	0	100.0
PAQW	1 Apr – 31 Aug	0	100.0	373	89.9	2	99.9
IDSW	1 Oct – 30 Sep	0	100.0	0	100.0	0	100.0
IHRA	1 Apr – 31 Aug	2	99.9	6	99.8	5	99.9
LMNW	1 Oct – 30 Sep	0	100.0	17	99.9	2	100.0
LMNA	1 Apr – 31 Aug	0	100.0	0	100.0	0	100.0
LGSW	1 Oct – 30 Sep	0	100.0	595	93.2	5	99.9
LGSA	1 Apr – 31 Aug	0	100.0	0	100.0	0	100.0
LGNW	1 Oct – 30 Sep	1	100.0*	1	100.0*	1	100.0*
LWG	1 Apr – 31 Aug	0	100.0	0	100.0	0	100.0
ANQW	1 Apr – 31 Aug	0	100.0	1	100.0*	2	99.9
LEWI	1 Apr – 31 Aug	1	100.0	36	99.0	1	100.0
PEKI	1 Apr – 31 Aug	0	100.0	10	99.7	0	100.0
DWQI	1 Oct – 30 Sep	112	97.0	114	96.9	174	95.3

Notes:

* Denotes value that was rounded up to 100 percent

Bold font highlight cases where there were one or more anomalous/missing values

Table G-8. Summary of the total hours of barometric pressure, total dissolved gas, and temperature data that were missing or considered invalid in the 2014 water year.

Reason	BP		TDG		BP+TDG		Temperature		All		
	hours	%	hours	%	hours	% of hours	% of bad data	hours	%	hours	%
Pressure Low	0		959	1.12	959	1.12	67.32	0		959	1.12
Missed transmit	2	0.00	0		2	0.00	0.14	1	0.00	3	0.00
Missing data	0		5	0.01	5	0.01	0.35	5	0.01	10	0.01
Spike	0		1	0.00	1	0.00	0.07	0		1	0.00
Inspection	3	0.00	23	0.03	26	0.03	1.82	8	0.01	34	0.04
Defective membrane	0		108	0.13	108	0.13	7.57	0		108	0.13
Defective sonde	0		6	0.01	6	0.01	0.42	4	0.00	10	0.01
DCP failure	111	0.13	112	0.13	223	0.26	15.64	113	0.13	336	0.39
Cable failure	48	0.06	47	0.05	95	0.11	6.66	48	0.06	143	0.17
Totals	164	0.19	1,261	1.47	1,425	1.66	100.00	179	0.21	1,604	1.87

Table G-9. Number and percent of all missing or invalid barometric pressure data for each FMS station during the 2014 water year, along with the reasons for those designations.

Station ID	<u>Pressure Too Low</u>		<u>Missed Transmit</u>		<u>Missing DCP Data</u>		<u>Spike</u>		<u>Inspection</u>		<u>Defective Membrane</u>		<u>Defective Sonde</u>		<u>DCP Failure</u>		<u>Cable Failure</u>		
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	
MCPW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48	0.55
MCNA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAQW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IDSW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IHRA	-	-	2	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LMNW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LMNA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGSW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGSA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGNW	-	-	-	-	-	-	-	-	1	0.01	-	-	-	-	-	-	-	-	-
LWG	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ANQW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LEWI	-	-	-	-	-	-	-	-	1	0.03	-	-	-	-	-	-	-	-	-
PEKI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DWQI	-	-	-	-	-	-	-	-	1	0.03	-	-	-	-	111	3.02	-	-	-

Table G-10. Number and percent of all missing or invalid total dissolved gas data for each FMS station during the 2014 water year, along with the reasons for those designations.

Station ID	<u>Pressure Too Low</u>		<u>Missed Transmit</u>		<u>Missing DCP Data</u>		<u>Spike</u>		<u>Inspection</u>		<u>Defective Membrane</u>		<u>Defective Sonde</u>		<u>DCP Failure</u>		<u>Cable Failure</u>	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
MCPW	-	-	-	-	-	-	-	-	1	0.01	-	-	-	-	-	-	47	0.54
MCNA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAQW	371	10.10	-	-	-	-	-	-	2	0.05	-	-	-	-	-	-	-	-
IDSW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IHRA	-	-	-	-	-	-	-	-	-	-	-	-	6	0.16	-	-	-	-
LMNW	-	-	-	-	-	-	-	-	2	0.02	15	0.17	-	-	-	-	-	-
LMNA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGSW	589	6.72	5	0.06	-	-	-	-	1	0.01	-	-	-	-	-	-	-	-
LGSA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGNW	-	-	-	-	-	-	-	-	1	0.01	-	-	-	-	-	-	-	-
LWG	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ANQW	-	-	-	-	-	-	-	-	2	0.05	-	-	-	-	-	-	-	-
LEWI	-	-	-	-	-	-	-	-	2	0.05	34	0.93	-	-	-	-	-	-
PEKI	-	-	-	-	-	-	1	0.03	9	0.24	-	-	-	-	-	-	-	-
DWQI	-	-	-	-	-	-	-	-	3	0.08	59	1.61	-	-	112	3.05	-	-

Table G-11. Number and percent of all missing or invalid temperature data for each FMS station during the 2014 water year, along with the reasons for those designations.

Station ID	<u>Pressure Too Low</u>		<u>Missed Transmit</u>		<u>Missing DCP Data</u>		<u>Spike</u>		<u>Inspection</u>		<u>Defective Membrane</u>		<u>Defective Sonde</u>		<u>DCP Failure</u>		<u>Cable Failure</u>		
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	
MCPW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48	0.55
MCNA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PAQW	-	-	-	-	-	-	-	-	2	0.05	-	-	-	-	-	-	-	-	-
IDSW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IHRA	-	-	1	0.03	-	-	-	-	-	-	-	-	4	0.11	-	-	-	-	-
LMNW	-	-	-	-	-	-	-	-	2	0.02	-	-	-	-	-	-	-	-	-
LMNA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGSW	-	-	5	0.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGSA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGNW	-	-	-	-	-	-	-	-	1	0.01	-	-	-	-	-	-	-	-	-
LWG	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ANQW	-	-	-	-	-	-	-	-	1	0.03	-	-	-	-	-	-	-	-	-
LEWI	-	-	-	-	-	-	-	-	1	0.03	-	-	-	-	-	-	-	-	-
PEKI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DWQI	-	-	-	-	-	-	-	-	1	0.03	-	-	-	-	113	3.07	-	-	-