QUALITY ASSURANCE PROJECT PLAN
LUMMI NATION CONTINUOUS AQUIFER LEVEL MONITORING PROJECT

Version 1.1a

Water Resources Division
Natural Resources Department
Lummi Indian Business Council

Prepared for EPA Region 10

July 2021

Lummi Nation Continuous Aquifer Level Monitoring Project Quality Assurance Project Plan Approval (A1):

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Recipients identified on this distribution list will be sent updated versions of this document or copies of minor change letters for this document immediately after they are approved. Recipients listed may also obtain the most current copy of the approved Quality Assurance Project Plan (QAPP) by contacting the Water Resources Manager.

REVISION RECORD

Approval	Date	Responsible Person	Description of Change	Location of Change
1	October 2018	Kara Kuhlman	Initial Approval and Release of Version 1.0	N/A
1.1	December 2019	Kara Kuhlman	Staffing updates (new staff)	Distribution List, Section 1.2
			Remove completed studies	Section 1.1
			Reporting frequency increased from annual to every two years	Sections 3.1, 5.2, 11.2
			Replace sign-out board with informing supervisor	Section 7.2
			Update file locations	Section 7.6
			Update equipment used	Sections 8.2, 9
1.1a	July 2021	Kara Kuhlman	Change EPA Tribal Coordinator to Michael Ortiz	Signature page, Distribution List
			Remove ZAPS Technologies LiquID Station Continuous Water Quality Monitoring Study. The study has been completed.	Section 1.1
			Correct zero accuracy check frequency	Section 7.5.2, 8.1.2
			Correction of logger replacement frequency. Loggers are only replaced if quality assurance acceptance criteria are not met.	Section 7.1, 8.1.3, 10.5
			Correct frequency of Water Quality Assessment Report from annual to every two years	Section 3.1, 10.9
			Change STORET to WQX	Sections 3.1, 10.1

SIGNATURE PAGE

Document: Continuous Aquifer Level Monitoring QAPP

Version 1.1a

The following technical staff have read this manual. A copy of this page will be distributed to the employee training record file.

Signature	**Date**
Name (printed)	**Title**

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1. DOCUMENT AND PROJECT ORGANIZATION

1.1 Document Organization

This document is organized following Environmental Protection Agency (EPA) Requirements for Quality Assurance Project Plans (EPA 2001, reissued 2006a) with the companion document Guidance for Quality Assurance Project Plans (EPA 2002). Where a letter and number follow a section title (*e.g.,* Distribution List [A3]), they indicate the corresponding section in the EPA Requirements for Quality Assurance Project Plans.

The Lummi Nation Continuous Aquifer Level Monitoring (CALM) Project is a component of the Lummi Nation Water Quality Monitoring (WQM) Program. The overall quality system for the WQM Program is outlined in a Quality Management Plan (QMP), which serves as the umbrella document for the WQM Program and its component projects. Individual Quality Assurance Project Plans (QAPPs) have been developed for each individual project within the WQM Program. The individual projects include the following:

- Ambient Surface Water Quality Monitoring Project
- Ambient Groundwater Quality and Quantity Monitoring Project
- Continuous Water Temperature Monitoring Project
- First Flush Monitoring Project
- Department of Health Support (National Shellfish Sanitation Program) Project
- Nutrient, Metal, and Hydrocarbon Monitoring Project
- Continuous Water Level Monitoring Project (this document)
- Lummi Peninsula Groundwater Settlement Agreement Compliance Monitoring Project

In addition, Standard Operating Procedures (SOPs) have been developed for each instrument used or parameter measured.

1.2 Project Organization (A4)

The Lummi Nation Continuous Aquifer Level Monitoring (CALM) Project is administered and implemented through the Lummi Water Resources Division (LWRD), a division within the Lummi Natural Resources Department (LNR), contained under the Lummi Indian Business Council (LIBC). An organizational chart of the individuals participating in the CALM Project is provided in the QMP. A complete and detailed discussion of the structure of the WQM Program, including organization charts identifying the components of all WQM Program projects and individuals participating in the WQM Program are provided in the QMP (LWRD 2021c).

The Water Resources Specialist II is the primary staff person responsible for CALM Project coordination, including maintaining the official, approved QAPP. The Water Resources Specialist II, Water Resources Technician II, and Natural Resources Technician II are responsible for implementing the CALM Project. The Water Resources Specialist II supervises the Water

Resources Technician II and the Natural Resources Technician II and provides approval and oversight of the CALM Project. The Water Resources Manager evaluates compliance with project goals and makes recommendations to the LNR Director and Deputy Director, who make decisions based upon data collected as part of this project. The Database Manager created and maintains the Datalogger Database and Water Database and is the primary staff member responsible for database training and documentation.

1.3 Special Training Requirements and Certification (A8)

Details on the roles, contact information, position requirements, and qualifications held by the individuals responsible for managing and implementing the CALM Project are listed in detail in the QMP. The QMP also includes details on the required and recommended training and certification for all staff involved in the WQM Program. Supervisors and the Water Resources Manager are responsible for ensuring staff are qualified and trained.

2. PROBLEM DEFINITION AND BACKGROUND (A5)

2.1 Project Summary

The Lummi Nation CALM Project has been ongoing since 2008, and is focused on monitoring aquifer levels on the Lummi Indian Reservation (Reservation) on a continuous basis. The CALM Project will continue to provide aquifer level data at four groundwater sites on the Reservation to determine seasonal aquifer level variations and characterize the risk of groundwater mining. The CALM Project supplements the Lummi Nation Ambient Ground Water Quality and Quantity Monitoring Project (Ground Water Project) (LWRD 2021a). Summaries of the Ground Water Project and other Lummi Nation water quality monitoring projects within the WQM Program are provided in the QMP.

2.2 Groundwater

As summarized in the QMP, there are numerous threats to Lummi Nation Waters.[1] The QMP provides a detailed description of Lummi Nation Waters and the geographical location of the Reservation. Groundwater resources on the Reservation are vulnerable to groundwater mining and salt water intrusion because the Reservation is located in a coastal area with most of the existing water supply wells within a half-mile of marine waters (LWRD 1997). The majority of residential development has occurred along the marine shoreline placing the most vulnerable portion of aquifers at risk through direct pumping of groundwater near marine shorelines. Currently, groundwater supplies over 95% of the potable water used on the Reservation.

Two apparently separate potable ground water systems occur on the Reservation. One system is located in the northern upland area and appears to flow onto the Reservation from the north and drains to the west, south, and east. The second potable ground water system is located in the southern upland area of the Reservation (Lummi Peninsula) and is completely contained within the Reservation boundaries (LWRD 1997). The floodplain of the Lummi and Nooksack rivers, which contains a surface aquifer that is saline (Cline 1974), separates the two potable groundwater systems. A third potable water system may exist on Portage Island, but information on the water quality and the potential yield of this system is limited and inconclusive. Additional details on ground water resources and water quality are provided in the QMP.

2.3 Project Context

The CALM Project is implemented by the LWRD, which has the overall goal of protecting treaty rights to water of sufficient quantity and quality to (a) support the purposes of the Reservation as a permanent economically viable homeland for the Lummi People, and (b) to support a

[1] Pursuant to 17.09.010 of the Lummi Code of Laws, Lummi Nation Water includes all fresh and marine waters that originate or flow in, into, or through the Reservation, or that are stored on the Reservation, whether found on the surface of the earth or underground, and all Lummi Nation tribal reserved water rights.

sustainable harvestable surplus of salmon and shellfish sufficient to maintain a moderate living standard.

The CALM Project is a component of the Lummi Nation Water Quality Monitoring Program (WQM Program). The goals of the WQM Program are threefold:

1. To establish the baseline conditions of surface and ground waters on and flowing onto the Reservation;
2. To use this information to evaluate regulatory compliance of waters flowing onto the Reservation; and
3. To support the development and implementation of a water quality regulatory program (*e.g.,* Lummi Code of Laws Title 17, Water Quality Standards) on the Reservation.

The WQM Program is an important element of the Comprehensive Water Resources Management Program (CWRMP). Related ground water monitoring projects include the Ground Water Project and the Lummi Peninsula Ground Water Settlement Agreement Compliance Project (Settlement Compliance Project) (LWRD 2021b). Additional details on project context and related projects are provided in the QMP. Applicable criteria and action limits are also provided in the QMP.

2.4 Project Justification

An ample supply of good quality groundwater is needed to serve the purposes of the Reservation as a permanent and economically viable homeland for the Lummi People. Water level measurements collected five times per year as part of the Ground Water Project do not provide the sufficient resolution to determine seasonal and annual trends in aquifer level. To provide a higher resolution of trend analysis, continuous monitoring of groundwater level is required. Groundwater level trends are an important component in determining risk of groundwater mining, salt water intrusion, and availability of Reservation groundwater.

The data collected as part of this project are used to identify trends (seasonal, annual, and multi-year), establish baseline conditions, and assist in the evaluation of risk of groundwater mining and saltwater intrusion in groundwater systems on the Reservation. Details on the justification of the experimental design are provided in Section 6.1.

3. PROJECT DESCRIPTION (A6)

The Lummi Nation CALM Project has been ongoing since 2008. The overall objective of the CALM Project is to achieve the overall LWRD mission and the WQM Program goals (Section 2.3). Specifically, the CALM Project objectives are to:

1. Provide high quality data sufficient to establish baseline conditions of Lummi Nation Waters;
2. Protect groundwater supplies from groundwater mining and saltwater intrusion; and
3. Support the development of a water quality regulatory program (*e.g.,* Lummi Code of Laws Title 17, Water Quality Standards) on the Reservation.

3.1 Project Description

The CALM Project is focused on monitoring the quantity of groundwater on the Reservation. Four groundwater sites have been selected to assist in characterizing the southern major potable aquifer system on the Reservation. Figure 3.1 provides a map of the sample site locations. The northern potable aquifer system will be characterized upon identification of suitable groundwater site(s) for aquifer level monitoring following procedures outlined in this QAPP.

Aquifer level measurements are taken hourly at four wells using Telog continuous water level loggers (Telog logger, or logger). The Telog loggers measure pressure (psi) and convert the measurement to height of water above the logger (feet). Loggers are maintained and data are downloaded quarterly. The data collected as part of this Project are used to identify seasonal, annual, and multi-year trends; establish baseline conditions; and evaluate risk of groundwater mining and saltwater intrusion.

As the potability of the groundwater resources on the Reservation is of utmost concern, continuous monitoring of water levels as part of the CALM Project, combined with measurement of chloride concentrations, water use, and pump rates as part of the Ground Water Project and Settlement Compliance Project, can provide indications of potential groundwater mining and saltwater intrusion. Based on these data, measures can be implemented (*e.g.,* reduce duration or rate of pumping) to reduce risk of groundwater mining and saltwater intrusion.

A summary of aquifer level data, including identification of trends over the period of record, is included in the Water Quality Assessment Report provided every-other year to the EPA to fulfill Clean Water Act Section 106 grant funding requirements by March 31 of the year following the two-year reporting period (EPA 2006b). Data are not submitted to EPA as the Water Quality Exchange (WQX) does not currently support the import of continuous datasets.

Continuous data collection occurs year-round. Maintenance activities and data download activities occur quarterly in March, June, September, and December. Data analysis and report preparation is conducted in January-March of the year following the two-year reporting period. The data package (Water Quality Assessment Report) is scheduled for March 31 of the year

following data collection, every other year. It is anticipated that hourly water level measurements at all sites will be collected as scheduled. Equipment failure may result in a loss of data. Staffing limitations and budget constraints may restrict planned site visit frequency. However, data downloading activities conducted less frequently than planned may not necessarily result in data loss, as the Telog loggers are programmed to store data for periods longer than the time between scheduled maintenance and download activities.

Quality Assurance/Quality Control (QA/QC) procedures include logger calibrations, zero accuracy checks, paired water level readings, and maintenance activities as specified in this QAPP (Section 7 and 8) and the Telog Water Level Logger SOP (LWRD 2018b).

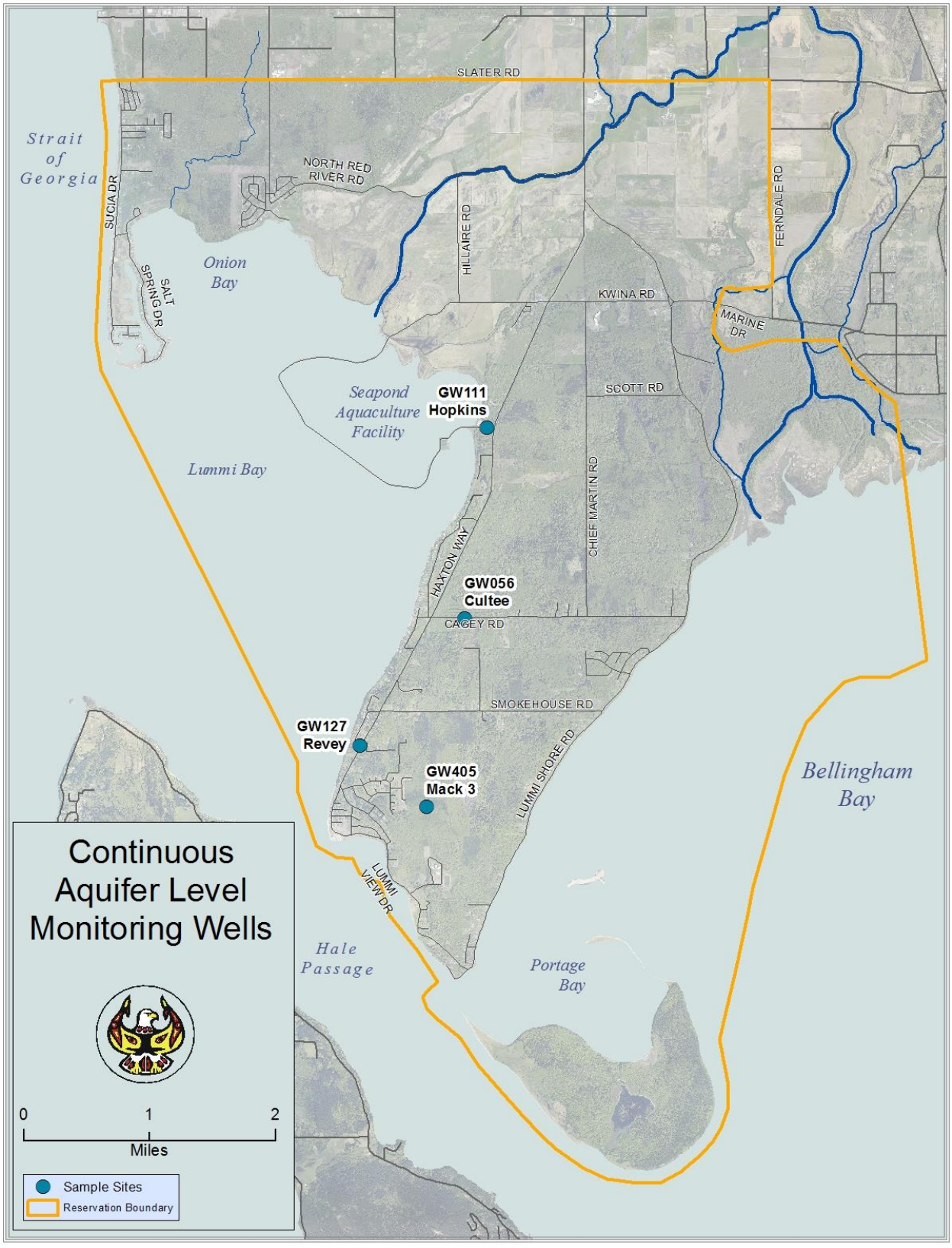

Figure 3.1 Continuous Aquifer Level Monitoring Sample Site Locations

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4. QUALITY OBJECTIVES AND CRITERIA (A7)

The overall performance standard for the CALM Project is the collection of high-quality data sufficient to meet project goals. Data must be of sufficient quality (*i.e.,* known precision, accuracy, bias, traceability, completeness, and representativeness) to support scientifically valid, legally defensible decisions. Project quality control activities are designed to indicate data quality in the field and prompt corrective actions at that time, if necessary. In addition, quality control activities provide the necessary information to assess and quantify data quality and comparability for data analysis and to ensure the reliability and usefulness of the aquifer level data for evaluation of trends, impairment, and risk of groundwater mining and saltwater intrusion.

4.1 Measurement Performance/Acceptance Criteria

Quality assurance/quality control (QA/QC) procedures include: instrument calibration by the manufacturer, zero accuracy checks, paired water level measurements, and maintenance activities as required by the Telog Water Level Logger SOP (Section 8).

The overall error acceptance criterion for the CALM Project is 0.15 feet. The acceptance criterion for maximum minus minimum total depth ($C_{max} - C_{min}$) is 0.05 feet. The acceptance criterion of calibration drift calculated during quarterly paired water level measurements (difference in initial and quarterly average total depth; $X_{deployment} - X_{current}$) is 0.05 feet. The acceptance criterion for zero accuracy checks is 0.05 feet. Corrective actions are taken or the logger is returned to the manufacturer for recalibration is acceptance criteria are exceeded.

Project action limits include decreasing water levels that are unusual or unexpected for the site. Additional details on project action limits are included in the QMP.

4.2 Precision

Precision can be calculated during paired static water level measurements. If measurements collected using the well probe remain steady (within 0.02 feet), the difference in instantaneous logger measurements can be used to calculate precision (*e.g.,* range, standard deviation, variance).

4.3 Accuracy and Bias

As described above the overall Project error acceptance criterion is 0.15 feet. Actual error/bias at zero can be calculated using data from zero accuracy checks. An estimate of error/bias can be calculated using data from paired water level measurements (difference in initial and quarterly average total depth; $X_{deployment} - X_{current}$). Instrument measurement accuracy and bias are specified by the manufacturer. See Telog Water Level Logger SOP for details. Telog loggers are calibrated by the manufacturer and accuracy is checked in the field. If the logger accuracy checks fail to meet acceptance criteria, corrective actions are taken to determine and correct the problem.

4.4 Representativeness

Representativeness of water level measurements is ensured through the selection of groundwater sampling sites. Details on the selection of sites are provided in Section 6.

4.5 Comparability

Although data have been collected as part of the CALM Project since 2008, data collected prior to the approval of this QAPP were collected without approved QA/QC procedures or a formal QAPP. Usability and comparability of pre-QAPP data will be determined on a case-by-case basis considering calibration records, QA/QC activity results, and professional judgment. All data gathering activities have been recorded and saved on field datasheets, field notebooks, and in the Water Database.

Data collected for this Project following this QAPP will be comparable. Only data with known and acceptable accuracy, precision, and traceability will be used for data analysis, reporting, and decision making. Information regarding data quality allows for comparison of data collected at different times over the period of record within the CALM Project and with other WQM Program projects, including the Ground Water Project and Settlement Compliance Project. CALM Project data may also be compared to non-WQM Program sources of data, such as water level data collected by the Lummi Water District, assuming quality control information is available for non-WQM Program data.

4.6 Completeness

The goal of the CALM Project is for hourly recording of aquifer level measurements to be made on a continuous basis year-round, and for data to be downloaded and maintenance activities performed at all sample sites four times per year. Downloading and maintenance activities are equally distributed throughout the year (quarterly during the last month of the quarter), but do not have to occur on specific days.

Data are considered complete when all efforts have been taken to collect the data. It is anticipated that hourly water level measurements at all sites will be collected as scheduled. Equipment failure may result in loss of data. Staffing limitations and budget constraints may restrict planned site visit frequency. However, data downloading activities conducted less frequently than planned may not necessarily result in data loss, as the Telog loggers are programmed to store data for periods longer than the time between scheduled maintenance and downloading activities. If fewer than 75% of the planned measurements are collected in a calendar year, the experimental design of this project will be re-evaluated.

Data gaps may affect future analysis of baseline conditions and comparison to the period of record, but do not immediately compromise the integrity of the monitoring project because monitoring is not attempting to answer a specific hypothesis. Data gaps are addressed on a case-by-case basis. Missing data may be due to staff turnover, resource constraints, equipment failure, corrective actions, or logistical problems. Corrective actions are undertaken to remedy conditions that create missing data to prevent data gaps in the future.

4.7 Range/Sensitivity

The sensitivity and range are determined by the equipment manufacturer. See Telog Water Level Logger SOP for details. The goal of the CALM Project is to collect data with sufficient resolution (sensitivity) to establish baseline conditions, identify trends, evaluate risk of groundwater mining and saltwater intrusion, and support the development and implementation of a water quality regulatory program on the Reservation. Deficiencies in sensitivity are evaluated on a case-by-case basis and corrected for future monitoring.

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5. DOCUMENTS AND RECORDS (A9)

5.1 Quality Assurance Project Plan Distribution

The Water Resources Specialist II is responsible for ensuring that the people listed on the Distribution List for this QAPP have the most current version of the QAPP. Records are maintained by the Water Resources Specialist II documenting substantial and minor version changes, and the Water Resources Manager is responsible for the distribution of minor change letters and revised QAPPs. Details on documenting QAPP revisions, including version number conventions, are included in the QMP.

5.2 Data Report Package

Results of the CALM Project are included in the Water Quality Assessment Report, which summarizes the results of the WQM Program projects implemented by the LWRD. The reports include analysis of water quantity data for the two-year reporting period as well as for the period of record. The report is provided to the EPA Project Officer every-other year by March 31 of the year after the two-year reporting period, following approval by the Water Resources Manager and the LNR Deputy Director.

5.3 Documentation and Storage

The QMP provides detailed requirements for project document storage, including field datasheets and electronic data.

In summary, the Water Resources Specialist II is responsible for maintaining and storing all documents and records associated with the CALM Project. All continuous data are stored in the Datalogger Database, which is saved on LIBC servers that are backed up nightly, and in back up Excel spreadsheets also saved on LIBC servers.

All run details, manufacturer calibrations, completed QA/QC procedures (*i.e.,* accuracy checks), site visit observations, notes on issues or concerns, corrective actions, and outcomes are recorded either directly into the Water Database in real time using the iPad or are recorded on field datasheets and transcribed into the Water Database. Field data entry QA/QC is completed by the Water Resources Specialist II within one week of trip date. All paper records (*e.g.,* field datasheets and QA/QC reports) are stored by the Water Resources Specialist II in the LWRD office. All electronic records are saved in the Water Database and in a data archive folder on secure LIBC servers, which are backed up nightly. Details on QA/QC of data entry into the Water Database are provided in the Water Database User Guide and QMP.

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6. EXPERIMENTAL DESIGN (B1)

As previously described, the CALM Project is designed to achieve the following objectives:

1. Provide high quality data sufficient to establish baseline conditions of Lummi Nation Waters;
2. Protect groundwater supplies from groundwater mining and saltwater intrusion; and
3. Support the development of a water quality regulatory program (*e.g.,* Lummi Code of Laws Title 17, Water Quality Standards) on the Reservation.

The CALM Project is ongoing and not intended to prove or disprove a specific hypothesis.

6.1 Project Structure and Sample Sites

In order to characterize water levels in the primary southern potable aquifer system on the Reservation, located on the Lummi Peninsula, four groundwater sample sites (Figure 3.1) were selected for continuous aquifer level monitoring:

- Cultee (GW056)
- Hopkins (GW111)
- Revey (GW127)
- Mackenzie #3 (GW405)

All four sample sites are located in the southern potable aquifer and are inactive groundwater wells (*i.e.,* no water is pumped from these wells). Sample sites were selected to represent aquifer-wide conditions as practicable. The spatial representativeness is limited by the lack of existing, inactive groundwater wells in some parts of the Reservation, particularly along the interior of the Lummi Peninsula.

Detailed maps, descriptions of sample locations, and driving directions to sample sites are provided to field personnel in the Field Reference Manual to ensure that sites are sampled on location (LWRD 2019a). Sample site access is usually not a problem. If sites are inaccessible, the sample site is skipped for that sample run, the sample site is returned to at a later time, or the sample run is rescheduled. The QMP provides details on site inaccessibility.

At each site data from the loggers are downloaded, maintenance activities are performed, as needed, and QA/QC activities are conducted. A zero accuracy check is conducted annually by measuring Telog logger readings in dry air (see Telog Water Level Logger SOP). Three paired measurements of Telog logger instantaneous water level readings and water level measurements collected using a well probe are conducted quarterly during each site visit. Maintenance activities include checking batteries, desiccant packs, and vent filters.

Water level data are required in order to assess the risk of groundwater mining and saltwater intrusion. All data collection is critical as representative and complete data of quantifiable quality are required to meet the goals of the CALM Project.

Typically, all four CALM Project sites are visited on the same trip. For ease of access, Mackenzie #4 (GW422), a site within the Ground Water Project, is visited concurrently during site visits to Mackenzie #3 (GW405) as part of the CALM Project due to the remoteness of these wells.

The northern potable aquifer system will be characterized upon identification of suitable groundwater site(s) for aquifer level monitoring. Upon identification, data collection activities will be conducted at these sites following the procedures outlined in this QAPP.

7. DATA COLLECTION (B2)

Sampling methods (B2) are described below. No physical water quality samples are collected as part of the CALM Project (B3). This section describes safety during data collection activities, equipment required for sample runs, the site visit sequence, logger preparation, logger deployment, and field visit activities.

7.1 Sampling Method Overview

Quarterly, data are downloaded from the Telog water level loggers and paired measurement of water level using the Telog logger and well probe are made at each sample site. Maintenance activities, including changing batteries and desiccant packs, are performed as needed. Zero accuracy checks are conducted annually, or as needed based on paired water level measurements. Paired water level measurements and field notes are recorded in the Site Comments section for the trip in the Water Database. Continuous water level data are downloaded to Telogers for Windows and saved in Excel spreadsheets and the Datalogger Database.

7.2 Safety

All field work is conducted by teams of two or more. All procedures listed in the Lummi Water Resources Division Health and Safety Plan (LWRD 2015) are followed while conducting field work outlined in this QAPP. Safety is not addressed in detail in this document; however, no water quality measurement is worth risking injury or death. To ensure that hazards are identified and addressed, field personnel must maintain a general awareness of hazards and possess the ability to respond appropriately. Field personnel must be aware of the environment, use common sense and training, and not exceed their abilities or limits. Field personnel always carry a cell phone and car charger, and inform their supervisor of planned fieldwork, including the time of departure, the time of the scheduled return, and the general location of field work.

7.3 Field Visit Sequence

The field visit sequence followed varies for the three types of field visits:

- Deployment
- Annual site visit
- Quarterly site visit

Groundwater sites are visited quarterly. During site visits, data are downloaded and QA/QC and maintenance activities are conducted. Annually, additional QA/QC activities are conducted to ensure loggers are functioning properly.

7.3.1 Initial Deployment

The following sequence is used during initial deployment of the logger at a new monitoring well or during redeployment of a logger at an existing monitoring well. For redeployment, the previously deployed logger is first removed.

1. Loggers are calibrated (as needed), programmed, and prepared for deployment (Section 7.4)
2. Zero accuracy check is conducted (Section 7.5.2)
    - Prior to departure into the field
    - Prior to deployment of logger in the field
3. Logger is deployed (Section 7.5.3)
4. Paired water level measurements collected for logger (Section 7.5.4)

7.3.2 Annual Field Visit

The following sequence is used during annual field visits:

1. In the field, data are downloaded from the deployed logger (Section 7.5.1, Telog Water Level Logger SOP)
2. Paired water level measurements are collected (Section 7.5.4)
3. Deployed logger is removed from the well and zero accuracy check is conducted (Section 7.5.2)
4. Any additional QA/QC activities are conducted as needed, depending on the results of the paired water level check and zero accuracy check
    - Corrective actions are listed in Section 8.4, Table 8.1. Decision tree attached as Appendix B
5. Maintenance activities are conducted, as needed (Section 7.5.5)
6. Downloaded data are saved (Section 7.6) and data management activities are conducted (Section 10)

7.3.3 Quarterly Field Visit

The following sequence is used during the remaining three quarterly field visits:

1. Data are downloaded (Section 7.5.1; Telog Water Level Logger SOP)
2. Paired water level measurements collected (Section 7.5.4)
3. Any additional QA/QC activities are conducted as needed, depending on the results of the paired water level check
    - Corrective actions are listed in Section 8.4, Table 8.1. Decision tree attached as Appendix B
4. Maintenance activities are conducted, as needed (Section 7.5.5)
5. Data are saved (Section 7.6) and data management activities are conducted (Section 10)

7.4 Logger Preparation

7.4.1 Calibration

Prior to deployment, Telog loggers are calibrated by the manufacturer as described in the Telog Water Level Logger SOP.

7.4.2 Logger Programming

Prior to deployment, the Telog loggers are programmed to record measurements every hour and to display units as feet of water. The Telog Water Level Logger SOP provides detailed instructions for logger setup. The specific details provided here should be entered into the appropriate fields during logger setup:

- Recorder Name is the name of the groundwater well
- Recording interval is 1 hour
- Sample rate is 15 minutes

7.4.3 Maintenance

Prior to deployment, batteries and desiccant packs are attached to the inside lid of the recorder. The vent filter is checked for proper function. Details are provided in the Telog Water Level Logger SOP.

7.4.4 Pre-Deployment Preparation

Prior to logger deployment, the following data are recorded on the field datasheet:

1. Total depth of well.
    - This information can be found in the well log for a given groundwater well site.
2. Minimum and maximum water level at a given groundwater well site for the period of record.
    - This information can be found as water level measurements collected using a well probe in the Water Database or existing continuous water level measurements saved in the Datalogger Database, Telogers for Windows, or Excel.
3. Calculated length of cable needed to place the logger below the minimum water level historically present in the well and above the depth that would cause the logger's psi rating to be exceeded during maximum water levels historically present at the site.
    - Conversion factors for converting psi to feet of water are found in the Telog R-2100e Series Recorders Hardware and Installation Manual (Telog 1995).
    - Measure and mark the needed length of Telog logger cable. Note that the pressure sensor is located at the bottom of the sensor; include the length of the sensor during measurement of cable length needed. The logger will be secured to the well casing at the marked location of the cable.

7.5 Field Visit

The following activities are conducted during quarterly field visits. Activities are conducted in the order specified in Section 7.3. Note that slightly different procedures are followed for annual and quarterly field visits. Similarly, different activities and procedures may apply for currently deployed loggers and replacement loggers. Differences in procedure are specified in the sections below.

7.5.1 Download Data

Continuous data are downloaded from the Telog logger using the field laptop, Telogers for Windows software, and Telog serial port connector. Detailed steps for downloading data are provided in the Telog Water Level Logger SOP.

Examine data to determine whether any problems with the logger are apparent, such as data gaps, zero water level measurements, or measurements that exceed the psi rating of the logger. Corrective actions are conducted to prevent data problems from recurring (Section 8.4).

7.5.2 Zero Accuracy Check

A zero accuracy check is conducted for replacement loggers prior to deployment, deployed loggers after removal from the well, annually for deployed loggers, and occasionally for deployed loggers that may or may not be replaced depending on the outcome of QA/QC activities.

A zero accuracy check is conducted by viewing the instantaneous readings from the logger in air. If functioning properly, when the logger is held in the air (*i.e.,* not under water), the instantaneous readings should show zero. See Telog Water Level Logger SOP for instructions for viewing instantaneous readings.

The acceptance criterion for the zero accuracy check is ≤0.05 feet. If the acceptance criterion is not met (*i.e.,* logger reads >0.05 feet), corrective actions are attempted.

Note that if pressure sensor is cleaned as part of corrective actions, data collected during previous deployment period should be associated with the pre-cleaning zero accuracy check result. The post-cleaning zero accuracy check result informs the continued use of the logger.

7.5.3 Field Deployment

In the field, the previously marked location on the logger cable (Section 7.4.4) is attached to a strain relief cable. The strain relief cable is secured to an eye-bolt attached to the well casing. The pressure sensor and cable are carefully lowered into the well.

The remaining cable is bundled neatly and zip tied. Prior to departure from the well site, the cable bundle is placed in the well housing followed by the recorder. The well casing cover is secured by hand tightening the nuts and bolts.

7.5.4 Paired Water Level

Paired measurements using a well probe and the Telog logger provide an accuracy check of logger function (including calibration drift throughout the deployment period), confirmation of logger placement, and allows for conversion of units for data analysis. Paired measurements are conducted during deployment (or redeployment), annual field visits, and quarterly field visits. Details for conducting paired water level measurements follow.

1. Set logger to show instantaneous reading. See Telog Water Level Logger SOP for details.
2. Record instantaneous Telog logger reading (A_1).
    - Telog logger reading is recorded prior to taking measurement with the well probe. Use of the well probe to measure water level causes a disturbance of the water surface of the well that is often registered by the Telog logger.
    - Record time and reading on the CALM Project field datasheet (Appendix A).
3. Collect water level measurements using a Waterline Envirotech 500 ft well probe or Waterline Envirotech 300 ft Olympic well probe (B_1). See Well Water Level SOP for details.
    - Record time and reading on the CALM Project field datasheet (Appendix A).
4. Repeat steps 2 and 3 two times. The second paired readings (A_2 and B_2) are collected one minute after the first paired reading. The third paired readings (A_3 and B_3) are collected two minutes after the second paired reading. All three paired measurements are collected within a three minute period. Details for collecting water level measurement using a well probe are provided in the Well Water Level SOP (LWRD 2019b).
5. For each paired reading, sum the instantaneous reading ($A_{1\text{-}3}$) and well probe reading ($B_{1\text{-}3}$) to obtain three total depth measurements ($C_{1\text{-}3}$).
6. Subtract the minimum total depth (C_{min}) from the maximum total depth (C_{max}).
    - Acceptance criterion is ≤0.05 feet.
    - If acceptance criterion is met (difference ≤0.05 feet), continue to the next step.
    - If acceptance criterion is not met (difference >0.05 feet), attempt corrective actions (Section 8.4).
7. Calculate the average total depth for the current field visit (mean[C1,C2,C3] = $X_{current}$).
    - When conducting paired water level readings after deployment of a replacement logger, ensure that the average total depth ($X_{deployment}$) matches the measured depth of logger placement determined in Section 7.4.4. If the sensor is located too deep or too shallow in the well, adjust the placement of the stress relief cable as needed.
8. For currently deployed loggers, compare the average total depth for the current field visit ($X_{current}$) to the average total depth obtained during the initial deployment ($X_{deployment}$). For replacement loggers just deployed, the following steps do not apply.
    - The acceptance criterion is ±0.05 feet.

- If the acceptance criterion is met (difference >0.05 or <-0.05 feet), record the value on field datasheet and continue with the site visit.
- If the acceptance criterion is not met (difference ≤0.05 or ≥-0.05 feet), attempt corrective actions (Section 8.4).

Figure 7.1 shows a schematic of water level measurements made during paired water level readings that illustrates the three related measurements (well probe measurement A, Telog logger measurement B, and total depth C) required for completion of QA/QC calculations and unit conversion. Figure 7.2 shows an example of calculations conducted in steps 6 and 7.

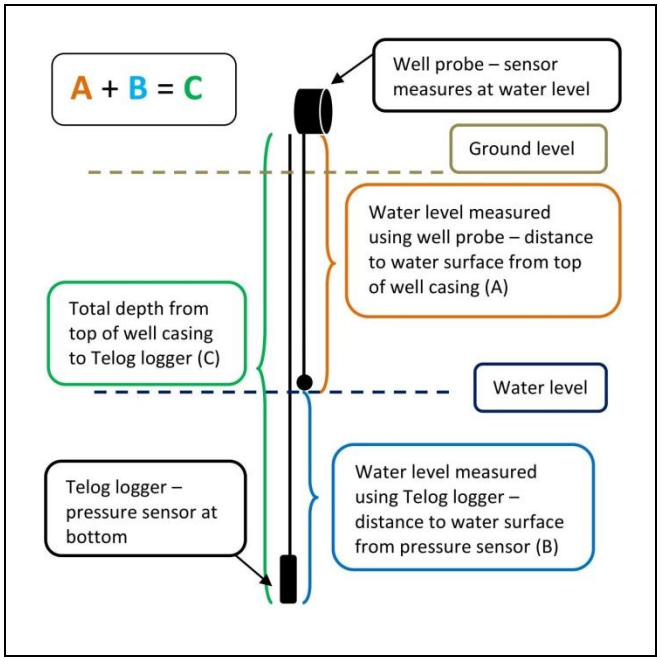

Figure 7.1 Schematic of Water Level Measurements Collected Using Well Probe and Telog Logger

Figure also illustrates calculation and conversion from one measurement to another. See also Section 10.5 for unit conversion.

Paired Water Level Reading Accuracy Check

Paired reading number	Time	Hand reading (feet) A	Logger reading (feet) B	Total Depth (feet) C
Paired reading 1	10:40	71.53	5.02	76.55
Paired reading 2	10:41	71.53	5.04	76.57
Paired reading 3	10:43	71.55	4.98	76.53

Maximum total depth (C_{max})
– Minimum total depth (C_{min})

76.57
– 76.53
0.05

Average ($X_{current}$):
(total depth 1 [C_1]+ total depth 2 [C_2] +
total depth 3 [C_3]) / 3

$\frac{(76.55 + 76.57 + 76.53)}{3}$ = 76.55 feet

Figure 7.2 Example Calculations for Paired Water Level Measurement

7.5.5 Conduct Maintenance Activities

Conduct maintenance activities (*e.g.,* inspect and change battery, desiccant pack, and vent filter), as needed, as specified in the Telog Water Level Logger SOP.

7.6 Saving Data

Upon return to the lab from the field, data are reviewed and converted to files saved on the secure LIBC server following instructions provided in the Telog Water Level Logger SOP. Determine the end date of the previous download, and use this date as the data download start date. The data download end date will be the most recent data available. Files are initially saved on the field laptop (C:\\CALM) in the appropriate well folder (YYYY Data\Well name Well ID) using the file naming convention below:

- The well number, underscore, data download start date (year, month, date format), underscore, “to”, underscore, data download end date (year, month, date format).
- WellNumber_DataDownloadStartDate(YYYYMMDD)_to_DataDownloadEndDate(YYYYMMDD), for example GW056_20120601_to_20121231

These files are saved to the appropriate well folder on the Z: Drive (Z/GIS Public/JamieM/Datalogger Data/Well Datalogger Data) when network access is available. Additional details on data management are provided in Section 10.

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8. QUALITY CONTROL AND EQUIPMENT USE

This section outlines QA/QC activities (B5), equipment testing, inspections, maintenance (B6), and calibration (B7) required as part of the CALM Project. Quality control activities are integral to equipment maintenance and provide information to the sampler and analyst about equipment condition and data reliability. Equipment problems or failure to meet QA/QC activity acceptance criteria initiates corrective actions. A summary of corrective actions are provided in Section 8.4 of this QAPP, with additional details provided in the Telog Water Level Logger SOP and the QMP. Determination and documentation of control action effectiveness is described in the QMP.

The goal of QA/QC activities for the CALM Project is to ensure that measurements have a known accuracy, precision, and traceability. Project QA/QC activities are listed in this section and in the Telog Water Level Logger and Well Water Level SOPs.

8.1 Quality Control (B5)

Quality control procedures for the CALM Project include instrument calibration, field accuracy checks, appropriate deployment techniques, and data review. Field accuracy checks include zero accuracy checks and paired water level measurements. Paired water level measurements require calculation of error on field datasheets to determine compliance with acceptance criteria (Section 7.5.4 and Appendix A).

8.1.1 Calibration (B7)

Telog loggers are calibrated according to manufacturer specifications. See Telog Water Level Logger SOP for details.

8.1.2 Zero Accuracy Checks

Zero accuracy checks are always conducted prior to initial deployment, after removal of a logger for replacement, annually for deployed loggers, and as needed during quarterly field visits to check Telog logger function. The zero accuracy check is a traditional accuracy check as the logger should read zero when in dry air. Deviation from the acceptance criterion (0.05 feet) triggers corrective actions for evaluation of logger function. Detailed instructions for conducting zero accuracy checks are provided in Section 7.5.2 and corrective actions are provided in Section 8.4.

8.1.3 Paired Water Level

Paired water level measurements using a well probe and the Telog logger provide an accuracy check of logger function, confirmation of logger placement, and allows for conversion of units for data analysis. Detailed instructions for conducting paired water level accuracy checks during deployment and quarterly field visits are provided in Section 7.5.4. Detailed instructions for measuring water level using a well probe are provided in the Well Water Level SOP.

During initial deployment, the paired readings allow for confirmation of logger placement. The average total depth during deployment ($X_{deployment}$), calculated as the average sum of well probe reading (A; feet from top of well casing to the surface of the water) and Telog logger reading (B, feet of water above the logger), should match the intended depth of placement for the Telog logger.

The paired water level readings are not a traditional accuracy check in which the reading is compared to a standard. Note that the value of the water level measurements of the two instruments will not be the same. The Telog logger measures the distance to water level above the pressure sensor while a well probe measures distance to water level below a specified measuring point at the top of the well casing. The paired readings allow for determination of sensor function in two ways: the range of multiple measurements and the comparison of the average measurement to previous measurements.

The pairing of three water level readings allows for a determination of precision. If water level is not changing during the three paired measurements, neither instrument should detect a change in water level. If measurements collected using the well probe do not detect changes in water level (range within 0.02 feet), the precision of the Telog logger alone can be calculated (*e.g.,* standard deviation, variance, or range). If water level is changing during the three paired measurements, the well probe measurement (A) and logger reading (B) should change in opposite directions by the same magnitude (Figure 7.1); for example, if the depth to water level measurement of the well probe increases by 0.04 feet, the water level measurement of the Telog logger should decrease by 0.04 feet. Because the Telog logger does not change its position in the well, the sum of the depth from the well casing to the water surface plus the depth from the pressure sensor to the water surface (total depth) should not change. If the sum (total depth) does change throughout the three paired water level readings, as calculated as the maximum total depth minus the minimum total depth ($C_{max} – C_{min}$), it may indicate error of the Telog logger or error of the well probe. For this reason, if the maximum total depth minus the minimum total depth ($C_{max} – C_{min}$) exceeds the acceptance criterion (≤0.05 feet), the Telog logger is further evaluated for proper function using corrective actions (Section 8.4).

The averaging of the three total depth measurements ($X_{current}$) and comparison to previous averages (*i.e.,* during initial deployment) provides a measure of calibration drift. As the placement depth of the Telog logger is unlikely to change during the deployment, assuming appropriate procedures for deployment are followed, the sum of the logger reading and well probe measurement (*i.e.,* depth from the top of the well casing to the Telog logger) should not change during the deployment period. If it does, as measured by subtracting the current field visit average total depth ($X_{current}$) from the initial deployment average total depth ($X_{deployment}$), either Telog logger error or well probe error must account for the difference. The steps described in Sections 7.5.4 and 8.4 (illustrated in Appendix B) provide various checks for determining the source of the error. If the difference in current field visit average total depth ($X_{current}$) and initial deployment average total depth ($X_{deployment}$) exceeds the acceptance criterion (±0.05 feet), the Telog logger is further evaluated for proper function using corrective actions (Section 8.4).

Finally, the paired water level readings allow for conversion of units for data analysis. The logger measurement of water level as the depth (in feet) of water above the logger is a relative measurement, as the depth of the logger in the well may change for each deployment period. To allow for comparability of measurements across several deployments, units are converted to depth (in feet) to the water surface from the top of the well casing (or other designated measuring point). Details on unit conversion are provided in Section 10.7. See also Figure 7.1.

8.1.4 Appropriate Deployment Techniques

Deployment techniques as described in Section 7.4.4 and 7.5.3 are required to ensure high quality data. Error is introduced if deployment techniques are not appropriately followed, and can cause the rejection of data due to poor data quality.

8.1.5 Data Review

Review of the data for gaps, errors, and drift is required prior to the use of data for data analysis and reporting (Section 10.4). Data are corrected (Section 10.5), as needed, and qualifiers assigned to data (Section 10.6) for tracking of data quality. Finally, data units are converted to standard units (Section 10.7) to allow for comparability among deployments.

8.2 Equipment Maintenance (B6)

Telog logger maintenance activities are the responsibility of the Water Resources Specialist II, assisted by the Water Resources Technician II. Telog logger maintenance, including battery and desiccant replacement, occurs during quarterly field visits following instructions provided in the Telog Water Level Logger SOP.

The Waterline Envirotech 500 ft well probes require maintenance and cleaning by the manufacturer as specified by the Well Water Level SOP.

An equipment module is included as part of the Water Database. The equipment module sends the Water Resources Specialist II and Water Resources Technician II email reminders of needed maintenance activities and deadlines according to manufacturer specifications. Details on the equipment module are provided in the QMP and Water Database User Guide (LWRD 2018a).

8.3 Acceptance Criteria and Control Limits

Cumulative error allowed for the CALM Project is 0.15 feet, and is made up of the following acceptance criteria:

- The acceptance criterion for variation (maximum minus minimum value) of paired water level measurements is ≤0.05 feet.
- The acceptance criterion of calibration drift calculated during quarterly paired water level measurements (difference between current field visit average summed paired measurement and initial deployment average summed paired measurement) is ±0.05 feet.
- The acceptance criterion for zero accuracy checks is ≤0.05 feet.

Corrective actions are taken or the logger is returned to the manufacturer for recalibration if acceptance criteria are exceeded. Details on determination and documentation of the effectiveness of control activities are included in the QMP.

8.4 Corrective Actions

The goals of corrective actions are to solve the problems at hand and to eliminate or reduce the occurrence of the problems in the future. Problems detected during logger use, data download, QA/QC activities, or data management result in actions to correct the problem (see also Telog Water Level Logger SOP and Well Water Level SOP). If the problem cannot be resolved on-site, the Telog logger is removed from the well and returned to the manufacturer for evaluation and recalibration. Equipment problems, corrective actions, and outcomes are recorded in the Water Database as described in the QMP and Water Database User Guide.

Suggested corrective actions for a variety of problems are listed in Table 8.1.

Table 8.1 Corrective Actions

Problem	Corrective Action
Cannot download data	Attempt troubleshooting techniques (Telog Water Level Logger SOP).
Zero accuracy check fails to meet acceptance criterion (≤0.05 feet)	Check and correct, as needed, the scaling in the deployment settings (Telog Water Level Logger SOP).
	Clean pressure sensor gently (Telog Water Level Logger SOP). Note that when the pressure sensor is cleaned, data collected during previous deployment period should be associated with the pre-cleaning zero accuracy check result. The post-cleaning zero accuracy check result informs field personnel of the appropriateness of re-deploying the current logger for another deployment period.
	Repeat zero accuracy check. If continues to fail to meet acceptance criteria, return to manufacturer for evaluation and recalibration.
Maximum minus minimum total depth ($C_{max} – C_{min}$) fails to meet acceptance criterion (≤0.05 feet)	Ensure best practices are used for collecting measurements using the well probe (Well Water Level SOP). Note that operator error or well probe problems can be disguised as logger problems during this step.
	Ensure best practices are used for recording instantaneous Telog logger readings. Ensure well probe is not disturbing the water surface before or during logger readings.
	If three well probe readings remained the same (within 0.02 feet), but Telog logger readings varied, calculate precision of the Telog logger.
	Clean pressure sensor gently (Telog Water Level Logger SOP). Note that when the pressure sensor is cleaned, data collected during previous deployment period should be associated with the pre-cleaning paired water level result. The post-cleaning paired water level result informs field personnel of the appropriateness of re-deploying the current logger for another deployment period.

Table 8.1 Corrective Actions

Problem	Corrective Action
	Repeat paired water level measurements using best practices.
	Conduct zero accuracy check. Calculate accuracy and precision of the instrument and compare to other measurements of precision, if available.
	Remove logger from well and return to manufacturer for evaluation and recalibration.
Difference in quarterly average total depth ($X_{current}$) and initial deployment total depth ($X_{deployment}$) fails to meet acceptance criterion (±0.05 feet)	Check and correct scaling in deployment settings (Telog Water Level Logger SOP).
	Ensure that the logger cable has not been tangled, pinched, caught on something inside the well, or slipped through the strain relief cable since the last deployment.
	Ensure that the well probe cable or steel tape has not stretched or been nicked. Use best practices when collecting well water level measurement with well probe (Well Water Level SOP) and ensure that the cable or tape drops unimpeded into the well.
	Repeat paired water level accuracy check. If repeated paired accuracy check fails to meet acceptance criteria, use professional judgment to determine whether failure to meet accuracy check is due to user error, instability in the water level, or equipment malfunction. If equipment malfunction is suspected, remove Telog logger from the well and return to manufacturer for evaluation and recalibration.
Failed accuracy checks when loggers will be replaced	Attempt corrective actions as described above to ensure that accuracy checks were appropriately conducted. Note that if pressure sensor is cleaned as part of corrective actions, data collected during previous deployment period should be associated with the pre-cleaning zero accuracy check result.
Logger readings exceed maximum based on psi rating	Adjust pressure sensor placement in the well to ensure that water level above sensor does not exceed maximum psi rating.
	If range of water levels in wells is too large to maintain logger both under water and within the psi rating at all times, select logger with higher psi rating.
Logger dewatered	Adjust pressure sensor placement in the well to ensure that water is present above the sensor at all times.
No data downloaded or data gaps are present	Replace battery and desiccant pack.
	Ensure data logging frequency is set at 1 hour.

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9. SUPPLIES AND CONSUMABLES (B8)

The Water Resources Specialist II is responsible for ensuring that critical supplies and consumables are ready for use. Equipment is kept in good working order and supplies are regularly inventoried and stocked by the Water Resources Specialist II and Water Resources Technician II to ensure availability. Equipment required for implementation of the CALM Project are stored in the LNR office, lab, and storage locker. Details on supply ordering, stocking levels, and management are provided in the QMP. Details on equipment and supply inspection are listed in the equipment SOPs.

Supplies and consumables used in the CALM Project include:

Data Recording:

- Field laptop
    - Telog serial port connector
    - Telogers for Windows software
    - CALM Project field datasheets (Appendix A)
- iPad
- Field clipboard with hard copies of CALM Project field datasheets (Appendix A) and waterproof pen and/or pencil

General:

- Distilled water in labeled squeeze bottles
- Bleach water in labeled squeeze bottle
- Tool chest, including well keys, two adjustable wrenches, hammer, stopwatch, flashlight, 9 volt batteries

Aquifer Level Monitoring Equipment:

- Telog Water Level Loggers
    - Calibrated and meeting accuracy checks as specified in this QAPP and the Telog Water Level Logger SOP
- Waterline Envirotech 500 ft well probe
- Battery packs and digital voltage multimeter
- Desiccant packs
- Velcro
- Scissors
- Hardware including nuts and bolts of various sizes
- Strain relief cables

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10. DATA MANAGEMENT (B10)

The Water Resources Specialist II is responsible for management of CALM Project data with support and supervision provided by the Water Resources Manager and the Database Manager. Data collected as part of the CALM Project are stored in two databases. Site visit information and QA/QC data are saved in the Water Database. Verified and validated continuous aquifer level data are saved in the Datalogger Database.

10.1 Data Management Summary

As previously described, data are downloaded from the Telog loggers during quarterly field visits as specified in the Telog Water Level Logger SOP. Continuous aquifer level data are saved as .CSV files on the field laptop during field visits and transferred to secure LIBC servers, which are backed up nightly, upon return to the office (Z:\GISpublic\JamieM\Datalogger Data\Well Datalogger Data). Raw data files are saved in the appropriate well folder using the following format: WellNumber_DataDownloadStartDate(YYYYMMDD)_to_DataDownloadEndDate (YYYYMMDD). Each data file contains aquifer level data collected between quarterly field visits. Each data file has associated QA/QC data collected during the quarterly field visit during which the data were downloaded saved as Excel datasheets and/or in the Water Database.

During data management, the .CSV file is resaved as an .XLS file. Quality assurance and quality control data are reviewed to determine the usability of the data (Section 10.3). Data are screened and data errors are identified and corrected (Section 10.4). Data are corrected, if appropriate (Section 10.5). Throughout the data management process, data qualifiers are associated with the data (Section 10.6).

Continuous aquifer level data units, collected as feet of water above the logger, are converted to depth (in feet) to water surface from a defined measuring point for that well (top of the well casing or access tube) (Section 10.7).

Prior to upload of all verified and validated data, a new .CSV or .XLS file is created for the purposes of the upload. Data are generally only uploaded to the Datalogger Database if method and QA/QC acceptance criteria are met, however data that have been corrected or otherwise modified are also uploaded to the Datalogger Database with appropriate data qualifiers labeling modified data as such. Any rejected data are not uploaded to the Datalogger Database; these data are deleted from the upload file, but are retained in the raw data file for documentation. Data are reviewed for appropriate format, presence of QA qualifier, and uploaded to the Datalogger Database (Section 10.8).

Continuous aquifer level monitoring data are not currently submitted to EPA as WQX does not support the transfer of continuous data as of the writing of this QAPP. If upload of continuous data becomes available, CALM Project data will be transmitted to EPA via WQX upon approval by the Water Resources Manager and the LNR Deputy Director.

10.2 Sample Tracking and Data Recording

Details on data entry and use of the Water Database are provided in the QMP and Water Database User Guide. A summary of sample tracking and data recording follows.

Every groundwater sample site has a unique numerical identifier. The site identifier is used to track well water level measurements collected at the site. Typically, QA/QC information and site observations for each site visit are entered directly into the Water Database in real time via an iPad. When datasheets are used, the site identifier is recorded (a copy of the CALM Project datasheet is included in Appendix A).

Continuous water level data downloaded from Telog loggers are reviewed, verified, and validated prior to upload to the Datalogger Database. Site number, logger serial number, and other metadata are also saved in the Datalogger Database.

10.3 QA/QC Data

Continuous data are checked against QA/QC data collected during initial deployment and quarterly field visits. When QA/QC acceptance criteria are not met, professional judgment is used to determine the course of action. Data can be (a) excluded from analysis and reporting (Rejected) or (b) corrected. See Section 10.5 for details on data correction.

10.4 Data Screening and Identification of Data Errors

Prior to inclusion in the Datalogger Database, data are screened for errors based on time and minimum and maximum detection limits.

Pre- and post-deployment observations are removed. Using field notes or datasheets listing the exact time loggers were deployed, recovered, or subjected to a zero accuracy check, aquifer level measurements logged prior to deployment, prior to and after zero accuracy checks, and after recovery are removed from the dataset to eliminate incorrect measurements. A one-hour buffer period is also applied; observations within the first hour after deployment are removed to ensure that the logger aquifer level readings have stabilized and to eliminate any pre-deployment measurements that may have been collected.

Values <0.15 feet water above the logger are excluded, as the logger may have been dewatered. The deployment depth of the logger is adjusted accordingly to ensure that the logger remains under water throughout the deployment period.

Values exceeding the psi rating of the logger are also excluded as these values exceed the detection limits of the instrument. The maximum depth is calculated from the psi rating of the logger, the mAmp range of the logger, and conversion unit provided in the Telog Manual (Telog 1994; page 25). The deployment depth of the logger is adjusted accordingly to ensure that the logger remains below the maximum depth throughout the deployment period.

10.5 Data Correction

Data are corrected based on results of quarterly field accuracy checks, as needed. Data that met all QA/QC acceptance criteria are not corrected. Data that failed QA/QC acceptance criteria can still be used for data analysis and reporting if they are adjusted to remove a sufficient amount of error to meet the overall error acceptance criterion for the CALM Project (0.15 feet). Note that data corrections are made to all values recorded during the deployment period (from the last field visit or initial deployment to the current field visit during which data were downloaded).

If results of zero accuracy checks conducted throughout the deployment remained steady (within 0.02 feet), the data can be adjusted by the average zero accuracy check value. To determine whether the overall error acceptance criterion for the Project was met after data adjustment, sum the following:

- The maximum minus minimum total depth ($C_{max} - C_{min}$)
- Absolute value of the difference between the field visit average total depth and the previous quarter's average total depth ($X_{current} - X_{deployment}$)

If the sum of the two meets the overall Project error acceptance criterion (0.15 feet), a data qualifier is assigned to all data in the file and data can be uploaded to the Datalogger Database.

If the sum of the two does not meet the overall Project error acceptance criterion, data can be further adjusted by a correction factor based on the difference between the field visit average total depth ($X_{current}$) and the previous quarter's average total depth ($X_{previous}$) or the initial deployment ($X_{deployment}$), if deployment occurred during the previous quarter's site visit. The correction factor is determined by examining average total depth results for all field visits at the site since the initial deployment. In general, data can be corrected by applying a constant correction factor or by linearly interpolating a correction factor. A constant correction factor is applied if calibration drift occurred suddenly or due to a slip of the logger cable in the strain relief housing. A constant correction factor is applied to the period of time the additional error was present (*e.g.,* start of the sudden additional sensor error through to the end of the deployment quarter). A linearly interpolated correction factor is used if a gradual change in calibration drift has occurred. The correction factor is linearly interpolated from deployment start (*e.g.,* no or minimum correction) to deployment end (*e.g.,* maximum correction) and the appropriate correction factor is applied to each data point based on time. The correction factor can be either a percentage or integer. A percentage correction factor is recommended as it reduces the occurrence of negative values (Wagner et al. 2006).

Remaining error is calculated as:

- The maximum minus minimum total depth ($C_{max} - C_{min}$)
- If applicable: Absolute value of the difference between the previous quarter's average total depth[2] and the initial deployment average total depth ($X_{previous} - X_{deployment}$)

[2] Note that if sensor cleaning occurred as a corrective action during the previous quarter's field visit, the post-cleaning value will be used for $X_{previous}$.

If the remaining error meets the overall Project error acceptance criterion, a data qualifier is assigned to all data in the file and data can be uploaded to the Datalogger Database. If the remaining error does not meet the overall Project error acceptance criterion, the data are rejected and are not uploaded to the Datalogger Database.

Professional judgment is used during data correction to ensure that data adjustment is appropriate and that data will meet the overall Project error acceptance criterion. Notes about the data adjustments are recorded in the Excel spreadsheet and a data qualifier is associated with the data in the Datalogger Database.

10.6 Data Qualifiers

Data qualifiers provide information about the quality of the data. These qualifiers, once manually assigned, will be accessible within the Datalogger Database and Excel spreadsheets. The following data qualifiers can be assigned to the data:

- F: Final
    - Data met all QA/QC acceptance criteria during initial deployment and quarterly field visit during which data were downloaded. Data are verified and validated as acceptable for use in data analysis and reporting. These data are uploaded to the Datalogger Database.
- C: Corrected
    - Data did not meet all QA/QC acceptance criteria during quarterly field visit during which data were downloaded. Data have been adjusted to reduce error to meet the overall Project error acceptance criterion. Data are verified and validated as acceptable for use in data analysis and reporting. These data are uploaded to the Datalogger Database.
- R: Rejected
    - Data did not meet all QA/QC acceptance criteria during initial deployment and/or quarterly field visit during which data were downloaded. Data are of poor quality and not appropriate for use in data analysis or reporting. These data are not uploaded to the Datalogger Database.

Data qualified as Acceptable and Corrected are considered validated and acceptable for use in data analysis and reporting. Data qualified as Rejected are not considered validated; therefore these data are not acceptable for use in data analysis or reporting.

10.7 Unit Conversion

Continuous aquifer level data, logged as feet of water above the logger, are converted to depth (in feet) to water surface from a defined measuring point for that well (top of the well casing or access tube). Data are converted using the data collected during paired water level measurements during logger deployment and quarterly accuracy checks (Figure 7.1). Generally, the average of the quarterly average total depth and the deployment average total depth is calculated and used as the total depth from measuring point to logger. When data have been

adjusted due to calibration drift (difference between quarterly average total depth and the deployment average total depth), the deployment average total depth is used as the total depth from measuring point to logger. The logger reading is then subtracted from the total depth value to determine depth to water level (in feet) from the designated measuring point.

10.8 Datalogger Database

The Datalogger Database is an Access-based database for storage and organization of continuous data. Data can be uploaded to the Datalogger Database in .CSV or .XLS format. Note that the parameter for upload is 'Water Level – Relative' as the values are not absolute or compared to a recognized vertical datum, such as Mean Sea Level or NAVD88. Details on uploading data into the Datalogger Database are provided in the Datalogger Data Viewer User Guide (LWRD 2013).

10.9 Data Analysis

Data are analyzed for seasonal, annual, and multi-year trends. Analysis is restricted to validated data for each well individually, due to the relative measurement parameter. If well-to-well comparisons are to be conducted, all data are converted to absolute measurements (adjusted to Mean Sea Level or other recognized vertical datum). Additional data analyses may include calculation of precision and accuracy/bias using QA/QC data. Summary data and trends are reported in the Water Quality Assessment Report, submitted to the EPA every other year.

10.10 Non-Direct Measurements (B9)

Non-direct measurements are not currently routinely used as part of the CALM Project. The Lummi Water District maintains water level loggers in select groundwater supply wells, but these data are not currently available to LWRD and have unknown data quality. Details on documentation of non-direct measurement and external data, including data quality, are included in the QMP in the event that non-Project data are acquired for use to supplement data collected as part of the CALM Project.

10.11 Data Review and Usability (D1, D2, D3)

Data quality is ensured by data review, verification, and validation. Data verification is the process of evaluating the correctness and compliance of a data set with the requirements outlined in relevant QAPPs and SOPs. Methods of data verification include:

- Equipment calibration, logger deployment, and QA/QC checks following methods outlined in this QAPP and the Telog Water Level Logger SOP
- Data entry QA/QC review
- Data screening, identification of data errors, and data adjustment
- Assignment of data qualifiers based on QA/QC results and data adjustments

Data validation is a sample-specific process that evaluates the data to determine the analytical quality of a specific data set. Methods of data validation include:

- Assignment of data qualifiers for validated acceptable data (F or C)
- Assignment of data qualifier for rejected, not validated, not acceptable data (R)
- Upload of only validated data with appropriate associated data qualifier

Data qualifiers serve as both indicators of whether data have been modified (*i.e.,* corrected or adjusted based on QA/QC data) and as the final grade (or validation status) of the data. For this reason they are included both as verification and validation methods. Upload of only validated data (*i.e.,* data qualifier of A or C) to the Datalogger Database ensures that only validated data that are acceptable for use in data analysis and reporting are used for such activities.

The CALM Project is ongoing and not designed to prove or disprove specific hypotheses. Uncertainties of the data are documented in this QAPP (*i.e.,* the overall project error acceptance criterion) and in data qualifiers associated with data in Excel spreadsheets and the Datalogger Database. Rejected data should not be used for data analysis, reporting, or decision making. Final and Corrected data have been verified and validated, and determined to be of sufficient quality to use for data analysis, reporting, and decision making. The Water Resources Specialist II is responsible for quantifying or qualifying data quality to data users.

11. OVERSIGHT AND REPORTING

11.1 Assessments and Response Actions (C1)

Section 1 of this QAPP and the QMP list the key personnel and their responsibilities. In summary, the person conducting the monitoring (primarily the Water Resources Specialist II and Water Resources Technician II) is responsible for performing all data collection activities, QA/QC activities, and data management. The Water Resources Specialist II is responsible for screening, correcting, and uploading data to the Datalogger Database, with support from the Water Resources Technician II and Database Manager. The Water Resources Manager ensures that QA/QC objectives and reporting requirements are achieved.

Operator error and equipment problems detected during quarterly QA/QC activities will initiate corrective actions (Section 8.4). Quality control activities also inform potential data correction factors that may be applied (Section 10.5), as appropriate, and data qualifier assignment (Section 10.6). Project action limits and assessments are described in the QMP.

11.2 Reports to Management (C2)

The Water Resources Specialist II is responsible for evaluating aquifer level and QA/QC data and reporting to the Water Resources Manager regularly and as needed if problems are detected. When problems are detected and not resolved through standard practices or are of a more complex nature than the staff conducting water quality sampling typically address, the Water Resources Specialist II, Water Resources Technician II, and the Water Resources Manager will jointly develop an action plan to remedy the problem with clear roles, responsibilities, and timelines. The Water Resources Manager is immediately alerted if significantly decreasing aquifer levels are detected. Assessments are described in the QMP.

The Water Resources Specialist II prepares a Water Quality Assessment Report that summarizes the continuous aquifer level data for the two-year reporting period, compares the results with the data for the period of record, and documents risk of groundwater mining. These reports are reviewed and approved by the Water Resources Manager and the LNR Deputy Director, and approved reports are transmitted to the EPA every-other year by March 31st of the year following the two-year reporting period. The Water Resources Manager submits bi-annual (twice per year) progress reports to the EPA Project Officer that describe program status, problems, remedies, and schedules.

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12. ACRONYMS AND ABBREVIATIONS

CALM	Continuous Aquifer Level Monitoring [Project]
CWRMP	Comprehensive Water Resources Management Program
EPA	Environmental Protection Agency
LIBC	Lummi Indian Business Council
LNR	Lummi Natural Resources Department
LWRD	Lummi Water Resources Division
psi	Pounds per Square Inch
QAPP	Quality Assurance Project Plan
QMP	Quality Management Plan
QA/QC	Quality Assurance/Quality Control
SOP	Standard Operating Procedure
WQM	Lummi Nation Water Quality Monitoring [Program]
WQX	Water Quality Exchange

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13. REFERENCES

13.1 Literature Cited

Cline, D.R. 1974. A Ground Water Investigation of the Lummi Indian Reservation Area, Washington. Tacoma, U.S. Geological Survey, Open-File Report.

Environmental Protection Agency (EPA). 2001. EPA Requirements for Quality Assurance Project Plans. EPA QA/R-5. EPA/240/B-01/003. Washington DC. March.

EPA. 2002. Guidance for Quality Assurance Project Plans. EPA QA/G-6. Washington DC. December.

EPA. 2006a. Memorandum from Reggie Cheatham, Director, Quality Staff, to Assistant and Regional Administrators re: Reissue of Agency-wide Quality System Documents (QA/R2, QA/R-5, QA/G-7, and QA/G-10). Washington DC. May 31.

EPA. 2006b. Final Guidance of Awards of Grants to Indian Tribes under Section 106 of the Clean Water Act. Office of Water. Office of Wastewater Management. EPA 832-R-06-003. Washington DC.

Lummi Water Resources Division (LWRD). 1997. Lummi Nation Wellhead Protection Program – Phase I. Prepared for the Lummi Indian Business Council. Lummi Reservation, Washington. November.

LWRD. 2013. Datalogger Data Viewer User Guide Version 1.0. Prepared for the Lummi Indian Business Council. Lummi Reservation, Washington. April.

LWRD. 2015. Lummi Nation Water Resources Division Health and Safety Plan. Prepared for the Lummi Indian Business Council. Lummi Reservation, Washington. April.

LWRD. 2018a. Water Database User Guide. Prepared for the Lummi Indian Business Council. Lummi Reservation, Washington. October.

LWRD. 2019a. Lummi Nation Water Quality Monitoring Program: Field Reference Manual. Internal Document. April.

Telog Instruments, Inc. 1995. Telog R-2100e Series Recorders Hardware and Installation Manual. Victor, New York. August.

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and B.A. Smith. 2006. Guidelines and Standard Procedures for Continuous Water-Quality Monitoring – Station Operation, Record Computation, and Data Reporting: U.S. Geological Survey Techniques and Methods 1-D3. Available http://pubs.water.usgs.gov/tm1d3.

13.2 QMP, QAPPs, SOPs

LWRD. 2018b. Standard Operating Procedures #012: Telog Water Level Logger. Version 1.0. Prepared for the Lummi Indian Business Council. Lummi Reservation, Washington. October.

LWRD. 2019b. Standard Operating Procedures #011: Well Water Level. Version 1.1. Prepared for the Lummi Indian Business Council. Lummi Reservation, Washington. December.

LWRD. 2021a. Quality Assurance Project Plan: Lummi Nation Ambient Ground Water Quality and Quantity Monitoring Project. Version 1.2. Prepared for the Lummi Indian Business Council. Lummi Reservation, Washington. July.

LWRD. 2021b. Quality Assurance Project Plan: Lummi Peninsula Ground Water Settlement Agreement Compliance Project. Version 1.1a. Prepared for the Lummi Indian Business Council. Lummi Reservation, Washington. July.

LWRD. 2021c. Quality Management Plan for the Lummi Nation Water Quality Monitoring Program. Version 1.2. Prepared for the Lummi Indian Business Council. Lummi Reservation, Washington. July.

APPENDIX A. CALM PROJECT FIELD DATASHEET

Figure 13.1 illustrates page 1 of the CALM Project field datasheet. The orange fields signify data to be filled out prior to the field visit. Blue field signify fields that will be automatically calculated in Excel. Figure 13.2 illustrates page 2 of the CALM Project field datasheet. This secondary datasheet is used when additional accuracy checks are conducted after corrective activities.

Continuous Aquifer Level Monitoring Project - Field Datasheet

Date		**Pre-Deployment Information**	
Site ID		Total depth of well	
Telog Logger S/N		Historical min water level	
Output (mAmp)		Historical max water level	
Pressure Rating (psi)		Maximum depth of logger	

Zero Accuracy Check - Required for Deployment, Optional for Quarterly Checks (see QAPP)

Reading		Meets Acceptance Criterion (0.05 feet)? ☐ Yes ☐ No (see QAPP)

Paired Water Level Reading Accuracy Check

Time	Logger reading (feet)	Hand reading (feet)	Sum of paired readings	Maximum-minimum summed paired readings
			0	0
			0	Meets Acceptance Criterion (0.05 feet)?
			0	
	Summed Paired Average		0	☐ Yes ☐ No (see QAPP)
Summed Paired Average from last deployment				
Deployment-Current Summed Paired Average			0	
Meets Acceptance Criterion (0.05 feet)? ☐ Yes ☐ No (see QAPP)				

Site Visit Notes

Maintenance

Battery change	☐ Yes
Desiccant change	☐ Yes
Vent change	☐ Yes

Additional accuracy checks/notes

Removed for manufacturer recalibration?

☐ Yes ☐ No (see QAPP)

Figure 13.1 CALM Project Field Datasheet (page 1)

Continuous Aquifer Level Monitoring Project - Field Datasheet (Additional Data)

Date		**Use this datasheet for accuracy checks conducted after corrective actions.**			**Site Visit Notes**
Site ID					
Telog Logger S/N					
Output (mAmp)					
Pressure Rating (psi)					
Zero Accuracy Check - Required for Deployment, Optional for Quarterly Checks (see QAPP)					
Reading	Meets Acceptance Criterion (0.05 feet)? ☐ Yes ☐ No (see QAPP)				
Paired Water Level Reading Accuracy Check					
Time	Logger reading (feet)	Hand reading (feet)	Sum of paired readings	Maximum-minimum summed paired readings	
			0	0	
			0	Meets Acceptance Criterion (0.05 feet)?	
			0		
	Summed Paired Average		0	☐ Yes ☐ No (see QAPP)	
Summed Paired Average from last deployment			0		
Deployment-Current Summed Paired Average			0		
Meets Acceptance Criterion (0.05 feet)? ☐ Yes ☐ No (see QAPP)					
Corrective actions conducted					
					Removed for manufacturer recalibration?
					☐ Yes ☐ No (see QAPP)

Figure 13.2 CALM Project Field Datasheet (page 2)

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APPENDIX B. PAIRED WATER LEVEL DECISION TREE

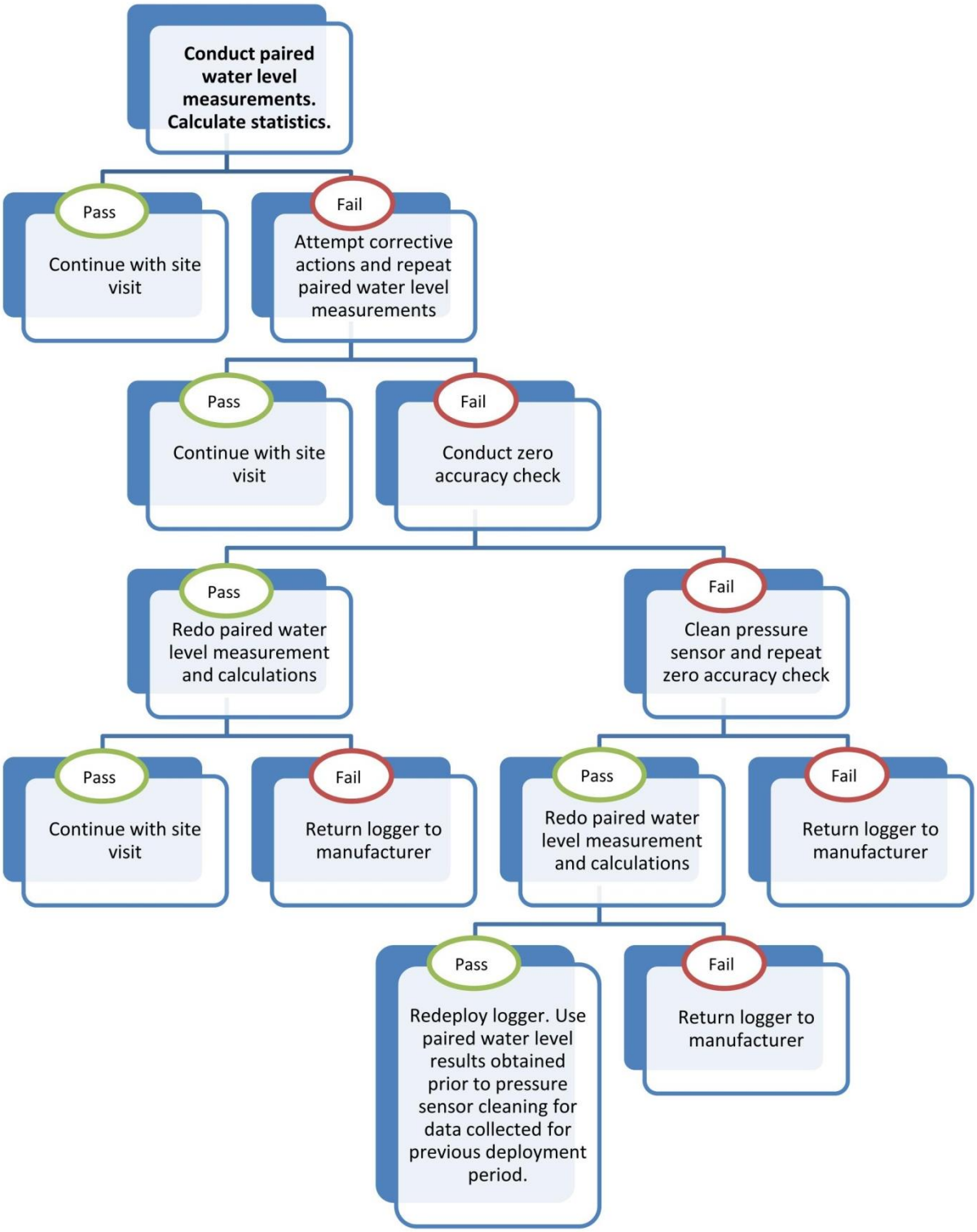

Figure 13.3 Paired Water Level Decision Tree