Priest Rapids Hydroelectric Project (P-2114)

Quality Assurance Project Plan for Monitoring Selected Water Quality Parameters within the Priest Rapids Hydroelectric Project:

2018 Update

License Article 401(a)(23)

By
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Executive Summary

This updated Quality Assurance Project Plan (QAPP) provides details on water quality monitoring methods that Public Utility District No. 2 of Grant County, Washington (Grant PUD) will implement to help meet conditions of the 401 Water Quality Certification (WQC) issued by the Washington Department of Ecology (WDOE). Water quality parameters that will continued to be monitored under this QAPP include total dissolved gas (TDG), water temperature, dissolved oxygen (DO), pH, and turbidity.

Water quality monitoring conducted under this QAPP will be done via Grant PUD's Fixed Site Water Quality Monitoring Program (FSM Program). Information provided in this updated QAPP includes the following:

- Purpose and objectives of the FSM Program
- List of parameters to be monitored
- Organization and schedule
- Data quality objectives
- Descriptions and maps of the monitoring locations
- Monitoring methods, procedures, and equipment
- Analytical methods
- Quality control procedures, including descriptions of calibration, maintenance, and data handling and assessment procedures
- Reporting protocols
- Provisions for adaptive management

The primary purpose of Grant PUD's FSM Program is to provide information on water quality conditions within the Priest Rapids Hydroelectric Project (Project), as well as to verify compliance with applicable water quality standards and conditions within the Project's 401 WQC. Continued implementation of the QAPP will help assure that water quality data collected by the FSM Program will continue to be of sufficient quality. Adaptive management provisions in this QAPP will help determine potential changes to monitoring methods, locations, etc. that may be warranted, and updates will be made to this QAPP accordingly, subject to WDOE and Federal Energy Regulatory Commission (FERC) approval.

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%SAT	percent saturation
7Q10 flow	highest seven consecutive day average flow with a 10-year recurrence frequency
Biological Opinion	National Marine Fisheries Service's Biological Opinion for the Priest Rapids Hydroelectric Project
Chelan PUD	Public Utility District No. 1 of Chelan County, Washington
Corps	U.S. Army Corps of Engineers
DO	dissolved oxygen
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FSM station(s)	fixed-site monitoring station(s)
GAP	Gas Abatement Plan
GBT	gas bubble trauma
Grant PUD	Public Utility District No. 2 of Grant County, Washington
kcfs	thousand cubic feet per second
mg/L	milligrams per liter
mm Hg	millimeters of mercury
MW	megawatt
NIST	National Institute of Standards and Technology
NMFS	National Marine Fisheries Service
NTU	Nephelometric Turbidity Units
PRFB	Priest Rapids Juvenile Fish Bypass
PRCC	Priest Rapids Coordinating Committee
Project	Priest Rapids Hydroelectric Project
QAPP	quality assurance project plan

QA/QC	quality assurance/quality control
RM	river mile
TDG	total dissolved gas
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WFB	Wanapum Juvenile Fish Bypass
WDOE	Washington Department of Ecology
WQC	water quality certification

1.0 Introduction

Public Utility District No. 2 of Grant County, Washington (Grant PUD) owns and operates the Priest Rapids Hydroelectric Project (Project). The Project is licensed as Project No. 2114 by the Federal Energy Regulatory Commission (FERC), and includes the Wanapum and Priest Rapids developments. A 401 water quality certification (WQC) for the operation of the Project was issued by the Washington Department of Ecology (WDOE) on April 3, 2007 (WDOE 2007), amended on March 6, 2008 and effective on issuance of the FERC license to operate the Project in April of 2008 (FERC 2008).

Section 6.7.1 of the WQC required Grant PUD to submit for WDOE approval a Quality Assurance Project Plan (QAPP) for each parameter to be monitored under the 401 WQC. Approval of the QAPP was received by WDOE on January 30, 2009 and by FERC on July 16, 2009. This document serves as that update to the 2009 QAPP (Hendrick 2009). Updates within this QAPP include the following:

- Reporting protocols
- QA/QC controls
- Updated maps of monitoring locations
- Updated equipment
- Data collection frequency (for pH, dissolved oxygen (DO), and turbidity)
- Updated personnel and responsibilities table
- Updated calibration and maintenance procedures

Various sections of the 401 WQC require Grant PUD to monitor total dissolved gas (TDG), water temperature, dissolved oxygen (DO), and pH throughout the Project (WDOE 2007). Grant PUD will continue implementation of its Fixed Site Water Quality Monitoring Program (FSM Program) to continue to meet the 401 WQC water quality monitoring requirements. This QAPP update provides details on parameters to be monitored, maps of sampling locations, and descriptions of the purpose of the monitoring; sampling frequency, sampling procedures and equipment, and analytical methods, quality control procedures, data handling and data assessment procedures, and reporting protocols of the FSM program.

This updated QAPP was prepared using the following publications and references as guidelines, as applicable to the goals and objectives of the Grant PUD's FSM program:

1). WDOE guideline publication for preparing QAPPs (WDOE 2004, 2016 revisions);
2). U.S. Geological Survey (USGS) National Field Manual for Collection of Water Quality Data (Gibs et. al 2007, 2014 revisions); and
3). Grant PUD's Quality Assurance and Quality Control (QA/QC) procedures as described in Duvall and Dresser (2003) and additional QA/QC controls included in Grant PUD's 2009 QAPP (Hendrick 2009).

1.1 Priest Rapids Project Description

The Project is located on the mid-Columbia River in central Washington State (Figure 1). From its headwaters in Canada, the Columbia River extends 1,214 miles, with 460 miles in Canada and 754 miles in the United States. The Columbia River watershed drains an area of approximately 258,500 square miles in the Pacific Northwest. The following states and provinces lie within the Columbia River Basin: Washington, Oregon, and Idaho, the western portion of Montana, the southeastern portion of British Columbia, and small areas of Wyoming, Nevada, and Utah.

Grant County, the fourth largest county in Washington State, is located in the approximate center of the state, remote from major population areas. This region of Washington, being on the dry (east) side of the Cascade Mountain Range, is arid and receives approximately 7 inches of precipitation in an average year. The Columbia River forms part of the western boundary of Grant County, and touches again at the county's most northern corner at Grand Coulee Dam. The Project is located on that portion of the Columbia River that makes up the western boundary of Grant County. The Project also touches Benton, Yakima, Kittitas, Douglas, and Chelan counties. In all, the Project encompasses 58 miles of the Columbia River from river mile (RM) 395 at Rock Island Dam to RM 453 two miles below Priest Rapids Dam. The Project is located in a largely undeveloped and undisturbed landscape. Development along the Project is limited to a few smaller communities and scattered tracts of irrigated farm land.

The Project is part of the much larger 13,600 Megawatt (MW), seven dam, upper/mid-Columbia River hydroelectric system which extends from near the U.S./Canada border to the beginning of the Hanford Reach, a total of 351 RMs. The Project's location at the downstream end of this highly integrated system of hydropower facilities adds significantly to the complexity of Project operations and also poses significant challenges with respect to managing TDG and other water quality parameters.

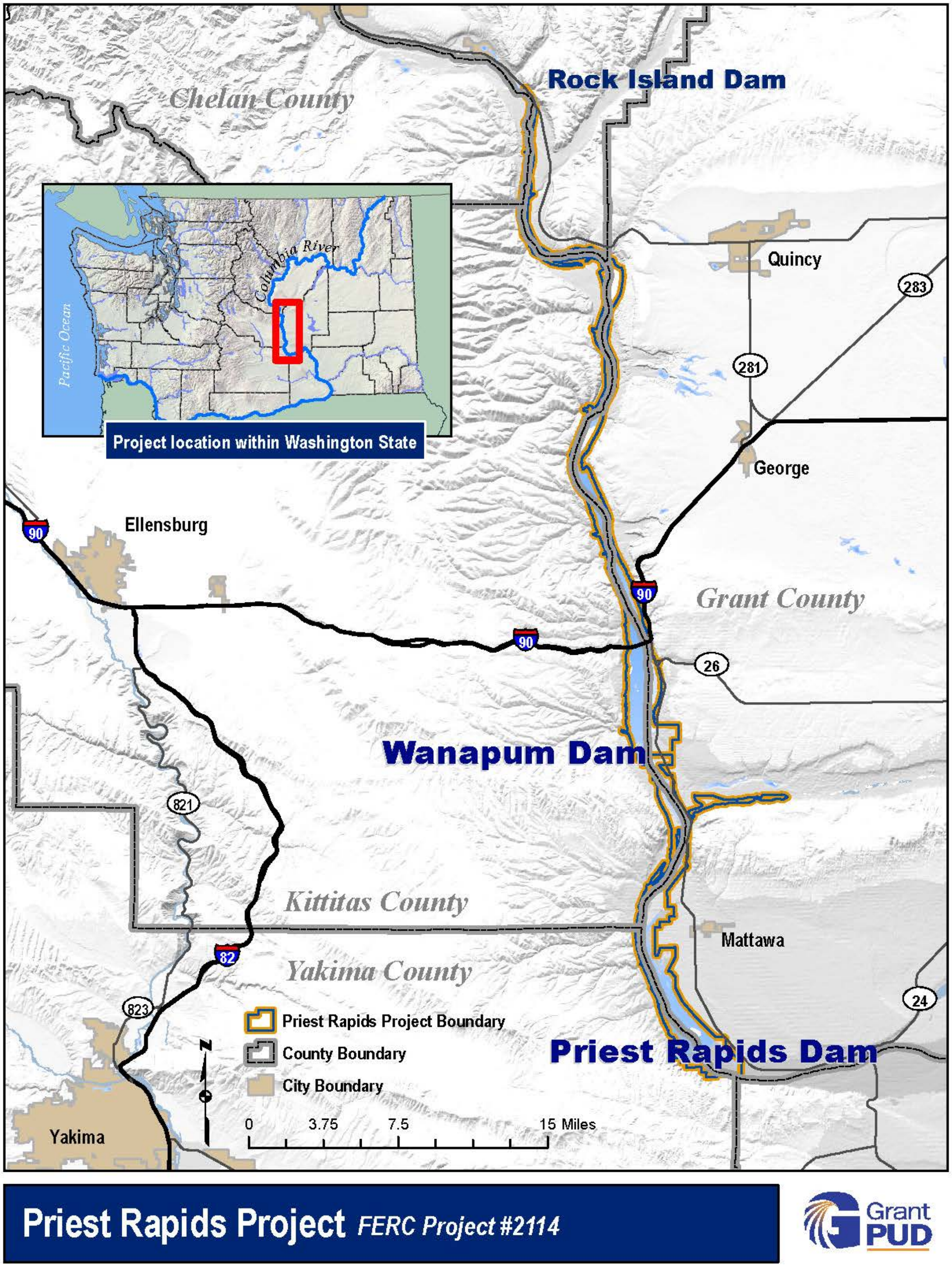

Figure 1 **The Priest Rapids Project is located in central Washington State on the mid-Columbia River.**

The first two water resource developments encountered on the Columbia River downstream of the U.S./Canada border are Grand Coulee and Chief Joseph dams, located at RM 597 and RM 544, respectively. Both of these hydro projects are federally owned and operated and are not, therefore, subject to FERC jurisdiction. Grand Coulee, at 6,809 MW, is the largest hydroelectric generating facility in the United States. Lake Roosevelt, the reservoir formed by Grand Coulee Dam, is over 151 miles long and contains 5.2 million acre-feet (MAF) of usable water storage. The operation of the federally operated Grand Coulee and Chief Joseph Projects generally establishes the flow, TDG, and temperature regime for the entire mid-Columbia River system.

Three Public Utility Districts (PUDs) own and operate the next five hydroelectric projects below Chief Joseph Dam, all of which are subject to FERC jurisdiction. The first facility downstream of Chief Joseph Dam is the Wells Project at RM 516, owned and operated by PUD No. 1 of Douglas County (Douglas PUD). The Rocky Reach Project, at RM 474, is owned and operated by PUD No. 1 of Chelan County (Chelan PUD), as is the Rock Island Project at RM 453.5. The next dams are Grant PUD’s Wanapum (RM 415.8) and Priest Rapids (RM 397.1) developments.

The Wanapum Reservoir is 38 miles long and extends to the tailwater of Rock Island Dam. The reservoir has an approximate surface area of 14,680 acres. The drainage area of the Columbia River at the dam is 90,900 square miles. Priest Rapids Reservoir is approximately 18 miles long and extends to the tailwater of Wanapum Dam. The impoundment has an approximate surface area of 7,725 acres. Above Priest Rapids Dam, the Columbia River drains an area of nearly 96,000 square miles. The total area encompassed by the FERC-licensed Project boundary is 34,380 acres, consisting of those lands necessary for the safe and efficient operation and maintenance of the Project and for other useful purposes, such as recreation, shoreline control, and protection of environmental resources.

The Wanapum development consists of a 14,680-acre reservoir (Wanapum Reservoir) and an 8,637-foot-long by 186.5-foot-high dam spanning the Columbia River (Wanapum Dam). The dam consists of left and right embankment sections; left and right concrete gravity dam sections; left and right bank fish passage structures, each with an upstream fish ladder; a gated spillway; a downstream fish passage structure (the Wanapum juvenile Fish Bypass (WFB)); and a powerhouse containing ten vertical shaft integrated Kaplan turbine/generator sets with a total authorized installed capacity (best gate) of 735 MW (Figure 2).

The Priest Rapids development consists of a 7,725-acre reservoir (Priest Rapids Reservoir) and a 10,103-foot-long by 179.5-foot-high dam spanning the Columbia River (Priest Rapids Dam). The dam consists of left and right embankment sections; left and right concrete gravity dam sections; left and right bank fish passage structures, each with an upstream fish ladder; a gated spillway section; a downstream fish passage structure (the Priest Rapids juvenile Fish Bypass (PRFB)); and a powerhouse containing ten vertical shaft integrated Kaplan turbine/generator sets with a total authorized installed capacity of 675 MW (best gate) (Figure 3).

Figure 2 **Aerial photograph of Wanapum Dam, mid-Columbia River, WA.**

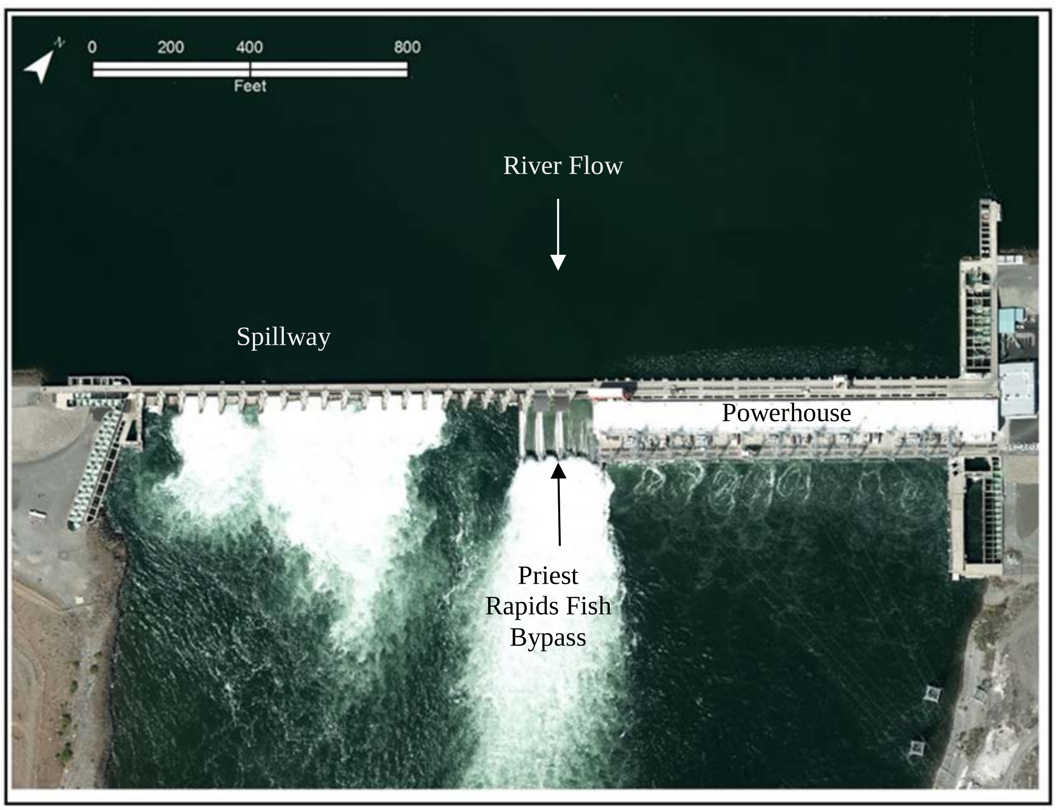

Figure 3 **Aerial photograph of Priest Rapids Dam, mid-Columbia River, WA.**

2.0 Regulatory Framework

Section 6.0 of the 401 WQC (WDOE 2007) contains water quality conditions that Grant PUD must comply with, many of which require regular monitoring of TDG, water temperature, DO, and pH. Although turbidity monitoring is not required by the 401 WQC, Grant PUD will continue monitoring turbidity on a periodic basis as described in this QAPP. The following sections detail the water quality monitoring requirements and numeric standards for each parameter to be monitored.

2.1 Total Dissolved Gas

Washington state water quality standards are established by the WDOE for TDG during the non-fish-spill and fish-spill seasons (see Washington Administrative Code (WAC) 173-201A-200(1)(f)). The current standard for TDG (in percent saturation (%SAT)) during the non-fish spill season (September 1 through March 31) is 110 %SAT for any hourly measurement. The current standard for TDG (in %SAT) during the fish-spill season (April 1 through August 31) is 120 %SAT in the tailrace of the dam spilling water for fish and 115 %SAT in the forebay of the next downstream dam, based on the average of the twelve highest consecutive hourly readings in a twenty-four hour period. A one-hour, 125 %SAT maximum standard for TDG also applies throughout the Project.

Section 6.4.1(d) of the 401 WQC (WDOE 2007) notes that even when TDG levels in the tailrace of a dam exceed 120 %SAT, that dam may be deemed in compliance with TDG water quality standards if both the following apply:

- TDG levels in the dam's forebay exceed 120 %SAT, and
- The dam does not further increase TDG levels in the tailrace

Section 5.0(b) of the 401 WQC (WDOE 2007) and WAC 173-201A-200(f)(i) provide that the TDG standard for both Wanapum and Priest Rapids dams shall be waived if flows exceed the "7Q10 flood flow," which is the highest seven consecutive day average flow with a ten-year recurrence frequency. The 7Q10 flood flow was calculated to be 264 thousand cubic feet per second (kcfs) for both Wanapum and Priest Rapids dams.

In 2004, WDOE established a TDG Total Maximum Daily Load (TMDL) for the mid-Columbia River which set TDG allocations for each dam (WDOE 2004a). According to section 6.4.1(f) of the 401 WQC, Grant PUD shall be "…deemed in compliance with the TDG TMDL…" while it remains in compliance with the 401 WQC (WDOE 2007).

Section 6.4.10 of the 401 WQC requires Grant PUD to maintain a TDG monitoring program at its fixed-site monitoring stations (FSM stations; see Section 6.1 of this QAPP) throughout the year, and that TDG measurements shall occur on an hourly basis. Monitoring results shall be made available electronically to the public:

"…as close to the time of occurrence as technology will reasonable allow" (WDOE 2007).

2.1.1 Water Temperature

WAC 173-201A-602 designates the segment of the Columbia River within the Project as salmonid spawning, rearing, and migration; therefore, water temperature must remain below

17.5°C, as measured by the 7-day average of the daily maximum temperatures (7-DADMax). When a water body's temperature is warmer than the criteria (or within 0.3°C of the criteria) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the 7-DADMax temperature of that water body to increase more than 0.3°C. In addition, WAC 173-201A-602 provides that temperatures below Priest Rapids Dam shall not exceed a maximum daily (1-DMax) of 20.0°C due to human activities. When natural conditions exceed a 1-DMax of 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed $t = 34/(T + 9)$.

Certain sections of the Columbia River within the Project are classified as impaired for temperature under Section 303(d) of the Clean Water Act. Portions of the Columbia River upstream of the Project are also classified as impaired for temperature. WDOE has indicated that a Total Maximum Daily Load (TMDL) for temperature is expected to be developed by the Environmental Protection Agency (EPA) that will establish a final wasteload and load allocation for temperature (WDOE 2007).

2.1.2 Dissolved Oxygen, pH, and Turbidity

The water quality criteria for DO within the Project require that DO be greater than 8.0 milligrams per liter (mg/L). When DO is lower than the criteria (or within 0.2 mg/L of the criteria) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the DO of that water body to decrease more than 0.2 mg/L (WAC 173-201A-200(1)(f)).

WAC 173-201A-200(1)(g) provides that pH shall be within the range of 6.5 to 8.5 units with a human-caused variation within the above range of less than 0.5 units.

WAC 173-201A-200 (1)(e) provides that turbidity levels shall not be >5 Nephelometric Turbidity Units (NTU) over background turbidity when the background is 50 NTU or less.

Section 6.6.1(a) of the 401 WQC requires Grant PUD to periodically monitor both pH and DO for the term of the FERC license. Although turbidity monitoring is not required by the 401 WQC, Grant PUD will monitor turbidity on a periodic basis as described in this QAPP.

3.0 Project Description

This QAPP provides details and updates on Grant PUD's Fixed-Site Water Quality Monitoring Program (FSM Program). In general this QAPP provides descriptions of the following:

- Purpose and objectives of the FSM Program;
- List of parameters to be monitored;
- Organization and schedule;
- Data quality objectives;
- Descriptions and maps of the monitoring locations;
- Monitoring methods, procedures, and equipment;

- Analytical methods;
- Quality control procedures, including descriptions of calibration, maintenance, and data handling and assessment procedures;
- Reporting protocols; and
- Provisions for adaptive management

3.1 Fixed-Site Monitoring Program

Grant PUD operates and maintains four fixed-site water quality monitoring stations (FSM stations) that record water depth (meters (m)), barometric pressure (millimeters of mercury (mm Hg)), TDG (mm Hg), temperature (°C), dissolved oxygen (DO; milligrams per liter (mg/L)), pH (units), and turbidity (Nephelometric Turbidity Units (NTU)) as a part of its FSM Program. Barometric pressure, TDG, and temperature are monitored and reported on an hourly basis, while depth, DO, pH, and turbidity are monitored on a bi-weekly basis. TDG is measured in mm Hg at each FSM station and converted to %SAT using the barometric pressure measurements recorded by a certified barometer located at each FSM station. The conversion equation is as follows:

$$\text{TDG in \%SAT} = (\text{TDG mm Hg} / \text{barometric pressure mm Hg}) \times 100$$

Each FSM station is equipped with a HydroLab Corporation Model DS5X, DS5A, DS4A, or Minisonde multi-parameter probe (multi-probe) enclosed in a submerged conduit. Multi-probes are connected to an automated system that allows Grant PUD to monitor and report barometric pressure, TDG, and water temperature on an hourly basis. A National Institute of Standards and Technology (NIST) certified barometer located at each FSM station provides the barometric pressure readings necessary to correct the partial pressure readings taken by the multi-probes.

The data logging system at each of Grant PUD’s FSM stations consist of the same basic equipment. This includes the multi-probe enclosed in a submerged perforated conduit or standpipe, which is connected to a Sutron Corporation 9210 data collection platform (DCP). Multi-probes are interrogated every 15-minutes and data is archived within the DCP. The DCPs are then interrogated via radio transmission onto Grant PUD’s fiber-optic network, which then transfers the data into a secure database (using Sutron’s XConnect database software). Duplicates of the raw data are made available on Grant PUD’s water quality website (see Section 6.5.4).

3.2 Purpose and Objectives

The purpose of Grant PUD’s FSM Program is to provide information on water quality conditions within the Project, as well as to verify compliance with applicable water quality standards and conditions within the 401 WQC. The following list provides the monitoring requirements of the 401 WQC (WDOE 2007) with the relevant sections of the 401 WQC shown for reference:

- Conduct hourly TDG monitoring throughout the year within the forebay and tailrace of Wanapum and Priest Rapids dams (Section 6.4.10);
    - o TDG data shall be made available electronically to the public as close to the time of occurrence as technology will reasonably allow (Section 6.4.11(a)),

- Conduct a TDG compliance analysis in year 2024 in accordance with Grant PUD's compliance GAP (Grant PUD 2018a);
- Grant PUD shall provide a temperature monitoring program through a QAPP (Section 6.5.1);
- Grant PUD shall continue to provide periodic monitoring of pH and DO in the Project (Section 6.6.1(a));
- Grant PUD shall provide water quality monitoring results and summary reports to WDOE by March 1 of each year (Section 6.7.3); and
- Grant PUD shall make available to the public all water quality monitoring data and results collected as part of the 401 WQC on its website or other readily assessable means (Section 6.1.19).

The following list provides a summary of the purpose and objectives of Grant PUDs FSM Program:

- Collect water quality data within the Project to track trends in water quality; data will be used in annual water quality summary reports;
- Post water quality monitoring data onto Grant PUD's water quality website, available for public use;
- Verify compliance with conditions of the Project's 401 WQC and Washington States water quality standards for temperature, TDG, DO, and pH; and
- Help guide Grant PUD's fish-spill program by using TDG data collected during the fish-spill season to help make adjustments to fish-spill amounts in order to remain within water quality standards for TDG (as reasonable and feasible), in consultation with appropriate stakeholders according to procedures outlined in Grant PUD's currently approved gas abatement plan.

The purpose and objectives of the FSM Program will be met using the following basic methods. Because Grant PUD's FSM Program has been in place since 2001, with the most recent update to the system in the fall of 2017, no new actions are required to begin the program. The FSM Program's purpose and objectives will be met by simply continuing Grant PUD's existing FSM Program with a few minor additions as described in this updated QAPP. Additional details on the FSM Program will be presented in the following sections; the generalized list below provides a summary of actions that will be continued/maintained to meet the purpose and objectives:

- Continue to use Hydrolab (or equivalent) multi-parameter water quality probes to collect temperature, TDG, DO, pH, and turbidity data;
- Maintain and/or update current FSM stations used to continually monitor water quality parameters within the Wanapum and Priest Rapids dam forebay and tailrace areas;
- Maintain current FSM station data transmission software/hardware that allows for TDG and temperature data to be transmitted to Grant PUD's water quality website within two hours of being collected;
- Continue to conduct periodic grab-sample monitoring of DO, pH, and turbidity data;

- Maintain current QA/QC procedures to assure data is accurate and reliable; and
- Apply the adaptive management process to the FSM Program in order to allow for changes, modifications, and improvements based on monitoring results, regulatory changes, operational or structural changes to either Wanapum or Priest Rapids dams, requirements in TMDLs. etc.

Grant PUD will review and update this QAPP, annually or as needed, and implement any changes to the plan pending WDOE and FERC approval.

3.3 Parameters to be Monitored

In order to meet the purpose and objectives outlined above, Grant PUD will monitor TDG, temperature, DO, pH, and turbidity at its FSM stations. The following sections provide further detail on the parameters to be monitored.

3.3.1 Total Dissolved Gas

TDG will be measured on an hourly basis using a Hydrolab TDG sensor, which uses a pressure transducer mounted behind a rigid gas-permeable silicone membrane to measure amount of total gaseous compounds dissolved in a liquid. The measurement quality objectives, range, precision, accuracy, and resolution of the TDG sensor are provided in Table 1, below. TDG will be measured in mm Hg and then converted to %SAT using barometric pressure measurements recorded by a NIST certified barometer located at each FSM station. The conversion equation is as follows:

$$\text{TDG in \%SAT} = (\text{TDG mm Hg} / \text{barometric pressure mm Hg}) \times 100$$

The TDG sensor is connected to a Hydrolab multi-probe, which transmits data to a Sutron 9210 DCP where it is then transmitted to the FSM database (see Section 4.0). Raw TDG data will be made available to Grant PUD’s water quality website within approximately two hours of delay from the time of measurement. The primary use of data will be to:

- Comply with the requirements of the 401 WQC (WDOE 2007);
- Verify compliance with WDOE’s TDG water quality standards; and
- Help guide Grant PUD’s fish-spill program by using TDG data collected during the fish-spill season to help make adjustments to fish-spill amounts in order to remain within water quality standards for TDG (as reasonable and feasible), in consultation with appropriate stakeholders according to procedures outlined in Grant PUD’s currently approved gas abatement plan.
- Concurrent with the each 5-Year update of the GAP, Grant PUD will perform a compliance analyses similar to the Year 10 Report (Grant PUD 2018), using the previous 10 years of TDG data to ensure that Project operations continue to meet a similar level of compliance demonstrated within the Year 10 Report. The compliance analysis will include a descriptive characterization of the TDG data and an overall compliance assessment for the Project with respect to the TDG water quality standards.

3.3.2 Water Temperature

Water temperature will be measured on an hourly basis at each FSM station using a Hydrolab 30k ohm variable resistance thermistor. The measurement quality objectives, metrics, range, precision, accuracy, and resolution of the temperature sensor are provided in Table 1, below. The sensor is connected to a Hydrolab multi-probe, which transmits data to a Sutron 9210 DCP where it is then transmitted to the FSM database (see Section 4.0). Raw temperature data will be made available to Grant PUD's water quality website within approximately two hours of delay from time of measurement. The primary use of data will be to:

- Comply with the requirements of the 401 WQC (WDOE 2007);
- Verify compliance with WDOE's water temperature standards;
- Track changes in water temperatures over time.

3.3.3 Dissolved Oxygen, pH, and Turbidity

DO, pH, and turbidity data will be measured on a periodic basis at each FSM station using Hydrolab DO, pH, and turbidity sensors. The measurement quality objectives, metrics, range, precision, accuracy, and resolution of the DO, pH, and turbidity sensors are provided in Table 1, below. These sensors are connected to a Hydrolab multi-probe that will be used as the "grab-sample" probe during regular FSM station maintenance and multi-probe deployment activities (monthly). DO, pH, and turbidity data will be made available on Grant PUD's water quality website (via the water quality monitoring report(s)) after it is collected; the primary use of the data will be to:

- Comply with the requirements of the 401 WQC (WDOE 2007); and
- Track compliance with WDOE's water quality standards for DO and pH.

Because DO, pH, and turbidity will be measured using grab-sample methods, staff collecting the measurements will follow pre-established protocol to collect and record the measurements. The protocols include the following (see also section 6.3 of this QAPP):

- Allow the multi-probe adequate time to equilibrate to river conditions; this will be done by allowing TDG to come within 10 mm Hg of the TDG value recorded by the existing FSM station probe. This typically takes 15–30 minutes depending on TDG levels and time of the year;
- Measure DO, pH, and turbidity from well mixed portions of the river. Grab-sample measurements will be taken from the FSM station standpipe, which are all located mid-channel within the main flow currents at a minimum depth of three meters;
- Collect all measurements from the same locations within the river. Because all measurements will be taken from the FSM station standpipes, each measurement will be taken from the same location within the Project and measurements will be taken from each FSM station on the same day to determine spatial and temporal variations;

- Record measurements on hand-held PDA using Hydrolab's Hydras 3 software; date, time, personnel, multi-probe serial number, and other notes will be recorded with each measurement; and
- Five measurements will be taken every minute to make a composite measurement (average of the five measurements).

A summary of the water quality parameters to be monitored under this QAPP can be found in Table 1, below.

Table 1 Water quality parameters to be monitored.

Parameter	Location(s)	Frequency	Metric	Standards
Total Dissolved Gas	Forebay and tailrace of each dam	Hourly	mm Hg; converted to %SAT	non fish-spill season: <110% saturation fish-spill season: <115% in forebay, <120% in tailrace, and <125% hourly maximum
Water Temperature	Forebay and tailrace of each dam	Hourly	˚C	If Natural <18˚C, then <2.8 ˚C increase If natural >18˚C, then >0.3˚C increase
Turbidity	Forebay and tailrace of each dam	Monthly	nephelometric turbidity unit (NTU)	<5 NTU increase above background (upstream) conditions
pH	Forebay and tailrace of each dam	Monthly	pH units	6.5 – 8.5 units
Dissolved Oxygen	Forebay and tailrace of each dam	Monthly	milligrams per liter (mg/L)	>8.0 mg/L

3.4 Organization and Schedule

This section provides details on the organization and schedule of the FSM Program. Because Grant PUD's FSM Program was initiated during the relicensing period and has been operational since 2001, following the QA/QC guidelines and procedures outlined by Grant PUD's 2009 QAPP (Hendrick 2009), many of these activities are on-going and will continue for the life of the FERC license (FERC 2008). There are some new activities and procedures, regulatory requirements, as well as updates to the initial software/hardware that were not included in the initial QAPP (Hendrick 2009), and those updates and implementation schedules are reflected in this updated QAPP. Table 2 provides the individuals at Grant PUD with key responsibilities in the continued implementation of the FSM Program.

Table 2 List of key personnel and responsibilities.

Personnel	Title	Responsibilities	Contact information
Ross Hendrick	Manager of License and Environmental Compliance	Management, report review, and communication with WDOE and outside agencies/public	509-754-5088, ext. 2468; rhendr1@gcpud.org
Carson Keeler	Senior Biologist	Field work, calibration scheduling, program oversight, data collection, probe calibration and maintenance, data QA/QC, data analysis and QA/QC, report generation, and communication with WDOE.	509-754-5088, ext. 2687; ckeeler1@gcpud.org
Ted Harris	Electronic Tech IV	Telecommunications management – FSM station communication (both radio and fiber)	509-754-5088, ext. 4004; tharris@gcpud.org
Suresh Nalla	Program Analyst V	Data transmission support - Sutron XConnect Software	509-754-5088, ext. 2413; Snalla@gcpud.org
Breean Zimmerman (WDOE)	Hydropower Projects Manager. Water Quality Program – WDOE Central Regional Office	Grant PUD's contact for all correspondence related to the 401 Water Quality Certification	509-575-2808; bzim461@ecy.wa.gov

The following table provides a summary of the schedule that will be followed for continued implementation of the FSM Program. Additional details are provided in the relevant sections.

Table 3 Schedule of Fixed-Site Water Quality Monitoring Program (FSM Program) activities.

Activity	Purpose	Schedule	Frequency	Key Personnel (see also Table 2)
Implement FSM Program per QAPP	Collect water quality data from fixed locations and time periods; comply with 401 WQC	On-going	Life of FERC license	All (see Table 2)
Collect TDG Data	Comply with 401 WQC and help guide fish-spill program; collect trend data to compare with historical data. Continue tracking reasonable compliance with TDG standards	On-going	Hourly; Life of FERC license	Hendrick/Keeler
Collect temperature data	Comply with 401 WQC; collect trend data to compare with historical data	On-going	Hourly; Life of FERC license	Keeler
Collect DO/pH/turbidity data	Comply with 401 WQC; collect trend data to compare with historical data	On-going	Monthly	Keeler
Conduct QA/QC checks	Comply with 401 WQC; assure that data is accurate and reliable	On-going	Varies; see relevant sections of QAPP	Hendrick/Keeler
Post water quality data to web-site	Make data available to public per conditions of 401 WQC	On-going	Varies; see relevant sections of QAPP	Keeler
Calibrate water quality probes	Assure accurate data is being collected, prevent sensor drift, error, and/or failure	On-going	Monthly, or as needed based on QA/QC data checks	Keeler
Perform routine maintenance at FSM locations	Check functionality/condition of battery and solar power supply, cables, radio connections, hardware, standpipe, etc.	On-going	As needed and at least once prior to April 1 and again prior to October 1 of each year	Keeler/Harris
Conduct ice-bath checks of temperature sensors	Verify accuracy of temperature sensors against NIST thermometer	Prior to spring to April 15	Annually	Keeler
Conduct annual FSM Program meetings	Continued coordination between all responsible parties, discuss trouble-shooting procedures, calibration methods, software/hardware issues, etc.	On-going	Periodic, or as needed	All (see Table 2)
Conduct field audit of calibration, maintenance, and deployment methods	Assure proper implementation of this QAPP, determine need for adjustments to methods (through adaptive management)	By December 1 of each year	Annually	Hendrick/Keeler
Attend regional TDG monitoring and QA/QC meeting	Present results of FSM program, discuss QA/QC methods of other dam operators	End of Year (Nov/Dec)	Annually as determined by U.S. Corps of Engineers (hosts)	Keeler

Activity	Purpose	Schedule	Frequency	Key Personnel (see also Table 2)
Attend regional water quality meetings, forms, and trainings	Stay current with regionally accepted water quality monitoring methods, equipment, and QA/QC procedures; apply adaptive management to FSM Program as needed	As needed	As needed	Hendrick/Keeler
Water quality monitoring summary report	Summarize previous year's water quality monitoring results	March 1	Annual report	Keeler
Review/Update QAPP as needed	Application of adaptive management to water quality monitoring program	April 15	QAPP shall be reviewed annually and updates made as needed	Hendrick/Keeler

4.0 Data Quality Objectives

The overall purpose of monitoring the parameters discussed in this QAPP are to monitor changes or trends in water quality within the Project and to determine compliance with water quality standards, which have been established, in part, to help assure the biological objectives of the Project can be met. Making decisions on changes in water quality compared to historical data, or if water quality standards are being achieved must be made based on data that passes data quality objectives.

The WDOE (2004, revised 2016) indicates that when data will be used to select between two clear alternative conditions or to determine compliance with a standard, quality objectives need to be specified at two levels: Decision (or Data) quality objectives (DQOs) and measurement quality objectives (MQOs). DQOs are needed to determine the number of samples that must be taken to meet the objectives of the project. MQOs specify how good the data must be in order to meet the objectives of the project. For Grant PUD's FSM Program, DQOs will be measured by the data representativeness, completeness, and comparability (described in detail below). Obtainment of MQOs will be determined by comparing data collected with specific data quality indicators such as precision, bias, and sensitivity. Following manufacturer recommendations of multi-probe use, calibration, and maintenance are also considered MQOs of the FSM Program and are explained in Section 6.0 of this updated QAPP.

4.1 Decision Quality Objectives

For this effort, data collection methods will be designed in such a manner that the results can be used to determine if the water quality criteria have been met; therefore, quality objectives at the level of the decision are required. These objectives will be met by carefully determining the number of measurements taken to represent a given condition.

The success of obtaining these objectives can be measured by ensuring that the representativeness, completeness and comparability are controlled. Each is described below.

4.1.1 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition. For this investigation, representativeness is a qualitative parameter that is primarily concerned with proper design of the sampling program, and can be best satisfied by ensuring that the monitoring locations are properly located with a sufficient number of data collected. For the FSM Program, data will be collected from monitoring locations fixed within the middle of the river channel (see section 6.1) at the appropriate depth (see section 6.2.2), and will be collected at frequencies that will provide sufficient data to determine trends and if water quality standards are being met (see section 6.2.1).

4.1.2 Comparability

The comparability criterion is a qualitative characteristic that expresses the confidence with which one data set can be compared to another. Principal comparability issues are field sampling techniques, and standardized concentration units and reporting formats. Data comparability is achieved using standard field sampling techniques and measuring methods; however, comparability is limited by the other MQOs because only when precision and bias (accuracy) are known can data sets be compared with confidence. For the FSM Program, water quality parameters are monitored using standard units of measurement at fixed locations, and therefore data will be comparable to both historical data collected/reported by Juul (2003) and Normandeau (2000) and in the subsequent years after this updated QAPP is implemented.

4.1.3 Completeness

Completeness is defined as the percentage of valid analytical determinations compared to the total number of determinations. Typical field or electronics problems may result in completeness of less than 100 percent, and therefore a reasonable completeness goal is 90 percent, which will be the goal of the FSM Program. Completeness will be evaluated and documented throughout all monitoring, and corrective actions taken as warranted on a case-by-case basis through adaptive management (see section 7.0).

4.2 Measurement Quality Objectives

The term “data quality” refers to the level of uncertainty associated with a particular data set. Data quality associated with environmental measurement is a function of the sampling plan rationale and procedures used to collect the samples, as well as the monitoring methods and instrumentation used in making the measurements. Uncertainty cannot be eliminated entirely from environmental data. However, quality assurance programs effective in measuring uncertainty in data are employed to monitor and control deviation from the desired DQOs. Sources of uncertainty that can be traced to the sampling component are poor sampling plan design, incorrect sample handling, faulty sample transportation (if applicable), and inconsistent use of standard operating procedures (SOPs). The most common sources of uncertainty that can be traced to the analytical component of the total measurement system are calibration and contamination (i.e. equipment not “resetting” or fully equilibrating in a new sampling location). One of the primary goals of this updated QAPP is to ensure that the data collected are of known and documented quality and useful for the purposes for which they are intended. The procedures described are designed to obtain data quality indicators for each field procedure and analytical method. To ensure that quality data continues to be produced, systematic checks must show that test results and field procedures remain reproducible, and that the methodology employed is actually measuring the parameters in an acceptable manner. For the field measurements to be conducted under this updated QAPP (including TDG, temperature, DO, pH, and turbidity) many MQOs can be specified. Each of the MQOs that pertain to this updated QAPP is further discussed below. The goals for this effort are outlined in Table 4.

Table 4 Measurement quality objectives

Parameter	Smallest Reference Level for Decision making	Range of Instrument	Bias/Accuracy	Sensitivity/ Resolution
Total Dissolved Gas	1% Saturation	400 to 1400 mmHg	+/- 1.5 mmHg	1.0 mmHg (0.1% sat.)
Water Temperature	0.3˚C	-5 to 50˚C	+/- 0.1˚C	0.01˚C
pH	0.5 units	0 to 14 units	+/- 0.2 units	0.01 units
Turbidity	5 NTU	0 to 100 NTU	+/- 1% of range	0.1 NTU
Dissolved Oxygen	0.2 mg/L	0 to 50 mg/L	+/- 0.1 mg/L at < 8 mg/L +/- 0.2 mg/L at > 8 mg/L	0.01 mg/L

4.2.1 Precision

Precision is a measure of the reproducibility of an analysis or set of analyses under a given set of conditions and generally refers to the distribution of a set of reported values about the mean. The overall precision of a sampling event has both a sampling and an analytical component. The precision provides transparency into presence of random error such as field sampling procedures, handling, and data collection/analysis method. A reduction of precision could be introduced to this work in several ways including using equipment that is not sensitive enough (see section 5.2.3 below), collecting measurements over a large spatial or temporal regime, using a wide range of types of equipment, etc. The FSM Program will use the same type of equipment to monitor water quality (Hydrolab® multi-probes) over a small spatial and temporal regime. A means of determining the precision of a measurement is to conduct duplicate sampling (e.g. making the same measurement in the same location at approximately the same time with the same type of equipment) and looking at the variability in results. As part of the FSM Program, duplicate sampling will occur each time a newly calibrated multi-probe is deployed (see Section 6.0).

4.2.2 Bias

Bias (otherwise known as accuracy) is the difference between the population mean and the true value of the parameter being measured. Bias in measurements obtained under this updated QAPP may be introduced by faults in the sampling design (e.g. all of the temperature measurements collected in one location that is not indicative of the mixed flow or strata of interest), inability to measure all forms of the parameter of interest (e.g. inability of a thermometer to reach a temperature regime needed due to physical obstacles), improper or insufficient calibration of instrumentation and/or equipment. Bias will be minimized by following standard protocols for calibration and maintenance, and by following field protocols for stabilization of the multi-probes.

4.2.3 Sensitivity

Sensitivity denotes the rate at which the analytical response varies with the concentration of the parameter being measured, or the lowest concentration of a parameter that can be detected (often referred to as “resolution” for water quality equipment). For this work, equipment must be selected that provides tight enough tolerances to ensure that the data collected are described to the necessary precision. For example, if water criterion for temperature is concerned with a temperature shift of greater than 0.3 degrees Celsius, then the equipment should be able to measure the water temperature with sensitivity less than 0.3 degrees Celsius, preferably by an order of magnitude. Often, the accuracy is much larger than the resolution. If this is the case, the accuracy is the smallest verifiable value reported by the instrument. All of the sensors used for the FMS Program have sensitivities less than required to determine compliance with water quality standards (see Table 4).

5.0 Methods

The following sections provide the methods that will be used to meet the purpose and objectives of the FSM Program.

5.1 Monitoring Locations

All water quality parameters discussed in this updated QAPP will be measured at Grant PUD’s existing FSM stations, located in the forebay and tailrace of Wanapum and Priest Rapids dams.

Section 6.4.10(a) of the 401 WQC (WDOE 2007) required Grant PUD to either move the TDG tailrace compliance locations to within 2,000 feet of Wanapum Dam and 1,500 feet of Priest Rapids Dam, or provide WDOE with a method and schedule for establishing new FSM stations, with indexing to the current FSM stations as needed. A Total Dissolved Gas Compliance Monitoring Location report (Grant PUD 2010) was sent to WDOE on April 16, 2010 for approval. WDOE approved the report on July 15, 2010 to use the current FSM locations during non-fish passage periods (WDOE 2010).

5.1.1 Wanapum Dam

The Wanapum Dam forebay FSM station is located near Turbine Unit 10 (N46°5229.008, W119°5817.150 - Datum WGS 84) and is affixed to the catwalk approximately mid-channel (Figure 4–5). The Wanapum tailrace FSM station is located approximately 3.2 miles downstream of Wanapum Dam. The tailrace standpipe is located at mid-channel and is attached to the downstream side of Beverly Bridge, (N46°5001.538, W119°5631.884 - Datum WGS 84; Figure 4 and Figure 6–7).

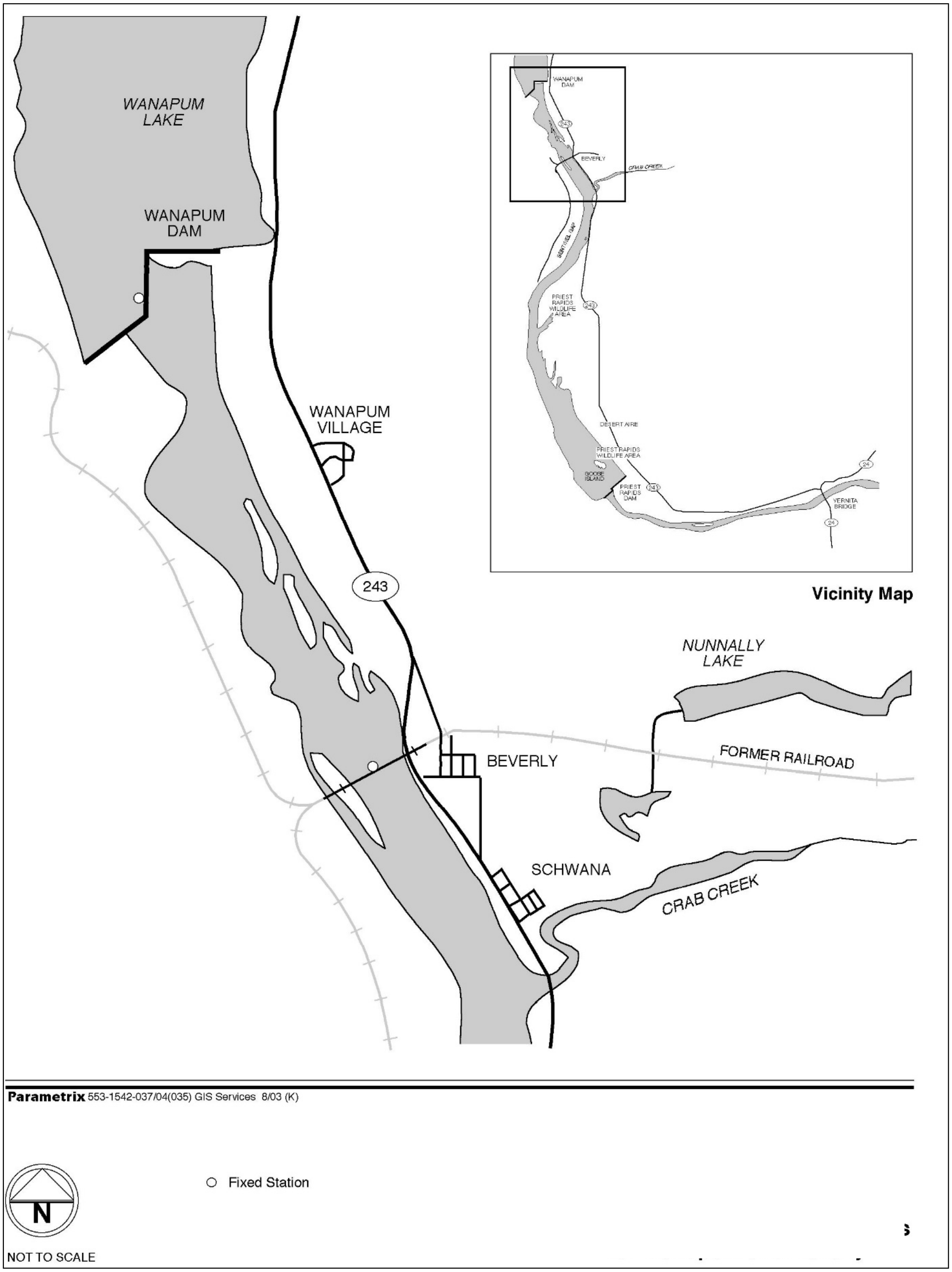

Figure 4 Location of water quality fixed-site monitoring stations (FSM stations) for Wanapum Dam.

Figure 5 **Photograph of Wanapum Dam forebay water quality fixed-site monitoring station (FSM station), Priest Rapids Project, mid-Columbia River.**

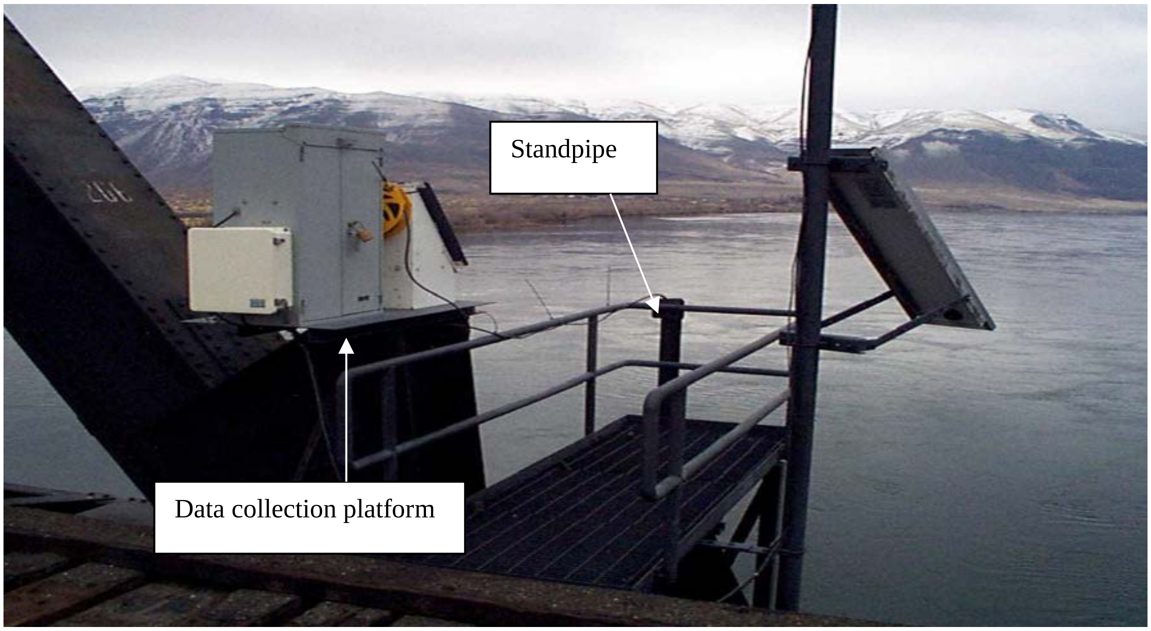

Figure 6 **Photograph of Wanapum Dam tailrace water quality fixed-site monitoring station, looking downstream from Beverly Bridge. Priest Rapids Project, mid-Columbia River.**

Figure 7 Photograph of Wanapum Dam tailrace water quality fixed-site monitoring station (FSM station), looking upstream at Beverly Bridge. Priest Rapids Project, mid-Columbia River.

5.1.2 Priest Rapids Dam

The FSM station in the forebay of Priest Rapids Dam is attached to the pier nose directly between the powerhouse and spillway and is located at mid-channel and approximately the center of the dam (N46°3840.324, W119°5436.633 - Datum WGS 84; Figures 8 and 9). The Priest Rapids Dam tailrace FSM station is located nine miles downstream of Priest Rapids Dam at Vernita Bridge. It is also located at mid channel and attached to a center support of the bridge (N46°3831.197, W119°4357.447 - Datum WGS 84; Figures 8 and 10).

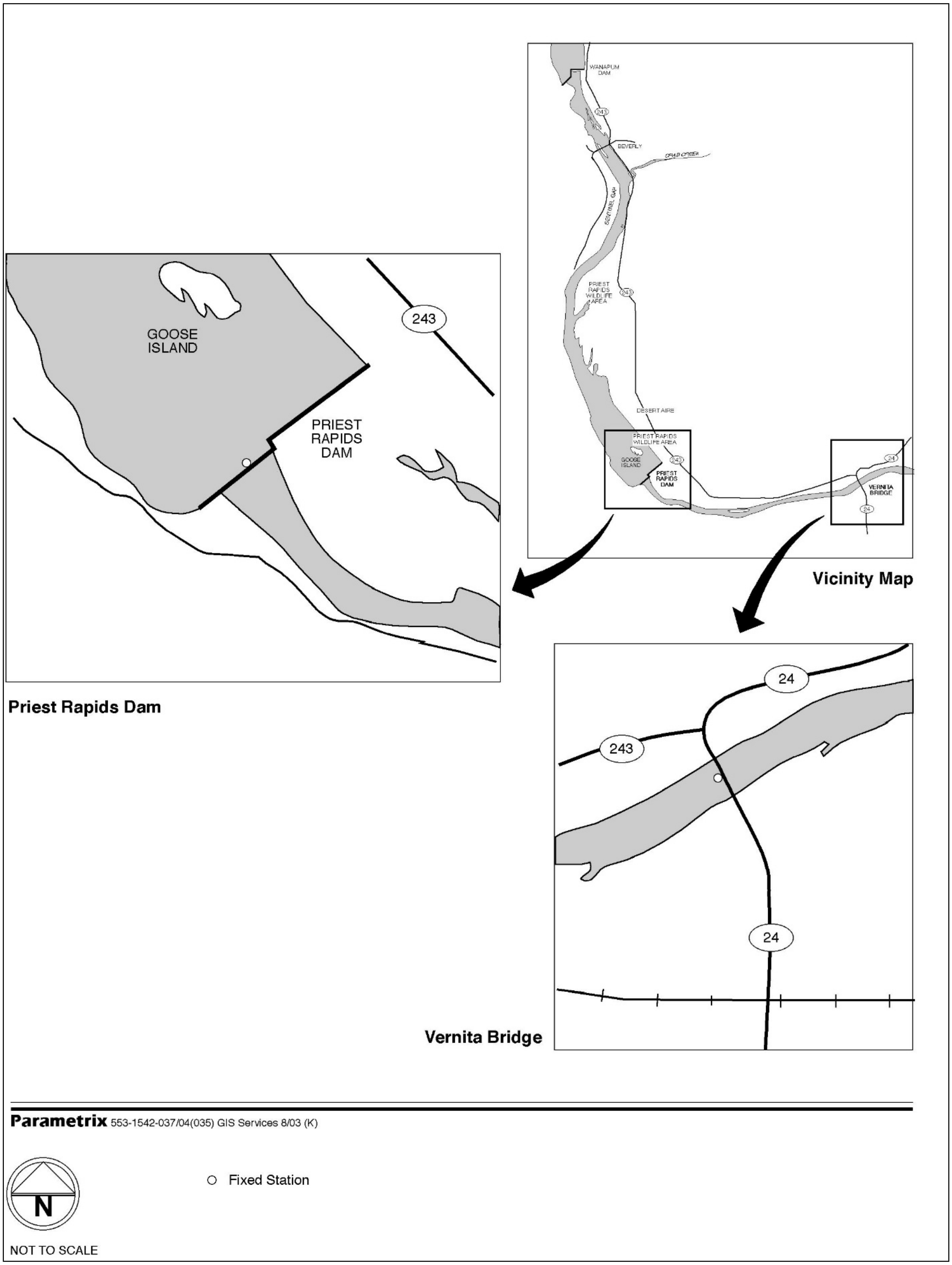
WANAPUM DAM
243
BEVERLY
CRAB CREEK
SENTINEL GAP
PRIEST RAPIDS WILDLIFE AREA
243
DESERT AIRE
PRIEST RAPIDS WILDLIFE AREA
GOOSE ISLAND
243
PRIEST RAPIDS DAM
24
VERNITA BRIDGE
24
Vicinity Map
GOOSE ISLAND
243
PRIEST RAPIDS DAM
Priest Rapids Dam
24
243
24
Vernita Bridge
Parametrix 553-1542-037/04(035) GIS Services 8/03 (K)
Fixed Station
N
NOT TO SCALE

Figure 8 **Location of water quality fixed-site monitoring stations (FSM stations) for Priest Rapids Dam.**

Figure 9 **Photograph of Priest Rapids Dam forebay water quality fixed-site monitoring station (FSM station), looking to the west. Priest Rapids Project, mid-Columbia River.**

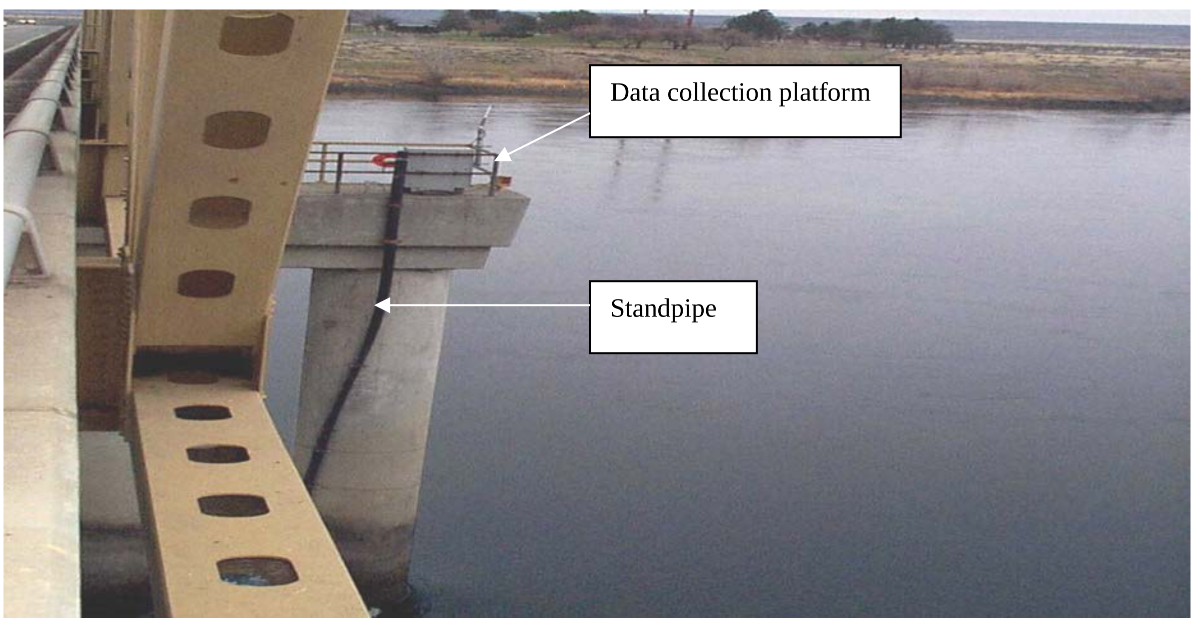

Figure 10 **Photograph of Priest Rapids Dam tailrace water quality fixed-site monitoring station (FSM station), looking to the west from Vernita Bridge. Priest Rapids Project, mid-Columbia River.**

5.2 Monitoring Procedures

The following sections present the monitoring procedures that will be used at part of Grant PUD's FSM Program, designed to meet the DQOs and MQOs.

5.2.1 Frequency

Table 1 provides the frequency that each water quality parameter will be measured. These frequencies follow the requirements of the 401 WQC (WDOE 2007), which provide that TDG and water temperature be monitored on an hourly basis, while DO and pH be monitored on a "periodic basis." Grant PUD will also continue to collect turbidity data as part of the DO and pH periodic monitoring. The monthly grab-sample approach to the DO, pH, and turbidity monitoring follow Grant PUD's calibration and maintenance schedule for the water quality probes at the FSM stations, and allow for DO, pH, and turbidity measurements to be taken with the quality assurance/quality control (QA/QC) probe (see Section 6.3). The QA/QC probe is used to check accuracy and precision of newly deployed probes with those that have just been taken out, and is used at each site during probe deployment. Therefore DO, pH, and turbidity measurements will be taken from the multi-probe on the same day at each FSM station. Furthermore, measuring DO, pH, and turbidity with a newly calibrated water quality probe will reduce potential bias or sensor drift issues that can occur with DO, pH, and turbidity sensors that are left in the river for extended periods of time and are monitoring on an hourly bias. For example, pH probes can appear to calibrate satisfactorily but still not provide accurate field measurements due to the high-ionic strength of the pH buffers (typically 8,000 to 10,000 μmhos/cm) used for calibration versus the relatively low-ionic strength of the water in the Columbia River (usually 95 to 150 μmhos/cm).

5.2.2 Monitoring Depth

The monitoring depth of the hourly TDG and water temperature measurements will vary with forebay and tailrace elevations throughout the year. Given the depth of the standpipes at each FSM station, the depths should range between three and five meters. The periodic grab-samples of DO, pH, and turbidity should be measured as consistently as possible at the same depths during each monitoring event, while prioritizing the goal of capturing the condition of the mixed flow. Again, depending on forebay and tailrace elevations the depth of measurement is anticipated to be three to five meters from the surface.

5.2.3 Equipment

The equipment used for this monitoring effort will be Hydrolab multi-probes. Appendix B provides information on Hydrolab DS5X, DS5A, DS4A, or Minisonde multi-parameter probe (multi-probe). Hydrolab probes are used throughout the Columbia River Basin, including use by other Columbia River dam operators (e.g. Chelan PUD 2007, Tanner 2003, and Corps 2008).

5.3 Calibration and Maintenance

Calibration and maintenance of the individual sensors of the Hydrolab multi-probes will follow the manufactures recommendations and regionally accepted methods used by other resource agencies conducting similar monitoring programs, such as the USGS, U.S. Army Corps of Engineers (Corps), and other mid-Columbia River Dam operators. The general calibration, maintenance, and deployment methods (see below) for the multi-probes also follow regionally accepted methods.

To ensure accurate data collection, Grant PUD replaces multi-probes on a monthly scale, or as needed based on daily QA/QC data review. Grant PUD has also established Probe Quality Assurance and Control (PQAC) SOPs to assure that data collection is accurate, reliable and consistent, and to minimize data loss. The PQAC SOPs have been modeled after USGS quality assurance and control methods (Tanner 2001 and 2003) and is updated as new techniques in maintenance and calibration are developed. In addition, Grant PUD staff will attend Hydrolab workshops, specialized training sessions, and/or regional QA/QC meetings to maintain consistency with new methodologies and techniques.

The first procedure in the PQAC SOP includes recording information regarding the FSM station location, date, time, equipment serial numbers and calibration data. The PQAC process allows Grant PUD to record data from three different instruments and compare data sets to verify precision.

The most current, real time data is recorded from the existing probe (field multi-probe) to be removed. A calibrated QA/QC probe is deployed into the secondary standpipe. The QA/QC probe is allowed to fully stabilize and equilibrate after immersion. The sensor depth of all three probes is recorded to assure compensation depth has been achieved.

Once equilibration is reached by the QA/QC probe (when TDG of the QA/QC probe is within 10 mm Hg of the existing probe), the date/time and real time data for depth, water temperature, DO, pH, TDG, and turbidity are recorded once every minute for approximately five minutes, with the average of those five measurements being taken as a composite measurement. This composite measurement consists of the grab-sample needed for DO, pH, and turbidity monitoring.

After data is collected from the QA/QC probe, the newly calibrated probe (replacement probe), which will remain at the location is deployed. After sufficient time is allowed for the probe to equilibrate (to within 10 mm Hg TDG of existing probe), the real time data values are recorded using a composite average of five readings taken every minute for five minutes. The values are then compared to the QA/QC readings and the data recorded by the field-probe. If the data sets from all three probes are comparable, consistent, and reasonable, the new probe is deployed and connected to the DCP.

At the end of each FSM multi-probe removal/deployment and maintenance activity, post-calibration procedures are performed on the removed field probe. The removed probes are then stored in the laboratory and calibrated following the maintenance and calibration procedures described above the day before it is to be re-deployed (during the next scheduled FSM station visit). If a problem is discovered during the calibration procedures; it is recorded and the multi-probe is shipped to the manufacturer for servicing or problem is discussed and solved over the phone with a Hydrolab technician. An entry is added to the troubleshooting logbook as to what actions were made to correct the problem.

The following sections provide details on the calibration methods for each individual sensor of the water quality multi-probe.

5.3.1 Total Dissolved Gas

As discussed in the above section, calibration, maintenance, and deployment of the TDG sensors will occur monthly or as needed based on daily data quality and review. Post-deployment maintenance methods for the TDG sensors include removing the TDG membranes from the removed multi-probes and cleaning them with a soft bristled brush and mild soap, and then allowing the membranes to air dry. TDG membranes are also visually inspected for leaks and condensation moisture trapped inside the membrane. The leaks will usually appear as large darker spots in the membrane and indicate that water has entered the silastic tubing. This can occur from either leaks through a tear in the membrane or water vapor diffusion causing condensation inside the membrane. Defective membranes are replaced before use. When not in use for extended periods of time, TDG sensors are covered with the storage cap and membranes are stored in a desiccator until future use.

To air calibrate TDG sensors, Grant PUD uses a certified mercury column barometer or portable field barometers that have been calibrated to a certified mercury column barometer. TDG is calibrated by comparing the instrument readings (in mm Hg) to those of the standard barometer at atmospheric conditions. TDG response slope checks are performed by adding known amounts of pressure, usually 200 mm Hg, directly to the transducer using a Netech Digimano 2000 digital pressure meter (certified to National Institute of Standards and Technology (NIST) traceable standard annually) to assure proper function and calibration. The membrane is bypassed during these calibrations so that the probe itself is calibrated, rather than the probe/membrane combination. Air calibrations are conducted pre- and post-deployment. If a TDG sensor does not meet post-deployment calibrations, all data collected by that sensor is considered suspect and additional review and quality checks are done to that data to determine if the sensor drifted during deployment. An inspection for leaks is performed on the membrane itself before completing calibration. One of the checks employed involves immersing the membrane in seltzer water (supersaturated with carbon dioxide). The expected result of a properly functioning membrane is an immediate jump in the TDG reading of at least 300 mm Hg above the barometer at atmospheric conditions; if the membrane fails to reach at least 300 mm Hg above the barometer reading, a new membrane is placed on the sensor and the seltzer water test is run again.

5.3.2 Water Temperature

Grant PUD follows the recommended maintenance for temperature sensors, which typically includes cleaning of the sensor to remove biological or chemical deposits. The temperature sensor is not removable and does not require any other maintenance accept to verify that the connection is securely fastened to the multi-probe. Grant PUD also conducts a visual check for damage.

Hydrolab does not currently require a calibration method for the temperature sensor, as they calibrate the temperature sensor during construction of the multi-probes. However, per the recommendation of WDOE (2009), Grant PUD will test all Hydrolab temperature sensors against a NIST thermometer at least once per year prior to the spring/summer monitoring period. Multi-probes and the NIST thermometer will be placed into an ice bath to verify temperature accuracy. Data collected during exposure to the ice bath will be compared to the certified thermometer to ensure that the temperature sensors of each respective multi-probe are performing properly. If inaccuracies are apparent in the Hydrolab temperature sensors, they will not be deployed for temperature monitoring until the problem causing the inaccuracy can be identified and corrected.

5.3.3 Dissolved Oxygen

In 2003, Hydrolab made commercially available a new DO sensor technology. A Luminescent Dissolved Oxygen (LDO) sensor was established to reduce the maintenance and calibration needs of previous technologies, such as the Clark Cell and Winkler Titration (Mitchell 2006). This sensor offers significant enhancements in terms of accuracy and sensor life over other existing technologies used to measure DO, including optodes using intensity-based measurements and the ability to self-correct for temperature and other changes in the sensor electronics (Mitchell 2006). Maintenance of the LDO sensor is simpler than the Clark Cell, consisting of cleaning the sensor with cotton swabs and distilled water to remove any excess debris or oil and replacing the protective cap once per year (Hach Company 2006). Starting in 2005, all new Hydrolab series 5 multi-probes were fitted with an LDO sensor for DO collection; and Grant PUD currently has eight series 5 multi-probes and uses them exclusively as the QA/QC probe used to collect DO, pH, and turbidity grab-samples.

5.3.4 pH

For pH, there are two types of sensors that are used for pH on the multi-probes deployed by Grant PUD. Both incorporate a glass electrode and pH reference electrode/Teflon junction. These sensors may be used in combination or used separately.

Maintenance includes cleaning the glass bulb with methanol and then gently scrubbing it with a cotton swab. The pH reference housing is filled with pH reference solution by gently pulling the housing out or by removing the housing using a flat head screwdriver, depending on style. Care is taken to avoid leaving air or bubbles inside the housing when finished.

Calibration entails rinsing the sensor(s) with distilled water and performing a pH response slope check using known pH standards, usually 7 and 10-pH standard. The sensor(s) are then submerged in 7-pH standard and pH readings are allowed to stabilize. The multi-probe is then reprogrammed to pH 7 which removes any prior deviation of greater than 0.01 units. This step is repeated using a pH 10 standard. All sensors are rinsed with distilled water before and after calibrations (Hydrolab 2006).

5.3.5 Turbidity

The multi-probes that Grant PUD deploys at its FSM stations have one of four different turbidity sensors. This includes the standard turbidity sensor (infrared and a photodiode detector), shutter turbidity, a 4-Beam turbidity sensor, or a self-cleaning sensor. All four of these turbidity sensors incorporate similar procedures for maintenance and calibration.

Maintenance on any of the four turbidity sensors is conducted by removing biological buildup and growth with a cotton swab. Calibration entails rinsing the sensor with distilled water and performing a turbidity response slope check using known turbidity standards, usually 0 and 40 NTUs. The sensor is submerged in 0 NTU standard (within a darken chamber and lid) and turbidity readings are allowed to stabilize. The multi-probe is then programmed to 0 NTUs. This step is repeated using a 40 NTU standard. All sensors are rinsed with distilled water before and after calibrations (Hydrolab 2006).

5.4 Analytical Methods

The analytical methods for data collected under this QAPP will center on two principle objectives:

1). Verify compliance with WDOE 401 WQC (2007) and WDOE water quality standards (WDOE 2006); and
2). Track water quality trend data over the entire FERC license for the Project (FERC 2008), adaptively managing the monitoring program based on data results, changes to Columbia River chemistry, use, and flows, and changes in the state water quality standards.

Analytical methods for each parameter to be monitored are included below.

5.4.1 Total Dissolved Gas

As explained in section 3.0, there are two different water quality standards for TDG that apply to the Project, both of which require TDG to be reported as %SAT. TDG data collected as part of Grant PUD's FSM Program will be measured in mm Hg and then converted to %SAT using barometric pressure measurements recorded by a certified barometer located at each FSM station. The conversion equation is as follows:

$$\text{TDG in \%SAT} = (\text{TDG mm Hg} / \text{barometric pressure mm Hg}) \times 100$$

During the non-fish-spill season, values that exceed 110 %SAT will be analyzed and compared to upstream (incoming conditions) and to Wanapum and Priest Rapids dam operations, as TDG does not typically exceed 110 %SAT in the Project unless involuntary spill is required at either Wanapum or Priest Rapids dams, or at an upstream dam.

During the fish-spill season, values that exceed the fish-spill season TDG standards will be compared to upstream (incoming conditions) and to Wanapum and Priest Rapids dam operations. If TDG values are above fish-spill season standards and are likely being caused by fish-spill operations, Grant PUD staff will consult with stakeholders and/or internal Grant PUD staff to determine if reductions in fish-spill operations are needed per various conditions set forth in Grant PUD's Biological Opinion (NMFS 2008), Salmon and Steelhead Settlement Agreement (Grant PUD 2006), 401 WQC (WDOE 2007), and 5-Year GAP (Grant PUD 2018a).

All TDG data will be reported in the annual water quality monitoring report that is due to WDOE March 1 of each year.

As detailed in the 401 WQC (WDOE 2007), the Year 10 Report (Grant PUD 2018), and 5-Year GAP (Grant PUD 2018a), Grant PUD has implemented both operational and structural TDG abatement measures that have helped Grant PUD obtain consistent compliance with TDG standards. A compliance analysis of the previous 10 years of TDG data will be completed every 5 years concurrent with the 5-year compliance GAP, which will help to ensure that Project operations continue to meet a similar level of compliance demonstrated in the Year 10 Report.

Additional TDG analytical methods will be incorporated as needed based on changes to Project operations, WDOE water quality standards, or other changes using adaptive management methods (see Section 7.0).

5.4.2 Water Temperature

Water temperature data collected as part of the FSM Program will be analyzed on a yearly basis by calculating mean-daily, maximum, and minimum values. Calculations will also be made to determine the 7-DADMax temperatures. Tabular and graphical displays of the mean-daily, maximum, minimum, and 7-DADMax temperature values will also be provided in the annual water quality monitoring report to WDOE, as will explanations of suspect, omitted, or lost data, and overall data completeness (based on percent of data meeting MQOs).

In 2015, and in accordance with Section 6.5.2 of the 401 WQC (WDOE 2007), Grant PUD conducted temperature modeling using a CE-QUAL-W2 model to determine Grant PUD's contribution, if any, to water temperature values recorded from 2003–2012 that were above WDOE water quality standards (NHC 2016). Final results from this modeling effort were sent to the WDOE on April 14, 2016.

Additional water temperature analytical methods will be incorporated into the annual updates to this QAPP as needed based on changes to Project operations, WDOE water quality standards, or other changes using adaptive management methods (see Section 7.0).

5.4.3 Dissolved Oxygen, pH, and Turbidity

DO, pH, and turbidity data collected as part of Grant PUD's FSM program will be reported within Grant PUD's annual water quality monitoring report to WDOE. Data will be evaluated and compared with the standards noted within Table 1 above (see Section 3.3.3).

Additional DO, pH, and turbidity analytical methods will be incorporated into the annual updates to this QAPP as needed based on changes to Project operations, WDOE water quality standards, or other changes using adaptive management methods (see Section 7.0).

5.5 Data Management and Quality Assessment

The following sections provide details on the management of water quality data collected under this QAPP, as well as the methods used to determine if data quality objectives have been met.

5.5.1 Real-Time Data

The hourly TDG and water temperature data that is transferred from the multi-probe to the Sutron DCP, and then to Grant PUD's water quality database is run by Sutron's XConnect software. This database runs on a secure server located at Grant PUD's Headquarters building in Ephrata, WA, which is backed-up daily. Hourly TDG and water temperature data are then transferred to Grant PUD's water quality website; this process typically produces a one to two-hour lag between time of collection and posting to the website. Daily summary reports (in Microsoft Excel spreadsheet format) are created each day (for previous day's data) and posted to the website. The data included in the daily summary reports have passed MQOs and are considered final. Data that does not pass MQOs are deleted from the report and a description of why the data did not meet data quality objectives, any required adjustments to the TDG or water temperature sensors, or other needed adjustments are recorded in a deleted data database. These deleted data will be presented in the annual water quality monitoring report under the QA/QC sections.

At the end of the monitoring season, real-time data will be assessed for quality based on the completeness of the data. The data quality objective for the real-time data (TDG and water temperature) will be that at least 90 percent of the real-time data meet MQOs.

5.5.2 Grab-Sample Data

The second component of data management is the grab-sample DO, pH, and turbidity data that is collected monthly. This data is recorded on a PDA using Hydrolab's Hydras 3 Pocket PC software, which is then transferred to an excel spreadsheet that is backed-up daily. The summary results from these data will be presented in the annual water quality monitoring report.

5.5.3 Calibration and Maintenance Data

All calibration and maintenance data collected for the FSM stations, including data from the Hydrolab sensors, BP sensors, etc. will be recorded on a PDA using Hydrolab's Hydras 3 software, which is then transferred to an excel spreadsheet and backed-up daily.

5.5.4 Water Quality Website

Currently, Grant PUD's water quality website provides hourly, daily summary, and monthly summary TDG and water temperature data recorded at each of Grant PUD's FSM stations, along with corresponding total river flow and spill volumes at each dam. Below is the link to Grant PUD's FSM website:

https://www.grantpud.org/water-quality

The following data and information is currently available at this website:

- Fixed Site Monitoring - Hourly Data: Provides daily ".xls" and ".csv" files showing data that has received QA/QC review and verification; includes calculation of 24-hour averages and average of 12 highest consecutive 3hourly TDG values. Hourly and mean daily total river flow, spill, and spill percentages from each dam are also included.
- Fixed Site Monitoring - Monthly Summary: A ".xls" file that provides daily mean values for TDG, water temperature, and flow/spill separated by month.
- 72 Hour Water Quality Information: Previous 72 hours (~2 hour delay) of TDG, water temperature, and flow/spill data that is considered preliminary, has not received final quality QA/QC review and verification, and is subject to change based on QA/QC review.
- Priest Rapids Smolt Monitoring: ".xls" file that presents gas bubble trauma (GBT) monitoring results, including date and number of fish examined, number and percent of fish with GBT signs, and ranking of GBT sign. For more information on Grant PUD's GBT monitoring program, see Grant PUD 2018.

- Water Quality Monitoring Report: Link to the current year water quality monitoring report.
- Quality Assurance Project Plan: Link to the most up-to-date QAPP for the Project.
- Total Dissolved Gas Abatement Plan: Link to the most up-to-date compliance GAP for the Project.

Data from previous years' can also be accessed from the Grant PUD's water quality website.

6.0 Adaptive Management

The 401 WQC (WDOE 2007) provides several adaptive management provisions that require Grant PUD to reexamine monitoring procedures, quality control, and analytical methods based on results of data (e.g. in or out of compliance with water quality standards, sudden deviations from historic trends, etc.), changes in operational, or changes in WDOE water quality standards. In addition, if the overall biological objectives for the Project or Columbia River basin change, adjustments to water quality monitoring objectives in this QAPP will also change, as needed. Any changes to this QAPP will be subject to WDOE and FERC approval and included in the annual updates to this QAPP as required by section 6.7.2 of the 401 WQC (WDOE 2007).

In addition to the adaptive management provisions above, Grant PUD will also adjust this QAPP based on changes to regional water quality methodologies, new or improved water quality monitoring equipment, and/or changes to calibration and maintenance methods.

6.1 Participation in Regional Forms and Trainings

Individual(s) responsible for the FSM Program oversight (see Table 2 in Section 3.4) will attend/participate at the Corps's year-end TDG monitoring and QA/QC meeting, at which presentations are made from the various agencies conducting TDG monitoring within the Columbia River Basin. Topics include data completeness, quality, calibration results, new or improved monitoring methods, etc. Agencies typically presenting at this meeting include the USGS, Corps, other mid-Columbia River PUDs, and private consultants. The FSM Program oversight individual responsible for carrying out the duties outlined within this QAPP will also make presentations to the groups and participate in round-table discussions at various water quality monitoring workshops, if available. They will also continue seek out available trainings related to water quality monitoring equipment, monitoring methods, etc. Adjustments to this QAPP will be made, as needed, based on relevant new information obtained from these regional forms and/or trainings, or by other means.

6.2 Audits

In order to assure that the proper measurement procedures are taking place and to determine if changes in the procedures are needed, two forms of audits will be conducted for the FSM Program: field audits and reporting audits, each of which is discussed below.

6.2.1 Field Audits

Once per year the FSM Program oversight individual will accompany Grant PUD water quality field staff into the field to monitor and audit all field activities including calibrations, maintenance, and multi-probe deployment methods, safety activities, and grab-sample collection methods. The auditor will focus on ensuring that all PQAC SOPs are followed, calibrations are conducted in compliance with manufacturers' specifications when applicable, and this QAPP is followed. The auditor will provide a brief write up of their observations including any deviations from QAPP and whether it should be changed or the process in the field needs to be addressed. The FSM Program oversight individual will be responsible for ensuring that if needed, any corrective actions meet WDOE and FERC approval, and that each corrective action is implemented. A subsequent audit may be required to ensure that the change has been successfully implemented.

6.2.2 Reporting Audits

It is the responsibility of the Grant PUD to ensure that all of the reporting requirements of the 401 WQC have been met. The individual responsible for the FSM Program oversight will also be responsible for keeping track of the mandated reporting and confirming that it has been met. Specifically, they will access the website as needed, to check that the necessary data are present, legible and correct. Additionally, they will review the annual reports to make sure that the data presented are accurate, and verifiable. Any deviations from requirements will be rectified and WDOE will be notified of the deviation and corrective action.

7.0 Reporting Protocols

The 401 WQC (WDOE 2007) provides detailed reporting requirements for water quality monitoring activities conducted by Grant PUD, including those activities covered under this QAPP (e.g. FSM Program). Per section 6.7.3 of the 401 WQC, data collected under this QAPP will be reported to WDOE on an annual basis by March 1 of each year. Additionally, all real-time TDG and water temperature data, daily summary reports, or other applicable information will be reported to Grant PUD's water quality website.

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Appendix A
Hydrolab Multi-Probe specifications

Minisonde Multiparameter Water Quality Sensor

Compact, lightweight 1.75" diameter housing fits into groundwater wells & boreholes

For maximum deployment life and minimum maintenance, this multiparameter water quality sonde offers Hydrolab's superior sensor technology on a multi-parameter platform. Their optimized combinations of sensors and accessories suit water quality monitoring applications in all environmental water sources, such as rivers, streams, lakes, reservoirs, oceans, bays, estuaries, and groundwater aquifers. Sensors are available to provide data for

Temperature	Depth	Conductivity	Salinity
Specific Conductance	TDS	Total Dissolved Gas	Turbidity
Dissolved Oxygen	pH	Chlorophyll	Blue Green Algae
Rhodamine WT	ORP	Ammonium	Chloride
Ambient Light (PAR)	Nitrate		

8 AA batteries: Long-term unattended operation can be achieved by paring the MS5 with the internal battery pack option.

Features & Benefits

- Optimized selection of parameters: Temperature, DO, Conductivity, pH plus >2 additional sensors
- 4 built-in expansion ports configured to fit your specific needs
- Measures up to 12 parameters simultaneously
- Field Tested Durability
- Available with Hach LDO optical dissolved oxygen sensor
- Capable of measurements using any of Hydrolab's 17 sensors
- Redundant data logging memory & internal power supply included
- Improved Power Management (minimal power consumption)
- 4 built-in expansion ports configured to fit your specific needs
- Measures up to 12 parameters simultaneously
- Optimized for long-term deployments in harsh environments
- Fits into wells & boreholes as small as 2 inches in diameter

SPECIFICATIONS for DS5, DS5X, & MINISONDE *(Subject to change without notice)*			
Dimensions DS5 & DS5X	**Dimensions MiniSonde**	**Weight**	**Battery Supply**
Diameter 3.5"/8.9 cm Length – 23"/58.4 cm	Diameter – 1.75"/4.4 cm Length – 29.5"/74.9 cm (w/battery pack)	DS5/DS5X: 7.4 lbs/3.35 kg (typical) MiniSonde: 2.9 lbs/1.3 kg (typ. w/battery pack)	DS5/DS5X: 8 C batteries MiniSonde: 8 AA batteries
Operating Temperature	**Maximum Depth**	**Communications Interfaces**	**Memory (all)**
-5.0° C to +50° C (all)	200 m (all)	RS-232, SDI-12, RS-485	>120,000 readings
SENSOR	**RANGE**	**ACCURACY**	**RESOLUTION**
Hach LDO	0 to 60* mg/L *Exceeds maximum natural concentrations	± 0.1 mg/L @ ± 8 mg/L ± 0.2 mg/L @ > 8 mg/L ± 10% reading > 20 mg/L	0.01 mg/L
Polarographic DO	0 to 50 mg/L	± 0.2 mg/L @ ±20mg/L ± 0.6 mg/L @ > 20 mg/L	0.01 mg/L
Conductivity	0 to 100 mS/cm	± (0.5% of reading + 0.001 mS/cm)	0.1%
Salinity	0 to 70 ppt	± 0.2 ppt	0.01 ppt
pH	0 to 14 pH units	± 0.2 units	0.01 units
Turbidity, Self-Cleaning	0-3000 NTU	Compared to StablCal ± 1% up to 100 NTU ± 3% from 100-400 NTU ± 5% from 400-3000 NTU	0.1 NTU from 0-400 NTU; 1 NTU for >400 NTU
Turbidity, 4 Beam	0-1000 NTU	3 (5% of reading + 1 NTU)	0.1 NTU from 0-100 NTU; 1 NTU for >100 NTU
Depth	0 to 10m (Vented Level) 0 to 25m 0 to 100m 0 to 200m	± 0.003 meters ± 0.05 meters ± 0.05 meters ± 0.1 meters	0.001 meters 0.01 meters 0.01 meters 0.1 meters
Chlorophyll a	*Dynamic Range* Low sensitivity: 0.03-500 µg/L Med. sensitivity: 0.03-50 µg/L High sensitivity: 0.03-5 µg/L	± 3% for signal level equivalents 0 of 1 ppb rhodamine WT dye or higher using a rhodamine sensor	0.01 µg/L
Blue Green Algae (fresh water or marine)	*Dynamic Range* Low sensitivity: 150-2,000,000 cells/mL Med. sensitivity: 150-200,000 cells/mL High sensitivity: 150-20,000 cells/mL	± 3% for signal level equivalents of 1 ppb rhodamine WT dye or higher using a rhodamine sensor	20 cells/mL
Rhodamine WT	*Dynamic Range* Low sensitivity: 0.04-1000 ppb Med. sensitivity: 0.04-100 ppb High sensitivity: 0.04-10 ppb	± 3% for signal level equivalents of 1 ppb rhodamine WT dye or higher using a rhodamine sensor	0.01 ppb
TDG (Total Dissolved Gas)	400 to 1400 mmHg	± 1.5 mmHg	1.0 mmHg
ORP	-999 to 999 mV	± 20 mV	1 mV
PAR	0 to 10,000 µmol $s^{-1}m^{-2}$	± 5% of reading	1 µmol $s^{-1}m^{-2}$
Temperature	-5 to 50°C	± 0.10°C	0.01°C
Ion Selective Electrodes			
Ammonia **Max Depth: 15 meters**	0 to 100 mg/L-N	Greater of ±5% of reading, or ±2 mg/L-N	0.01 mg/L-N
Nitrate **Max Depth: 15 meters**	0 to 100 mg/L-N	Greater of ±5% of reading, or ±2 mg/L-N	0.01 mg/L-N
Chloride **Max Depth: 15 meters**	0.5 to 18000 mg/L	Greater of ±5% of reading, or ±2 mg/L	4 digits

Hach LDO® Dissolved Oxygen

NEW! 2nd generation Hach LDO sensor technology. Hach - the premier provider of luminescent dissolved oxygen (LDO) technology since 2002

Only Hydrolab Series 5 sondes feature Hach LDO technology.

Features:

- No membranes = no air bubbles, no membrane relaxation, no maintenance
- Calibrations last without drift therefore deployments last longer, reducing frequency of maintenance trips to the field, saving time & money
- Highest accuracy & widest monitoring range available
- Compact housing allows complete integration into DS5X, DS5, or MS5
- Does not consume oxygen so passive fouling will not affect DO readings
- Rust design for long-lasting performance
- Manufactured& supported by Hach Hydromet, the experts in LDO technology

Specifications:

- Range: 0 - 60 mg/L
- Resolution: 0.01 mg/L
- Accuracy: +/- 0.1 mg/L at <8 mg/L
  +/- 10% reading >20 mg/L
  +/- 0.2 mg/L at >8 mg/L

pH Sensor

Hydrolab pH sensor uses glass bulb & refillable reference electrode for easily-maintained, long-lasting operation.

Features:

- KCl impregnated glass bulb is permeable to hydrogen ions; reference filled with 3M KCl and has a porous Teflon junction. Salt bridge is formed between the two, and a potential is measured.
- Choice of standard or integrated refillable reference
- Optionally paired with ORP sensor
- Reference electrode is easily refilled in seconds – independent of pH sensor
- pH sensor does not need replacement when reference electrode is depleted; simply refill the reference for years of sensor life

Specifications:

- Range: 0 to 14 pH units
- Resolution: 0.01 units
- Accuracy: +/- 0.2 units

Chlorophyll a (by Turner Designs)

The most accurate Chlorophyll a Sensor on a Multiprobe.

Features:

- Ultra-compact size designed for integration into t DS5X, DS5, & MS5
- Available with solid Secondary Standards to provide a quick, simple method to verify sensor's stability
- Secondary Standard can be adjusted to a known chlorophyll concentration
- 3 auto-selected gain ranges for a range of 0.03 to 500 Qg/l
- Electronic filtration of ambient light, efficient optical coupling, & quality optical components provide the most accurate measurement of Chlorophyll a.
- Incredibly fast response time through electronic filtration of ambient light
- Excellent turbidity rejection (small sample volume & quality optical filters)
- Cost optimized for affordability & value

Optical Characteristics:

- Light Source: Light Emitting Diode
- Detector: Photodiode
- Excitation Wavelength: Chl 460nm
- Emission Wavelength: Chl 685nm

Specifications:

- Minimum Detection Limit: 0.03 Qg/l
- Dynamic Range: Low sensitivity: 0.03-500Qg/L
- Med. sensitivity: 0.03-50Qg/L
- High sensitivity: 0.03-5Qg/L
- Resolution: 0.01 Qg/L
- Accuracy: +/- 3% for signal level equivalents of 1 ppb rhodamine WT dye or higher using a rhodamine sensor
- Sensor housing:
  Stainless steel: Standard housing for typical fresh water applications.
  Titanium option: Corrosion-resistant housing for use in aggressive saline environments such as oceans, bays and estuaries.

Rhodamine WT (by Turner Designs)

Hydrolab's Rhodamine WT sensor is the most accurate available on a multiprobe

Features:

- Ultra-compact design specifically for integration into DS5X, DS5, & MS5
- Secondary Standards Option for quick, simple verification of sensor's stability
- Secondary Standard can correlate to a known dye concentration.
- 3 auto-selected gain ranges provide measurements from 0.04 to 1000 ppb
- Electronic filtration of ambient light, efficient optical coupling & quality components produce the most accurate measurement of Rhodamine WT.
- Incredibly fast response time through electronic filtration of ambient light
- Excellent turbidity rejection (small sample volume & quality optical filters
- Cost-optimized for affordability & value

Optical Characteristics:

- Light Source: Light Emitting Diode
- Detector: Photodiode
- Excitation Wavelength: RWT 550 nm
- Emission Wavelength: RWT 600 nm

Specifications:

- Minimum Detection Limit: 0.04 ppb
- Dynamic Range: Low sensitivity: 0.04-1000 ppb
- Med. sensitivity: 0.04-100 ppb
- High sensitivity: 0.04-10 ppb
- Resolution: 0.01 ppb

- Accuracy: +/- 3% for signal level equivalents of 1 ppb rhodamine WT dye or higher using a rhodamine sensor
- Sensor housing:

  Stainless steel: Standard housing for typical fresh water applications.

  Titanium option: Corrosion-resistant housing for use in aggressive saline environments such as oceans, bays and estuaries.

Total Dissolved Gas (TDG)

Total Dissolved Gas (TDG) sensor uses a pressure transducer mounted behind a rigid gas-permeable silicone membrane to measure total gaseous compounds dissolved in a liquid.

Features:

- TDG is measured in units of pressure (mmHg)
- Pressure includes the partial pressure of all gas species dissolved in the water.

Benefits:

- Real-time measurement indicates water supersaturated with atmospheric gases, which can cause gas bubble gill disease in aquatic organisms.

Specifications

- Range: 400 to 1400 mmHg
- Accuracy: ± 1.5 mmHg
- Resolution: 1.0 mmHg

Dissolved Oxygen

Based on a standard EPA-approved Clark Cell design, trusted for over 30 years.

Features:

- Design based on a standard Clark Cell design, and paired with a sample circulator
- Measures the current resulting from the electrochemical reduction of oxygen diffusing through a selective membrane
- Provides a continuous, steady-state reading

Benefits:

- Low maintenance – no need to "recondition" the sensor
- Complies with Standard Methods Article 4500-OG & EPA article 360.1 that require sufficient sample flow across the membrane.
- Circulator improves response time & helps sweep away traces of pH electrolyte.

Specifications:

- Range: 0 to 50 mg/L
- Accuracy: +/- 0.2 mg/L for 20mg/L or less

  +/- 0.6 mg/L for over 20 mg/L
- Resolution: 0.01 mg/L

Li-Cor Ambient Light

The Photosynthetically Active Radiation (PAR) sensor measures sunlight intensity at a specified point in the water column.

Features:

- Single-PAR or dual-PAR sensor when a surface light sensor is needed.
- Available in flat or spherical form depending on desired light measurements.
- Measures real-time sunlight intensity (influences biota reliant on photosynthesis).

- Applications:

  Drinking water reservoir management (Algae bloom remediation is very expensive.).

  Primary production monitoring (organism growth - lower end of the food chain)

  General aquatic habitat study (submerged grasses & other plants)
- The DataSonde multiprobe measures PAR from the water column & the surface & integrates measurements with the rest of the data stream or logging record.

Specifications:

- Range: 0 to 10,000 Qmol s-1m-2
- Accuracy: ± 5% of reading
- Resolution: 1 Qmol s-1m-2

Turbidity: 4-Beam

Compliant with 4B-GLI Method 2 & perfect for profiling or spot-check turbidity measurements.

Features:

- 4B-GLI Method 2 compliant
- 4-beam sensor uses standard ba scatter, yet has multiple beams/references checking and rechecking accuracy

Benefits:

- Patented technology is immune to ambient light references; therefore, it is perfect for profiling in shallow rivers and streams
- Offers a unique, patented Quick-Cal Cube for calibration verification

Specifications:

- Range: 0-1000 NTU
- Accuracy: ± (5% of reading + 1 NTU)
- Resolution: NTU for 0-100 NTU;

  NTU for 100 NTU and greater

Turbidity (Self-cleaning)

Measures from 0 to 3000 NTU & includes a user-programmable cleaning system to remove any fouling or debris that could otherwise affect readings.

Features:

- ISO 7027 compliant
- User-programmable self-cleaning system can perform up to 10 cleaning cycles before each reading
- Accurately measures up to 3000 NTU

Benefits:

- Fixed parking position ensures consistent data collection after each cleaning cycle
- 3000 NTU range allows Turbidity tracking even during rain storms or other events that could cause abnormally high readings
- Exceptional linearity even in high NTU environments
- Utilizes small aperture technique to reduce false readings from particulates and other debris

Specifications:

- Range: 0-3000 NTU
- Accuracy (compared to StablCal):
  ± 1% up to 100 NTU,
  ± 3% from 100-400 NTU
  ± 5% from 400-3000 NTU
- Resolution: NTU from 0-400 NTU;
  NTU for >400 NTU
- Temperature Coefficient: 0.05%/C
- Sensor housing:
  Stainless steel: Standard housing for fresh water applications & depths to 200 M.
  Plastic: Corrosion-resistant for aggressive saline environments such as oceans, bays & estuaries. Rated to depths of 50 M.

Conductivity

Uses 4 graphite electrodes in an open cell design to provide extremely accurate & reliable data with virtually no maintenance.

Features:

- Design based on 4 graphite electrodes in an open cell design
- Measures current between 2 electrodes held at a fixed potential; additional electrodes are used to compensate for any fouling of the electrode surfaces.
- Sensor measurements used to derive Salinity, Total Dissolved Solids, and Resistivity

Benefits:

- Reduces measurement error from environment – sediment falls to the bottom of the cell & bubbles rise to the top. Reliable measurements in any condition.
- Easily maintained between deployments by cleaning with a Q-tip or cotton swab

Specifications:

- Range: 0-100 mS/cm
- Accuracy: ± (0.5% of reading + 0.001 mS/cm)
- Resolution: 0.001

Depth/Vented Level

High-stability, custom pressure sensor w/4 range options.

Features:

- Depth measures absolute hydrostatic pressure from an internal diaphragm
- Optimized for depths down to 10m, 25m, 100m, or 200m

Benefits:

- Vented level (0-10 m) uses a sealed dryer attached to a fixed cable that provides compensation for changes in barometric pressure.

Specifications:

- Range: 0 to 10m (Vented Level)
- Accuracy: +/- 0.003 meters
- Resolution: 0.001 meters
- Range: 0 to 25m
- Accuracy: +/- 0.05 meters
- Resolution: 0.01 meters
- Range: 0 to 100m
- Accuracy: +/- 0.05 meters
- Resolution: 0.01 meters
- Range: 0 to 200m
- Accuracy: +/- 0.1 meters
- Resolution: 0.1 meters

Blue-Green Algae (by Turner Designs)

Most accurate Blue-Green Algae sensor available on a multiprobe.

Features:

- Available in two forms, one for detecting phycocyanin (fresh water), and one for detecting phycoerythrin (marine water)
- Ultra-compact size design specifically for integration into DS5X, DS5, & MS5
- Secondary Standards provide quick & simple verification of sensor's stability
- Secondary Standard can correlate to a known Blue-Green Algae concentration.
- 3 auto-selected gain ranges: measurement range of 100 to 2,000,000 cells/mL for either phycocyanin or phycoerythrin.

Benefits:

- Real-time measurement identifies potential algal blooms before they become problematic, allowing time for corrective action
- Less expensive and more timely than cell counting or visual inspection
- Electronic ambient light filtration, efficient optical coupling & quality components provide the most accurate measurement of phycocyanin or phycoerythrin
- Incredibly fast response time through electronic filtration of ambient light
- Excellent turbidity rejection (small sample volume design & quality optical filters)
- Cost-optimized for affordability & value

Optical Characteristics:

- Light Source: Light Emitting Diode
- Detector: Photodiode
- Excitation Wavelength: Phycocyanin 590 nm
- Phycoerythrin 525 nm
- Emission Wavelength: Phycocyanin 650 nm
- Phycoerythrin 570 nm

Specifications:

- Minimum Detection Limit: 100 cells/mL
- Dynamic Range:
  Low sensitivity: 150-2,000,000 cells/mL
  Med. sensitivity: 150-200,000 cells/mL
  High sensitivity: 150-20,000 cells/mL
- Accuracy: +/- 3% for signal level equivalents of 1 ppb rhodamine WT dye or higher using a rhodamine sensor
- Resolution: 20 cells/mL
- Sensor housing:
  Stainless steel - Standard housing for typical fresh water applications.
  Titanium option - Corrosion-resistant housing for use in aggressive saline environments such as oceans, bays and estuaries.

Ion-Specific Electrodes

To measure Ammonia, Nitrate, or Chloride.

Features:

- ISE is a reference electrode immersed in a solution of fixed ion concentration separated by a membrane containing a chemical compound that reacts with the ion of interest, measuring electrical potential that varies with concentration.

Applications:

- Ammonia & Nitrate: Tracing movement of point or non-point source pollutants (i.e., runoff from agricultural operations), monitoring aquaculture for excessive waste concentrations, surveying nutrient levels in natural water bodies

- Chloride: Monitoring landfills for leaks, tracing movement of point or non-point source pollutants (i.e., storm water runoff) within a natural water body, monitoring estuaries for salinity changes, & salt water intrusion into ground or surface waters).

Benefits:

- Ammonia: High levels of accessible nitrogen (total ammonia is one form) can lead to an overabundance of microorganisms, resulting in mortality to higher organisms (such as fish and shrimp) because of depleted dissolved oxygen
- Nitrate: Small changes in biologically available nitrogen levels can dramatically affect the levels of microbiological, plant, and eventually, animal life.
- Chloride: Does not react with, or adsorb to, most components of rocks & soils, and so is easily transported through water columns; therefore, it is an effective tracer for pollution from chemicals moving from man-made sources into natural water bodies, or for salt water intrusion.

Specifications:

Ammonia

- Range: 0 to 100 mg/L-N
- Accuracy: Greater of +/- 5% of reading, or +/- 2 mg/L-N
- Resolution: 0.01 mg/L-N
- Max Depth: 15 meters

Nitrate

- Range: 0 to 100 mg/L-N
- Accuracy: Greater of +/- 5% of reading, or +/- 2 mg/L-N
- Resolution: 0.01 mg/L-N
- Max Depth: 15 meters

Chloride

- Range: 0.5 to 18,000 mg/L
- Accuracy: Greater of +/- 5% of reading, or +/- 2 mg/L-N
- Resolution: 4 digits
- Max Depth: 15 meters

ORP

Hydrolab's ORP sensor uses a simple platinum band that donates or accepts electrons to monitor chemical reactions, quantify ion activity, or determine the oxidizing or reducing properties of a solution.

Features:

- The state of the reaction is measured by the potential developed between and inert noble metal electrode (platinum) and a reference electrode (same reference for pH)
- Compliant with SM2580 B

Benefits:

- The ORP is greatly influenced by the presence or absence of molecular oxygen. Low redox potentials may be caused by extensive growth of heterotrophic microorganisms. Such is often the case in developing or polluted ecosystems where microorganisms utilize the available oxygen. Low ORP is another relative measure for biological oxygen demand.

Specifications:

- Range: -999 to 999 mV
- Accuracy: +/- 20 mV
- Resolution: 1 mV

Temperature

The Hydrolab temperature sensor is a 30k ohm variable resistance thermistor. The temperature sensor is included with every Hydrolab sonde.

Features:

- 316 Stainless Steel, 30k ohm thermistor
- Variable resistor

Benefits:

- Provides critical compensation for Dissolved Oxygen, Conductivity, pH, and nutrient sensors
- Compliant with EPA170.1 and SM2550B

Specifications:

- Range: -5 to 50 ° C
- Accuracy: +/- 0.10 ° C
- Resolution: 0.01 degrees ° C

SBE 56 Temperature Logger

The Sea-Bird Electronics (SBE) 56 is a compact, lightweight battery-powered temperature logger for use in depths down to 1500m. The SBE 56 also logs time and samples at user-programmable intervals from 0.5 seconds to 9 hours.

Features of the SBE 56

- Long-term deployment capabilities in fresh, estuarine, and saltwater environments
- High accuracy and low drift rate with no in-field calibrations required, reducing field costs
- Low power consumption: can be deployed for 31 days at 0.5-second intervals or almost 2-years at 15-second intervals
- USB interface for fast data upload and rapid redeployment
- Easy attachment to trawl nets for fisheries and aquaculture operations

Ordering

Cabling and mounting accessories are determined by the application and installation site.

The type and number of water quality sensors you include in your multi-parameter sonde determine pricing and ordering details.

For ordering information, please contact your Sutron Sales Manager or the Sales Administrator, (703) 406-2800.