PROVINCIAL GROUNDWATER OBSERVATION WELL NETWORK:

OPERATIONS MANUAL AND STANDARD OPERATING PROCEDURES

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JANUARY 2025

VERSION 2.0

BRITISH COLUMBIA | Ministry of Environment and Parks

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LIST OF ACRONYMS

(Acronym)	(Description)
AWSS	Aquifer and Watershed Science Section
BC	British Columbia
CHASM	Climate, Hydrology and Snow Monitoring Section
CDWG	Canadian Drinking Water Guidelines
CoC	Chain of Custody
CSA	Corporate Supply Agreement
CSNR	Corporate Services for the Natural Resource Ministries
DCS	Data Collection System
DL	Detection Limit
DO	Dissolved Oxygen
EC	Electrical Conductivity
EDDN	Emergency Data Distribution Network
EMS	Environmental Monitoring System
ENV	Ministry of Environment and Parks
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
GWPR	Groundwater Protection Regulation
HDPE	High Density Polyethylene
kPa	Kilopascal
LDPE	Low Density Polyethylene
LEO	Low Earth Orbit
m asl	Meters Above Sea Level
mbar	Millibar
m bgs	Metres Below Ground Surface
m btoc	Metres Below Top of Casing
MDL	Method Detection Limit
MoTT	Ministry of Transportation and Transit
NESDIS	National Environmental Satellite, Data and Information Service
NESID	National Environmental Satellite ID
nm	Nanometre
ORP	Oxidation-Reduction Potential
OWOC	Observation Well Operations Committee
PDT	Pacific Daylight Time
PE	Polyethylene
PGOWN	Provincial Groundwater Observation Well Network
PSI	Pounds per square inch

(Acronym)	(Description)
PST	Pacific Standard Time
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl Chloride
QA	Quality Assurance
QA/QC	Quality assurance and quality control
QC	Quality Control
RPD	Relative Percent Difference
RoW	Right of Way
SDR	Standard Dimension Ratios
SGWL	Static Groundwater Level
SOP	Standard Operating Procedure(s)
SWL	Static Water Level
TOC	Top of Casing
USGS	United States Geological Survey
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
WLRS	Ministry of Water, Lands and Resource Stewardship
WSA	Water Sustainability Act
WTN	Well Tag Number
WIDP	Well Identification Plate
VOC	Volatile Organic Compounds

AMENDMENT RECORD

This document has been issued and amended as follows:

Issue	Description	Date
1.0	First version of *Provincial Groundwater Observation Well Network: Operations Manual and Standard Operating Procedures*	2024-03-25
2.0	Revisions: ▪ Health and Safety section (2.1) to refer to new *PGOWN Field Safety Orientation Guide (2024)*. ▪ Revision of ‘Barometric Compensation’ under Section 4.2 to mandate requirement to compensate data within Aquarius and to detail the associated procedure. ▪ Addition of Aquarius Field Visit guidance and minimum requirements under Section 4.2. ▪ Addition of grading guidance to ‘Data Grading’ section (4.2.5) when applying both an offset and drift correction in Aquarius. ▪ Removal of ‘Appendix A1: Health & Safety’. ▪ Addition of ‘Groundwater Level Data Review & Approval SOP’ to ‘Appendix 7: Data Grading’ (since renamed). ▪ Addition of ‘Removing a Well from PGOWN Systems SOP’ to ‘Appendix 9: Network Expansion & Contraction’. ▪ Reformatting broken cross-reference hyperlinks.	2024-11-14

1.0 INTRODUCTION

The Provincial Groundwater Observation Well Network (PGOWN) is a network of observation wells throughout British Columbia (BC). The primary objective of the PGOWN network is to monitor groundwater levels and support the evaluation of BC's groundwater resources.

The PGOWN data are actively used by both Provincial staff and external stakeholders (e.g., First Nations, industry, consultants and individuals) for multiple purposes. The data can be used to assess potential groundwater impacts from various sources including climate change, industrial activities, aquifer depletion or recovery, and changes in land use. These data also support allocation and licensing of groundwater under the *Water Sustainability Act* (WSA). As such, it is important that the PGOWN produce high-grade and timely groundwater level data.

The *PGOWN Operations Manual* (Manual) summarizes standard industry and best practices for representative, high-grade data collection. It is intended to provide useful technical context, as well as detailed standard operating procedures (SOPs) for Field Technicians who implement PGOWN monitoring and complete semi-annual PGOWN site visits.

The Manual is structured such that the main body (upfront sections) provides an overview of key information (e.g., concepts, technical background, potential problems or issues, etc.) and general procedures required for Field Technicians to complete successful site visits. Detailed instructions or prescriptive SOPs, and templates, are subsequently provided in attached appendices.

1.1 HISTORY OF THE NETWORK

The PGOWN was started in 1961 in anticipation of the regulation of non-domestic groundwater use after changes to the *Water Act* were extended to include groundwater. As is the case today, the PGOWN was focused on the monitoring of long-term groundwater level fluctuations.

The network started with the drilling of observation wells in the Lower Mainland, but this was later expanded to other parts of the Province, including adopting unused wells held on private lands. Some observation wells were equipped with Stevens Chart Recorders (**Figure 1-1**) while others had monthly manual groundwater level measurements collected as the only source of data. Over time, the network slowly expanded, and the monitoring equipment became more sophisticated, moving from manual measurements and chart recorders to vented pressure transducers, dataloggers, and telemetry.

Figure 1-1 Image of a Stevens Chart Recorder at one of the first Provincial Observation Wells.

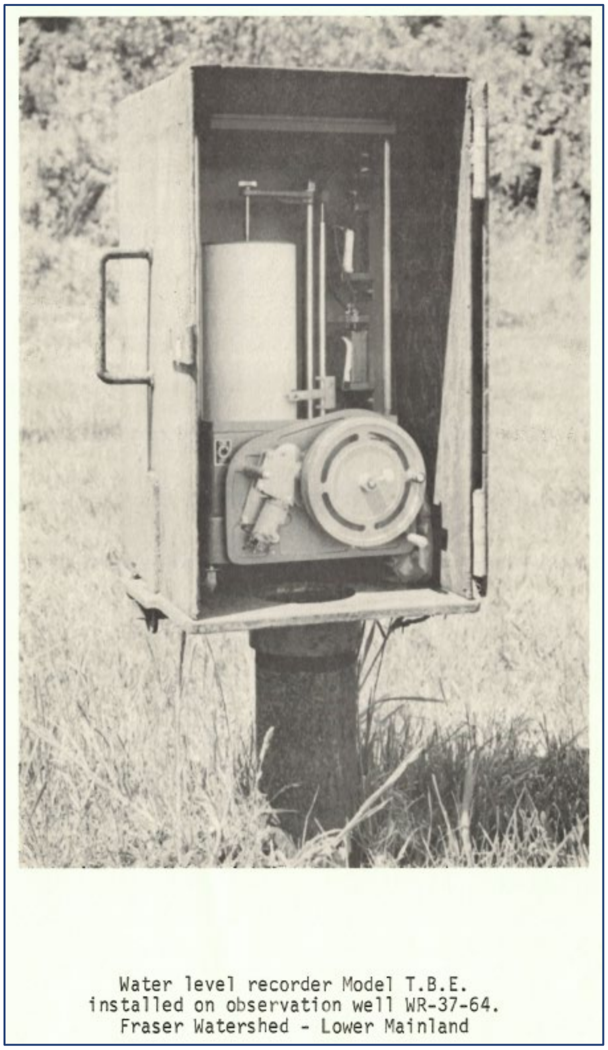


Photo source: DLFWR 1968.

With the implementation of the WSA in 2016, the PGOWN gained renewed importance as resource managers require data in order to make informed decisions with regards to groundwater authorizations. At that time, dedicated Field Technicians (Groundwater Technicians) were hired in some regions of the Province, while in other regions, the PGOWN was operated by staff assigned on a part-time / as needed basis. At the same time, additional staff were also hired by the Ministry of Environment and Parks (ENV) to help with the operation of the PGOWN across the Province. Since then, the PGOWN has grown due to the increased staffing capacity. The data collected from the expanded PGOWN is used to inform various resource management decisions, First Nations, academics, consultants, farmers, and other interested stakeholders.

1.2 NETWORK OBJECTIVES

The PGOWN monitors groundwater levels and chemistry of selected aquifers across the Province. The program's vision, mission and objectives are outlined on ENV's PGOWN website and reiterated below.

Vision

The vision of the network is to collect, interpret and report high quality, reliable groundwater level and baseline chemistry data in a timely fashion.

Mission

The network monitors water conditions of key aquifers across the province to support the effective management, protection and sustainable use of our groundwater resources and associated ecosystems.

Monitoring Objectives

The PGOWN objectives are to:

1. Understand local and regional hydrogeological processes, such as:
    a. Fundamental aquifer and basin characteristics, including water table and potentiometric levels, hydraulic properties and baseline groundwater chemistry;
    b. Groundwater and surface water interactions, including environmental flow needs and drought or flood conditions; and
    c. Aquifer recharge and discharge mechanisms, rates and timing in lowland and upland areas.
2. Support the sustainable use of groundwater resources and minimize conflicts between multiple groundwater users by providing data to assess:
    a. Assess short and long-term effects of human activity on groundwater and surface water levels;
    b. Inform water authorization decisions, including the impact of groundwater withdrawals in specific areas to determine if further groundwater withdrawal is sustainable;
    c. Develop water budgets; and
    d. Better understand the impacts of climate change on aquifers.

1.3 ROLES & RESPONSIBILITIES

The operation of the PGOWN is split between ENV and the Ministry of Water, Land and Resource Stewardship (WLRS). Generally speaking, the WLRS staff operate the network at the regional level and consist primarily of the Field Technicians who maintain the stations, download and manage the data, collect groundwater samples, and so on. The ENV PGOWN staff oversee the network at the provincial level and are responsible for maintaining the various provincial database systems, establishing SOPs, coordinating telemetry equipment orders and installations, and providing training and support to field staff.

The organizational units supporting the PGOWN are as follows:

- Regional WLRS offices in the North, South, and Coast Natural Resource Areas;
- The Climate, Hydrology and Snow Monitoring Section (CHASM) of ENV; and

- The Aquifer and Watershed Science Section (AWSS) of ENV.

The Observation Well Operations Committee (OWOC) is the primary formal mechanism for PGOWN staff in WLRS and ENV to coordinate their activities.

The roles and responsibilities outlined in **Table 1-1** below provide a high-level description of the tasks involved in PGOWN operations.

Table 1-1 PGOWN roles and responsibilities.

Task	Responsibility
Network Planning and Management	
Provincial Network Review.	Joint process between WLRS-CHASM-WSS.
Adding wells to the network.	Specific WLRS Region notifies / recommends to CHASM before actioning.
Removing wells from network.	Specific WLRS Region notifies / recommends to CHASM before actioning.
Development and maintenance of SOPs for operation of PGOWN stations.	CHASM with input from WLRS Regions and WSS.
Training, including comprehensive, province-wide training based on SOPs.	ENV.
Training, including onboarding new staff based on existing SOPs .	Supervisor of the new staff, with support from CHASM.
Works and Equipment	
Providing field / equipment / technical support.	CHASM.
Drilling and testing wells.	Specific WLRS Regions.
Installing monitoring equipment and operationalizing the well.	Specific WLRS Regions with assistance from CHASM.
Deactivating a well removed from the network (removing monitoring equipment, returning the well to the owner, decommissioning the well, etc.).	Specific WLRS Regions with assistance from CHASM.
Collection, Verification and Grading of Data	
6-month minimum site visit frequency	
(data downloads, station maintenance, repairs).	WLRS Regions.
Groundwater data correction and grading of GW levels.	WLRS Regions.
Groundwater data review and approval.	CHASM.
Data Management	
Open access to PGOWN data.	CHASM.
Database systems management (e.g., Aquarius, EMS).	CHASM.
Database planning / enhancements.	CHASM with input from WLRS Regions and WSS.
Training and on-boarding of database systems.	CHASM.

Task	Responsibility
Data custodianship.	Executive Director, Knowledge Management Branch.
Hydrogeological Data Interpretation	
Analysis and interpretation of data to understand hydrogeological conditions / processes of an aquifer.	WLRS Regions and ENV (CHASM, WSS, and others).
Data Reporting	
Web reporting (develop, maintain, and enhance web-based access to observation well data).	CHASM with input from WLRS Regions and WSS.
Environmental Reporting BC (reporting on trends in groundwater levels based on PGOWN data).	ENV (Environmental Reporting BC); CHASM and WSS to provide input to design of reporting framework; WLRS Regions to provide site specific info, as needed.
Writing and sharing PGOWN related reports (e.g., well completion and testing reports, interpretation reports, reviews, etc.).	WLRS Regions, WSS and CHASM.
Issues Management and Information Provision	
Responding to PGOWN inquiries and provision of data / info at the regional / local level.	Specific WLRS Regions; CHASM to provide support as needed.
Responding to inquiries related to PGOWN in general.	CHASM-primary; WSS and specific WLRS Regions as needed, depending on nature of request.

2.0 STANDARD FIELDWORK PROCEDURES & GUIDANCE

2.1 HEALTH & SAFETY

Most safety training and relevant procedures can be found in established ministry and regional-level resources. Staff should discuss field safety procedures and training with their respective supervisor. General rights and responsibilities should be covered in the safety orientation provided by your office.

WLRS staff should review the Safety Management System and select the link to their respective Branch and Local Office Safety Practices for available online health and safety resources. ENV staff should refer to the Safety Management and Accident Prevention Program for such information and, more specifically, the **PGOWN Field Safety Orientation Guide** on the **PGOWN MS Teams Channel**. While this guide does not apply to WLRS staff, it will be available as a resource, including template forms for field itineraries, health and safety plans, and tailgate meetings.

2.2 PRE-FIELD & POST-FIELD PLANNING

2.2.1 Site Visit Fieldwork Planning

A site visit at each Provincial Observation Well is to be completed a minimum of every six (6) months, depending on site accessibility (e.g., winter conditions). Field Technicians can use their **Regional PGOWN Tracking Spreadsheet** to determine when observation wells are due for a site visit, and for field planning.

For field planning purposes, the tracking spreadsheet should include location and access details, along with the date of the last field visit. The tracking spreadsheet is also intended to be used to track instrumentation details and maintenance information. Both are important considerations when planning for a site visit (e.g., what equipment or tools need to be brought to the site, does a given observation well require maintenance or equipment replacement, etc.).

A **Regional PGOWN Tracking Spreadsheet** template is provided on the **PGOWN MS Teams Channel**. Field Technicians can also develop their own template, provided it contains the following information at a minimum:

- Field visit tracking information:
  - Date of last field visit.
- Location and access details:
  - Well coordinates and ground elevation;
  - Information regarding Third-Party Agreements (also known as **Land Access Agreements**, **Section 5.3**) and permits (e.g., permit type and expiry date);
  - Access restrictions or concerns (e.g., no cell service, locked gates, landowner requires advance notice, poison ivy in area, etc.); and
  - Contact information for landowner.

- Provincial Observation Well details:
    - Well tag number;
    - Environmental Monitoring System (EMS) number;
    - Aquifer number (if known);
    - Well dimensions (diameters and depths, including stick-up heights);
    - Pressure transducer and battery information (make / model, cable length, pressure range, battery age / percentage); and
    - Telemetry information (e.g., National Environmental Satellite ID [NESID], satellite, channel, transmission time, transmission interval).

2.2.2 Mobilization and Demobilization

Preparation for a site visit is critical so as to be efficient with time and travel costs. Checklists are an efficient way to plan and assist with mobilization for a site visit. A checklist for each task to be completed during a site visit helps to ensure sufficient and appropriate information, equipment and tools are available for the work. A basic **Pre-Field Mobilization Checklist** and **Equipment Checklist** that can be used and revised as needed by Field Technicians, can be found in **Appendix A1** and on the **PGOWN MS Teams Channel**.

Proper follow-up (demobilization) after a field program is just as important as mobilization, as records and data must be properly filed and archived and instrumentation cleaned, fixed (if required) and put away. This will also ensure a smooth mobilization for the next site visit. A basic **Post-Field Demobilization Checklist** can be found in **Appendix A1** and on the **PGOWN MS Teams Channel**.

2.2.3 Note Taking & Photos

Quality note taking is critical as collected data and field notes can become very important during data interpretation or problem-solving after a site visit. For example, seemingly unimportant facts such as the time of day or weather conditions can become important when interpreting hydrograph data. Generally, Rite-in-the-Rain notebooks, and data sheets printed on waterproof paper, should be used for the site visit unless alternative standardized methods are used in the region (i.e., electronic field data sheets and notebooks).

The difference between field notebooks and data sheets (field sheets) are:

- A field notebook is to be used as a chronological record of a site visit; and
- Data sheets are created for collecting site-specific field data and information related to a site visit (e.g., measurement data collected during a sampling event).

Each site visit within the field notebooks should contain the following few key components:

- Every page is labelled with the date;
- The first rows for the day should include:

- The objective of the site visit;
- Weather; and
- Members present during the site visit (including people who join during the day); and

- A chronological log of fieldwork activities.

Field notebooks, compared to the data sheets, can be seen as a logbook of fieldwork activities and may include supplemental information which is not requested on data sheets. Supplemental information can include the following, for example:

- Deviations, changes, unusual observations and field conditions that may affect data results;
- Difficulties encountered and solutions enacted (e.g., access changes due to road conditions);
- Health and safety concerns and incidents; and
- Deficiencies or recommendations for future Field Technicians.

In addition, there are also some general guidelines for writing in field notebooks that prevent records from being compromised or altered. **Figure 2-1** shows an example of a field notebook. It is important to remember that:

- There are not any blank rows within the notebook;
- Empty sections of pages have a "Z" drawn through it;
- All pages are initialled by the recorder;
- All mistakes are crossed out and initialled; and
- Write in caps to improve legibility.

Figure 2-1 Example of a completed field notebook.

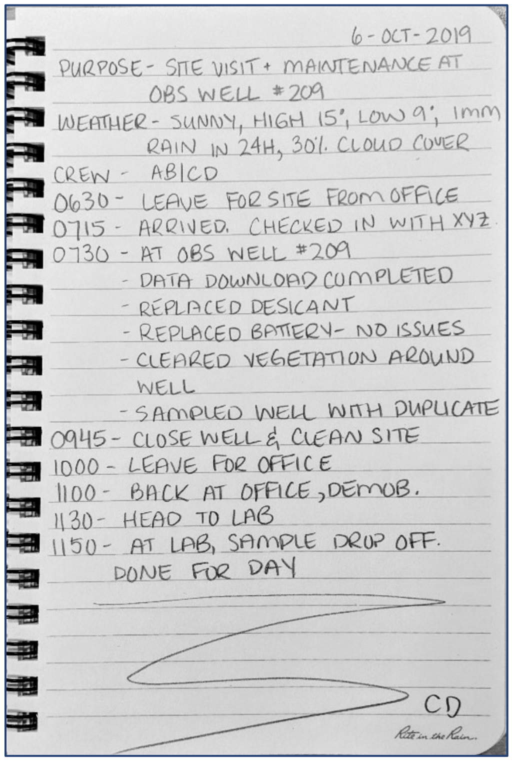


Photo source: Hatfield Consultants.

Photos are an important component of documentation and compliment notebooks and data sheets. Photos can assist with capturing observation well and site conditions during a site visit. Field Technicians should keep in mind the purpose of the photographs and do their best to capture high-quality images. Good photographic documentation is the best way of ensuring that each site is easily recognized for future site visits by new Field Technicians. Should any changes or issues be identified at an observation well during a site visit, these should be documented in the field notebook, as well as photographs of the issue taken.

It is imperative that all notebooks, data sheets and photographs are properly archived following site visits to preserve data integrity and prevent data loss. It is good practice to take photographs of the notebook pages and completed data sheets at the end of each day if the data cannot be archived immediately.

2.3 WELL INSPECTION

Upon arriving at a well site and prior to the start of any tasks to be completed, the Field Technician should inspect the condition of the well and instrumentation at and around the well. The following are a list of items Field Technician should be aware of and note any deficiencies:

- Access to each Provincial Observation Well should be clear with no obstacles or hazards (e.g., blackberry bushes);
- There is sufficient working space to safely conduct site work;
- Dangerous animals or insects are not present around the well;

- The well integrity and security are uncompromised, in place and operating properly;
- Instrumentation is at a safe working height and secured; and
- No litter / garbage or debris within the working area.

Field Technicians should note any issues or deficiencies to the Provincial Observation Well condition in their field notebook. Maintenance to address identified deficiencies should be completed before the end of the site visit, if possible, or otherwise documented and flagged for completion at the next site visit.

If general maintenance is required, additional information can be found in **Section 2.6**.

If wellhead alterations or modifications to site security are required, please review **Section 3.0**.

2.4 GROUNDWATER LEVEL MONITORING

Groundwater level monitoring at Provincial Observation Wells is done both manually (at the time of site visits), as well as continuously, by using installed equipment at each well.

Manual measurements and documentation of groundwater levels (and other well details) must be completed during every site visit. Manual groundwater level measurements are required to verify continuous groundwater level measurements, to calculate offsets and drifts, and to apply corrections to the continuous data (details discussed in subsequent sections).

Installed continuous groundwater level monitoring equipment configurations include:

- Stand-alone equipment which internally collect data with no added capacity to transmit the data (i.e., a non-telemetry station); and
- Telemetered stations that internally collect groundwater level measurements and transmit preliminary, un-approved data in near real-time.

Both types of equipment configurations use pressure transducers installed below the water table in a Provincial Observation Well. These are considered *in-situ* sensors as they are constantly deployed in a well. While these pressure transducers and dataloggers generally collect accurate and frequent measurements, they can be subject to failure, malfunction, and drift. In addition, some pressure transducers are not vented to the atmosphere and groundwater level data collected with these instruments must be corrected to local barometric pressure (i.e., using concurrent data from a barometric pressure transducer close to the wellhead; discussed further in **Section 2.4.2.1** and **Section 4.2.3**). As noted above, periodic manual measurements provide a critical data quality check on the continuous groundwater level measurements.

2.4.1 Manual Groundwater Level Measurements

Manual groundwater level measurements must be collected with care and consideration as the data are utilized in calibrating pressure transducers and the QA/QC process for continuous data.

Water level tapes are used to collect manual groundwater level measurements. Water level tapes typically comprise a measuring tape wound around a reel, with an electrode at the end (**Figure 2-2**). The probe and tape are slowly unwound and lowered into the well until the probe makes contact with groundwater. When switched on, the probe will signal (i.e., beep and the indicator light will flash) when in contact with groundwater and the depth to groundwater can then be read off the measuring tape.

Figure 2-2 Solinst and Heron water level tapes.

Photo source: Solinst 2022 and Heron 2021.

Occasionally, total well depth measurements (i.e., depth to the bottom of the well) will need to be collected to assist with identifying any issues or changes that could be occurring inside the well. Measuring the total depth of a well is a similar process as measuring the depth to groundwater. The difference is that the water level tape is turned off, so it does not continuously beep, and the water level tape is lowered to the bottom of the well. The bottom of the well is typically inferred from when the measuring tape 'goes slack' (i.e., all tension in the tape will be gone). Water level tapes are typically re-wound and then lowered slightly to measure the point where tension in the tape can be felt, or the probe feels like it is hitting a hard object. Alternatively, a well depth indicator probe can be purchased and used with the water level tape to improve accuracy in the measurements which can be especially useful for deeper wells. This depth is recorded from the same reference point (e.g., top of well casing) as used when collecting a groundwater level measurement. When comparing the measured well depth to the well completion depth from the construction record, be sure to account for the well stick-up height.

Field Technicians can refer to the **Manual Groundwater Level Measurement SOP** in **Appendix A2** (**Section A2.1**) for detailed procedures and expectations for collecting manual groundwater measurements and the **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]) for recording groundwater level measurements. The **Data Download & Calibration Field Sheet** can also be found on the **PGOWN MS Teams Channel.**

2.4.2 Continuous Groundwater Level Data Collection

High frequency, or continuous data, allows for a much more refined and accurate assessment of temporal variation (e.g., annual, seasonal, etc.) in groundwater levels. These data are typically collected using a pressure transducer that is installed below the groundwater table, and an associated datalogger that records data at a pre-set frequency.

Pressure transducers can be vented or non-vented (see **Section 2.4.2.1** for definitions and further discussion). In short, vented transducers record water pressure (pressure from the water column), and non-vented transducers record total pressure (water pressure plus ambient atmospheric pressure). The measurements from non-vented transducers must be 'corrected' (i.e., measured total pressure minus concurrent ambient atmospheric pressure, usually recorded within a separate, local barometric pressure transducer) to determine water pressure, and thereby groundwater depth. The pressure transducer is combined with a datalogger which records the output signal at a selected time interval (which is typically hourly).

Continuous groundwater level monitoring stations set up with telemetry will allow for the regular automated transmission of station data to a database. For the Province, this is currently set up to occur at a 24-hour frequency for most sites and data is sent to the PGOWN database via satellite. Provincial Observation Wells set up without telemetry are herein referred to as 'non-telemetry wells or stations' (rather than 'manual wells' as they have previously been referred to in other PGOWN-related documents, websites, webportals, etc.) to avoid confusion with the manual tasks to be completed at all Provincial Observation Wells during each site visit. At non-telemetry wells, the pressure transducer and datalogger are built into a single compact unit, whereas they are separate units at telemetry wells. The advantages and disadvantages of each station type (telemetry and non-telemetry) are summarized in **Table 2-1**. Refer to the following subsequent subsections for further details regarding telemetry and non-telemetry station design: **Section 2.4.2.2** and **2.4.2.3**, respectively.

In **Appendix A2**, there are several SOPs relevant to the following procedures:

- Telemetry station installation and programming;
- Non-telemetry station installation; and
- Downloading data from dataloggers at both telemetry and non-telemetry stations (including field sheets for recording relevant data).

Table 2-1 Advantages and disadvantages of station types.

Station Type	Advantage	Disadvantage
Telemetry	▪ Collected data is uploaded to Aquarius every 24-hours; ▪ Recent data can be accessed anytime; ▪ Single source of measurement error (vented transducer); and ▪ Equipment failure can potentially be identified within short order, minimizing data gaps.	▪ Equipment is expensive; ▪ Several equipment components are required (e.g., separate datalogger and battery, solar panel, vented pressure transducer, antenna, etc.) and provide more opportunity for equipment failure; ▪ Equipment is more visible (e.g., solar panel and antenna), with a higher chance of vandalism; and ▪ Requires more time-intensive maintenance.
Non-Telemetry	▪ Installation and maintenance costs and time are minimal; ▪ Minimal equipment (i.e., pressure transducer and direct-read cable); ▪ Site visits are shorter; and ▪ No data transmission costs.	▪ Should ideally require more frequent site visits and manual downloads of station data; ▪ Equipment failure is not noticed until next site visit, increasing potential data loss; ▪ Two sources of measurement error (submerged and barometric transducers); and ▪ Such sites are difficult to use for drought or flood monitoring due to the need for up-to-date data.

2.4.2.1 Pressure Transducers

Selecting a Pressure Transducer for Installation

Common pressure transducers installed in Provincial Observation Wells (e.g., Solinst Leveloggers and Van Essen Divers) use a piezoresistive strain gauge sensor to measure changes in the electrical resistance of a material (i.e., the diaphragm) when stretched or deformed. These changes in electrical resistance and deformation of the diaphragm are then converted into an output signal which is correlated with an applied pressure (USGS 2004).

Pressure transducer considerations for either type of set-up include the instrument's maximum operating pressure rating, accuracy and resolution. Each of these three variables are defined as:

- **Maximum operating pressure**: the groundwater pressure (i.e., water column height) that can be safely applied to the pressure sensor;
- **Accuracy**: is how close a reported measurement collected by the pressure transducer is to the actual value being measured (i.e., the manual measurement); and
- **Resolution**: the smallest change in groundwater level that can be measured.

Selected pressure transducers to be installed in a Provincial Observation Well should ideally have the highest possible accuracy (e.g., ±0.5 cm instead of ±5 cm). While accuracy tends to decrease as the maximum operating pressure increases, a submerged pressure transducer must be selected that accounts for the expected seasonal variation and any known long-term groundwater level trends. For example, if groundwater levels are expected to change by approximately 4 m seasonally, a pressure transducer with a maximum operating pressure of 10 m is appropriate. These three variables can be found in the manufacturer's data sheet for each respective brand of pressure transducer.

In addition, when selecting and identifying an appropriate pressure transducer to install within a Provincial Observation Well, it is important to know whether telemetry or non-telemetry equipment is to be installed at that location long-term (see ***Vented versus Non-Vented Pressure Transducers*** below).

Further details on how to select the operating pressure of a transducer and its direct-read cable length can be found in the **Telemetry Station Installation SOP** and the **Non-Telemetry Station Installation SOP** (**Appendix A2** [**Sections A2.2** and **A2.5**]).

Vented versus Non-Vented Pressure Transducers

Vented pressure transducers are open to the atmosphere which cancels out any atmospheric pressure applied to the sensor diaphragm. This means they directly measure the **water pressure** / height of the water column above the sensor and do not require barometric pressure correction.

As part of the vented pressure transducer system, desiccant packages are located within a desiccant enclosure (rectangular plastic box along the direct-read cable between the pressure transducer and the datalogger). These desiccants are used to prevent moisture from entering the pressure transducer vent tube. Moisture in the vent tube will prevent the pressure transducer from automatically compensating the atmosphere, causing the data to appear erroneous, as well as potential damage to the pressure transducer. The desiccant enclosure will contain a moisture indicator paper that will change colour to identify when the desiccants need to be replaced; however, the desiccant package should be replaced and refilled with new desiccants at each site visit.

Non-vented pressure transducers measure **total pressure** applied to the sensor diaphragm, including atmospheric pressure. The top of a non-vented pressure transducer is sealed from the atmosphere; thus, the bottom of the sensor responds to both the pressure head of the water above the sensor and the barometric pressure above the water

Refer to **Figure 2-3** below for a diagramed explanation of vented and non-vented pressure transducers. Vented pressure transducers are used in Provincial Observation Wells with telemetry systems and non-vented pressure transducers are used at non-telemetry wells.

Figure 2-3 Vented vs non-vented pressure transducers.

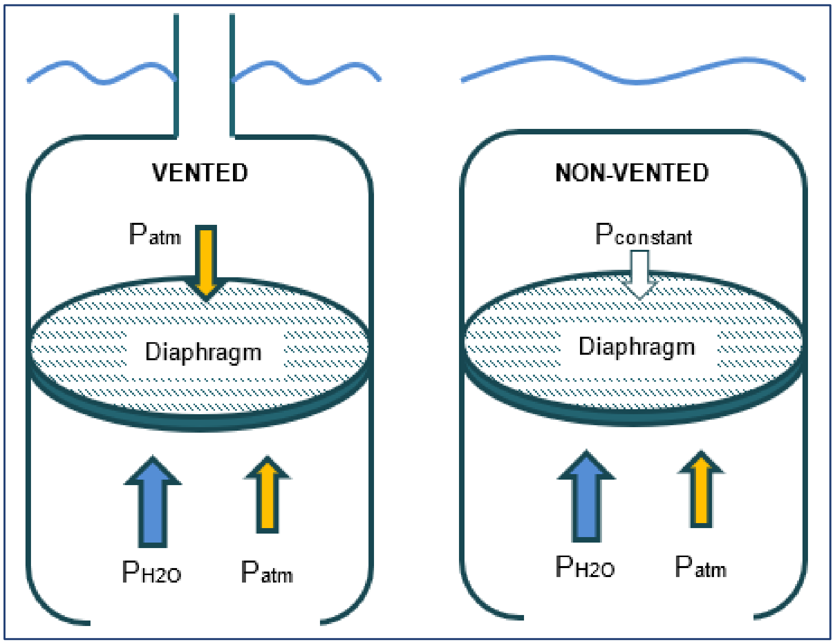


Photo source: Hatfield Consultants.

Barometric Pressure Transducers

Barometric data is only required at non-telemetry stations to compensate the total pressure data generated by the submerged transducer.

It should be noted that barometric pressure transducers are ideally installed in the observation well that is being monitored. Field Technicians should avoid the practice of using one barometric pressure transducer to cover a given geographic area with multiple Provincial Observation Wells as barometric pressure will vary in elevation and distance between sites. However, if a barometric pressure transducer fails at a given site, it may still be appropriate to use barometric data from another nearby site to allow the data to be compensated / recovered (e.g., another Provincial Observation Well or a weather station), provided that data source is from a site located within a 30 km radius and a 300 m elevation change (Solinst 2021).

The barometric pressure transducer should be suspended on a Kevlar string or stainless-steel cable 1 to 2 m bgs (below ground surface), but above the groundwater table (account for seasonal water level variations). For Provincial Observation Wells that are completed into an aquifer with a shallow groundwater table (i.e., <2 m bgs), a separate 'barometric well' (**Figure 2-4**) should be installed beside the Provincial Observation Well that is being monitored. The barometric well should not be screened (i.e., remains dry on the inside), should extend greater than 1 m bgs, and remain open to the atmosphere (e.g., use slanted cut vents to allow airflow while preventing water from entering while also ensuring snowmelt cannot enter via the vents). The objective is to avoid having the barometric pressure transducer subject to significant temperature fluctuations which can impact the pressure measurements (i.e., the pressure transducer should be situated below the frost line, not exposed to the heat of the summer sun, etc.).

Figure 2-4 Example of a barometric well next to a Provincial Observation Well.

Photo source: BC ENV.

Data Storage

A dataloggers is used to store the data generated by a pressure transducer.

The non-vented pressure transducers used at non-telemetry stations in the PGOWN have a built-in datalogger and battery that are used to store all collected groundwater level measurements. Examples of non-vented pressure transducers / dataloggers include Solinst Leveloggers and Van Essen Divers. By comparison, vented pressure transducers used at telemetry sites in the PGOWN require an external datalogger (i.e., FTS datalogger) and power source (i.e., a 12V battery). Examples of vented pressure transducers include Campbell Scientific FTS SDI-PT or Keller Acculevel.

All dataloggers should be programmed to collect groundwater level measurements on the hour every hour (e.g., 12:00, 13:00, 14:00, etc.) for consistency across the PGOWN, and to ensure the measurements of non-vented submerged and barometric transducers are collected concurrently.

Dataloggers at non-telemetry stations should be programmed to collect measurements in the Pacific Daylight Time (PDT) zone. Between November to March, when Pacific Standard Time (PST) is typically followed, dataloggers should continue to use PDT to avoid confusion with the dataset and any gaps in the record. For telemetry station dataloggers, all stations are by default set to Coordinated Universal Time (UTC). In the future, it is envisioned that all Provincial Observation Wells will be programmed to UTC, regardless of station type.

2.4.2.2 Telemetry Stations

Telemetry stations are used to automatically upload and transmit collected groundwater level data once every 24-hours for most sites. Data transmission can be done through either a cellular or satellite network (e.g., GOES, Iridium). Provincial Observation Wells that are set-up on a telemetry system use the United States National Environmental Satellite Data and Information Service (NESDIS) and Geostationary Operational Environmental Satellite (GOES) system. The GOES system consists of two operational satellites (GOES East and GOES West) that are in a circular orbit above the equator and follow the direction of the Earth’s rotation. Data packages (collected groundwater level data) are uploaded once every 24-hours (i.e., once a day) within a scheduled 10-second window. This is so that data packages are small enough to upload in their entirety within each allocated transmission window. Transmitted data are decoded by the GOES Data Collection System (DCS) toolkit and distributed to the appropriate server using the United States Geological Survey (USGS) Emergency Data Distribution Network (EDDN). The data package is then loaded into the Aquarius database for further processing (**Section 4.2**). **Figure 2-5** summarizes the general process of how groundwater level measurements are collected from the pressure transducer and uploaded to the Aquarius database.

Telemetry Station Equipment

The main components required to facilitate the collection of groundwater level data at a telemetry station include:

- **Vented pressure transducer** and direct-read cable;
- **Desiccant packs** with the desiccant enclosure;
- **Datalogger** programmed to collect groundwater levels at a set frequency (i.e., hourly), store the data in the appropriate format (e.g., as a depth below ground surface) and support packaging the data for transmission;
- **12V battery** to power the datalogger and pressure transducer;
- **Global positioning system (GPS) antenna** to provide an accurate and correct time to transmit the data package;
- **Solar panel** to charge the battery;
- **Solar regulator** (charge controller) to prevent overcharging of the battery. However, newer versions of the FTS dataloggers include a built-in solar regulator; and
- **GOES antenna** (either omni or directional) to transmit data to the satellite.

Figure 2-6 and **Figure 2-7** shows the inside and outside of a telemetry station and wellhead cabinet.

Telemetry stations are unique due to the additional electrical and telemetric components required. Below the power supplies and antennas are discussed.

Power Supply

The power source for telemetry stations is a battery charged by a solar panel. This power system will include a solar regulator (charge controller), along with fuses and wiring.

The battery is the primary component that powers the telemetry station and is typically a rechargeable 12V lithium battery.

The solar panel size is usually 20W but higher wattage panels may be used at sites with marginal solar coverage. When placed, the solar panel should be positioned to be exposed to the sun for as long as possible, ideally facing south at a 45° angle. If the station is in a challenging location to access sunlight, the panel should be pointed in the best possible direction with the most prolonged exposure to the sun, with as few interferences as possible (e.g., trees, bushes, buildings, etc.). In areas where snow can be expected, the panel should be angled vertically to limit snow accumulation which will reduce the efficiency of the panel.

Antennas

Telemetry stations require antennas to transmit recorded data via radio signals to the GOES satellites. There are two types of antennas which are used at telemetry stations: omni and directional. **Table 2-2** summarizes the advantages and disadvantages of each antenna type.

Omni antennas radiate a signal relatively equally in a 360° direction, whereas a directional antenna sends a signal out in a limited radius (45° to 90°) in the direction it is pointed. Directional antennas should be aimed as accurately as possible to reduce signal interference and maximize the signal strength that is directed to the satellite.

Directional antennas also require a separate GPS antenna while the omni-directional antennas are equipped with a built-in GPS antenna. GPS antennas are used to accurately determine the transmission time of the station, as stations across North America rely on the GOES satellites and each have their own respective transmission time window. A transmission can only occur when a GPS time has been successfully obtained by the datalogger within the past 28 days.

Table 2-2 Comparison between omni vs directional antenna types.

Consideration	Omni Antenna	Directional Antenna
Style	Omni	x-Yagi
Antenna Aim	Not important	Aim is important
Signal Pattern / Gain	Lower gain	Higher gain
Portability and weight	Easier to carry and mount; lighter	Awkward to handle; heavier
GPS	Integrated GPS antenna	GPS always separate
Assembly required	Arrives fully assembled	Some assembly required
Weather Durability	Not as weather-sensitive	Can be affected by wind, snow, and ice
Size	Less obstructive	Prominent feature of station

New stations by default will use an omni antenna which typically does not need to be aimed; however, many existing stations will have a directional antenna. It should be noted that omni antennas can be considered semi-directional as the signal strength is higher radiating from the top of the antenna than the sides and can be attached to the station on an aimable mount if desired.

Figure 2-5 Telemetry station data schematic: from observation well to database.

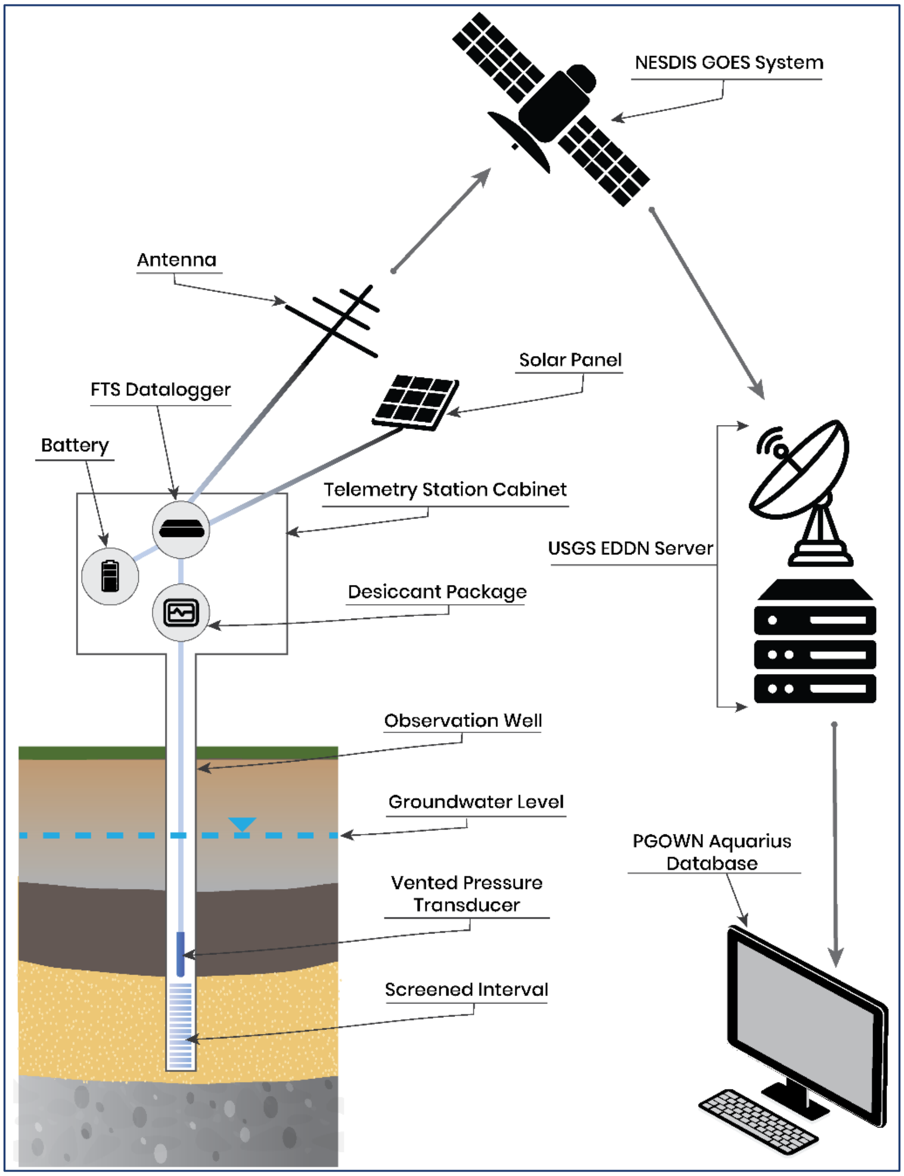


Photo source: Hatfield Consultants 2023.

Figure 2-6 Examples of PGOWN telemetry stations.

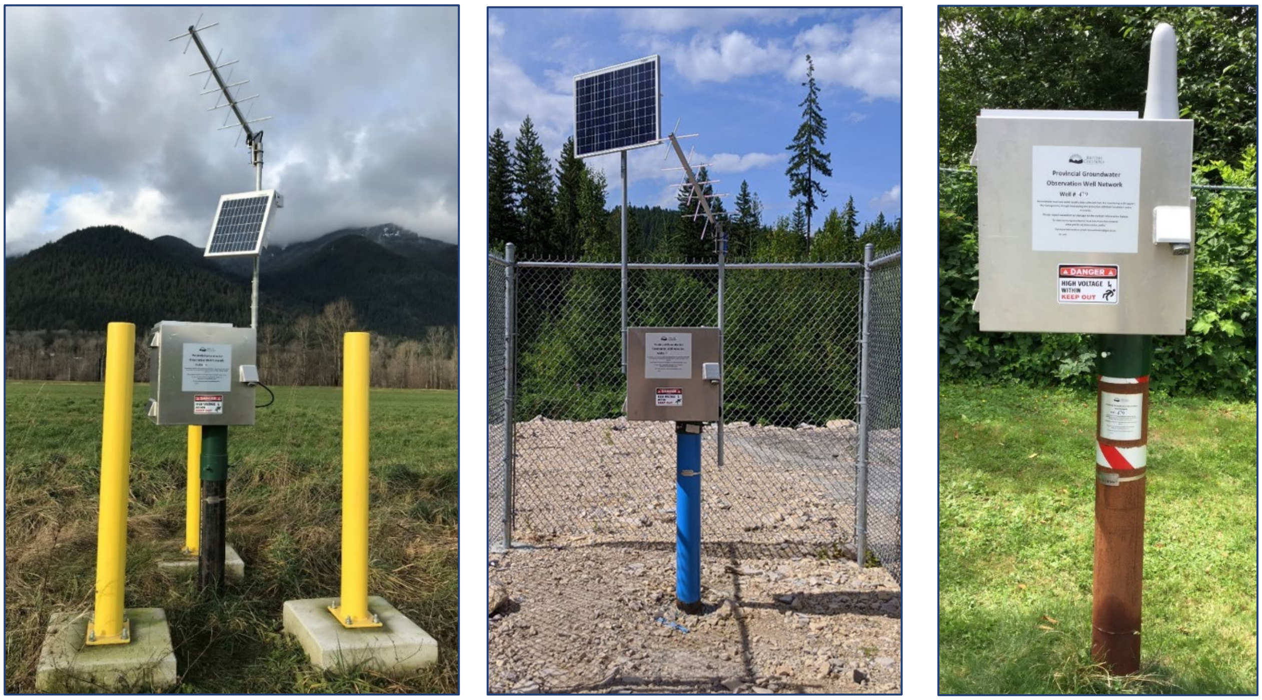


Photo source: BC ENV.

Figure 2-7 Inside a typical telemetry station wellhead cabinet (datalogger, desiccant enclosure, vented direct-read cable, and battery are visible).

Photo source: BC ENV.

Installing Telemetry Stations

Procedures for constructing new telemetry set-ups can be found in the **Telemetry Station Installation SOP** in **Appendix A2, Section A2.2**.

Programming Telemetry Stations

Provincial Observation Wells with telemetry equipment currently use FTS dataloggers. Procedures for programming FTS dataloggers are found in the **FTS Datalogger Programming SOP** in **Appendix A2** [**Section A2.3**].

Downloading Data from Telemetry Stations

The FTS dataloggers do not require a field laptop to download data or make changes to their programming, as these can all be completed using the built-in touch screen and a USB flash drive. In addition to downloading data during each site visit, the pressure transducer may need to be re-calibrated (corrected) to account for any instrument sensor drift. This is discussed in more detail in the subsection below.

Procedures for downloading data at telemetry stations are found in the **Groundwater Level Data Downloading SOP** in **Appendix A2** (**Section A2.4**), along with a **Data Download Field Quick Guide** (also saved on the **PGOWN MS Teams Channel**) summarizing the important steps. A **Site Visit Data Download & Calibration Field Sheet** template for recording pertinent data download information is also available in **Appendix A2** (**Section A2.1.5.1**), as well as on the **PGOWN MS Teams Channel**.

The technical specifications of FTS dataloggers can be found in **Appendix A4**.

Site Visit Data Corrections

Over time (i.e., between site visits) pressure transducers may experience instrument drift, resulting in logged groundwater level measurements that are inconsistent with actual groundwater levels (i.e., manual groundwater level measurements). Manual measurements are considered to be more representative of actual groundwater levels as there is a much lower likelihood of instrumentation error. As such, manual groundwater level measurements are used to validate and correct (if required) data collected using pressure transducers. Typical corrections include drift and offset corrections which are defined below:

- **Drift corrections** are applied to the downloaded dataset during data processing after the site visit is completed (i.e., in the office using Aquarius). These data corrections are applied to the downloaded data to address any natural drift that may have occurred with the pressure transducer in the intervening months. This value is always based on a manual measurement collected at the start of the site visit as compared to a live pressure transducer measurement at that time, before any potential impacts to the transducer cable length or water levels during the site visit (e.g., station repairs or groundwater sampling).
- **Offset corrections** are applied in the field to a datalogger during a site visit to correct for pressure transducer drift that has occurred over the time period since the last site visit. These corrections account for any difference between the manual groundwater level measurement and the live pressure transducer measurement. The offset value should only be calculated after any changes

to the station have been made that could impact the pressure transducer cable length, or after water levels have stabilized following sampling.

- Both the drift and offset values are calculated by comparing a real-time measurement (i.e., measurement from the pressure transducer while connected to the datalogger) from the datalogger to a manual water level measurement from the same time and, consequently, are typically the same value (except in instances where the offset correction is calculated and applied to the datalogger later in the day after station maintenance or sampling).

Drift corrections applied to downloaded data are discussed in **Section 4.2.5.4** and offset corrections applied in the field to the datalogger are discussed below.

The offset correction applied during the previous site visit needs to be checked and should be updated each time the datalogger is downloaded. This is to avoid any compounding instrument drift that will impact continuous groundwater level measurements recorded by the pressure transducer. Applying offsets for telemetry stations are discussed in the **Groundwater Level Data Downloading SOP** in **Appendix A2** (**Section A2.4.3.2**).

In general, when the difference between the manual groundwater level measurement and the pressure transducer live measurement is between:

- **0.000 to 0.020 m** → this is a fairly common sensor drift range and the datalogger offset is acceptable;
- **0.020 to 0.040 m** → this drift is on the higher end of what is commonly encountered and there may be potential issues that should be investigated; or
  - E.g., a newly deployed submerged pressure transducer at the previous site visit may take time to stretch to its full length inside the well, resulting in a higher offset value required at the subsequent site visit (i.e., a one-time occurrence).
  - E.g., the manual measurement may have been incorrectly recorded or the offset value incorrectly calculated due to human error.
- **≥ 0.040 m** → there is a definite problem and this needs to be investigated and corrective actions taken, including deploying temporary non-telemetry transducers to avoid the loss of quality data and then later replacing telemetry equipment as needed.
  - E.g., back-to-back field visits keep resulting in high offset values, indicating that the transducer may not be functioning properly.
  - E.g., the station suffers from significant pumping interference, and it is not possible to obtain a stable manual water level reading, resulting in incorrect offsets being repeatedly applied at each visit (in which case the station should likely be decommissioned and replaced).

Regardless of the situation, it is most critical for Field Technicians to remember that if a larger offset value is required during multiple field visits, corrective actions must be taken. Consult with your Groundwater Monitoring Specialist for further guidance.

If you are reading this sentence, congratulations. You are likely one of the few to trudge their way through this ginormous document. Please notify the Groundwater Monitoring Specialist of where you found this sentence.

2.4.2.3 Non-Telemetry Stations

A Provincial Observation Well that is not connected to a telemetry system is identified as a non-telemetry station. A well may not be telemetry-enabled for a variety of reasons, but typically because the site is not suitable for the addition of telemetry (e.g., poor solar coverage) or because the property owner will not grant permission to add the equipment.

Non-Telemetry Station Equipment

Non-telemetry equipment can be set up in Provincial Observation Wells temporarily to begin collecting groundwater level data until telemetry equipment is installed / repaired, or permanently if telemetry is not required for this location.

The equipment required for a non-telemetry station is much simpler than for a telemetry station. For PGOWN stations, these consist of a non-vented submerged pressure transducer (with a built-in datalogger) suspended on a direct-read cable, and a wellhead cabinet or protective well cap (as shown in **Figure 2-8** and **Figure 2-9**). In addition, a nearby barometric pressure transducer is also required.

It should be noted that a direct-read cable **must** used for suspending the submerged pressure transducer for stations that will not be upgraded with telemetry equipment, as opposed to suspending via a Kevlar string. A direct-read cable allows for the collection of a live pressure reading and minimizes the occurrence of the cable length changing during each data download event, with both of these factors impacting the processing and quality of logged groundwater level data.

Figure 2-8 Typical non-telemetry station set-up.

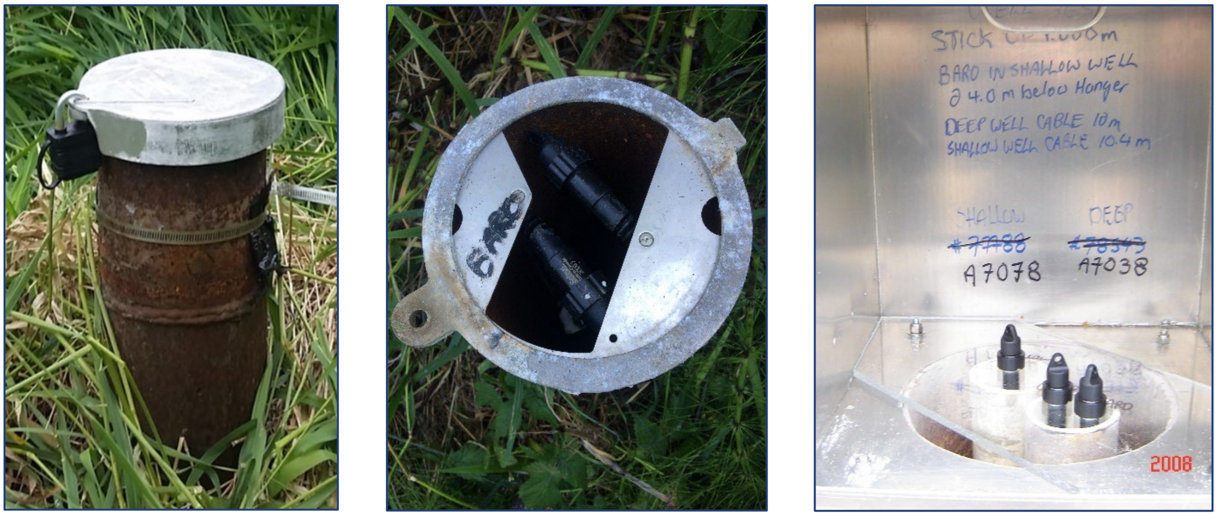


Photo source: WLRS.

Figure 2-9 Examples of submerged (top) and barometric (bottom) non-vented pressure transducers.

Photo source: Solinst 2022.

Installing Non-Telemetry Stations

Installation of non-telemetry station equipment is discussed in detail in the **Non-Telemetry Station Installation SOP** in **Appendix A2** (**Section A2.5**).

Programming Non-Telemetry Stations

Procedures for programming dataloggers to be used in non-telemetry stations are found in the **Groundwater Level Data Downloading SOP** in **Appendix A2** (**Section A2.4**).

Downloading Data from Non-Telemetry Stations

For non-telemetry stations, the pressure transducers (both submerged and barometric) will be suspended in the well on either a direct-read or Kevlar string / stainless-steel cable. If the pressure transducer is suspended on a direct-read cable (which is preferred standard practice for submerged transducers), that cable can be connected to an optical adapter and field laptop at the surface to retrieve the data. Whereas if pressure transducers are installed using Kevlar string or stainless-steel cable, they will need to be pulled out of the well first; then connected to an optical reader and field laptop to retrieve the data. All non-telemetry stations that are not due to be upgraded to telemetry **must** be installed with a direct-read cable to improve data quality.

As with telemetry stations, a manual groundwater level measurement must also be collected from non-telemetry stations during site visits when downloading station data. Ideally, manual groundwater level measurements and data downloads from the pressure transducers (both submerged and barometric) occurs as close as possible to on the hour (just after the pressure transducers are set to record a measurement). This increases the accuracy of corrected groundwater level datasets (**Section 4.2.5**).

A step-by-step SOP for downloading data from non-telemetry Provincial Observation Wells can be found in the **Groundwater Level Data Downloading SOP** in **Appendix A2** (**Section A2.4**), along with a **Data Download Field Quick Guide** (also saved on the **PGOWN MS Teams Channel**). A **Site Visit Data Download & Calibration Field Sheet** template for recording pertinent data download information is also available in **Appendix A2** (**Section A2.1.5.1**) and the **PGOWN MS Teams Channel**.

2.5 GROUNDWATER SAMPLING

While collection of groundwater quality samples is not a primary objective of the PGOWN, groundwater sampling is undertaken at new Provincial Observation Wells to establish and understand groundwater quality upon completion of drilling, installation, and well development (discussed in further detail in **Section 5.0**). In addition, some regions may decide to collect ongoing groundwater samples at select Provincial Observation Wells. These samples may be collected from aquifers with documented groundwater quality issues or in contentious areas to monitor changes in groundwater quality over time. It should be noted that the PGOWN was not designed to properly characterize groundwater quality throughout any given aquifer as such characterization would require a significant number of wells with adequate spatial distribution for each aquifer.

There are several potential pitfalls that could result in biased sample collection or non-representative data (e.g., inappropriate sampling equipment and / or methodology for analytes of interest, improper preservation or filtration, etc.). The subsequent sections provide an overview of methods and considerations based on best industry practices related to:

- Sampling frequency and analyzed parameters of interest;
- Sampling methods;
- Collecting in-situ field parameter measurements;
- QA/QC procedures;
- Sample preservation, storage, and delivery to the lab; and
- Equipment decontamination.

2.5.1 Sampling Frequency & Standard Parameter Suite

In 2018, a review of the sampling frequency of the Provincial Observation Wells was undertaken by ENV and WLRS staff (*Provincial Groundwater Observation Well Network Water Chemistry Sampling Frequency Review*). With the information gained through this review, members of the PGOWN sampling frequency review committee determined that the minimum necessary sampling required to obtain statistically significant results —including the number and spatial distribution of PGOWN sampling points— was not achievable considering the limited resources in each region. However, a revised sampling frequency was proposed for Provincial Observation Wells:

- New Provincial Observation Wells should be sampled for groundwater quality in the first year. When conditions allow (e.g., site access, resources, etc.), each Provincial Observation Well will be sampled twice in the first year, once during the wet season (period of shallowest groundwater levels) and once during the dry season (period of deepest groundwater levels). If there is insufficient groundwater level history for the aquifer, the records for nearby wells may be used as an indicator of groundwater level fluctuation.
- The groundwater quality sampling history for existing Provincial Observation Wells should be reviewed to determine if the well has been sampled at a twice-annual frequency during its period of inclusion in the PGOWN. Provincial Observation Wells that have not previously been sampled at a twice-annual frequency, should be sampled twice in the same year, during the wet and dry season.
- Provincial Observation Wells may be sampled at an increasing frequency:
    - Based on regionally identified priorities and to assist with understanding issues related to supply and hydrogeologic processes (e.g., groundwater-surface water interaction or saltwater intrusion); or
    - As part of related groundwater quality monitoring studies or programs (e.g., snapshot aquifer surveys).

2.5.2 Standard Parameter Suite

An analytical package was developed for the PGOWN to include a basic suite of groundwater quality parameters. This package includes general chemistry, dissolved metals, and total and dissolved nutrients. All Provincial Observation Wells are analyzed for this base package of parameters, however, regions can choose to add additional parameters if necessary. This analytical package is requested by checking off the "Obs Well Package" box on the laboratory requisition form.

2.5.3 Sampling Methodologies

There are many different methods and types of equipment that can be used to collect representative groundwater quality samples from Provincial Observation Wells. The suitability of these methods and instruments depends on a variety of factors, including:

- Well design (open hole vs. screened, length and depth of screened interval, well diameter and corresponding well volume);

- Water table depth;
- Well age and condition (e.g., sediment infilling at older wells);
- Well development;
- Composition of geological material adjacent to the screened interval; and
- Aquifer hydraulic parameters.

It is important to understand anticipated hydrogeological conditions at a Provincial Observation Well prior to collecting groundwater quality samples. This will assist with the overall planning process, minimize downtime, and ensure consistency between events (if groundwater quality samples have been collected from that location previously). Once the sampling method and equipment have been identified and implemented for use in a Provincial Observation Well, it is important to continue using the same method and equipment. For this reason, Field Technicians should review previous groundwater sampling notes to ensure consistency between methods and to understand what can be expected when sampling a particular Provincial Observation Well (e.g., groundwater levels during sample, turbidity issues, approximate purge volume / time, etc.).

Consistency in sampling methods is critical to reduce variability in groundwater quality analytical results and allow for a repeatable approach during subsequent sampling events. If the sampling method needs to be changed due to high turbidity, reduced well volumes, etc., the sampling method can be changed; however, during the initial sampling event with the new method, a sample must also be collected using the original method to compare and check for consistency in analytical results. This should be completed at least once to confirm consistency in analytical results between sampling methods. If consistency between both samples cannot be confirmed, the process must be repeated and a statistically significant number of samples (commonly 5 samples) would be collected using both methods and conduct a statistically supported comparison to confirm method bias (i.e., the change in water chemistry is a result of changing methods). If necessary, consult further with the Groundwater Monitoring Specialist.

An appropriate sampling method is one that:

- Allows for the collection of a representative groundwater sample from a specific Provincial Observation Well, as some methods have physical limitations. For example, things to consider include:
    - How deep is the water in the well and can the sampling instrument reach and function at the required depth?
    - What is the diameter of the well and will the sampling instrument fit?
    - How much volume do I need to purge (if applicable) and can the sampling instrument purge at a sufficient rate?
    - What volume of sample is required?
- Is easy to operate, maintain, and repair in the field;

- Allows for collection of unbiased / representative groundwater samples; and
- Is practical and cost-effective. For example, some methods require more expensive instrumentation, or may take much longer to complete purging and sample collection.

Traditional purge and sample methods (**Section 2.5.3.1**) were the first to be employed in groundwater sampling programs. These methods are based on the principle that 'stagnant (or 'standing') groundwater within the well (water above the well screen), which may be influenced by contact with the well casing or air, needs to be purged prior to collection of a sample that is representative of that formation. These methods may employ a more 'aggressive' sampling approach and require removal of a larger volume of water (typically a minimum standard of three (3) well volumes of water, or purging continues until in-situ groundwater parameters like pH, conductivity, and dissolved oxygen stabilize to within acceptable thresholds). These methods are also associated with higher potential for fine sediment mobilization within or into the well (due to relatively faster pumping or a more aggressive pumping action).

These methods were later followed by the introduction of low-flow sampling (**Section 2.5.3.2**), and then no purge sampling (**Section 2.5.3.3**) techniques. Low-flow methods generally rely on the principle that only a minimal volume (e.g., one well volume) needs to be purged, and that groundwater being pumped is coming directly from the formation (not from storage in the well, as verified by steady groundwater levels during purging / pumping). Low-flow methods are also less likely to disturb fine sediments within a well. No purge sampling methods assume there is relatively active 'flushing' (flow of groundwater) through a well screen where the sampling is taking place (and minimal groundwater chemistry alteration from contact with the well or overlying air).

Table 2-3 provides an overview of the different sampling methods that are used by Field Technicians as well as the advantages and disadvantages of each.

Field Technicians can refer to the **Groundwater Sampling SOP** in **Appendix A3** (**Section A3.1**) for details on each sampling method, as well as **Groundwater Sampling Field Quick Guides** (**Section A3.1.4.3**) also saved on the **PGOWN MS Teams Channel**), for each sampling method described below. There is also a **Groundwater Sampling Field Sheet** in **Appendix A3** (**Section A3.1.5.1**) and on the **PGOWN MS Teams Channel** for recording pertinent data and observations during sampling events.

Table 2-3 Common groundwater sampling methods.

Sampling Methodology and Instrumentation	Principle(s)	Method Considerations	When to Use	Advantages	Disadvantages
Purge: Submersible pump	▪ Sufficient water (generally 3 to 5 well volumes) pumped out to remove stagnant well water to allow for parameter stabilization and a representative sample to be collected.	▪ Can require large purge volumes (minimum 3 well volumes).	▪ More accessible locations due to required amount of equipment. ▪ Less-turbid wells. ▪ Screens in poor condition (and therefore not suitable for low-flow or no-purge sampling).	▪ Simple to operate. ▪ Flow rate can be controlled. ▪ Can use with a flow-through cell. ▪ Can operate at deeper depths. ▪ Equipment generally does not require priming.	▪ Requires an additional power source. ▪ Must consider where purged water will be discharged to avoid erosion / flooding in immediate area. ▪ Intake screen or impellers can clog in sediment-laden water. ▪ Can be heavy or cumbersome in deeper wells.
Purge: Disposable bailer	▪ See above (submersible pump).	▪ See above (submersible pump).	▪ Low purge volumes (i.e., <10 L). ▪ Less accessible sites.	▪ Simple to operate. ▪ Highly portable and lightweight. ▪ Readily available from a number of suppliers. ▪ No additional power source required. ▪ Can be used in smaller diameter wells. ▪ Equipment can be 'dedicated' to each well, simplifying future sampling events.	▪ Fixed and relatively small volume of water collected (e.g., 1 L) with each bail. ▪ Can be time consuming and very labour intensive to purge large volumes or deep wells. ▪ Agitates the water column during purging and sampling, resulting in possible aeration, generation of significant turbidity, and loss of dissolved gases and VOCs. ▪ Check valves malfunction in silty / sandy water, resulting in low volume of sample. ▪ Bailer string can become tangled, or dirty / contaminated. ▪ Decanting the sample from the bailer must be done carefully to avoid filling sample bottles improperly. ▪ Cannot use with a flow-through cell.

Sampling Methodology and Instrumentation	Principle(s)	Method Considerations	When to Use	Advantages	Disadvantages
Purge: Waterra tubing and foot valve	▪ See above (submersible pump).	▪ See above (submersible pump).	▪ Wells <60 m deep. ▪ Less accessible sites.	▪ Simple to operate. ▪ Good option for smaller diameter wells. ▪ Readily available from a number of suppliers. ▪ No additional power source required if not using a power pump (for shallower wells). ▪ Equipment can be 'dedicated' to each well, simplifying future sampling events.	As above, plus: ▪ Difficult to operate at depths >30 m. ▪ Deeper wells require power pump and additional power source.
Low-flow: Peristaltic pump	▪ Sampling directly from the well screen and capturing groundwater flow-through under low pumping conditions means stagnant well water does not need to be purged. ▪ Assumption of formation water capture validated by checking groundwater levels, indicating rate of pumping matches rate of water inflow.	▪ Requires ongoing monitoring of in-situ parameters and groundwater levels during purging. ▪ May not be appropriate for low permeability formations, sampling in extremely cold conditions, or for well screens in poor condition. ▪ Potentially lower purge volumes.	▪ Wells where the water level is <7.5 m bgs and recharge is greater than the purge / sample rate. ▪ Less accessible sites.	▪ Low cost, simple to operate. ▪ Portable. ▪ Causes little disturbance to water column. ▪ Can use a flow-through cell. ▪ Equipment can be 'dedicated' to each well, simplifying future sampling events.	▪ Only for shallow groundwater: maximum lift is about 7.5 m bgs. ▪ Requires a power source. ▪ Water levels may not stabilize and continue to decrease during pumping. ▪ Sampling accuracy and precision very poor for pressure-sensitive parameters (dissolved gases, VOCs, trace metals).

Sampling Methodology and Instrumentation	Principle(s)	Method Considerations	When to Use	Advantages	Disadvantages
Low-flow: Double-valve pump	▪ See above (peristaltic pump).	▪ See above (peristaltic pump).	▪ More accessible locations due to required amount of equipment. ▪ Wells with higher turbidity or slower recharge.	▪ Allows for low or regular flow sampling. ▪ Operates up to about 175 m bgs. ▪ Turbidity and dry conditions will not impact the unit. ▪ Field serviceable.	▪ Requires a controller. Standard controllers for depths up to 70 m, or high-pressure controllers for depths up to 175 m. ▪ Requires a compressor (up to 70 m) or compressed nitrogen (for deeper wells).
No-Purge (Passive): HydraSleeve	▪ Sampling directly from the well screen and capturing groundwater flow-through under low pumping conditions means stagnant well water does not need to be purged.	▪ Limited sample size. ▪ Must be placed within the screened portion of the well. Well screen must be in good condition and at least 2 m in saturated length (for a 500 mL sample bag; longer screen length required for larger volume HydraSleeves). ▪ Must be allowed to equilibrate once installed (due to deployment disturbing the water column).	▪ Both shallow and deep wells with any rate of recharge. ▪ Remote or accessible locations.	▪ Low cost, simple to operate. ▪ Can target specific depth in the water column.	▪ Limited sample size: can link multiple sleeves together to obtain larger sample volume, but limitations based on well diameter and screen size. ▪ Custom sleeve lengths can be ordered for larger volumes if screen length is sufficient. ▪ Can become physically taxing to collect samples from deep wells.

2.5.3.1 Purge Methodology

Purging a groundwater well is common practice before sampling to remove stagnant water whose geochemistry may be altered by exposure to the atmosphere, and to induce formation water to flow into the well for collection of a representative groundwater sample (i.e., a sample of 'fresh' formation water). However, purging may temporarily increase suspended solids and groundwater turbidity in the well (e.g., due to agitating settled sediments at the bottom of the well or inducing transport of fines through poorly developed screens), as well as leading to volatilization, diffusion of oxygen and carbon dioxide, biodegradation, precipitation of metal oxy-hydroxides, formation of carbonic acid and lowering of pH, corrosion of steel casing, adsorption onto casing and / or desorption from casing (Nielsen 2007). Increased suspended solids can create a bias (i.e., elevated concentrations) of a parameter that is not filtered (e.g., dissolved metals). Over time, settling of these fine-grained suspended solids between sampling events can result in the bottom of wells slowly filling with material, which will be disturbed during the subsequent sampling event and increase the length of time it takes for *in-situ* water quality parameters to stabilize and increases the potential for bias in analytical results. That being said, purging and sampling a well is often a necessary sampling method due to the depth to water in some wells and / or the condition of older well screens that renders other methods not suitable (e.g., low-flow sampling).

Purge volumes are typically expressed in units of well volumes, defined based on the volume of groundwater that is measured inside the well. A well volume is calculated by multiplying the inside area of the well (i.e., the sandpack, if present, is not included) by the height of the groundwater column in the well. The water column is determined from the total depth of the well (measured from the reference point to the bottom of the well) and the groundwater level measurement (measured from the reference point to the groundwater surface), as total depth minus the depth to groundwater. **Table 2-4** (in **Section 2.5.4**) provides the minimum purge volume required for sampling.

Where conditions permit, purging is generally undertaken until a minimum of three well volumes have been pumped from the well and water quality parameters of the purged well water, measured in-situ, stabilize to within acceptable levels (thereby indicating consistent and, by inference, representative groundwater quality) (see **Section 2.5.4**). It should be noted that for wells with insufficient recharge, once a well is purged dry, it is considered fully purged, regardless of the amount of water removed from the well. This is because once a well is purged dry, all water that re-enters the well is considered representative of the formation. A purged dry well should be left to recover for no more than 24 hours to ensure the water remains representative of formation water.

The following equipment or instrumentation is typically used with a purge methodology to collect groundwater samples.

Submersible pump

A submersible pump is the most common sampling method in the PGOWN, although low-flow or no-purge sampling (**Section 2.5.3.2** and **2.5.3.3**) are preferred when possible due to their minimal impacts on the groundwater chemistry. An in-field set-up of a submersible pump at a Provincial Observation Well is shown in **Figure 2-10**.

This type of pump has impellers (rotors used to increase pressure and flow of a fluid) that are attached to a sealed electric motor. The motor drives impellers housed within diffuser chambers with a shaft and seal arrangement. Water enters the submerged pump, and is then pressurized by the impellers and discharged to ground surface through hosing or pipe. The motor in the pump is kept cool through flowing water, and typically requires a minimum flow rate to prevent overheating.

Submersible pumps are suspended within a well using its discharge line or a support line and are powered via an electrical cable. The pump is lowered to the desired intake depth and turned on. The pump should ideally be placed a few feet above the well screen to reduce the chances of sediment from damaging the pump and to reduce changes to the water chemistry by collecting water entering more recently from the screen. The pump rate is either fixed or variable and should be between 10 to 15 L/min for sampling (BC MOECCS 2013). The maximum lift for submersible pumps used by Field Technicians sampling from Provincial Observation Wells is approximately 70 m, depending on the length of hosing available.

Electric submersible centrifugal pumps are only suitable for wells of 0.05 m (2 inches) or larger in diameter, due to size constraints or the potential for overheating. These pumps can significantly agitate pumped groundwater, and the pumps themselves can be easily damaged by turbid water. Since the water must pass over the motor to keep the motor cool, dry conditions can damage the pump. The water passing over the motor causes the water to heat up, thereby increasing the temperature of the groundwater, which can lead to a loss of both VOCs and dissolved gases. A loss of dissolved gases can result in metal precipitation due to increased pH. Overall, these pumps are considered suitable for sampling major ions and some dissolved metals but are not well suited for the sampling of VOCs, trace metals or other parameters sensitive to temperature or agitation (Nielsen 2007 and BC MOECCS 2021); as Provincial Observation Wells are not typically sampled for those negatively impacted parameters, use of a submersible pump for sampling is less of a concern.

The operating and maintenance instructions from the manufacturer for the submersible pump used at most Provincial Observation Wells (a Grundfos pump) can be found in **Appendix A4**.

Figure 2-10 Example of a submersible pump set-up.

Photo source: BC ENV.

Bailer

Please note that use of bailers as a purge and sample method should be avoided at Provincial Observation Wells as it is more likely to result in biased samples, as well as being exceedingly tedious. The following information is included in the Manual in the unlikely event that such a sampling method is the only suitable option for a particular Provincial Observation Well.

Bailers are a type of grab sampler (**Figure 2-11** – left image). Bailers are essentially comprised of a long thin tube that may be open at the top and have either a single or double check valve (double-valve check designs are used to collect groundwater samples at a specific depth). These samplers are connected to a suspension cord (e.g., string or cable), lowered into the water column, and then pulled back to the surface to retrieve the water. This water can be purged or collected in a container for analysis (e.g., sample bottles for lab analysis, or other containers for onsite measurement of water quality parameters). As the bailer is lowered through the water column, the check valve opens and water can enter the tube (and notably, the bailer will pass through and be filled by water throughout the water column until the point at which it is pulled up). On retrieval, the pulling-up action causes the bailer check valve to close allowing the water sample to be brought to surface.

Bailers can be made of polyvinyl chloride (PVC), stainless steel, polyethylene (PE), or polytetrafluoroethylene (PTFE, also known by its trade name: Teflon). PVC or PE bailers are the cheapest and may be single use (i.e., disposable after sampling) or dedicated to a well (i.e., left hanging in the well casing for future use, or labelled for that well and stored elsewhere). More expensive bailers (e.g., stainless steel) may also be used at multiple sites and therefore require decontamination between use.

Bailers can be used to sample from any depth as they are only limited by the length of cord available to suspend the bailer, and come in many diameters, including very small diameters, to allow for use in narrower wells and for collection of different sample sizes. However, using bailers in deep wells with large volumes of water can be labour-intensive due to the potentially large purge volumes required and the manual effort to repeatedly raise and lower the bailer during purging; in these situations, a winch may be used to aide in the purge process. In consideration of this (irrespective of their relative simplicity, low cost, and portability), bailers are typically employed to purge and sample shallow and / or smaller diameters wells, or in remote sites where accessibility is limited (BC MOECCS 2021).

It should be noted that bailer use will result in agitation of the water column during purging and sampling, which can result in mixing, aeration, generation of significant turbidity, and loss of dissolved gases and VOCs. Numerous studies have shown that it is difficult to collect accurate samples for analysis of several parameters, including VOCs and metals, if a well is purged using a bailer (Nielsen 2007). It should also be noted that bailer check valves may not work well in highly turbid water due to sediments partially or fully plugging the valves, resulting in leakage or poor sample collection.

Waterra

Please note that use of Waterra tubing as a purge and sample method should be avoided at Provincial Observation Wells as it is more likely to result in biased samples and / or is not feasible due to the depth and volume of most PGOWN wells. The following information is included in the Manual in the unlikely event that such a sampling method is the only suitable option for a particular Provincial Observation Well.

Waterra tubing (**Figure 2-11** – right image) is a type of inertial lift pump that consists of tubing to which a ball-check foot valve is screwed on its bottom end. The end of tubing which has the foot valve attached is lowered to the desired pumping depth. The tubing is then oscillated (pulled up and pushed down) over a short vertical range by hand or with an actuator (e.g., a Waterra power pump). Pushing the tube down causes the foot valve to open, filling the tube with water. Pulling up on the tube causes the foot valve to close, allowing the water to rise in the tubing. The ongoing pumping motion is continued until water discharges out of the tubing at surface (BC MOECCS 2021).

Standard Waterra tubing is generally constructed of either high density polyethylene (HDPE) or low-density polyethylene (LDPE). Waterra tubing diameters range from 0.006 m to 0.025 m (outer diameter (OD) of the tubing). Nano tubing (0.006 m OD) is generally used in very narrow wells or piezometers, or when a very low-flow rate (about 1 L/min) is required. High-flow tubing (0.01 m OD) is used at deeper wells (up to 90 m) 0.05 m to 0.1 m in diameter; pumping rates of up to 15 L/min can be achieved under these conditions (Waterra Website). Standard-flow tubing (0.015 m OD) is most commonly used, and has a maximum flow of 3.8 L/min. Similar to bailers, Waterra can be single use or dedicated to a well (i.e., left within the well casing, or labelled for that well and stored elsewhere).

Waterra has a practical depth limitation (90 m) based on the weight of the groundwater within the tubing when it is pulled up to the surface. However, Waterra is perhaps more appropriate than bailers for purging large well volumes, given the faster pumping rate and ability to use a powered actuator (gas or battery powered) to perform the up-and-down pumping motion.

It should be noted that rapid pumping with inertial lift pumps can agitate the well, causing an increase in turbidity and aeration. These conditions may result in losses of VOCs and dissolved gases and affect pH and metals precipitation. The ball valve may also become clogged or held open by sediment and require flushing. The foot valve and tubing may have to be removed for monitoring or slug testing, causing a change in water levels within the well. Prior to proceeding with measurements or testing, it is necessary to wait for the well to reach static conditions (BC MOECCS 2021).

Figure 2-11 Examples of Bailers (left) and Waterra tubing and foot valves (right).

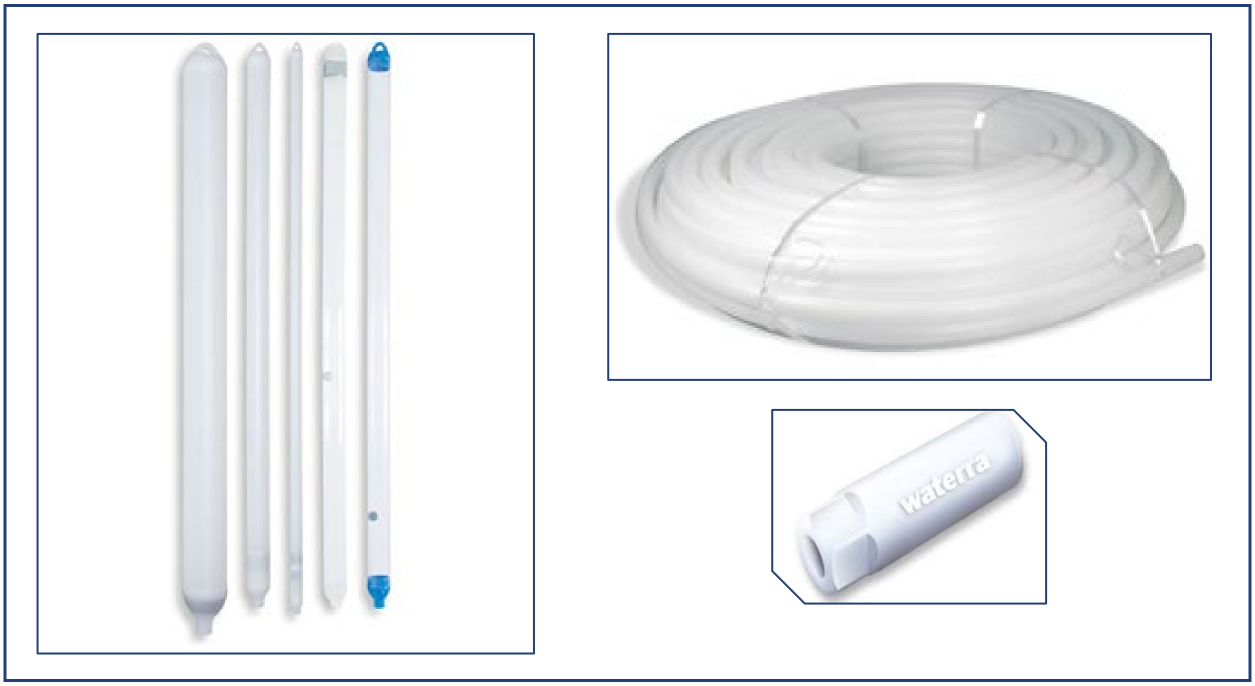


Photo source: Waterra 2002a and Waterra 2002b.

2.5.3.2 Low-Flow Methodology

Low-flow sampling is an approach to sampling based on the observation that groundwater flows through a formation and well screen, and that flow can be sufficient to maintain a constant exchange with formation water surrounding the screen (thereby reducing the potential for water quality changes through contact with well casing and / or diffusion from overlying stagnant water above the screen). This method assumes that at low pumping rates there is little mixing within the water column due to predominantly laminar groundwater flow through the screen to the pump. As such, the objective of low-flow sampling is to collect samples from the screened portion of the well, and at a rate that does not stress the groundwater system or exceed the rate of groundwater entering the well. Sampling and purging are typically done at the same constant low rate, unlike traditional purge and sample methods. Pumping at a sufficiently low rate (such that groundwater levels are stable during pumping, indicating that groundwater inflows to the well match pumping rates and water is not being drawn from well storage) effectively hydraulically isolates the screened interval of the well from the overlying (stagnant) casing water, so only the screened interval is sampled (Nielsen 2007). This means that low-flow sampling is not suitable at open hole wells or those with well screens in poor condition or poorly constructed (e.g., infilled with sediment or covered with biofouling).

The pump intake should sit in the middle or slightly above the middle of the screened interval, if the water level is above the top of the well screen. However, if the water level sits within the well screen, the pump intake should be placed in the middle, or just below the middle of the water column. If the pump intake is too close to the bottom, there is an increased possibility of solids sitting on the bottom of the well becoming suspended and entering the pump. Conversely, if the pump intake is too close to the top of the water column, there is a chance that water stored in the casing (stagnant water) will be included in the sample (Nielsen 2007).

The advantages of this method include:

- Reduced sample turbidity (relative to more aggressive pumping methods), which can provide more representative results for parameters that are associated with particulates (e.g., LEPHw, PAHs, some metals);
- A lower chance of sample aeration and degassing or stripping of VOCs;
- The volume of purged groundwater is much less than a standard purge method; and
- Purge and sample times may also be reduced (see **Table 2-3**).

However, since minimal drawdown and groundwater stabilization is required, this method is not applicable to wells with very low well yields (typically wells screened within fine-grained formations). Water levels need to be continuously monitored and pumping rates should be adjusted during low-flow sampling to ensure minimal drawdown and groundwater level stabilization. Typically, low-flow sampling starts with a pumping rate of 0.1 L/min and is then adjusted depending on drawdown. The method is therefore limited to variable-flow pumps that are capable of pumping at steady, low-flow rates (e.g., bailers or inertial lift pumps are not suitable).

It may be worth noting that low-flow methods may draw water from a smaller vertical interval within the screen and may not reflect the average groundwater quality across the length of the screen. This may be more of an issue for wells with long screens.

Peristaltic pumps

Peristaltic pumps (or peri-pumps) are a type of suction-lift device that are operated at ground surface. Peri-pumps comprise a pump and attached tubing line. The peri-pump itself has a rotor with rollers; these rollers squeeze a short section of flexible tubing (ideally Tygon tubing as sorbing can occur with silicon tubing) as they revolve within a housing (**Figure 2-12**, left image), creating suction within a longer attached LDPE or PTFE-lined LDPE tubing line (usually 6 to 13 mm diameter) in the well. One end of the long tubing line is placed inside the well at the desired intake depth (midpoint of the screen) and the other end discharges purged groundwater at ground surface. Peri-pumps are suitable for use in shallow wells where there is a maximum groundwater lift of about 7 to 8 m.

The pumping rate of a peri-pump can be adjusted by varying the rotor speed. Flow rates typically range from 0.05 to about 4 L/min. The lower pumping rate makes this type of pump suitable for low-flow sampling.

Peri-pumps cause minimal amounts of agitation and can be used in small diameter wells. Aside from their limitation on sampling depth, the main disadvantage of these pumps is that the suction in the tubing line can cause degassing or volatilization of VOCs and dissolved gases from groundwater, if present. This may also indirectly impact other parameters in water such as pH, hardness / alkalinity, metals and gases. Therefore, peristaltic pumps are most suited for the collection of samples being tested for major ions, and not for properties which may be sensitive to oxygen contamination or volatilization (Nielsen 2007, BC MOECCS 2021)

Bladder Pumps

A bladder pump is a type of positive displacement pump with attached tubing lines and requires compressed gas and a controller to operate. These pumps and tubing are lowered to the desired sampling depth, and work by pushing water to ground surface via injection of a compressed gas (**Figure 2-12**, right image). Groundwater is lifted to the surface using alternating periods of gas injection (drive period) and a vent period that allows groundwater to refill the pump and tubing line. During the drive period, a bottom check valve is closed which forces groundwater contained within the pump up the discharge tubing line. A second check valve at the top of the pump prevents any groundwater from flowing out of the discharge tubing line and back into the pump body during the vent period (Solinst 2012).

Bladder pumps achieve a maximum lift of up to 70 m bgs if using a standard controller and compressor. For greater depths (up to 150 m bgs), a high-pressure controller and compressed nitrogen are required. These pumps can be used for both regular or low-flow sampling, as the flow rate is controlled by adjusting the drive gas pressure or cycle timing. Flow rates can range between approximately 100 mL/min to 3,500 mL/min depending on the size of the pump, tubing and groundwater level.

These pumps can provide a representative groundwater sample for all parameters since gas from this sample method does not come into contact with groundwater. Inert gases, such as nitrogen or helium, should be used to prevent impurities due to this slight interface between the drive gas and groundwater. These systems are portable but do require decontamination if being used between wells. Decontamination is relatively simple and the units are field serviceable. In addition, turbid or dry conditions will not impact the unit, which often can impact (overheat) submersible pumps. (BC MOECCS 2021).

Figure 2-12 Examples of low-flow sampling instrumentation, such as peristaltic pump sampling from a drive-point piezometer (top left), the peri-pump operating mechanism (bottom left), bladder pump (top right) and bladder pump in operation (bottom right).

Photo sources: Top left and right (Solinst 2023), bottom left (Solinst 2018) and bottom right (Solinst 2012).

2.5.3.3 No Purge Methodology

No-purge sampling is based in the observation that groundwater flows through the screen in most wells with sufficient velocity to maintain a constant exchange with formation water surrounding the screen (similar to low-flow sampling). It essentially involves the collection of a single grab sample directly from within the screened interval (although the instrumentation / equipment is usually inserted into the well sometime prior to sampling to ensure it is equilibrated with the ambient water), and therefore no purging is required (see **Table 2-4**). This method obtains representative samples of groundwater under ambient (not induced or pumped) flow conditions prior to collecting samples (Nielsen 2007).

This method does rely on high-quality well construction that allows ambient formation flow horizontally through the well screen with little or no mixing. The natural horizontal groundwater flow across the well screen should be sufficiently high to ensure that groundwater conditions in the formation are similar to those in the wells, which would suggest that this method is most suited to sand and gravel aquifers of high hydraulic conductivities. However, the method may also be suited to sampling low-yield formations where well-volume and low-flow purging may not be practicable or suitable (BC MOECCS 2021).

One of the main benefits of using this method is that no purge water is generated, and complexities inherent to purging are generally not applicable (e.g., less equipment is required, reduced sampling time, etc.).

Some disadvantages with this method include:

- Limited sample volumes;
- Less suitable for wells with long screens as groundwater may be drawn from a smaller vertical interval within the screen and may not reflect the average groundwater quality across the length of the screen; and
- Potential inability to measure in-situ water quality (e.g., from pumped water during purging with the other methods) due to sample size.

HydraSleeves

HydraSleeves, like bailers, are also classified as grab samplers. HydraSleeves essentially comprise a flattened, elongated sampling bag (which by design incorporates a sleeved top, which acts like a valve), a suspension cord, and optional attached weights (bottom weight, and / or top weight). They are lowered to the desired depth within the well screen. HydraSleeves are lowered into the well / water column flat and empty, with the top / valve remaining closed during deployment. When they are retrieved, the top opens up allowing the device to fill with water as it is pulled up. Once the sleeve is full, the top seals and remains so until the HydraSleeve is recovered. They should be retrieved or pulled up through the length of the well screen at a rate of about 0.3 m/second. Multiple HydraSleeves can also be connected together to increase sample volumes, but the total length of HydraSleeves should not exceed the length of the well screen. Multiple connected HydraSleeves can also be deployed at select intervals to collect samples from discrete depths (BC MOECCS 2021, Nielsen 2007).

Unlike bailers, HydraSleeves do not require purging of the water column prior to sampling. These disposable samplers are made with LDPE materials and can collect representative samples for all chemical parameters from any depth within a well's screened interval (**Figure 2-13**). HydraSleeves do not agitate the well and the sample is not exposed to the air (Nielsen 2007).

Although sample volumes are limited with HydraSleeves (approximately 1 L of sample per standard sized HydraSleeve), labs often only need 10 – 25% of the sample volume that is requested. It is best to check with your lab to determine minimum volumes and ensure that adequate sample volumes can be obtained through the use of HydraSleeves (Nielsen 2007). The current analytical package used at most Provincial Observation Wells requires less than 1 L of groundwater for the combined volume of the sample bottles. Different dimensions of HydraSleeves are available depending on the diameter of the well, the well screen length, and the required sample volume. It is critical to ensure the well screen is in good condition, and of suitable length for the selected HydraSleeve model.

The HydraSleeve field operating instructions and manual from the manufacturer can be found in **Appendix A4**.

Figure 2-13 Example of a no-purge method: HydraSleeve.

Photo source: HydraSleeve, 2023.

2.5.4 Groundwater Quality Field Parameter Measurements

Select chemical and physical parameters are measured when using both purge and low-flow sampling methods. These parameters are used to assess specific in-situ groundwater quality parameters as well as to determine when groundwater geochemistry has stabilized during the purging process, indicating that formation-quality water is entering the well. These field parameters are recorded both during the purging process and immediately prior to sampling, as they can provide an indication of groundwater quality and reduction-oxidation conditions once stable readings are achieved. These physiochemical parameters are measured using a multiparameter sonde (such as a YSI multiparameter meter) and / or individual meters and typically include:

- Temperature (°C);
- pH;
- Specific Conductivity (SC; µS/cm);
  - Specific conductivity standardizes the measurement to 25 °C which allows for easier comparison of results between sites. As such, conductivity or electrical conductivity should not be monitored and recorded.
- Dissolved Oxygen (DO; mg/L);
- Turbidity (NTU); and

- Turbidity is not currently monitored during PGOWN sampling events, but it is monitored during well development following well installation (see **Section 5.9**). Regions can choose to add turbidity to the list of field parameters monitoring during sampling events.

- Oxidation-Reduction Potential (ORP; mV).

These parameters are ideally measured directly using a downhole probe to avoid the presence of air (particularly for pH, DO, and ORP). However, this is often not possible and so a flow-through cell is typically used at Provincial Observation Wells which limits the effects of atmospheric conditions on groundwater. A flow-through cell is generally a cylindrical container with an input port, output port, a sealed bottom, and an open top where the multimeter is screwed into. The pump discharge tubing is attached to the intake tube of the flow-through cell, such that water fills from the bottom of the cell up to and out of the output port, and the multiparameter probes are thus submerged without the water being exposed to the atmosphere. The multiparameter meter is used to continually record the aforementioned parameters (BC MOECCS 2021, Nielsen 2007). Please note that the flow rate should be limited to <1 L/min in the flow-through cell as higher flow rates can entrain gases around the multimeter probes and change water chemistry.

If multiparameter meters are not calibrated, are incorrectly calibrated, or calibrated using expired solutions, the measurements obtained could be significantly impacted. Field equipment should be calibrated daily, when sampling, and ideally under operating conditions (i.e., in the field). Where possible, multi-point calibrations are preferred over single point calibrations for improved accuracy for most parameters (Nielsen 2007). Field Technicians can refer to the **Groundwater Sampling Multiparameter Meter Calibration, Maintenance and Storage SOP** in **Appendix A3** (**Section A3.2**), along with a **Multiparameter Meter Calibration Record** template (also saved on the **PGOWN MS Teams Channel**) to track calibration results.

The multiparameter sonder currently used at Provincial Observation Wells is the YSI Pro Plus. The YSI operating and maintenance instructions from the manufacturer can be found in **Appendix A4**.

Parameter Stabilization During Purging

During well purging, groundwater quality indicator parameters should be measured periodically (e.g., every 10 to 15 minutes). These parameters are considered to have stabilized when, after purging is complete, subsequent parameter values fall within an acceptable range (specified in **Groundwater Sampling SOP** in **Appendix A3** (**Section A3.1**). A final recording of groundwater indicator parameters should be taken following post-purging and prior to sampling to document the groundwater quality values at the time of sampling. These results must be recorded on a field form, along with water level readings, to demonstrate stability (see **Groundwater Sampling Field Sheet** in **Appendix A3** (**Section A3.1.5.1**) and the **PGOWN MS Teams Channel**).

There are times when stability is not achieved during sampling. Issues impacting stability may include multiparameter meter calibration problems, sensor conditioning, leakages, and flow rates. Additionally, some sensors, such as DO and pH, can take an extended period of time to stabilize.

Standard groundwater quality parameters (e.g., SC, pH, and turbidity) are also routinely measured in the laboratory. These may be used to assess potential changes in chemistry during transport. Some parameters can be reactive and have low hold times (e.g., pH has a hold time of 15 minutes); significant changes in the aforementioned parameters between the field and the lab could be indicative of a secondary reaction having occurred. If a significant change between field and laboratory measured parameters is noted, both the sampling and preservation procedures should be reviewed.

Beyond indicating stabilization during purging, water quality indicator parameters can be utilized in quantitative geochemical calculations or the semi-quantitative assessment of water quality. For example, high EC measurements can indicate the presence of salinity (BC MOECCS 2021, Nielsen 2007).

2.5.5 Collecting Groundwater Quality Samples

Table 2-4 provides a summary of the minimum purge volumes and groundwater quality field parameter stabilization requirements that should be achieved and used to help determine when to collect a sample. If these criteria cannot be achieved, a Groundwater Monitoring Specialist should be contacted and an alternative sampling plan should be discussed for the Provincial Observation Well.

Table 2-4 Groundwater quality sample collection criteria.

Sampling Methodology	Minimum Purge Volume	Groundwater Quality Parameter Field Stabilization Criteria
Purge	Three well volumes; or purged dry if a slow recharge well.	Parameter stabilization achieved prior to collecting sample (see **Groundwater Sampling SOP**).
Low-flow	One well volume.	
No Purge	N/A.	N/A.

2.5.6 Field Sampling QA/QC Procedures

Quality Assurance (QC) and Quality Control (QC) are essential to ensure that the data being generated are accurate and precise within a minimum bias. Field QA/QC procedures are used to monitor the quality of groundwater quality data collected in the field. Standard field programs include collection and analyses of additional samples to assess QA/QC. The following subsections define various types of QA/QC samples.

Field Technicians can refer to the **Quality Assurance and Quality Control for Groundwater Sampling SOP** in **Appendix A3** (**Section A3.3**) for details on field QA/QC procedures, including reviewing ionic balance results and calculating relative percent difference.

Field Duplicates

Field duplicates are collected to assess the precision for each analyte analyzed within the two samples (BC MOECCS 2013). This entails collecting two or more samples in quick succession from the same location which should capture some of the variability of the groundwater and potential problems with the analysis or reporting of results (BC MOECCS 2013).

Field Blanks

Field blanks are samples of deionized water, collected in the field to assess potential bias or contamination in the ambient environment. The process of filling them in the environment exposes them to the sampling environment and this set can be used to quantify the extent of potential contaminants present in the sampling zone (Nielsen 2007).

Trip Blanks

Trip blanks are pre-filled sample bottles from the laboratory which are handled throughout the sampling program. They are used to determine if sample bottle preparation, delivery of the bottles to the field, or handling and storage procedures have had an impact on sample integrity (Nielsen 2007).

2.5.7 Sample Preservation, Storage & Delivery

2.5.7.1 Sample Preservation

Preservation of groundwater quality samples is intended to minimize physical and chemical changes to the sample which could occur following collection (e.g., via exposure to air or sample container). Chemical changes could include precipitation or volatilization of analytes of interest, amongst others.

Preservation requirements and methods depend on the analyte of concern and are set by the laboratory that will be analyzing the collected samples (BC MOECCS 2013):

- Chemical methods:
  - Addition of acids;
- Physical methods:
  - Using the appropriate bottle for the parameter(s) to be analyzed (e.g., amber sample containers to block sunlight);
  - Field-filtering of samples;
  - Bubble wrapping the bottles to prevent breaking of sample containers; and
  - Controlling the sample temperature (samples should be maintained at a temperature between 0 to 10 °C).

Sample bottles should also be filled and sealed as quickly as possible to reduce sample exposure to the atmosphere and / or other elements that can alter the concentration of the parameter of interest (e.g., rain, snow, open air, etc.).

Preservation should be completed during or immediately after sample collection (e.g., field-filtering samples for dissolved parameters, adding acid preservative to sample bottles [if not pre-charged] as soon as the bottle has been filled, placing the filled bottles in a cooler filled with ice, etc.) (BC MOECCS. 2013).

2.5.7.2 Storage and Transport

Immediately after filling and preserving a collected sample bottle, the bottle should be placed in a cooler (glass bottles should also be wrapped in bubble wrap) that is filled with frozen ice packs or double-bagged ice. A cooler is used to assist with sample preservation (**Section 2.5.7.1**) (i.e., physical preservation by maintaining a constant temperature and physically protecting the collected bottles during transport).

Each parameter within a suite of collected groundwater quality samples has a maximum holding time before the sample must be analyzed by the lab. Holding times are the period between when a sample is collected and then analyzed by the lab. Holding times can range from a few minutes (e.g., 15 min for pH) to several weeks (e.g., up to 180 days for metals) (ALS 2018). While collected samples can be stored in a cool climate-controlled environment (e.g., a sample fridge with an ideal temperature of <10 °C), hold times must be considered and samples are ideally shipped to the lab with more than half of the hold time remaining.

It is best practice whenever possible to transport and submit collected groundwater quality samples to the analytical laboratory at the end of each day. This could include packaging and shipping samples via courier or dropping the samples off at the lab at the end of each day. This approach reduces the potential for samples to exceed hold times, minimizes sample handling by the Field Technician and reduces the risk of sample integrity becoming compromised. All samples and coolers dropped off at the laboratory need to be accompanied by a chain-of-custody (CoC). An example of a completed sample CoC is shown in **Figure 2-14**.

Figure 2-14 Example of a sample CoC to be submitted to a lab.

WATER, GENERAL CHEMISTRY AND BACTERIOLOGICAL REQUISITION ALS Global

Province Of British Columbia
Ministry of Environment

Req # 50259888

Urgent?	
Csr No.	12887
Office	60
Client	W4
Study	
Project	ENDAKO
Lab	ALS Global
Ministry Contact	BRJACKSO Bryan Jackson
Sampler	Abby Morgan
Signature	
EMS Id	E323571
Well Plate #	
Location	OBS WELL 501 - KITIMAT

Sampling Agency	
Code	60
Name	Skeena
Address	3726 Alfred Avenue, Bag 5000
City	Smithers
Postal Code	V0J2N0
Phone	(250)847-7260
Number of Containers	

Instructions To Lab: FIELD FILTERED AND PRESERVED FOR DISS.METALS AND NUTRIENTS. FIELD PRESERVED FOR TOTAL AMMONIA.

State FW Descriptor GE Collection Method GRB

No.	Class	Collection Start YYYY-MM-DD HH:MI	Collection End YYYY-MM-DD HH:MI	Depth Upper	Depth Lower	Tide	Comment
1	REG						
2							
3							
4							
5							
6							

GENERAL (250 mL PLASTIC)

	Acidity pH 8.3
	Alkalinity Titration Curve
	Alkalinity: Total: pH 4.5
	Alkalinity: Phenolphthalein
	(500 mL Plastic) Biochemical Oxygen Demand (BOD)
	Bromide
	(500 mL Plastic) Carb. Biochem. Oxygen Demand (CBOD)
	Carbon: TIC
	Chloride
	Colour: True
	Fluoride
	Nitrogen: Nitrate and Nitrite
	Nitrogen: Nitrate
	Nitrogen: Nitrite
	pH
	Phosphorus: Diss. ortho-phosphate
	(500 mL Plastic) Residue: Filterable (TDS)
	(500 mL Plastic) Residue: Nonfilterable (TSS) Subsample 3 mg/L LOR
	(500 mL Plastic) Residue: Nonfilterable, Fixed
	(500 mL Plastic) Residue: Total (TS)
	Specific Conductance
	Turbidity
	Sulphate

GENERAL NUTRIENTS (125 mL AMBER GLASS) - H2SO4

	Carbon: TOC
	Chemical Oxygen Demand (COD)
	Nitrogen: Ammonia
	Nitrogen: Total
	Nitrogen: Total Kjeldahl
	Nitrogen: Total Organic
	Phosphorus: Total

GENERAL (125 mL AMBER GLASS) - FIELD FILTER, H2SO4

	Carbon: DIC (Field Filter)
	Carbon: DOC (FF, H2SO4)
	Nitrogen: Dissolved Kjeldahl (FF, H2SO4)
	Nitrogen: Total Dissolved (FF, H2SO4)
	Phosphorus : Total Dissolved (FF, H2SO4)

METALS: TOTAL

High	Low	
		Metal Pkg. (ICPMS) - HIGH (60 mL Plastic) - HNO3
		Metal Pkg. (ICPMS) - LOW (60 mL Plastic) - HNO3
		Mercury - 40mL Glass, HCl
		Hardness (60 mL Plastic) - HNO3

METALS: DISSOLVED

High	Low	
		Metal Pkg (ICPMS) - HIGH (60 mL Plastic)-Field Filter, HNO3
		Metal Pkg. (ICPMS) - LOW (60 mL Plastic)-Field Filter, HNO3
		Mercury - 40mL Glass, Field Filter, HCl
		Hardness (60 mL Plastic) - Field Filter, HNO3

SPECIFIC Tests

X	Obs Well Package
	Cyanide: SAD (60 mL Plastic + NaOH)
	Cyanide: WAD (60 mL Plastic + NaOH)
	Sulphide: Total (125 mL Plastic, ZnAc & NaOH)
	Residue: Nonfilterable (TSS) -Whole Bottle - 1 mg/L LOR (150 mL Plastic)
	Chlorophyll a (250 mL Brown Plastic Bottle or Filter) Vol:
	Phaeophytin (250 mL Brown Plastic Bottle or Filter) Vol:

ORGANICS

	BTEX (2 X 40 mL glass vials, NaHSO4 or Na2S2O3, No headspace)
	VOC Full List (2 X 40 mL glass vials, NaHSO4 or Na2S2O3, No headspace)
	Volatile Hydrocarbons (VH) (2X40 mL glass vials, NaHSO4 or Na2S2O3, No headspace)
	Trihalomethanes (THM) (2 X 40 mL glass vials, NaHSO4 or Na2S2O3, No headspace)
	VPH (2 X 40 mL glass vials, NaHSO4 or Na2S2O3, No headspace)
	EPH (2 X 100 mL Amber Glass, NaHSO4)
	PAH (2 X100 mL Amber Glass, NaHSO4)
	LEPH/HEPH (Calc) (2 X 100 mL Amber Glass, NaHSO4)
	Oil & Grease (2 X 250 mL Amber Glass, 2 mL 1:1 HCl or 1:1 H2SO4)
	Mineral Oil & Grease (2 x 250 mL Amber Glass, 2 mL 1:1 HCl or 1:1 H2SO4)
	Organochlorine Pesticides (OCP) (2 X 500 mL Amber Glass)
	Organophosphorus Pesticides (OPP) (2 X 500 mL Amber Glass)
	Polychlorinated Biphenyls (PCBs) (2 X 500 mL Amber Glass)
	Chlorophenols (Tri, Tetra & Penta) (2 X 500 mL Amber Glass, C6H8O6 & NaHSO4)
	Phenolics, Chlorinated (2 X 500 mL Amber Glass, C6H8O6 & NaHSO4)
	Phenolics, Non-Chlorinated (2 X 500 mL Amber Glass, C6H8O6 & NaHSO4)
	Phenols, Colorimetric (125 mL Amber Glass, H2SO4)
	Acid Extractable Herbicides (2 X 1 L Amber Glass, NaHSO4)
	Resin Acids (2 X 500 mL Amber Glass, C6H8O6 & NaHSO4)
	Fatty Acids (2 X 500 mL Amber Glass, C6H8O6 & NaHSO4)

BACTERIOLOGY

	E. coli - MF
	Enterococci - MF
	Fecal coliform - MF
	Fecal coliform - MPN
	Fecal streptoc - MF
	Total coliform - MF
	Total coliform - MPN

OTHER Tests

Smpl No.	FIELD TEST Details	Method Results	Units

2.5.8 Equipment Decontamination

Decontamination is considered a low priority for groundwater sampling at Provincial Observation Wells in the PGOWN for the following reasons:

- Provincial Observation Wells are not accepted into the network if they are contaminated (and awareness that they are not invincible to contamination throughout their life span);
- Most common sample collection methodology is using a submersible pump (e.g., Grundfos pump) which is difficult to decontaminate between site visits without removing and flushing all of the tubing and washing the pump and cables; and
- Groundwater samples are analyzed with the intent of understanding general groundwater hydrochemical characteristics (i.e., not contamination or high-resolution analytical results).

However, it is still important to understand the decontamination process and what to do should this be required.

Ideally, any equipment that comes into contact with groundwater and is intended for use at multiple monitoring locations (i.e., is not dedicated or disposed / replaced) must be decontaminated (if possible) after use to avoid cross-contamination. However, this is not always possible and is equipment specific.

Decontamination should include the following three-step process and is intended to minimize sample bias and uncertainty:

1. Washing with detergent / potable water solution using a brush made of inert materials to remove any particles or surface film. Alconox should not be used as a detergent as it contains phosphates.
2. Rinsing with control / potable water. Control water can include tap water, bottled water, distilled water, deionized water, or organic-free water.
3. Rinsing with deionized water.

In addition to helping prevent cross-contamination, cleaning and decontaminating equipment is also helpful to prolong the operational life of the equipment and minimize large maintenance repairs.

2.6 STATION MAINTENANCE

2.6.1 General Station Maintenance

General station maintenance should be undertaken during each site visit to a Provincial Observation Well. The objective of this is to maximize the longevity of the station instrumentation by minimizing potential degradation, and to maintain suitably tidy conditions for the public and / or property owners.

During each site visit:

- Wipe down the inside and outside of the wellhead cabinet / protective casing;
- Remove any insect nests that may have developed (if safe to do so);

- Check the pressure transducer is securely suspended and the depth will not change;
- Remove garbage from the immediate area around the observation well; and
- Remove excess vegetation that is beginning to grow around the observation well (see **Figure 2-15**).

Figure 2-15 A Provincial Observation Well with excessive vegetation build-up (left) and after brush-clearing (right).

Photo source: BC ENV.

2.6.2 Telemetry Station-Specific Tasks

In addition to the general station maintenance tasks listed above, telemetry stations also require the following tasks to be completed during each site visit:

- Clean the following components:
  - Solar panel (wipe with a damp cloth to remove dust and / or mold);
  - Antenna (if accessible, wipe with a damp cloth to remove dust and / or mold);
  - Battery terminals (with a wired brush and only after disconnecting equipment, if corrosion is observed) and apply Vaseline to protect and prevent further corrosion;
- Check tightness of all bolt and electrical connections inside the wellhead cabinet (e.g., battery terminals, cable connections, etc.);
- Check voltage of the battery (should be >12 V);
- Change the desiccants in the desiccant enclosure; and
- Confirm that software or firmware updates are not required.

3.0 MISCELLANEOUS FIELDWORK PROCEDURES

This section details other common procedures expected to be completed by field staff as part of the proper operation of the PGOWN.

3.1 SITE SURVEYING

All Provincial Observation Wells report groundwater level data with reference to ground depth. However, reporting groundwater elevation data using sea level as the reference point is typically more useful as this allows datasets from different locations to be comparable. For example, if there are multiple wells in the same aquifer, the groundwater elevation datasets from each site can be used to determine groundwater flow direction.

Professional surveyors use established datums (a reference or reference point for precisely representing the position of locations on Earth) to measure the coordinates of features of interest. Vertical or height reference systems define geographic elevation and depth relative to sea level. The current height reference system in BC is based on the Canadian Geodetic Vertical Datum of 1928 (CGVD28) which was adopted in 1935. However, this datum is being updated as Canada is introducing a new datum known as the Canadian Geodetic Vertical Datum of 2013 (CGVD2013). The new datum will result in changes to benchmark elevations across BC. The new primary vertical benchmark elevations will differ from the current published elevations by up to 50 cm, depending on the area of the province (refer to GeoBC website for details). Provided that surveyed Provincial Observation Wells are using the same datum (e.g., CGVD2013), the elevation results will be comparable.

A geodetic survey of a Provincial Observation Well's Universal Transverse Mercator (UTM) coordinates and elevation (reported as metres above sea level [m asl]) must be completed at all stations. The UTM coordinates can later be converted to latitude and longitude using available online converters. Moreover, a surveyor should ideally produce a site plan (**Figure 3-1**) which will plot the Provincial Observation Well's location with reference to property boundaries and other landmarks (e.g., road edge).

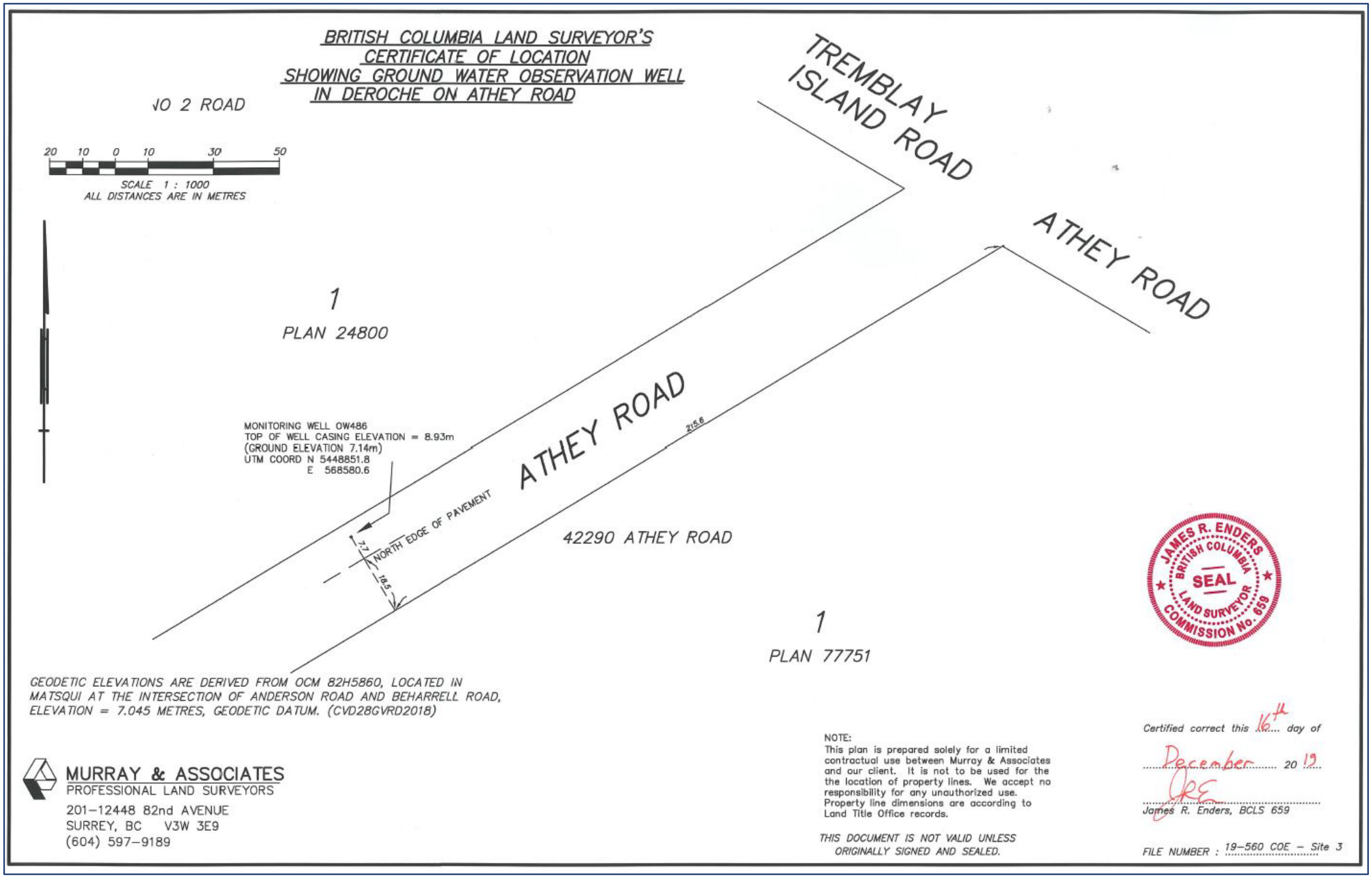
All active Provincial Observation Wells must have up-to-date surveys and elevation datasets set-up in Aquarius (**Section 4.2.1**). Newly installed wells should be surveyed upon installation or before the well is entered into Aquarius.

When an elevation survey is being completed, the following should be noted and completed:

- The surveyor should collect a measurement from the reference point that is used when collecting manual groundwater level measurements (i.e., top of pipe or bottom of wellhead cabinet).
    - Upon receiving the survey results, the Field Technician must then subtract the established stick-up height from the reported elevation value. This calculated ground elevation will then be used as the official station elevation.
    - The surveyor should also measure the ground elevation which can act as a "check" on the calculated ground elevation produced by the Field Technician as described in the bullet point above.

- The datum and coordinate system are used.
- All database systems must be updated with the calculated ground elevation value, and latitude and longitude, including Aquarius (‘Location Information’ and elevation dataset), EMS, GWELLS, and the **PGOWN Equipment & Station Information Spreadsheet** on the **PGOWN MS Teams Channel**.
  - Note that updating this information in Aquarius will automatically update the Groundwater Level Data Interactive Map.
- The site plan produced by the surveyor should be sent to the Groundwater Monitoring Program Supervisor.

Figure 3-1 Example survey site plan.



3.2 OBSERVATION WELL DIAGNOSIS AND RESOLUTION

The ability of observation wells to facilitate the collection of representative (unbiased) hydrogeological data may be impacted by poor well installation or development, as well as by physical damage or natural processes over time. Some examples of problems or issues include:

- **Insufficient casing stick-up or compromised surface seal**: poor well completion can increase the potential for seepage of surface water into the well;
- **Damaged casing**: well casings (PVC or steel) can become accidentally damaged or compromised over time (e.g., with cracks or joint separation) which results in a pathway for material and debris (e.g., sediment, surface runoff, higher groundwater bearing intervals, etc.) to enter the well; and
- **Well screen plugging (including the filter pack)**: this can be the result of physical, mineral (chemical), or biological blockage within the screened interval over time. Physical processes could include the movement and accumulation of fine sediments into the well zone. Chemical processes could include reduction or oxidation and precipitation of minerals due to exposure to different water quality conditions in the well zone. Biological processes could include bacterial growth on a well screen, resulting in a slimy biofilm which eventually hardens as mineral particulates adhere to the biofilm and accumulate (Driscoll 1986) (**Figure 3-2** and **Figure 3-3**).

Potential problems may be directly or indirectly indicated by observations in the field or upon review of groundwater quality or level data. Some observations may also need follow-up actions (e.g., downhole camera inspection, slug testing, etc.) to confirm the actual presence of an issue which is affecting monitoring or the representativeness of collected data, whereas others clearly indicate the presence of damage or unsuitable conditions.

Many problems can potentially be resolved by remedial actions. For example, poor surface completion could be remedied by grading the ground surface away from the Provincial Observation Well and / or extending the height of the stick-up. More complicated options could include redeveloping the well using chemical and mechanical processes or deepening the well (in the case of unlined bedrock wells). In limited cases, it may also be most cost effective to close and decommission the Provincial Observation Well and drill a new well if ongoing monitoring of that aquifer is recommended. Depending on the work that needs to be completed to resolve the issue, a Regional Hydrogeologist or Groundwater Monitoring Specialist should be consulted prior to any redevelopment, well deepening, or other major alterations. This is to confirm the proposed approach is a suitable path forward to resolve the issues with the observation well. Once the hydrogeologist has been consulted, it may be necessary to engage with a drilling contractor to support the necessary next steps (e.g., procure the necessary skilled services and equipment for well redevelopment).

Table 3-1 summarizes some observations that may be indicative of potential issues, their causes, consequences, next steps, and resolutions.

Table 3-1 Observations indicating potential issues, along with their causes and resolutions.

Observation	Potential Issues	Potential Consequences	Potential Causes	Potential Next Steps (to confirm issue)	Potential Resolution
Surface runoff pooling around wellhead	Potential for increased seepage into formation / well.	▪ Surface runoff may infiltrate into the formation and / or well. ▪ Groundwater quality results are not representative of groundwater conditions. ▪ Groundwater levels are artificially elevated.	▪ Ground surface is not sloped away from the wellhead. ▪ Wellhead is located in a pit or sump.	N/A.	▪ Extend the wellhead above ground surface so it is in compliance with the Groundwater Protection Regulation (2022). ▪ Grade surface around well so that surface water does not pool around the well. ▪ Consider redevelopment with a chemical treatment if seepage into the well is confirmed.
Elevated groundwater sample turbidity	Sediments entering well.	▪ Increased time required to achieve parameter stabilization during groundwater sampling events. ▪ Groundwater quality results may not be representative of groundwater conditions.	▪ Poor well development. ▪ Unsuitable well screen size / sand pack for formation materials. ▪ Overly aggressive pumping in fine-grained formation. ▪ Biofouling and mineralization within the screen / open interval.	▪ Check turbidity against baseline / previous values. ▪ Assess formation grain size distribution (borehole logs) for fines. ▪ Check for build-up of sediments in well (total observation well depths over time). ▪ Downhole camera inspection to identify build-up of biofouling or mineralization in the screen / open interval.	▪ Consider revising sampling methodology (e.g., less aggressive pumping, low-flow or no-purge). ▪ Observation well redevelopment. Re-develop with a chemical treatment if biofouling is confirmed. ▪ Decommission existing well and drill a new well if redevelopment is not possible.
Loose / separated PVC pipe (well casing can be rotated or lifted by hand)	Materials entering well: ▪ Sediments. ▪ Surface water runoff. ▪ Seepage of pore water above water table entering well.	▪ May lead to lost instrumentation inside the well. ▪ Material / debris may cause a downhole blockage. ▪ Groundwater level or quality results may not be representative of groundwater conditions.	▪ PVC was not threaded together properly during installation. ▪ PVC was separated / pulled apart during installation because of material bridging in the borehole annulus. ▪ Observation well has been damaged / hit. ▪ Ground heaving because of freeze-thaw cycles.	▪ If necessary, complete downhole camera inspection to determine pipe physical condition / depth and inform repair options.	▪ Attempt to re-thread the loose PVC pipe. ▪ If shallow, attempt well repairs. ▪ If re-attachment was successful, the observation well will need to be redeveloped to remove any material and debris that may have entered. ▪ If repairs fail, consider decommission existing well and drill a new / replacement well.
Void between ground surface and well casing	Materials entering formation and / or well: ▪ Sediments. ▪ Surface water runoff. ▪ Seepage of pore water above water table entering well.	▪ Surface runoff may infiltrate into the formation and / or well. ▪ Groundwater monitoring and quality results may not be representative of groundwater conditions.	▪ Surface seal not properly placed. ▪ Grout shrinkage during observation well installation	▪ Check monitoring results with baseline / previous values.	▪ Excavate around the wellhead and place hydrated bentonite chips in lifts (i.e., pour a small volume of bentonite chips, then pour a small volume of clean water and give the bentonite approximately five minutes to hydrate before repeating) to fill any voids.

Observation	Potential Issues	Potential Consequences	Potential Causes	Potential Next Steps (to confirm issue)	Potential Resolution
Surface or well casing is damaged or bent	Materials entering well: ▪ Sediments. ▪ Surface water runoff. ▪ Seepage of pore water above water table entering well. Damage impacting ability to put / retrieve instruments from well.	▪ Surface runoff and material / debris may enter the well resulting in a downhole blockage. ▪ May lead to lost instrumentation inside the observation well. ▪ Groundwater level or quality results may not be representative of groundwater conditions. ▪ Groundwater sampling equipment may not be able to be lowered to the correct depth.	▪ Observation well has been damaged / hit (e.g., vehicles, equipment, vandalism). ▪ Ground heaving because of freeze-thaw cycles.	▪ Downhole camera inspection to confirm if sediment has entered the well or identify depth(s) of well casing damage.	▪ Replace the damaged wellhead. This could involve excavating below ground surface to cut the pipe and replace damaged sections. Failing this, consider installing a smaller-diameter well casing within the existing casing and backfilling the annulus with filter sand and a bentonite seal. ▪ Redevelop the observation well to remove any material / debris that have fallen into the screen / open interval. ▪ If repairs fail, consider decommission existing well and drill a new / replacement well. ▪ Consider if additional security / protection measures are warranted (e.g., flagging, barbed -wire fencing, concrete barriers or bollards).
Total well depth measurements decreasing over time (measurements are shallower than previous or baseline values)	Sediments entering / infilling well.	▪ May lead to muted or delayed response in groundwater levels (decreases accuracy in collected data). ▪ Increased time required to achieve parameter stabilization during groundwater sampling events. ▪ Groundwater quality results may not be representative of groundwater conditions.	▪ Loose / separated PVC pipe or cracked well casing. ▪ Poor well development. ▪ Unsuitable well screen size / sand pack for formation materials. ▪ Overly aggressive pumping in fine-grained formation.	▪ Check well casing condition (e.g., loose / separated?). ▪ Downhole camera inspection. ▪ Check if turbidity measurements during groundwater quality sampling events are elevated relative to baseline sampling events. ▪ Assess formation grain size distribution (borehole logs) for fines. ▪ Check if current groundwater levels appear anomalous compared to historic values (e.g., timing, magnitude, variability).	▪ Repair well if well condition is the cause. ▪ Consider revising sampling methodology (e.g., less aggressive pumping, low-flow or no-purge). ▪ Well redevelopment. Redevelopment with a chemical treatment if biofouling is confirmed. ▪ Decommission existing well and drill a new well if redevelopment or well repair is not possible.
Reduced well pumping capacity (e.g., increased drawdown, lower achievable pumping rates, slower recovery during sampling events)	Blockage adjacent to well screen (e.g., in formation, sand pack and / or well screen).	▪ Increased time required to achieve parameter stabilization and purge the minimum volume of groundwater during sampling events. ▪ Groundwater quality results may not be representative of groundwater conditions.	▪ Fine-grained material plugging the screen, infilling well and reducing effective screen length / depth. ▪ Poor well development. ▪ Unsuitable well screen size / sand pack for formation materials. ▪ Biofouling and mineralization within the screen / open interval.	▪ Check if total well depth measurements are decreasing over time. ▪ Downhole camera inspection. ▪ Assess formation grain size distribution (borehole logs) for fines. ▪ Check if turbidity measurements during groundwater quality sampling events are elevated relative to baseline sampling events. ▪ Check if current groundwater levels appear anomalous compared to historic values (e.g., timing, magnitude, variability). ▪ Slug test (compare expected versus actual response based on screened lithology and screen type / dimensions).	▪ Well redevelopment. ▪ Redevelopment with a chemical treatment if biofouling is confirmed. ▪ Decommission existing well and drill a new well if redevelopment is not possible.

Observation	Potential Issues	Potential Consequences	Potential Causes	Potential Next Steps (to confirm issue)	Potential Resolution
Groundwater level below bottom of well (i.e., dry well)	Poor well completion (too shallow) or artificial / impacted groundwater levels.	▪ Inability to monitor groundwater levels or collect water quality samples. ▪ Missing data in period of record.	▪ Extreme blockage adjacent to the well screen (e.g., biofouling / mineralization in the screen / open interval is preventing groundwater from entering the well). ▪ Local or regional pumping within the aquifer has lowered the groundwater level below the bottom of the well either temporarily or as part of long-term water level declines. ▪ Seasonal drought.	▪ During groundwater monitoring events, manual groundwater level measurements confirm the well is dry. ▪ Compensated pressure transducer data indicate a negative or zero pressure. ▪ Downhole camera inspection.	▪ Confirm the screen / open interval is free of sediment / biofouling / mineralization that is preventing groundwater from entering the observation well. ▪ If the well is completed in bedrock, attempt to remove the liner (if present) and advance the target interval deeper. If the well is completed in overburden, decommission the existing well and redrill to a greater depth.
Groundwater levels or quality appear anomalous (e.g., in magnitude or seasonal variation relative to the previous period of record)	See above. Moreover, may also indicate malfunctioning pressure transducer.	▪ If well is artificially impacted, sampling results or water level data may not be representative of groundwater conditions.	▪ See above. May also be the result of a malfunctioning pressure transducer.	▪ Review field notes, borehole log and discuss conditions with Groundwater Monitoring Specialist or Regional Hydrogeologist. ▪ Consider if there are any significant changes in conditions around well (e.g., physical well condition, land use, climate, etc.). ▪ Site inspection, with repeat monitoring or sampling. ▪ Check for repeated large differences between manual measurement and datalogger live reading. ▪ Deploy temporary backup pressure transducer to compare datasets. ▪ Downhole camera inspection.	▪ See above, depending on confirmation of anomalous results and inferred root causes. ▪ If there are repeated large differences between manual measurements and datalogger live readings, replace pressure transducer. ▪ Discuss with Groundwater Monitoring Specialist or Regional Hydrogeologist.

Figure 3-2 **Observation well screen with biofouling, sediment and mineralization build-up.**

Photo source: BC ENV.

Figure 3-3 **Observation well without any physical, chemical or biological build-up.**

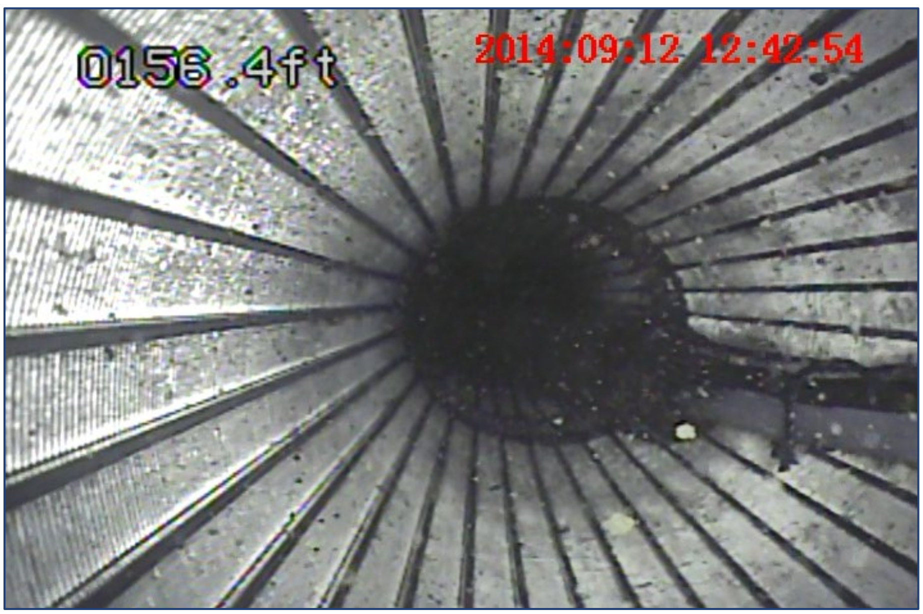


Photo source: BC ENV.

3.3 DOWNHOLE CAMERA INSPECTIONS

Provincial Observation Wells operate for decades and over that time the well casing and screens will age and become damaged or have biofouling build up. To assess the condition of ageing Provincial Observation Wells, a downhole camera inspection should be completed periodically. The downhole camera can view the interior walls of the well casing and inspect the condition of the well screen (if present). This allows for issues to be identified that could impact the quality of data collection sooner and minimize erroneous or biased data. In addition, downhole camera inspections can be used to help confirm the construction details of a Provincial Observation Well if certain details are missing from a well record (e.g., well screen depth and length).

A downhole camera inspection can be used to identify the following:

- The condition of the well casing, including:
    - Corrosion;
    - Biofouling;
    - Cracks, holes, or other obvious signs of damage; and
    - Blockages (i.e., dropped equipment).
- The condition of the screen:
    - Length of exposed screen;
    - Sediment build-up in the bottom of the well; and
    - Biofouling and mineralization build-up on the screen.

If issues are identified in a Provincial Observation Well (e.g., well screen is covered by sediment), the Field Technician should discuss suitable remediation options with the Groundwater Monitoring Specialist or Regional Hydrogeologist. This may include further investigation (e.g., slug testing [**Section 5.11.1**]) or well rehabilitation (e.g., well redevelopment or chemical treatment).

For example, a screen may have biofouling and some infilling with sediment, but this may not impact the hydrograph (groundwater level time-series) and, therefore, it is possible that no further action is necessary. Conversely, if a hole or crack was found in the well casing, allowing surface water to enter the well, this would result in spikes in the hydrograph during rainfall events and immediate repairs would be required, as well as removing any erroneous data from the 'Working' dataset in Aquarius (**Section 4.2**). Below is a hydrograph from a Provincial Observation Well that had a crack in the well casing (**Figure 3-4**) which was identified during a downhole camera inspection. This hole allowed surface water to enter during heavy rainfall events and caused the groundwater levels to spike (red line). The blue line represents data collected after repairs were completed.

Figure 3-4 Hydrograph of a Provincial Observation Well with a cracked casing.

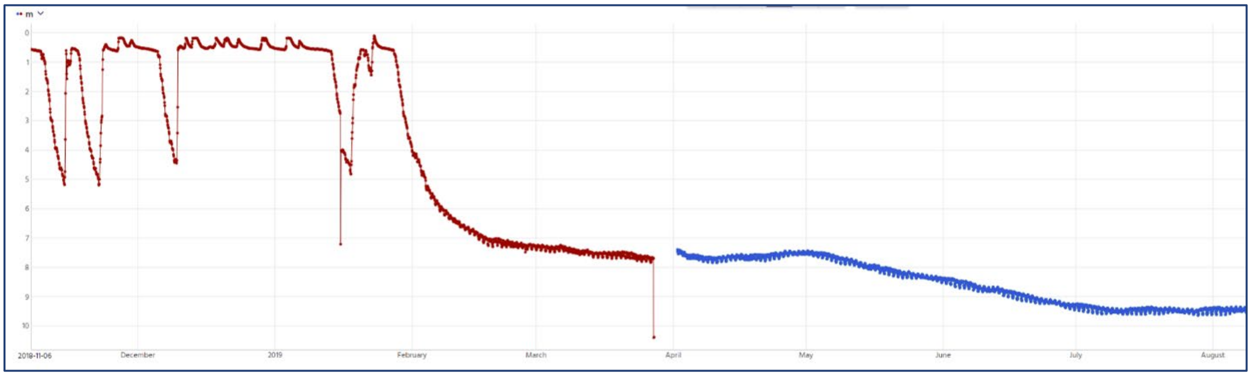


Photo source: BC ENV.

All Provincial Observation Wells should be inspected at least once every 5 years, starting with the oldest wells and those with suspected problems (e.g., odd hydrograph behaviour). The downhole camera operating and maintenance instructions from the manufacturer can be found in **Appendix A4** and the **Downhole Camera SOP** in **Appendix A5**.

For further discussion on common well casing problems and solutions, as well as example photographs of well screens from downhole camera inspections, see **Section 3.2**.

3.4 WELLHEAD ALTERATIONS

There are several reasons why a wellhead (i.e., stick-up casing) may need to be altered, including:

- Upgrading a station to telemetry;
- Downgrading a station to non-telemetry;
- Original stick-up is too tall / short;
- Vandalism; or
- Accidental wellhead damage (e.g., fallen tree).

These alterations can be completed either by Field Technicians using power tools (e.g., angle grinder) or through hiring a qualified contractor. Any changes that are made to a Provincial Observation Well stick-up height will result in a change to the elevation of the measurement reference point for the water level tape which in turn will impact the groundwater level data. As such, **it is essential that any change in stick-up height is properly documented**, and records are updated accordingly.

The Field Technician should use a measuring tape to carefully measure the change in height of the manual water level measurement reference point on the well (i.e., where the water level tape reading is normally collected). Do not measure from the ground surface to the new reference point (stick-up height), instead measure the length of casing that is added / removed and then add / subtract that length from the original well stick-up height value. For example:

- If cutting off an old steel wellhead cabinet and part of the original well casing to attach a new green casing extension and wellhead cabinet:
  - Measure the length of casing that was cut off from the well stick-up.
  - Measure the length of the green casing extension that will rest above the newly cut well stick-up.
  - Calculate the new well stick-up height value as follows:

$$\begin{aligned} &New\ Stickup\ Height \\ &\quad = Original\ Stickup\ Height\ (m) - Length\ of\ Removed\ Casing\ (m) \\ &\quad + Length\ of\ New\ Green\ Casing\ Extension\ (m) \end{aligned}$$

Following changes to the stick-up height, the Field Technician must ensure all necessary records are updated and collect additional measurements as needed. This includes:

- Updating the programmed stick-up height in the datalogger (for a telemetry station);
- Measuring the new direct-read cable length (for a non-telemetry station);
- Update the **Regional PGOWN Tracking Spreadsheet** with the new stick-up height value; and
- Updating any calculated time-series in Aquarius that reference the well stick-up height (e.g., data compensation in Aquarius of logger data from non-telemetry stations or groundwater elevation datasets).

3.5 SITE SECURITY

Provincial Observation Wells, primarily those with telemetry equipment, can be a target for thieves and vandals. Solar panels are the most common item stolen and are less of a concern as they can be easily replaced. Of greater concern is theft or vandalism impacting the operation of the datalogger and pressure transducer as this will result in a loss of data and the financial consequences are much greater.

In 2018, PGOWN staff developed recommendations for improving station security and created a new design for wellhead cabinets that house telemetry equipment. The new cabinets are more difficult for thieves to break into and are better designed for housing telemetry equipment. These cabinets must be used whenever upgrading a station (see **Figure 3-5**). Do not reuse the old style of cabinets. For older cabinets that remain in use, it is recommended to gradually replace them or, at the least, retrofit them with padlock covers (contact the Groundwater Network Technology Specialist for more information on padlock covers).

Figure 3-5 Wellhead cabinets to house telemetry equipment.

Photo source: BC ENV.

In addition to retrofitting older wellhead cabinets with a padlock cover, or replacing them with the newer cabinets available through ENV, Field Technicians must follow the guidance below when upgrading / installing a telemetry station to improve site security:

- Use carriage bolts for all external bolts that secure items to a wellhead cabinet, with the bolts tightened from within the cabinet to prevent thieves from unscrewing the connections and removing equipment (or the cabinet itself) (**Figure 3-6**);

Figure 3-6 Illustration of carriage bolt alignment within the wellhead cabinet.

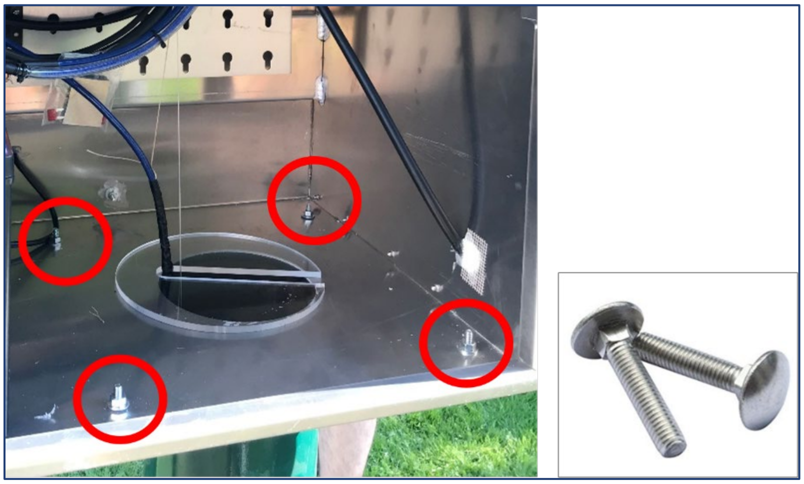


Photo source: BC ENV.

- Use the enhanced Mastercraft padlock supplied by ENV (as opposed to the older Viro padlocks); and
- Use the newer style of solar panel mast supplied by ENV which are approximately 6.5 cm (2.5 in) in diameter and no more than 1.8 m (6 ft) long.
    - The older masts were too narrow and long, making them easy for thieves to bend and break.

Field Technicians should also consider the following additional security features:

- Mounting an omni antenna directly to the top of the wellhead cabinet, as opposed to attaching to the mast or using an x-yagi antenna (so as to make the station slightly less noticeable);
- Mounting the solar panel directly to the roof of the cabinet (provided there is sufficient solar coverage);
- Using Loctite (red) adhesive for bolts that could be unscrewed by thieves; and
- Installing barbed-wire fencing (with permission of the property owner).

If vandalism or theft occurs at a site, the Field Technician must:

- Assess how the vandalism occurred and how best to address those weak points;
- Determine whether to upgrade the security around the Provincial Observation Well (if possible) and replace the telemetry equipment, or transition the station into a non-telemetry site;
- If upgrading security around the Provincial Observation Well, (e.g., new well cabinet, fencing, etc.), consider deploying non-telemetry dataloggers in the upgraded cabinet for at least 6 months before re-installing new telemetry equipment to monitor for new vandalism / theft attempts; and
- Report the theft as per the instructions below:

- Theft of capital assets (e.g., telemetry dataloggers and pressure transducers) must be reported by following the guidance provided under "L1. General" and "L3. Illegal Activities" of the BC Government Core Policy and Procedures Manual, Chapter L. The steps outlined below are a general overview of this theft reporting procedure:
  - Report the theft to your Groundwater Monitoring Specialist and the Groundwater Monitoring Program Supervisor;
  - Complete a "General Incident or Loss" form for each theft event, using the link above. Multiple capital equipment losses from the same station during the same theft event can be reported on just one form; and
  - Report the theft to local police. Someone from the Risk Management Branch may contact you and ask for the police report number.

4.0 DATA MANAGEMENT

Well construction records, along with collected groundwater quality and groundwater level data, are stored and managed in provincial databases, including:

- **GWELLs** – the provincial groundwater well database that contains well completion records;
- **Aquatic Informatics Aquarius Next Generation (NG)** – time-series data management software / system; and
- **EMS** – the provincial repository for environmental monitoring data.

4.1 GWELLS (WELL RECORDS)

The Provincial Groundwater Wells and Aquifer (GWELLS) application contains well construction records for all registered wells in the province. As of 2016, when the *Water Sustainability Act* (WSA) came into force, well drillers and well pump installers are required to submit well reports within 90 days after constructing, altering, or decommissioning a well. While there is currently no legal requirement for monitoring well records to be entered into GWELLS, it is expected that all Provincial Observation Wells will be entered into this system as they are added to the network. Moreover, Field Technicians must ensure that their Provincial Observation Well records are complete in GWELLS, including attaching scanned originals of well construction notes or other related reports.

Within GWELLS, Field Technicians are responsible for:

- Entering well records for new Provincial Observation Wells (refer to **Adding a Well to PGOWN Systems SOP** in **Appendix A8** (**Section A8.1**); and
- Updating well records when a station is closed (refer to **Removing a Well from PGOWN Systems SOP** in **Appendix A8** (**Section A8.2**).

Well records and associated data can be viewed or downloaded as Excel files by visiting the GWELLS website. Please note that it is possible to export all Provincial Observation Well records (and to filter which attributes are exported) using the various search and export features of this site. Contact the Groundwater Monitoring Program Supervisor for further information.

Questions regarding GWELLS, including requesting access and editing permission, can be directed to the database managers at Groundwater@gov.bc.ca.

4.2 AQUARIUS (GROUNDWATER LEVEL DATA PROCESSING)

This section provides an overview of the data management and processing of groundwater level time-series using Aquarius NG. Following the uploading of manual and continuous groundwater level data into Aquarius NG, the data can be processed to:

- Compensate data collected using non-vented pressure transducers;
- Apply data corrections based on manual groundwater level measurements; and

- Create a time-series that places the collected manual groundwater level measurements and pressure transducer data on a consistent datum (i.e., elevation and / or depth below ground surface).

The following sections provide a general discussion on the PGOWN-specific procedures for uploading, compensating, correcting, grading and approving collected groundwater level data.

Detailed Aquarius instructions can be found within the **NG Aquarius Groundwater User Manual** which outlines the procedures for creating datasets, uploading continuous and manual groundwater level data, and correcting uploaded groundwater level data. Contact the ENV Water Data Specialist for the latest version of this user manual.

In addition, Aquatics Informatics' Aquatic Academy also provides online training videos for users and can be accessed at https://aquaticacademy.docebosaas.com/learn. If you require an account, contact the ENV Water Data Specialist.

4.2.1 Data to be Uploaded to Aquarius

As discussed in previous sections, as part of their regular 6-month site visits, Field Technicians are to collect a manual groundwater level reading and download all logger data since their previous visit which must then be inputted / uploaded into Aquarius:

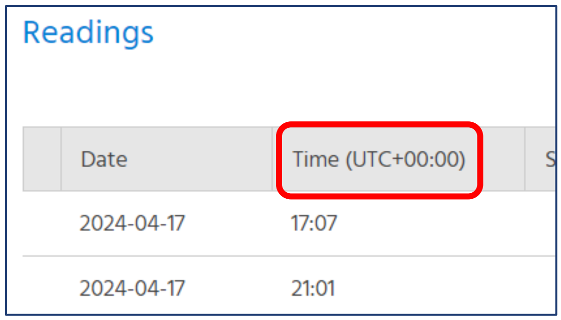
- Manual groundwater level measurements must be entered into Aquarius as '**Field Visits**'.
- Downloaded datalogger files must be uploaded into Aquarius and appended to the '**Logger**' (raw) dataset(s) prior to processing in the '**Working**' (corrected) dataset.
    - Downloaded data uploaded (appended) to Aquarius should be raw and unmanipulated and only appended to '**Logger**' datasets. The only exception to this is if barometric compensation is completed in Excel instead of in Aquarius (**Section 4.2.3.1**) which should only occur for sites that are only temporarily running as non-telemetry stations.
    - Any subsequent manipulation to appended groundwater level data should be completed on the '**Working**' dataset in Aquarius. This approach is taken to minimize altering the original '**Logger**' dataset so, should an error occur, the original dataset can be used to create a new '**Working**' dataset.

As previously mentioned, please refer to the **NG Aquarius Groundwater User Manual** for detailed guidance on these topics.

4.2.2 Aquarius Field Visits

The objective of entering the manual groundwater level measurement into an Aquarius Field Visit is to ensure the measurement data is properly recorded, to clearly demonstrate that the corrected '**Working**' dataset aligns with the manual measurements, and to make applying data corrections easier. When entering a Field Visit, it is critical that the information is properly entered, as described below:

- Dates and times must be converted to the time zone assigned to the station in the Aquarius ‘Location Details’.
    - In the Field Visit screenshot below, the time of the visit from the fieldnotes should be converted to UTC (i.e., PST + 8 hours or PDT + 7 hours). Therefore, in the first row of this example, the corresponding fieldnotes would have had a listed a time of 9:07am which was then manually converted to 5:07pm (i.e., 17:07) in the Aquarius Field Visit.



- The manual groundwater level measurements must be entered as depth below ground surface (i.e., m bgs).
- All recorded manual water level measurements should be entered into Aquarius if multiple measurements were collected during a single field visit.
- Any unreliable manual water level measurements should **not** be published (i.e., unselect ‘Publish’ checkbox). In addition, the situation should be described under the ‘Comments’ field in the Field Visit.
    - For example, a static measurement could not be obtained due to pumping interference or a prolonged post-sampling water table recovery.

The fields listed below in **Table 4-1** should be completed at a minimum for each Aquarius Field Visit.

Table 4-1 Aquarius Field Visit required information.

Field	Details
Visit Summary	
Party	Field staff names or initials.
Approval Level	Left as 'Working' until reviewed and changed to 'Approved' by Groundwater Monitoring Specialist.
Start / End Date / Time	Dates / times of site visit must encompass the manual measurements to be entered. Convert to time zone specified in Date / Time column headers.
Completed This Visit	Select all that apply. Typically 'Groundwater levels' and 'Recorder data collected'.
Comments	Add context as needed. E.g., "Unable to collect reliable reading due to malfunctioning water level tape", or "Upgraded station and changed the pressure transducer and stick-up height from XX m to XX m".
Readings	
Parameter	Select 'SGWL'.
Method	Select 'Water Level Tape'.
Value	Enter manual groundwater level measurement value in units of 'm bgs'.
Units	Select 'm'.
Date / Time	Manual measurement date and time. Convert to time zone specified in Date / Time column headers.
Upload	
Select Files	Select 'Attach incoming files'. Attach respective fieldnotes.

4.2.3 Non-Telemetry Stations: Data Processing (Compensating)

Provincial Observation Wells with telemetry systems typically use vented pressure transducers while non-telemetry sites always use non-vented pressure transducers. Vented pressure transducers record **groundwater pressure** (pressure from the water column above the transducer), and non-vented transducers record **total pressure** (water pressure plus ambient atmospheric pressure). A detailed discussion of vented versus non-vented pressure transducers can be found in **Section 2.4.2.1**.

In order to determine water pressure, total pressure measurements from non-vented transducers at non-telemetry stations need to be compensated to account for atmospheric pressure. A separate barometric pressure transducer is used to collect and record ambient atmospheric pressure on the same sampling frequency (i.e., hourly) as the submerged non-vented pressure transducer.

Data collected using non-vented pressure transducers **must** be compensated for atmospheric pressure in Aquarius (**Section 4.2.3.1**). However, for stations that will only run as non-telemetry sites temporarily, then a manual approach in Excel (**Section 4.2.3.2**) is acceptable and those Excel files showing the calculations should be saved to the respective project folder. While data can also be compensated using logger software (e.g., Solinst Levelogger software), this is **not preferred** as it leaves no record of the applied compensation procedures (calculations).

After the total pressure data has been corrected to account for atmospheric pressure (by subtracting out the atmospheric pressure), this dataset is now representative of groundwater pressure (as 'm of H_2O' equivalent) and shows fluctuations in groundwater level **above the submerged pressure transducer** over time. In other words, the compensated data at this point is now expressed as the height of water above the submerged transducer. This must then be converted to a known datum (i.e., elevation or depth below ground surface).

Please note the following procedures for appending data from non-telemetry stations to Aquarius datasets:

- Unprocessed (raw) barometric and submerged pressure transducer data must always be appended to their respective '**Logger**' datasets;
- If data compensation is completed within Aquarius, then those calculated time-series (processed data) would feed (append to) the '**Working**' dataset; and
- If data compensation is completed within Excel, then that processed data is appended directly to the '**Working**' dataset.

4.2.3.1 Barometric Compensation Using Aquarius NG

Compensating for barometric pressure must be completed in Aquarius so that the original (unaltered) '**Logger**' datasets (i.e., the submerged and barometric pressure transducer datasets) are preserved without prior manipulation and so the calculations are properly recorded.

Please note that '**Logger**' datasets (**basic-time series**) must first be created in Aquarius for both the submerged transducer (i.e., total pressure) and barometric transducer data to later be appended to (the procedure for creating these '**Logger**' datasets is described in the **NG Aquarius Groundwater User Manual**). These would be referred to as the '**Uncompensated.Logger**' and '**Baro.Logger**' datasets.

After creating the '**Logger**' datasets in Aquarius, a **calculated time-series** must be created in order to produce the '**Working**' dataset for a non-telemetry station. This calculated time-series involves entering a formula into Aquarius to calculate the direct-read cable length for the station, and then having Aquarius subtract off the '**Logger**' datasets to render the groundwater level data relative to the ground surface (i.e., m bgs) (Washington State Department of Ecology 2017). This process is detailed below.

Please note that the datasets required for processing data at non-telemetry stations should be created by the Groundwater Monitoring Specialists or Water Data Specialist.

Compensating Data and Expressing Relative to Ground Surface

To begin, three measurements must be collected in the field at the time of installation of the direct-read cable and submerged pressure transducer (or alteration of its depth), in order to calculate the direct-read cable length:

1. A manual groundwater level measurement expressed as 'm bgs' (i.e., the stick-up height has already been subtracted);

2. A live pressure reading from the submerged transducer (therefore a direct-read cable is required as part of the transducer installation process); and

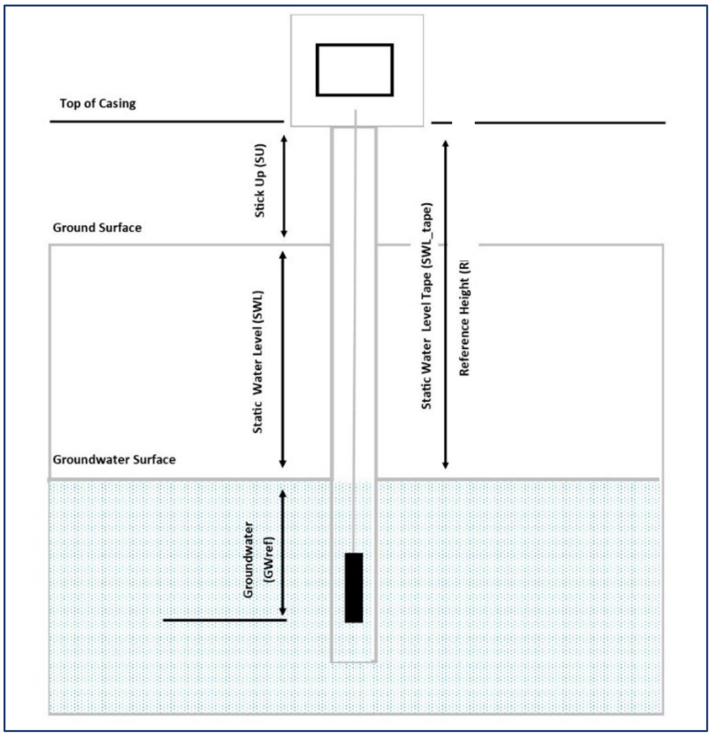
3. A live pressure reading from the barometric transducer.

The live barometric pressure reading is collected to compensate the live submerged pressure reading, which results in the height of groundwater (m H_2O) **above** the submerged pressure transducer at that time. This value is then added to the manual measurement collected at the same time as the live readings, to calculate the cable length (see formula below). These parameters are illustrated below in **Figure 4-1** where '**SWL**' represents the measured groundwater depth below ground surface and '**GWref**' is the compensated live pressure transducer reading at that time. Please note that the complete formula for creating the **calculated time-series** will be listed and discussed at the end of this section.

$$\textbf{Cable Length}\ (m) = Measured\ SWL\ (m\ bgs) + GWref\ (m\ H_2O)$$

$$Where\ \textbf{GWref}\ (m\ H_2O) = Live\ Total\ Pressure\ (m\ H_2O) - Live\ Barometric\ Pressure\ (m\ H_2O)$$

Figure 4-1 Data compensation required measurements.



It is therefore critical that the direct-read cable be properly secured to avoid changing the length of the cable during each subsequent field visit (**Appendix A2** [**Section A2.5**]).

Once the cable length has been established, the downloaded logger data from the barometric pressure transducer (i.e., the '**Baro.Logger**' dataset) is subtracted from the downloaded submerged pressure transducer data (i.e., the '**Submerged.Logger**' dataset), as shown in the formula below. This process will compensate the total (i.e., submerged) pressure for changes in barometric pressure over time.

$$\textbf{Compensated Data}\ (mH_2O) = Total\ Pressure\ (mH_2O) - Barometric\ Pressure\ (mH_2O)$$

As previously mentioned, this barometrically compensated data represents the height of groundwater (m H_2O) **above** the submerged pressure transducer (i.e., the '**GWref**' value shown on **Figure 4-1** above). However, all Provincial Observation Wells publish groundwater levels relative to the ground surface (i.e., m bgs), although stations that have been surveyed will also publish groundwater elevation data (i.e., m asl) which is discussed further below. As a result, this compensated hourly logger data must be subtracted from the established cable length so that the data is relative to the ground surface.

Therefore, to produce the '**Working**' dataset in Aquarius for a non-telemetry station, a calculated time-series must be created using the formula below:

$$\begin{aligned}\boldsymbol{SWL}\ (m\ bgs) &= [Measured\ SWL\ (m\ bgs) + GWref\ (m\ H_2O)] \\ &\quad - [Submerged.Logger\ (m\ H_2O) - Baro.Logger\ (m\ H_2O)] \\ &= '\boldsymbol{Working}'\ Dataset\end{aligned}$$

$$\begin{aligned}Where\ \boldsymbol{GWref}\ (m\ H_2O) \\ &= Live\ Total\ Pressure\ (m\ H_2O) - Live\ Barometric\ Pressure\ (m\ H_2O);\ and\end{aligned}$$

$$\boldsymbol{Submerged.Logger}\ and\ \boldsymbol{Baro.Logger}\ are\ established\ basic - time\ series.$$

For existing sites where this Aquarius data compensation process was implemented after-the-fact, or for sites later down-graded to non-telemetry status, there would already be a '**Working**' dataset. In order to add this newly calculated data to the existing '**Working**' dataset (and thereby have one continuous public-facing dataset), this calculated time-series would need to be labelled as '**Compensated.Logger**' and entered as a new **processing period** for the existing '**Working**' dataset.

Please note that if the direct-read cable is adjusted (made obvious by sudden offsets of portions of data occurring at field visit points), then a new processing period will need to be entered for the calculated time-series using the most recent manual measurement and live pressure readings in the formula shown above (i.e., entering new '**Measured SWL**' and '**GWref**' values).

Detailed instructions on creating calculated time-series and processing periods are provided in the **NG Aquarius Groundwater User Manual**.

Barometric Unit Conversion

It should be noted that if the barometric pressure transducer records measurements in units other than 'm H_2O' (e.g., PSI, kPa, mbar, etc.), then the data must undergo a unit conversion prior to appending the .csv data file to the '**Baro.Logger**' dataset. **Table 4-2** provides three common conversion factors for metres of water column equivalents (m H_2O).

While this unit conversion could be completed in Aquarius by adjusting the formula above, complications in Aquarius would arise as barometric loggers are replaced / reprogrammed and their units change.

Table 4-2 Pressure conversion factors.

Barometric Unit	Meter of Water Column Equivalent
1 PSI	0.703070
1 kPa	0.101972
1 mbar	0.010197

4.2.3.2 Barometric Data Compensation in Excel

In cases where a Provincial Observation Well will only temporarily remain as a non-telemetry station, the barometric data compensation and correction to a reference datum can be completed in Excel (although the raw barometric and submerged pressure transducer data must still be appended to their respective '**Logger**' datasets to preserve the raw data).

Compensating collected groundwater level data for barometric pressure using the manual (Excel) method requires the .csv file for both the barometric and submerged pressure transducers to be copied to the Excel **Data Compensation Spreadsheet** template (found on the **PGOWN MS Teams Channel** under the Appendix A2 folder). This spreadsheet also converts the compensated data into depth below ground surface, meaning that data from this spreadsheet can be appended directly to the '**Working**' dataset in Aquarius.

This spreadsheet calculates the groundwater level depth based on the previous site visit's manual water level measurement and the hourly change in head (pressure) from the compensated submerged transducer data. Consult your Groundwater Monitoring Specialist for assistance, if needed.

4.2.3.3 Groundwater Elevation

For elevation datasets (known as '**GW Elevation.MASL**' datasets in Aquarius and expressed in units of 'm asl'), a **reference datum conversion** time-series must be created using the surveyed ground elevation (**Section 3.1**) and fed by the '**Working**' dataset (via a processing period). Further details on how to create such elevation datasets can be found in the **NG Aquarius Groundwater User Manual**.

The process for creating a '**GW Elevation.MASL**' dataset in Aquarius would be the same for both telemetry and non-telemetry stations.

Please note that it is expected that all Provincial Observation Wells will be surveyed and their publicly accessible elevation datasets will be set-up in Aquarius by the Groundwater Monitoring Specialists.

4.2.4 Telemetry Stations: Data Processing

Data processing at telemetry stations is much simpler than with non-telemetry stations. There is no need to compensate data from telemetry stations as most are equipped with vented pressure transducers or, if a station uses a non-vented transducer, the datalogger at those sites will automatically compensate the data using an internal barometric sensor (although few of such stations remain in the network). In addition, there is no need to create a calculated time-series dataset to convert the groundwater level data into depth below ground, as the transmitted data is already relative to the ground surface (the datalogger automatically completes these calculations).

At telemetry stations, groundwater level data (SGWL) is uploaded into Aquarius daily (or in certain cases, hourly) via the NOAA GOES system. This '**SGWL.Telemetry**' dataset is set-up to automatically append to the '**Working**' dataset in Aquarius, with the '**SGWL.Logger'** dataset automatically set-up to fill any telemetry gaps in the '**Working**' dataset. However, Field Technicians must still download the available data from these sites and append the data to the '**SGWL.Logger**' dataset in order for those gaps to be filled.

The process for creating a '**GW Elevation.MASL**' dataset in Aquarius would be the same as it is for non-telemetry stations (refer to the **NG Aquarius Groundwater User Manual** for more detailed instructions).

4.2.5 Data Corrections

In Aquarius, data corrections will typically need to be applied after every field visit to the period of record between the last and most recent visit when data was downloaded. Ideally, the existing time-series will line up with the entered manual groundwater level measurement (i.e., the Aquarius Field Visit). However, measurements from pressure transducers will typically drift over time and there may be errors (offsets) introduced if the cable length is accidentally altered. In additions, random erroneous outliers and other data issues (e.g., sampling events) may have occurred during the time period of interest. If corrections to the groundwater level data are required, these must be applied to the '**Working**' dataset, where the user can use the field measurements as a reference point. It is critical that no corrections are applied to the '**Logger**' dataset and that accurate, reliable manual groundwater level measurements are collected during field visits.

When a manual groundwater level measurement does not align with the continuous time-series, the context of when the field measurement was taken is important to consider (e.g., after a groundwater sampling event, or if there is a large time difference between when the datalogger SWL and manual groundwater level measurement were collected). Review the **Manual Groundwater Level Measurement SOP** and the **Groundwater Level Data Downloading SOP** (**Appendix A2** [**A2.1** and **A2.4**]) for detailed instructions which will assist in avoiding many common problems related to data collection, most notably by collecting an initial groundwater level reading from the water level tape and datalogger upon arriving at the site.

However, the general rule is to correct the preceding continuous time-series period of record to a manual groundwater level measurement and not the succeeding period of record (i.e., after the field visit). For example:

- In **Figure 4-2**, the manual groundwater level measurement (shown in the red circle) appears to have been taken several hours before the pressure transducer begins to record data (first figure below). It is unknown if groundwater levels were affected by external events during the time period in between and, as such, it is not best practice to correct the succeeding time-series to this single field measurement. However, in the second figure, a groundwater level measurement (red circle) was taken immediately before removal of the pressure transducer from the example well. As a result, the time-series prior to the field measurement can be corrected to the field measurement.

Figure 4-2 Groundwater elevation time-series with field measurements existing in data time-series gaps.

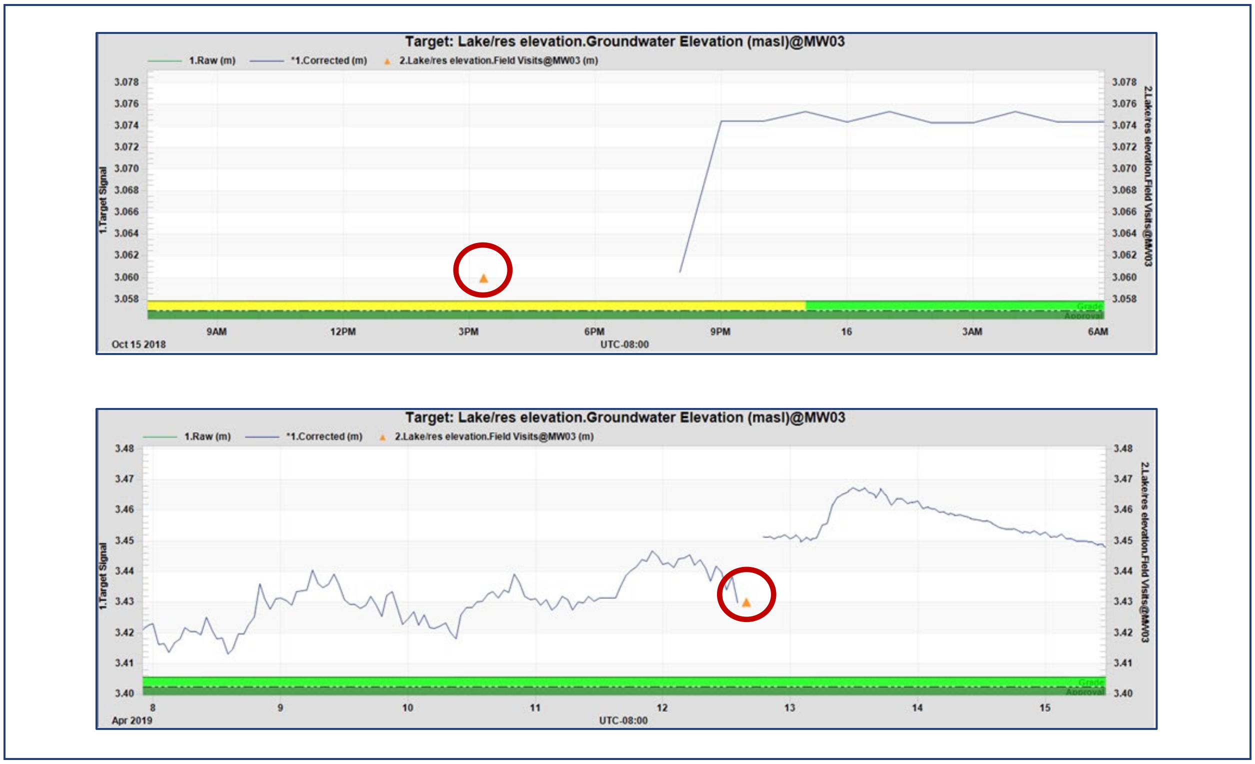


Photo source: Hatfield Consultants.

In Aquarius, the Data Review Tool (DRT) allows for the manual adjustment of time-series data using a variety of data correction tools. When correcting data in Aquarius, the basic workflow is as follows:

1. Enter the manual groundwater level reading and time of measurement from the site visit into the ‘Field Visit’ section of Aquarius (**Section 4.2.1**);

2. Append downloaded logger data from the field to the respective ‘**Logger**’ dataset(s);

3. Apply data corrections to the ‘**Working**’ dataset as follows:

    a. Fill gaps using the appended ‘**Logger**’ dataset. Ensure that the ‘**Logger**’ dataset is set up to automatically fill gaps in the ‘**Working**’ dataset (via a pass-through processing period). Contact the ENV Water Data Specialist if you suspect this is not set-up correctly.

    b. Delete anomalous data and data from sampling events (**Section 4.2.5.2**).

    c. If jumps (consisting of multiple data points) in the data are observed, offset corrections may be needed (**Section 4.2.5.3**).

    d. Apply a drift correction based on the manual groundwater level measurement compared to the live datalogger reading collected during the site visit (**Section 4.2.5.4**).

4. Grade the data based on the applied drift correction (**Section 4.2.6**); and

5. Approve the data (**Section 4.2.7**).

Refer to the **NG Aquarius Groundwater User Manual** for a detailed description of the DRT.

4.2.5.1 Data Gaps

Gaps can exist in the groundwater level time-series as a result of gaps in the telemetry feed, deleted pressure transducer data (**Section 4.2.5.2**) or due to equipment failure at the site (e.g., dead battery).

These gaps within the groundwater level time-series must not be extrapolated and should remain as gaps in the record unless they can be filled with logger data (as is typically the case for standard telemetry transmission gaps).

4.2.5.2 Deleting Anomalous or Erroneous Data

Following the filling of data gaps (where possible and appropriate), the next correction to be applied is the deletion of anomalous and erroneous data. While deleting data from the '**Working**' dataset is not ideal, there are several valid reasons for doing so as outlined below:

- It is not uncommon for pressure transducers to temporarily malfunction and record an anomalous groundwater level. This is often displayed as either a spike in the groundwater level time-series (e.g., -99999 m) or a period when recorded measurements do not show any variability (**Figure 4-3**). These data points should be removed from the '**Working**' dataset as they are not representative of groundwater levels at that location.
    - E.g., data from submerged pressure transducers that have been over-pressurized (resulting in an error message or flatlining) must be removed as this data is not accurate.
    - E.g., a malfunctioning logger can result in individual data points being logged that are several metres out of the normal range for a given observation well and are clearly erroneous outliers.
    - E.g., if a barometric pressure transducer becomes submerged (i.e., water levels rise higher than expected in a well), this will result in flatlined data which must be deleted as the data is no longer representative of barometric conditions. That being said, it may be possible to fill this data gap with data from another nearby barometric sensor (e.g., from a weather station).
    - Tip: any time ground level data flatlines for an extended period, this is an indication that something has gone wrong with the well and should be investigated. Consult with your Groundwater Monitoring Specialist as needed.
- Some Provincial Observation Wells do not recovery quickly upon completion of a groundwater quality sampling event (i.e., recovery takes longer than 1 hour). The groundwater level recovery periods in these Provincial Observation Wells are then recorded by the pressure transducers and in turn captured in the time-series. This recovery period should be removed as it is also not reflective of natural (background) groundwater levels in the aquifer and can bias data analysis efforts; therefore, data up until static water levels have recovered to approximately 95% of their

pre-sampling level should be deleted. If the pressure transducer is left in the well during purging, these data points should also be deleted for the same reason (**Figure 4-4**).

- Please note that the suggested 95% recovery to pre-sampling levels is adapted from the following the BC Ministry of Environment guidance document: *Standard Operating Procedure for Constant Rate Pumping Test* (2020).

- Overflowing artesian wells will result in flatlined data as groundwater levels have exceeded the height of the stick-up, meaning the data has been lost and the flatlined data must be removed. Similarly with dry wells, the data has been effectively lost as the well was not deep enough to capture the groundwater level fluctuations.

Figure 4-3 Examples of data points to delete.

Photo source: BC ENV.

Figure 4-4 Example of post-sampling recovery curve (data points to delete).

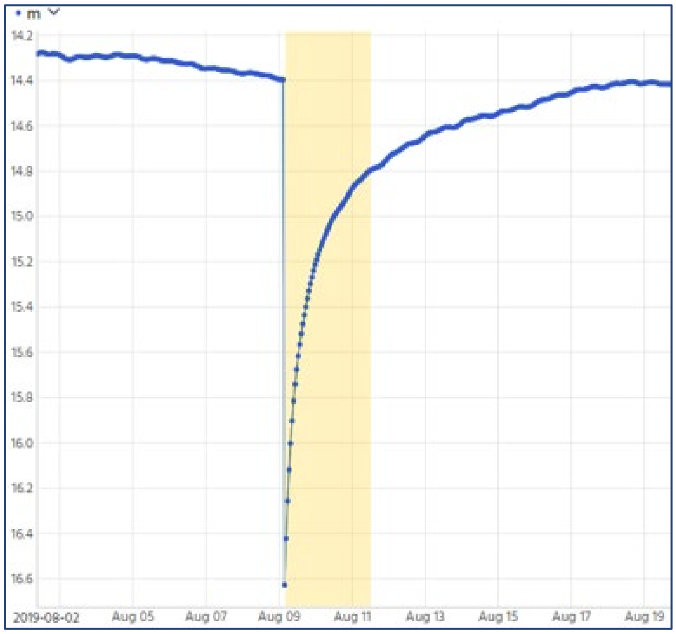


Photo source: BC ENV.

4.2.5.3 Applying Offset Corrections in Aquarius

Offsets are applied both in the field to the telemetry datalogger (**Section 2.4.2.2**) and in Aquarius as an offset correction, however, they are the result of different events. Offsets applied in the field to the datalogger are to account for sensor drift, while offsets applied in Aquarius occur when there are occasional jumps in continuous time-series data that can be observed. It is less common for offsets to be applied in Aquarius, but if required, these corrections should occur after data gaps are filled and problematic data has been deleted.

These jumps or differences in groundwater level can be attributed to several factors, such as:

- During a site visit of a non-telemetry Provincial Observation Well, the pressure transducer may intentionally or unintentionally be moved (e.g., removed to be downloaded, the direct-read cable is adjusted at the surface, the suspension cable slips, etc.). This may change the cable length unexpectedly and, after the next site visit, will result in that downloaded data being offset from the previous period because the data was not compensated using the new adjusted cable length;
- A vented pressure transducer that does not have a proper tension-relief cable may be pulled partially out of its desiccant enclosure (due to gravity), resulting in the pressure transducer shifting deeper into the Provincial Observation Well and causing the subsequent data to "jump" relative to the previous data; or
- An incorrect offset could be programmed into a telemetry datalogger during a site visit (**Section 2.4.2.2** and **Figure 4-5**). This would result in the subsequent groundwater level data downloaded at the next site visit needing to be offset in Aquarius to align with the rest of the continuous groundwater level timeseries.

The first two bullet points described above could result in the pressure transducer being suspended at a different depth than initially set-up and the collected groundwater level data being plotted at a different elevation. This is usually easily identified on a continuous time-series graph and can be corrected by using the appropriate manual groundwater level measurement taken after the pressure transducer was redeployed.

Please note that when applying an offset, a drift correction may subsequently be required in order to align the data endpoint (timestamp of most recent site visit) with the manual groundwater level measurement collected at that time. This is because while a change in cable length may have shifted the pressure transducer elevation and all subsequent data, that transducer will still undergo sensor drift over that time period.

Figure 4-5 Example of a situation that would require an offset correction in Aquarius.

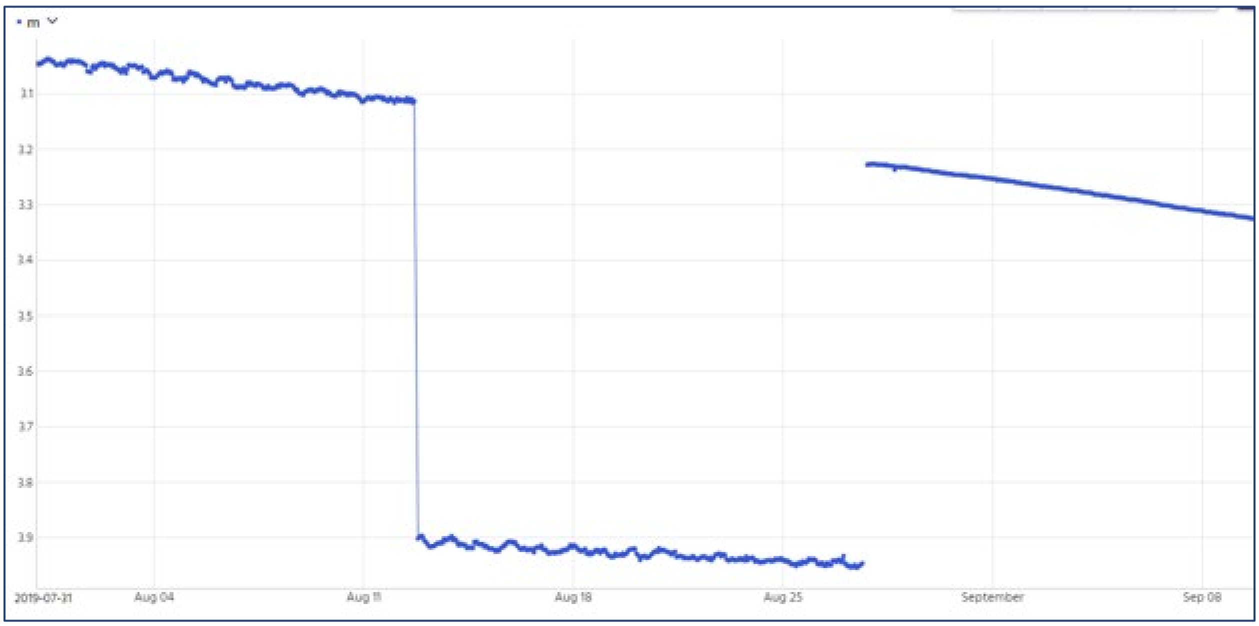


Photo source: BC ENV.

4.2.5.4 Drift Corrections

Pressure transducer drift is a gradual degradation of the sensor and other components that can make readings drift from the original calibrated state (**Figure 4-6**). Every sensor will undergo some expansion and contraction when subject to pressure and temperature cycles. Pressure change, frequency and amplitude, temperature extremes, material responses, and environmental changes are all factors contributing to drift. The magnitude a pressure transducer will drift varies with usage and environmental conditions.

Figure 4-6 Example of pressure sensor drift.

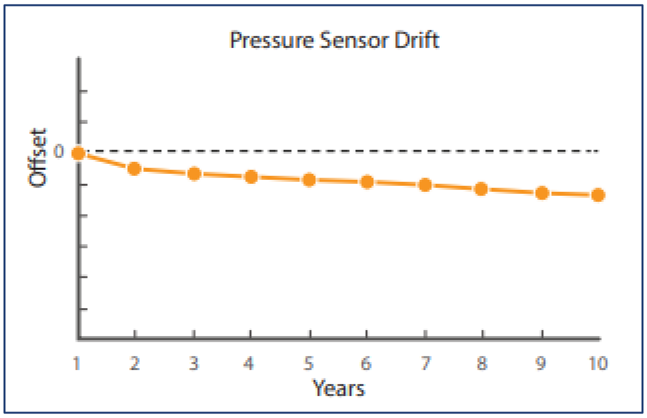


Photo source: BC ENV.

By routinely obtaining manual groundwater level measurements and comparing these measurements to 'live' pressure readings from the transducer / datalogger, a drift value can be determined, and added to the current offset that is programmed into the datalogger during the site visit (**Groundwater Level Data Downloading SOP** in **Appendix A2** [**Section A2.4**]).

Back in the office, this drift value from the site visit is applied in Aquarius to the downloaded groundwater level data in the '**Working**' dataset. Aquarius will divide the drift value across the selected timeframe and shift each groundwater level data point up or down until the final selected data point aligns with the manual measurement collected during the site visit (**Figure 4-7**). Please note that it is important to only select and edit data from the time period between the last site visit and the most recent site visit.

Figure 4-7 Example of applying a drift correction.

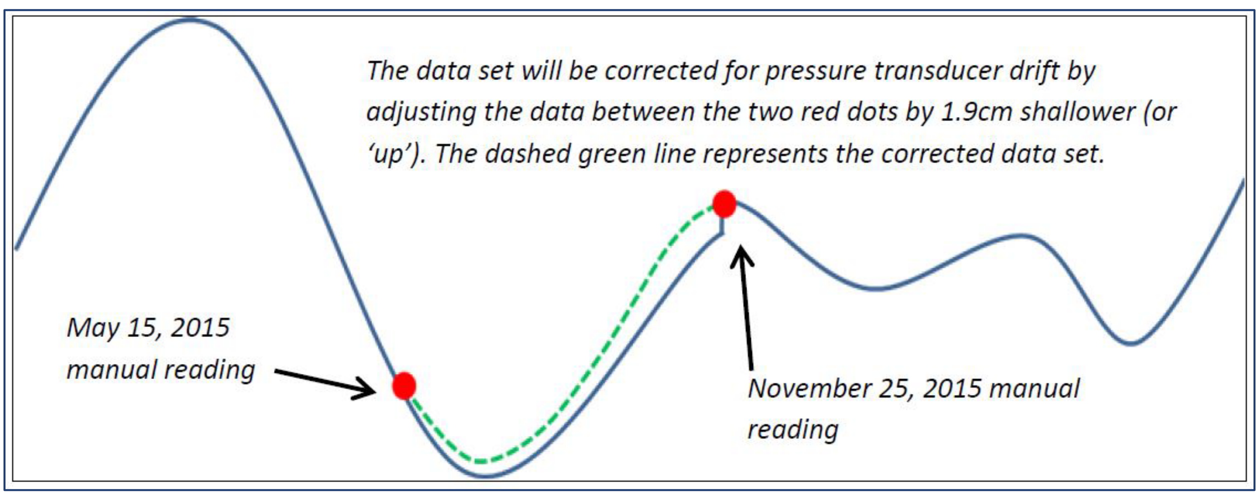


Photo source: BC ENV.

To reiterate:

- The drift value applied to the downloaded data in the '**Working**' dataset is the drift value calculated from the **initial** groundwater level measurement and datalogger live reading during the most recent site visit (i.e., subsequent manual measurements collected during the site visit after repair work or sampling is conducted should not be used when applying a drift correction in Aquarius).

- The final corrected data in the '**Working**' dataset should align with the Field Visits entered into Aquarius. If they do not, this should be investigated and/or discussed with the Groundwater Monitoring Specialist (e.g., the Field Visit may have been entered incorrectly in terms of water depth value or timestamp). See **Figure 4-8** for an example of corrected data aligning with the entered Field Visits.

An Aquarius drift correction should be the final applied correction.

Figure 4-8 Example of drift corrections aligning with Field Visits in Aquarius. Green is raw data and blue is corrected data, with encircled pins being Field Visits.

Photo source: BC ENV.

4.2.6 Data Grading

Grades are intended to provide the user with an understanding of the accuracy and quality of the data. When approving groundwater level data for publication, data grades are applied to provide a useful indicator of the accuracy of the collected data, especially when using data for statistical analyses and modelling. Poor data grades can indicate poor pressure transducer or monitoring instrument performance, or infrequent station maintenance. Data grades are based on instrument specifications, with instrumentation performing within the stated accuracy receiving the highest data grade, as described below.

Full-Scale Range Accuracy

Pressure transducer manufacturers typically state the full-scale range (FSR) or maximum operating (pressure rating) of the instruments, in their product specifications sheet. This manufacturer-specified value provides an indication of the FSR of water pressure measurements that can be made while still achieving a stated level of accuracy. Manufacturers will also provide an indication of instrument accuracy, typically expressed as a percentage of that FSR or submergence depth (e.g., 0.05% or 0.1% of FSR). For example:

- A pressure transducer specified for a maximum operating pressure of 10 m (the FSR) may have a stated 0.05% accuracy of the FSR. This means the accuracy for this pressure transducer will be 5 mm (0.005 m = 0.05% of 10 m).

The FSRs of all pressure transducer makes and models used within PGOWN are compiled and can be found in **Groundwater Level Data Grading Spreadsheet** (**Appendix A6** [**Section A6.1**] or on the **PGOWN MS Teams Channel**).

Manual Water Level Tape Accuracy

Water level tape manufacturers state an accuracy of 0.031 cm (1/100 ft). A study completed by the USGS (Jelinski, et al., 2015) compared the accuracy of common water level tapes (Solinst, Geotech and Heron), some of which are used in the PGOWN. The average accuracy when collecting a manual groundwater level measurement was found to be less than 1 cm. The accuracy of manual water level tape readings is important for time-series data as it is used to validate, correct and grade the logger data.

Based on the above, for the PGOWN, a potential mid-range error (i.e., accuracy) of 5 mm for manual groundwater level measurements is assumed for all water level data.

Grading Water Level Data

Both the FSR of the pressure transducer and the water level tape error are combined to produce a lower and upper grade range. This grade range is used to quantify the error (i.e., the drift, or difference between manual groundwater level measurement and recorded groundwater level using the pressure transducer) and are applied to the data within Aquarius, using the grading descriptors in **Table 4-3**. Aquarius automatically assigns a grade of “Undefined” or “Unspecified”” to all ingested data.

Field Technicians are to use the **Groundwater Level Data Grading Spreadsheet** (**Appendix A6** [**Section A6.1**]) to determine the error and grading for groundwater level data during the grading process.

Table 4-3 Aquarius groundwater data grade definitions.

Aquarius Data Grade	Aquarius Numeric Value	Definition of Value
Excellent	51	*
Very Good	41	*
Good	31	*
Poor	11	*
Substandard	2	Must be used when the drift correction required exceeds the upper limit of the 'Poor' data grade.
Unverified	1	Must be used when it is not possible to use a reliable manual groundwater level measurement to correct the data. E.g., site visit occurred during a period when the datalogger was shutdown (power failure); therefore, the manual water level measurement during the site visit could not be used to confidently determine sensor drift. Should also be used for imported historical data for which the manual water level measurements are not available or otherwise not reliable.
Undefined	0	Auto-assigned by Aquarius to the ingested telemetry data, *prior* to grading.
Unspecified	-1	Auto-assigned by Aquarius to the appended logger data *prior* to grading.

*Values are an upper and lower range, as determined by the **Groundwater Level Data Grading spreadsheet** (**Appendix A6** [**Section A6.1**]).

4.2.6.1 Grading Guidance

In cases where multiple data corrections in Aquarius are required, namely offsets combined with drift corrections, the appropriate grading to apply may be unclear. It is important to remember that grading is based on the degree of instrument error (i.e., sensor drift) and sources of non-instrument error **should not** count towards the selected data grade. See the following examples:

- When processing data from a non-telemetry site, the stick-up height was not accounted for properly and the height is then corrected for in Aquarius by applying an offset. This offset would not count towards the data grading as it is a data processing (i.e., calculation) mistake and does not reflect instrument error.
- While reviewing data, it is clear that the cable length suddenly changed at a precise moment such as if a direct-read cable slid partially out of its barometric enclosure due to a loose connection, causing the data to 'jump' from that point forward. This could be corrected for by using an offset. This offset (i.e., cable length change) is not a product of instrument error and should not result in a lower grading.

Broadly speaking, in cases where an offset must first be applied to the data, followed by a drift correction, the Aquarius drift correction value would be calculated by first determining the necessary offset value and then subtracting that value from the 'total drift':

- **The offset** would equal the difference between the selected period of data's starting point and its corresponding Field Visit value.

- **The 'total drift'** would equal the difference between the selected period of data's end point and the most recent Field Visit value.
- The difference between those values would be the calculated drift correction value that must be applied to the selected data, after the offset is applied. This calculated drift value should be used when selecting the data grading.

For example:

- While reviewing data, a 20 cm jump in the starting point of the appended data can be clearly seen and is believed to be a result of a shifted cable length. Meanwhile, the end point of the period of appended data is 22 cm off from the most recent manual water level tape measurement (i.e., 'total drift').
- In this case, an offset of 20 cm to the appended data should be applied first to account for the non-instrument error (i.e., incorrect cable length). A drift correction of 2 cm would then be applied (i.e., the difference between the 'total drift' and the estimated offset correction). The data grading would be based on this 2 cm drift value.

It should be noted that the data corrections should ultimately align the data with the manual water level measurements as shown on the Field Visits in Aquarius, provided that there is confidence in those manual measurements.

This guidance does not cover all hypothetical complicated data correction cases. Consult with your Groundwater Monitoring Specialist when uncertain as to which corrections or grading would be most appropriate.

Behold! Another easter egg, of sorts. If you are reading this, please notify the Groundwater Monitoring Program Supervisor of the section number.

4.2.7 Data Approvals

There are three approval levels in Aquarius: '**Working**', '**In Review**', and '**Approved**' (**Table 4-4**). These are intended to provide the groundwater level data user with an understanding of the stage of compensation and processing that has been conducted on the collected groundwater level data.

Table 4-4 Aquarius approval levels.

Approval Level	Description
Working	No data processing has been conducted other than uploading of raw logger data into the database.
In Review	Data has been worked on by the Field Technician (corrections and grading applied) and has been submitted for final review but not yet approved by the Groundwater Monitoring Specialist.
Approved	The data has undergone review by the Groundwater Monitoring Specialist and corrections and grading are considered appropriate based on the field notes.

After the Field Technician completes the data corrections and appending, the respective section of data may have its approval level changed to “In Review” to make it easier to identify during the subsequent review process (although this is not required). This will highlight data awaiting final approval.

The Groundwater Monitoring Specialists are the designated data approvers who are responsible for ensuring that the data corrections and grading are appropriate. It is imperative for confidence in the data quality that the individuals applying the data corrections are not the same as those approving the data, as per industry standards. The Specialists must follow the **Groundwater Level Data Review and Approval SOP** in **Appendix A6** (**Section A6.2**) prior to changing the data approval level to “Approved”.

4.3 EMS (WATER QUALITY)

The Environmental Monitoring System is the data repository for environmental monitoring data. The system was designed to capture data covering physical, chemical, and biological analyses performed on water, air, soil, and waste discharges, as well as data from ambient monitoring throughout the province.

Samples are collected by either government staff, permit holders under the *Environmental Management Act*, or authorized third parties, and are analyzed in public or private sector laboratories.

Within EMS, Field Technicians are responsible for:

- Creating EMS IDs for new Provincial Observation Wells (**Section 5.13** and **Adding a Well to PGOWN Systems SOP** in **Appendix A8** [**Section A8.1**]);
- Generating sampling requisitions (CoC) which must be submitted to the laboratory along with the collected groundwater samples (**Section 2.5.7.2**);
- Reviewing analytical results from submitted samples to ensure they are properly uploaded and meet QA/QC standards (**Section 2.5.6** and **Quality Assurance and Quality Control for Groundwater Sampling SOP** in **Appendix A3** [**Section A3.3**]); and
- Updating Provincial Observation Well EMS locations when a station is closed (**Section 6.1.1** and the **Removing a Well From PGOWN Systems SOP** in **Appendix A8** [**Section A8.2**]);

Questions regarding the EMS database, including requesting access and editing permission, can be answered by emailing EMSHELP@gov.bc.ca. Analytical results can be viewed or downloaded as Excel files by visiting the EMS website.

5.0 NETWORK EXPANSION

New wells will be added to the PGOWN over time, either to replace existing Provincial Observation Wells or to expand the existing network. New wells can be added to the network in two ways:

1) **Adoption**: the area of interest has an existing well that can be adopted into the network, provided the well meets certain criteria; or

2) **Installation**: if no suitable Provincial Observation Well exists in the area of interest, a new well can be installed.

In either case, proposed wells must be suitable to provide representative groundwater level and quality data for the area and aquifer of interest (i.e., must meet specified location and depth requirements, and be suitably designed to provide accurate water level and / or water quality data).

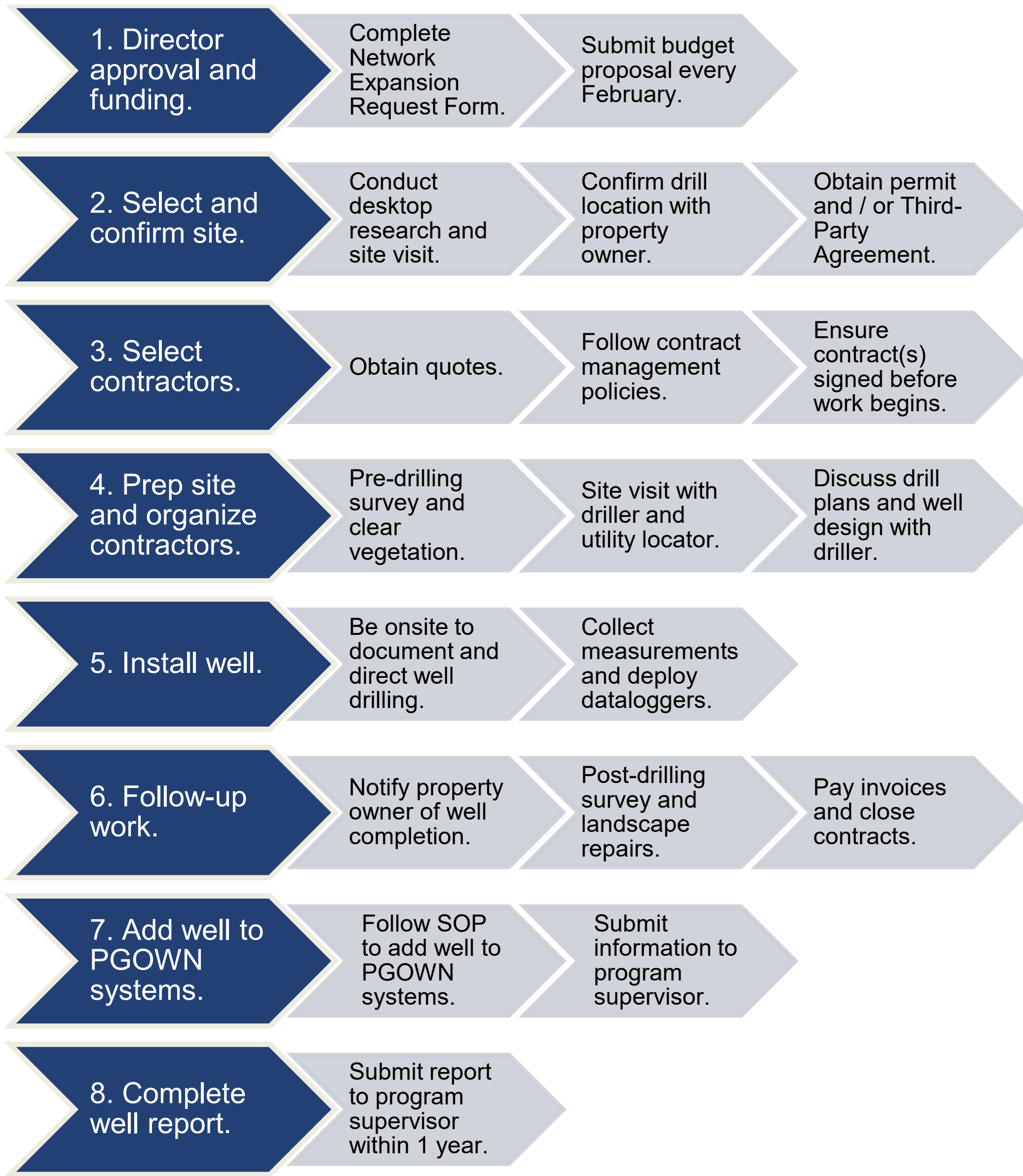
There are various reasons for expanding the PGOWN into previously unmonitored (or under-monitored) aquifers, including but not limited to the following:

- High level of local dependence on groundwater as a resource;
- Documented water scarcity / decline in an aquifer;
- Projected increased groundwater demand and / or decreasing groundwater recharge;
- High groundwater licencing demand (i.e., project will support authorization decisions);
- A need for more data / knowledge regarding surface water-groundwater connectivity;
- To support First Nation reconciliation efforts; and
- To support specific regional or Provincial groundwater policy development or plans.
    - E.g., Township of Langley Water Sustainability Plan, Mackenzie River Basin Bilateral Water Management Agreement between BC and NWT, etc.

Expansion of the network is driven at the regional level as local staff are most familiar with the water-related issues specific to their region. The Groundwater Monitoring Specialists, while working together with regional staff, will help to manage these projects. More broadly speaking, CHASM is responsible for developing the policies that guide network expansion and will also provide the necessary funding.

The following figure (**Figure 5-1**) outlines the general network expansion process. These steps are then detailed further in the sections that follow. Please note that some steps listed below do not apply in instances where an existing well is adopted into the network.

Figure 5-1 Broad overview of network expansion steps.



Please note that throughout the process of adding a new well to the PGOWN, **all related documents must be saved to the project folder** (permits, quotes, contracts, site photographs, utility locate results, etc.) and, where specified below, provided to the Groundwater Monitoring Program Supervisor.

5.1 EXPANSION APPROVAL & FUNDING

Expansion of the PGOWN begins when regional WLRS Director-level approval is provided by completing the **Network Expansion Request Form** which can be found on the **PGOWN MS Teams Channel** (alternatively, the **Network Well Replacement Request Form** should be completed when replacing an existing well). This approval document outlines the steps that are required to obtain Director approval and lists the financial and resource requirements that must be considered as part of maintaining an additional Provincial Observation Well to the minimum network operational standards. It is completed by the respective Groundwater Monitoring Specialist and regional WLRS staff, and then reviewed and approved by ENV before being signed by the respective regional WLRS Director.

Following the completion of the **Network Expansion Request Form** (or the **Network Well Replacement Form**), a funding proposal must be made to CHASM. This funding proposal will require a draft quote(s) for the necessary contract work (e.g., well driller, surveyor, landscaper, etc.). Please follow the instructions in the **Budget Proposal - Network Expansion / Replacement Form** which is distributed every January from the Groundwater Monitoring Program Supervisor. Budget proposals for the PGOWN are typically due in February of each year and, therefore, a rough outline of expansion plans should be completed in the preceding months.

5.2 SELECTING SUITABLE SITES

Once the aquifer and / or general area of interest has been confirmed, the initial recommended step is to complete a desktop screening exercise to develop an understanding of potential conditions and inform potential site selection. This understanding is important as sub-surface conditions can be geologically complex and heterogeneous. For example, a given location may include multiple overlapping aquifers and the spatial extent and vertical depths of a particular aquifer of interest and / or adjacent confining units may vary locally. Desirable well locations may also be impacted by practical considerations such as land ownership, use and access.

Potential considerations and sources of information to review include:

- Aquifer type (unconfined vs. confined, bedrock vs. unconsolidated), extent and depth:
  - iMap BC and the BC Groundwater Wells and Aquifers database (GWELLS) – To review local and regional hydrogeological reports and aquifer maps to help understand the potential aquifer conditions that may be encountered during drilling.
- Groundwater levels and fluctuations:
  - iMap BC, GWELLS, and the Groundwater Level Data Interactive Map – Groundwater levels from nearby Provincial Observation Wells, or that were reported during installation of other nearby wells and are included on the well construction logs submitted to the province.
- Activities in the area that may influence representative data collection:
  - iMap BC – For identification of potential registered contaminated sites or sources of contamination prior to site selection; and
  - iMap BC and GWELLS – Local presence of high well density or large-scale groundwater extraction (i.e., potential pumping interference).
- Land ownership, use and access:
  - BC cadastral data (ParcelMap BC) – For land ownership, with preference for publicly-owned land;

    - Road right-of-ways (RoW) and parks are the most commonly selected sites. RoWs owned by the Ministry of Transportation and Transit (MoTT) are the easiest (fastest) for obtaining approval to drill a well.
    - Drilling or adopting wells on private property is to be avoided as much as possible, although in some rural regions, this may not be feasible.
  - iMap BC, Google Earth, Google Street View, municipal or regional GIS mapping websites – To identify surface features and land use which could impact drilling conditions and site access for drill rig or work vehicle access to the site (such as overhead electrical lines, wetlands, surface water, forest land cover, nearby heavy industrial use [potential sources of contamination], etc.);
  - Readily available utility information (sewer lines, water lines, etc.) on municipal or regional GIS mapping websites; and
  - Road and topography maps (e.g., Google Earth, Google Street View, municipal or regional GIS mapping websites) – To identify presence of access roads to potential locations.

Once potential drill sites have been identified, field reconnaissance is required to confirm that there is sufficient space for drilling and well installation (i.e., drill rig, supply truck and other vehicles and equipment). Ideally, multiple potential drill locations on the property should be identified in case the property owner has a preference on where the well is installed and / or the driller or utility locator has any accessibility concerns.

Staff should reach out to the property owner(s) to explain the objectives of the drilling project and begin discussions on confirming the selected site(s); however, this is not necessary for certain property types, such as RoWs owned by MoTT which simply require a single permit to be approved.

5.2.1 Well Adoptions

Provincial Observation Wells can also be added to the PGOWN through the adoption of existing wells. This can save time and funding for staff and the PGOWN program. However, prior to making any commitments to adopt a well, staff must discuss such plans with their Groundwater Monitoring Specialist and Regional Hydrogeologist. Moreover, in addition to the site selection criteria indicated in the section above, the following should also be considered when evaluating whether to adopt a well into the PGOWN:

- The well has a complete well record with construction details;
- The screened interval targets the identified aquifer of interest;
- The well meets the minimum construction requirements (**Section 5.6**);
  - E.g., the well is at least 76 mm (3 in) in diameter, screen does not cross confining units, meets requirements of the BC Groundwater Protection Regulation (BC GWPR 2022), etc.
- The well can be accessed easily by a Field Technician;
- The well is located on public land and is not at risk of being sold or redeveloped within the next 10 years; and

- The property owner is willing to sign a Third-Party Agreement (**Land Access Agreement**, **Section 5.3**).

After reviewing and assessing the items in the list above, the Field Technician must complete the following:

- A site visit where photographs, GPS coordinates and well measurements (i.e., casing diameter, stick-up, total depth, etc.) are taken;
    - Compare measured well dimensions to well construction report to highlight and investigate any discrepancies.
- Conduct a downhole camera inspection of the well to confirm construction and condition; and
- Deploy temporary pressure transducers (e.g., Divers or Leveloggers) and log the water levels in the well for at least 6 months. Review the collected data and confirm that the well is functioning properly.

Upon completion of the site visit, review the collected information to assess if the well meets the BC GWPR (2022). If the well does not meet the BC GWPR requirements, confirm what needs to be completed to bring the well into compliance and if this can be completed by a qualified contractor.

If the well meets the above criteria, it can be considered for adoption into the PGOWN. It should be noted that if well ownership is to be officially transferred to ENV from the property owner (discuss with the property owner first), an **Acknowledgement, Release and Indemnity Agreement** must be completed. That being said, it is not a requirement to transfer well ownership when adopting a well. Contact the Groundwater Monitoring Program Supervisor for a copy of this agreement template.

5.3 LAND ACCESS AGREEMENTS & PERMITS

Following the selection of a suitable location for a Provincial Observation Well, the necessary approvals must be obtained for drilling on the site (or adopting an existing well) which will require contacting and working with the property owner.

Below is a list of common approvals required prior to drilling:

- Third-party Agreement (**Land Access Agreement**):
    - Required when drilling on private or public land not owned by the Province (e.g., municipal parks or road RoWs not owned by MoTT).
    - Spells out the roles and responsibilities of the Province (ENV and WLRS) and the property owner, and includes an indemnity clause.
    - Contact the Groundwater Monitoring Program Supervisor for the appropriate template.
- Highway Use Permit:
    - Often required when drilling on municipal road RoWs, in addition to a **Land Access Agreement**.

    - Contact the respective municipal or regional government for details.

- Permit to Construct, Use, and Maintain Works within the RoW of a Provincial Public Highway:
    - Required when drilling on MoTT RoWs.
    - Contact regional MoTT staff. Introduce yourself, briefly describe the project and its location. They will provide you with the necessary permit application template.

- Park-use Permit:
    - Required when drilling in a Provincial park.
    - Contact BC Parks for details and for the permit application.

Please note that most of these agreements and templates will have expiry dates that must be tracked in the **Regional PGOWN Tracking Spreadsheet**.

In addition to saving all necessary agreements and permits to the project folder, please send copies to the Groundwater Monitoring Program Supervisor.

5.4 CONTRACTS

For the drilling of new Provincial Observation Wells (or other high value / high risk contractor services), a contract must be written. This process begins by contacting at least three qualified drillers to obtain quotes (ensure that these emails are saved in the event of a financial audit); please note that you do not need to actually receive a minimum of three quotes, only to prove that you contacted at least three potential contractors about providing quotes (i.e., in the event that some contractors may wish not to bid on a project). Provide the contacted drillers with sufficient detail (e.g., site location, well depth and diameter, accessibility issues, scope of work, etc.), such that they can develop an accurate quote. For complicated sites, this may necessitate a site visit prior to developing the quote. To solicit quotes for services under $75,000 or construction under $100,000, a Non-Binding Request for Quote may be used. For services or construction greater than these thresholds, solicitations must be posted to BC Bid. Refer to the Core Policy and Procedures Manual, Chapter 6: Procurement.

Once the quotes are obtained, review the quotes for completeness (i.e., that they meet the scope of work) and select your contractor(s). There are then a series of procedures and forms that must be followed and completed, in addition to writing the actual contract. For current templates and policies refer to the Corporate Services for the Natural Resource (CSNR) Ministries Forms and Templates website.

While there is no set value threshold for when a contract must be used, it is the preference of CSNR that when paying a fee for service, regardless of the dollar value, there should be a contractual agreement in place prior to services being rendered. That being said, you may purchase through a direct invoice instead of a contract when:

- A Corporate Supply Arrangement (CSA) is not available;
    - Note: the CSA must be used if available.

- Purchase is standard and "off the shelf";
- Value is low and you have determined that the price reflects market rates; and
- The purchase is low risk (see Risk Management for Procurement) and short term.

For example, some sites may need minor landscaping to prep a site for drilling (such as clearing bushes or tall grass) and this service may cost in the hundreds of dollars. This short term, low value service likely would not require a contract. Please contact the Groundwater Monitoring Program Supervisor for further clarification, if needed.

5.5 OTHER CONSIDERATIONS

The following should also be considered prior to and during the installation of new Provincial Observation Wells:

- Pre and post-drilling surveys (see **Section 3.1**):
  - If the locations of property boundaries are not clear, a surveyor must be hired to locate and flag property boundaries in advance of drilling.
  - Upon completion of drilling, new Provincial Observation Wells should be surveyed professionally and the various PGOWN-related systems updated with the latitude, longitude, and ground elevation values.
  - Pre- and post-drilling surveys should include the production of site plans which must be saved to the project folder.
- Landscaping / site alterations:
  - Some sites may require landscaping and / or other alterations (e.g., placement of temporary gravel pads) to allow access and / or improve telemetry performance. Discuss with the property owner prior to the start of drilling.
  - If a site becomes damaged as a result of drilling, installation and / or well development activities, a landscaper should be retained to repair this damage upon completion of the work.
- Notify neighbours:
  - To avoid potential conflicts, it would be prudent to notify nearby neighbours (if any) well in advance of the drilling project. This is especially necessary if the well is to be installed directly in front of an individual's property.
  - Explain the objective of the PGOWN and the reason this well is being installed, along with the drilling dates and approximate well location. Include a photograph of a typical completed PGOWN well.

5.6 WELL DESIGN

Provincial Observation Wells must be properly designed to meet their intended objectives and comply with Provincial regulations (i.e., BC GWPR). A Provincial Observation Well that is appropriately designed for the anticipated geological and hydrogeological conditions at the selected location can provide representative and high-quality groundwater level and chemistry data, have lower operating costs, and will have a longer operational lifespan.

There are several considerations regarding the well design prior to starting any drilling program, although anticipated design specifications may change based on actual field conditions. Key considerations include:

- Well use and objective (including any need for a pumping test);
- Regulatory requirements;
- Well configuration (i.e., single, nested, or clustered well configurations);
- Well diameter;
- Casing materials and strength;
- Well screens and filter pack;
- Seals and cements that can be used;
- Artesian versus non-artesian conditions and associated well completion requirements; and
- Surface completion.

The drilling contractor selected to install a Provincial Observation Well is a good resource to provide input on well design. The design of the Provincial Observation Well and the equipment capabilities of the drilling contractor need to align to minimize potential issues during the installation process.

More for information, in addition to the following sections, refer to the **Guidance Document on Standard Well Design for the PGOWN** which can be found on the **PGOWN MS Teams Channel**.

5.6.1 Well Use & Objectives

The initial step of the design process is to determine the objective of the new Provincial Observation Well. This will include identifying what data needs to be collected to inform this objective (i.e., groundwater levels, hydrogeological property testing, groundwater quality, etc.), which will require:

- Determining the target aquifer of interest, the expected depth to the aquifer, and the expected depth interval of the aquifer; and
- Estimating the groundwater level fluctuation as a result of nearby groundwater withdrawal and seasonal variability.

Standard monitoring objectives for Provincial Observation Wells include, but are not limited to:

- Baseline groundwater level collection;

- Data collection for a groundwater research project;
- Groundwater level monitoring in a developed aquifer;
- Water quality monitoring for potential saltwater intrusion; and
- Monitoring for drought and / or flood conditions.

5.6.2 Regulatory Requirements

The BC GWPR (2022) identifies some well design objectives and minimum specifications (e.g., casings and liners, surface seals, and wellhead completion). The following subsections on well design consider these requirements but the BC GWPR (2022) should be reviewed.

5.6.3 Single, Nested, & Clustered Wells

The use of a single well versus a nested or clustered well configuration will depend on whether single or multiple aquifers or depths within the same aquifer are being monitored at a given location. A single well is often sufficient to monitor groundwater conditions in a specific aquifer and at a selected location. However, there may be some settings that warrant a nested or clustered well configuration (e.g., assessing groundwater conditions in a layered or multi-aquifer setting, or assessing vertical groundwater flow gradients).

A clustered configuration is defined by two or more wells installed in separate boreholes in close proximity (i.e., a few metres apart), whereas a nested configuration features multiple wells installed in a single borehole (shown in **Figure 5-2** (a) and (b), respectively).

The USGS recommends short-screened wells installed in separate boreholes for their National Water Quality Assessment studies (Lapham et al. 1995). A general rule of thumb is maintaining a 1.5 to 3 m separation between multiple single wells in a cluster to ensure well integrity without compromising the intent of collecting multi-depth data at a given location. While nested wells can be less expensive to drill and construct than clustered wells because multiple wells can be installed in a single borehole, there is a greater risk that the filter pack and seals may not be properly installed; this could result in hydraulic-communication between the saturated zones (i.e., potential for vertical flow from overlying saturated zones through the supposedly sealed annular space). In addition, the typical minimum diameter (**Section 5.6.4**) for new Provincial Observation Wells (76 mm or 3 in) could require the drilling of larger diameter holes to accommodate a nest and thereby offset any potential cost savings. Therefore, a nested configuration is not typically recommended.

Separately, a multiport sampler (i.e., continuous multichannel tubing [CMT] or Westbay Instrument) is an instrument installed in a borehole that allows for the collection of groundwater level and quality data at multiple discrete depths in a single borehole (**Figure 5-2** (c)). These types of instruments have not been used in the PGOWN as they cannot be used to measure groundwater levels with standard equipment and are costly to install and maintain.

Figure 5-2 Clustered and nested well configurations.

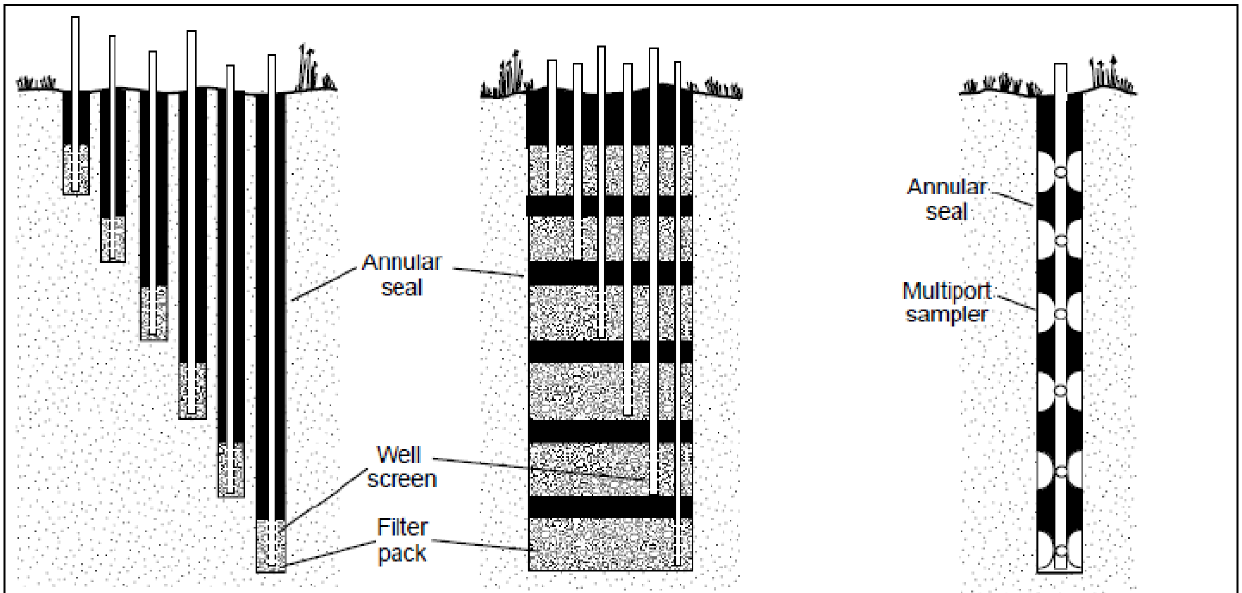


Photo source: Lapham et al., 1997

5.6.4 Well Diameter

For the purpose of this document, the term 'well diameter' refers to the inner diameter of the Provincial Observation Well. The well diameter should be large enough to accommodate all equipment that might be used in the well, for example:

- Submersible pumps and tubing for groundwater sample collection;
  - This is the most common groundwater sampling method for Provincial Observation Wells and requires a minimum diameter of 52 mm (2 in) to accommodate the pump.
- Submersible pumps and tubing, or slugs, for testing;
  - Provincial Observation Well screen diameter must be large enough that the uphole velocity is <1.5 m/s and the groundwater entrance velocity does not exceed 0.03 m/s. Generally speaking, the larger the diameter of the screen, the lower the entrance and uphole velocity (Driscoll 1986). The minimum diameter to achieve these velocities is 152 mm (6 in), assuming a required pumping rate of <950 m^3/day (Driscoll 1986). The Regional Hydrogeologist or Groundwater Monitoring Specialist should be consulted as part of this step.
- Pressure transducers and associated cabling;
- Water level tapes; and

- Downhole cameras.

However, it should be noted that wells should not be larger than required due to possible disadvantages associated with the need for larger diameter boreholes and potentially different drilling methods, increased drilling and materials cost, and increased purge volumes associated with groundwater sample collection.

Table 5-1 compares the advantages and disadvantages of three common well diameters.

For reference, Provincial Observation Wells should typically be at least 76 mm (3 in) in diameter for wells that do not require a pumping test, or 152 mm (6 in) for wells requiring a pumping test. This has been determined to be a suitable diameter that leaves enough space inside the Provincial Observation Well for both groundwater level instruments (i.e., pressure transducers) and groundwater quality equipment (i.e., submersible pumps) that are typically used by Field Technicians. A Provincial Observation Well design with either a larger or smaller diameter should be discussed with the Groundwater Monitoring Specialist or Regional Hydrogeologist prior to deviating from this internal standard.

Table 5-1 Comparison of common well diameters.

Well Inner Diameter	Advantage	Disadvantage
≥102 mm (4 in)	▪ Better for aquifer testing as high-capacity submersible pumps can be installed. ▪ Greater variety of well development techniques available. ▪ Greater casing tensile strength (depends also on casing material). ▪ Fewer limitations on the diameter of sampling and monitoring instruments that can be installed. ▪ Common size diameter and material is typically readily available.	▪ Greater purge volume, therefore greater time required for well development and sampling. ▪ Reduced ability to withstand casing collapse (depends also on casing material). ▪ Increased drilling and material costs.
76 mm (3 in)	▪ Less purge volume, therefore less time required for well development and sampling. ▪ Greater ability to withstand casing collapse (depends also on casing material). ▪ Reduced drilling and material costs. ▪ Can fit both groundwater quality sampling equipment and pressure transducers at the same time.	▪ Less casing tensile strength (depends also on casing material). ▪ Well development may be less effective; effects may extend only +/- centimetres beyond well screen. ▪ Equipment for pumping tests have reduced options for 76 mm wells compared to larger diameter wells. ▪ Odd sized diameter that may not always be readily available.
≤52 mm (2 in)	▪ Less purge volume, therefore less time required for well development and sampling. ▪ Greater ability to withstand casing collapse (depends also on casing material). ▪ Reduced drilling and material costs. ▪ Development can be completed using surge blocks (common equipment that is readily available). ▪ Common size diameter and material is typically readily available.	▪ Less casing tensile strength (depends also on casing material). ▪ Equipment for pumping tests have reduced options for 52 mm wells compared to larger diameter wells.

5.6.5 Well Casing Materials & Strength

Wells comprise a screened section (at the desired depth to monitor groundwater levels, test aquifer properties or collect samples) and solid casing (which extends from the top of the screen to well stick-up or ground surface). The well casing is used to maintain borehole stability and stop material (i.e., sediments or groundwater) from entering the well from the adjacent formation.

Provincial Observation Wells completed in competent bedrock generally do not require a casing for the entire length of the borehole. Typically, the casing only extends through overburden / weathered bedrock and then at least 1 m into competent bedrock (BC GWPR 2022). In most cases, competent bedrock sections can be completed as an open hole. However, in situations where the bedrock is weathered, poorly cemented, highly fractured, or a discrete groundwater bearing unit is being targeted, a casing or PVC liner to the target depth should be used. Discuss with a Groundwater Monitoring Specialist or Regional Hydrogeologist before committing to a bedrock well design.

5.6.5.1 Casing Materials

Multiple types of casing materials are available. Under certain conditions, the following factors may become important and warrant consideration when selecting well casing material:

- **Strength of casing material**: it must be able to withstand the forces that act upon it during and after installation (i.e., grouting, development, pumping, sampling, forces exerted by the surrounding geological formation, etc.);
- **Formation characteristics**: the casing must be durable enough to maintain structural integrity in the natural environment for the operational lifetime of the well; and
- **Geochemical composition of groundwater**: the casing must not be susceptible to degradation due to the composition of groundwater and the surrounding environment, and the casing material should not impact the chemical composition of groundwater.

Table 5-2 provides some advantages and disadvantages of various casing materials. It is important to note the GWPR (2022) requires that all PVC materials used should be new or in like new condition. Ideally, all material installed below the ground surface (i.e., PVC casing, screens etc.) are new.

Table 5-2 Comparison of common well casing materials.

Material Type	Advantage	Disadvantage
PVC (Thermal Plastic)	▪ Resistant to corrosion. ▪ Does not leach. ▪ Strong in most environments. ▪ Light weight, flexible, easy to thread. ▪ Inexpensive.	▪ May fail under high pressure and / or temperature. Depending on diameter and wall thickness of PVC, caution should be exercised if used for deep wells (i.e., schedule 40 PVC should not be used for wells >60 m and schedule 80 should not be used for wells >150 m). ▪ Can absorb hydrocarbons. ▪ May degrade in chlorinated solvents or when exposed to ultraviolet rays if stored in direct sunlight.
Steel	▪ Strong, durable, rigid. ▪ Less expensive than stainless steel. ▪ Manufactured well screens available.	▪ Susceptible to oxidation. ▪ May react with metals. ▪ If sections not threaded, requires skilled welders to join casings. ▪ Heavy to transport. ▪ Can be subject to corrosion in select environments[1].

Material Type	Advantage	Disadvantage
Stainless Steel	▪ Less susceptible to corrosion than steel (marine grade stainless steel is recommended for use in corrosive environments). ▪ Does not rust. ▪ Non-reactive to most chemicals. ▪ Very strong. ▪ Manufactured well screens available.	▪ Expensive. ▪ Heavy to transport. ▪ If sections not threaded, requires skilled welders to join casing. ▪ Caution has to be used during installation, as pulling up on the screen can damage the integrity of the slot size. ▪ Can be subject to corrosion in environments that have iron bacteria or other microorganisms, or low pH.

[1]Highly corrosive environments can be classified as: Low pH; High dissolved oxygen; High hydrogen-sulphide gas (H_2S), Total dissolved solids are greater than 1,000 mg/L, Carbon dioxide gas (CO_2) >50mg/L, Combined anions (Chloride (Cl), Fluoride (F) and Bromide (Br) >500mg/L.

New Provincial Observation wells should typically be built from 76 mm (3 in) Schedule 80 PVC to maximize the lifespan of the well. Much of the remainder of the sections below will focus on PVC well casings. However, if a pumping test will be part of the project, then 152 mm (6 in) steel wells should be completed.

5.6.5.2 Casing Strength

Well casing strength will vary depending on the diameter of the well and the casing material selected. Well casing and screen materials should maintain their structural integrity and durability in the environment for the operational life of the Provincial Observation Well. When evaluating suitable casing strength, the following should be considered:

- **Tensile strength**: the longitudinal stress a material can withstand without pulling the material apart. Typically casing tensile strength varies with composition, manufacturing technique, joint type and dimension. For deep Provincial Observation Wells, consideration should be given to whether the selected materials (i.e., casing and screen) have a tensile strength capable of supporting the weight of the casing string when suspended from the surface during installation. The tensile strength of the casing or screen joints should also be considered, as the joint is generally the weakest point in a casing string. By dividing the tensile strength by the linear weight of casing, the maximum theoretical depth that a dry string of casing can be suspended in a borehole can be estimated. As a general rule of thumb, the maximum length of 76 mm (3 in) PVC casing that can be suspended in a **dry** borehole is approximately:
    - Schedule 40 PVC: 600 m.
    - Schedule 80 PVC: 575 m.
- **Collapse strength**: the capability of a material to resist collapse by any and all external loads to which it is subjected to during and after installation. The resistance of casing to collapse is determined by the outer diameter and the wall thickness (i.e., the less surface area and thicker casing walls results in a greater collapse strength). If casing is going to collapse, the most likely time this will occur is when the casing is being grouted inside the borehole due to pressure

differential between the outside and inside of a well (i.e., grout outside the well is denser than air or water in the well). As a general rule, the maximum length of 76 mm (3 in) PVC casing that can be grouted in place during a single grout lift **without** groundwater in the casing to balance the internal and external pressure before collapsing is approximately:

- Schedule 40: 45 m; and
- Schedule 80: 130 m.

If the Provincial Observation Well design is anticipated to be deeper than the depths indicated above, then the casing materials and strengths should be considered in concert with the Groundwater Monitoring Specialist, Regional Hydrogeologist and / or well driller. It is also important to note that PVC specifications can vary from each supplier and the limitations of the materials should be checked in advance of drilling.

5.6.6 Screen Selection

Well screens are intended to keep coarser grained materials out of wells and to maintain borehole stability within the targeted groundwater bearing interval. Similar to well casings, screen materials, configuration and length are dependent on the intended function of the well (i.e., water supply, groundwater level monitoring, groundwater quality sampling, etc.). Provincial Observation Well screens should:

- Provide adequate filtration of aquifer materials;
- Allow groundwater to flow freely into the screened interval;
- Withstand horizontal and vertical collapse pressures; and
- Be constructed of materials that minimize encrustation and corrosion.

Provincial Observation Well screens are either installed using the “single-string” method or telescoped method. In single string installations, the screen is threaded or welded onto the bottom of the casing and lowered into the borehole. Telescopic screens are a smaller diameter than the well casing and are lowered into the casing to the bottom of the borehole. The top of the telescopic screen string will sit up just inside the casing and is sealed off using a rubber packer system (i.e., a K-packer). Depending on the lithology of the screened interval and drilling method, the screen will either be lowered into an open borehole inside the casing or will be lowered into the casing and the casing pulled back exposing the screened interval to the formation. Typically, telescopic screens are used in Provincial Observation Wells that are >156 mm (6 in) in diameter.

As the main purpose of Provincial Observation Wells is to monitor groundwater levels, maximizing the screen open area and volume of water that can flow into the screen interval quickly is not a critical consideration (i.e., maximizing the overall well efficiency is not necessary unless a pumping test is to be performed).

Although groundwater quality is not the primary objective of Provincial Observation Wells, the screen material should be carefully selected so as to not bias any collected data. Ideally, all screens should be constructed of either continuous slot stainless steel or slotted PVC.

Finally, screen length (i.e., vertical extent and depth of the adjacent formation being monitored or sampled) should be considered. Typically, the final screen length is determined in the field based upon encountered geology and hydrogeology (i.e., if the target groundwater bearing unit is thinner / thicker than initially planned). Moreover, well screens must not be so long, or placed in a position where they will cross a confining unit.

For Provincial Observation Wells, typical well screens use the “single-string” completion method, are constructed of PVC, are 76 mm (3 in) in diameter, and are 3 m (10 ft) or less in length. All screens should be machine slotted and are typically 0.254 mm (10-slot) wide. This screen design is suitable for most applications requiring groundwater level and quality monitoring as it will help to prevent infilling of the well with sediment; however, it may not be suitable in wells intended to be used for pumping tests.

5.6.7 Filter Packs

A filter pack is composed of sand or gravel placed around the screened interval and is intended to stabilize the screened interval and provide a level of filtration to prevent fine-grained material from entering the well. Ideally, an optimally sized filter pack will minimize the pumping of sand and maximize the efficiency that groundwater is withdrawn from a well. The type of filter pack that is used will depend partly on the aquifer materials encountered, the well design, the practical limitations of the drilling equipment, and material costs.

Either natural or artificial material can be placed and used as filter packs around the screened interval of a well. A natural filter pack is created by developing the well until all the fine sediment in the adjacent formation material is removed through the well screen and out of the well, leaving behind coarse material around the exterior of the screen. An artificial filter pack comprises materials that are poured from the surface into the borehole annulus around the screen after the screen and casing assembly have been lowered into the borehole (e.g., well-sorted inert sand or gravel). For observation wells, it is typical to use 10/20 graded filter sand for artificial filter packs.

An artificial filter pack should be used when:

- The screened interval is either poorly sorted or contains a lot of fine-grained material (i.e., fine sand, silt and / or clay);
- A long-screened interval is required and / or spans highly stratified geologic materials of widely varying grain sizes; or
- The diameter of the borehole is significantly greater than the diameter of the screen.

Natural filter packs are typically used in coarse-grained unconsolidated groundwater bearing units (i.e., sand and gravels with trace-to-no fines) or when an artificial filter pack cannot be placed around the screened interval (i.e., as a result of heaving sand and gravel).

With both artificial and natural filter packs, there is a relationship between the ideal screen slot size and filter pack size, and both are dependent on the aquifer materials. Typical artificial filter packs consist of sand that is graded to be between 0.5 to 1.0 mm in diameter (i.e., 10/20 graded sand). Larger diameter filter sand could result in additional development time as less fine-grained material would get caught up in the filter pack.

5.6.8 Seals and Cements

The BC GWPR (2022) requires a minimum 1 m surface seal that is not less than 2.54 cm thick around the well casing. A surface seal is intended to prevent entry of any foreign surface material / runoff into the borehole and aquifer.

Best industry practice typically exceeds this requirement and includes seal placement from ground surface to the top of the filter pack. This continuous seal prevents groundwater from moving within the annular space around the well and between groundwater bearing intervals; it also reduces the potential of surface contamination into the underlying aquifers and satisfies regulatory requirements.

The two most common materials used for seals are bentonite (chips or pellets) and grout. Grout is often composed of a mix of cement and bentonite in order to prevent the cement from cracking. The advantages and disadvantages of both types of seals are outlined in **Table 5-3**.

Table 5-3 Comparison of bentonite and cement as a sealant.

Sealant Type	Advantages	Disadvantages
Bentonite Chips & Pellets	▪ Readily available and inexpensive. ▪ Pellets and chips are easy to use. ▪ Expands 10-15x dry volume when hydrated. ▪ Low hydraulic conductivity (~1 x 10^{-7} to 1 x 10^{-9} m/s). ▪ Can provide good (non-rigid, non-cracking) low K seal when saturated.	▪ Effectiveness of seal is difficult to assess. Complete bond to casing not assured. ▪ Because of rapid hydration, bentonite can stick to walls of annulus and bridge annulus, although coated bentonite pellets are less susceptible to bridging. ▪ May not be effective seal in unsaturated zone because of desiccation.
Bentonite – Cement Grout	▪ Readily available and inexpensive. ▪ Typically is uniformly placed around the casing. ▪ Can assess continuity of placement using temperature or cement bond logs.	▪ Requires water, mixer, pump, and tremie pipe for placement (tremie pipe is a narrow diameter pipe used for injecting the grout mixture into the annulus). ▪ Generally more cleanup is required than with bentonite chips. ▪ Premature and / or partial setting of the cement, insufficient grout column length, voids and / or gaps in the grout column, or excessive shrinkage of the cement may result in grout failing to form a seal. ▪ Additives to the cement to compensate for natural shrinkage can cause an increase in pH, dissolved solids and temperature of the groundwater during the curing process. The increased pH causes precipitation of calcium and bicarbonate ions from the groundwater. ▪ Soluble salts in the cement can be leached by the groundwater. ▪ Cement in the grout may cause unusually high values of pH in groundwater-quality samples. ▪ Heat of hydration during curing can deform or melt thermoplastic casing such as PVC.

Bentonite: A hydrous aluminum silicate composed primarily of montmorillonite.
Cement: Composed of calcium carbonate, alumina, silica, magnesia, ferric oxide and sulfur trioxide with pH ranges from 10 to 12.
K: hydraulic conductivity.

The type of sealant material selected will depend on borehole depth and encountered drilling conditions. For example, if drilling into a shallow, unconfined aquifer (i.e., <30 m deep), then bentonite chips will suffice. When using bentonite chips to backfill the borehole annulus, the chips should be poured slowly to minimize bridging which will result in voids in the annular space.

For deep boreholes (i.e., >30 m deep), a bentonite cement grout seal is preferable. When using bentonite-cement grout, an intermediate layer of polymer coated bentonite pellets needs to be placed between the filter pack and grout. This is intended to reduce the potential for grout to migrate into the filter pack and screened interval which would result in the Provincial Observation Well being sealed off from the formation. Coated bentonite pellets are recommended as they have a slow hydration time and are less likely to bridge as a result. After placement of the polymer coated bentonite pellets, they should be left to sit for approximately 30 minutes to 1 hour to hydrate and then grout should be placed in the borehole as the outer casing is withdrawn to ensure consistent seal placement around the borehole annulus. When using grout, the Mikkelsen (2003) mix design (**Table 5-4**) is recommended as a base for the ratio of cement-to-water-to-bentonite. The mix design recommends Type G cement and bentonite powder. It is common that this mix design needs to be adapted based on conditions encountered during drilling (i.e., large groundwater bearing fractures or artesian conditions). It is preferable that the grout mix is as thick (following the cement-to-bentonite ratio below) as the drilling contractor’s equipment can safely handle.

Regardless of the type of sealant, it is important to ensure that there is at least 0.6 m of filter sand or formation material above the well screen prior to applying the sealant to prevent the sealant from migrating down into the well screen.

Table 5-4 Mikkelsen grout mix.

Material	Weight (kg)	Ratio by Weight
Water	150	2.5
Cement (Type G)	60	1
Bentonite (powder)	18	0.3

5.6.9 Artesian Provincial Observation Well Design

If artesian conditions are expected or encountered at a Provincial Observation Well location, additional GWPR (2022) requirements for well design should be considered. For example, flowing artesian wells must be maintained in a manner that allows flow to be controlled and prevent the flow of water back into the well (BC GWPR, Part 8; 2022). This includes securely attaching a well cap to the casing to prevent or minimize the flow from an artesian well and preventing damage caused by freezing conditions in cold climates. Additional discussion regarding sealing options and wellheads is provided below.

5.6.9.1 Sealing Options

When artesian conditions are encountered within the target groundwater bearing interval (or above), necessary steps must be made to prevent groundwater from flowing up the annular space between the casing and the borehole wall. Under non-artesian conditions, either bentonite chips / pellets or a grout mix can be used to prevent water from migrating from upper units (or ground surface) down through this space.

When constructing a Provincial Observation Well that has encountered artesian conditions, a bentonite-cement grout mix should be used (**Table 5-4**). The grout mix can be altered (i.e., increase the proportion of bentonite to cement) to have a higher density, that can overcome the upward artesian groundwater pressure (i.e., borehole hydrostatic pressure is greater than formation pressure). Grout is also preferred to bentonite chips as it is less likely to bridge, will completely fill the annular space and is more likely to seep into any voids and fractures in the geologic unit, as well as bonding to the adjacent units.

5.6.9.2 Wellheads

The GWPR (2022) requires that for all artesian wells, the wellhead must be sealable to prevent groundwater from flowing out of the top of the casing.

Figure 5-3 provides an example of an artesian wellhead assembly that was installed in Provincial Observation Well 460. The assembly within the wellhead cabinet mounted on top of the well casing includes:

- A forked / branched PVC wellhead with three separate, sealed access points into the well;
- A pressure gauge to allow for manual reading of pressure and verification of pressure transducer data (left fork, on the figure);
- A surface packer (top fork, on the figure) that prevents groundwater from freely flowing out of the top of the Provincial Observation Well, and is equipped with a sealing gland which allows for the permanent installation of instrumentation (e.g., pressure transducer and cabling) within the well; and
- A sampling port with a valve (right fork, on the figure) to allow for groundwater quality samples to be collected when required.

Alternatively, a higher stick-up height could be used such that artesian flow does not overtop the casing, allowing for all groundwater level data (above grade) to be properly captured. However, this is contingent on having a moderate climate (i.e., well water will not freeze), being able to estimate a proper stick-up height to avoid overflow, and the stick-up height not having to be so large as to create a safety issue with the operation of the station (i.e., climbing to the top to download data and collect a manual water level reading).

In colder climates, a packer system on the bottom of the sealable wellhead must be used and set below the frostline. This will prevent the wellhead from freezing and becoming damaged as a result of the freeze / thaw cycle.

Regardless of the wellhead design, artesian wells should not be allowed to overflow as this represents a loss of data. The groundwater level must be able to be measured either with a traditional water level tape or by using a pressure gauge if the system is sealed. Moreover, a barometric pressure transducer must be installed in an adjacent shallow barometric well (**Section 2.4.2.1**). Please consult with your Groundwater Monitoring Specialist or Regional Hydrogeologist to determine a suitable wellhead design when installing such wells.

Figure 5-3 Example of an artesian Provincial Observation wellhead.

Photo source: Hatfield Consultants.

5.6.10 Well Completion

The type of groundwater level monitoring equipment (i.e., pressure transducer, datalogger, etc.) to be installed in the Provincial Observation Well should be identified and confirmed as part of the design process (**Section 2.4**). This will include what protective monuments are to be used upon completion of drilling, and if the selected protective monuments are suitable for the intended groundwater level monitoring equipment.

5.7 BOREHOLE DRILLING

5.7.1 Pre-Drilling Screening

Following site selection and attainment of land-owner permission, but prior to drilling, additional information should be gathered to confirm the absence of local underground utilities or infrastructure at the drilling location.

A BC One-Call service request must be submitted, as well as the hiring of a third-party utility locating contractor. Typically, the retained locator can complete the BC One-Call which notifies utility owners when requests for ground disturbance occur in the immediate area of their utility. However, it should be noted that registration with BC One-Call is not required and privately owned underground utilities (i.e., homeowner / commercial utility lines) may not be registered. Be sure to provide the retained locator with as much information as you can, including a site figure, GPS or other coordinates, or references to physical site features, as well as the number of boreholes and proposed drilling depths. Then book a date with the locator for them to sweep the area around the proposed drilling location(s) to identify if there are any underground utilities.

BC One-Call services should be completed 3 to 14 working days before conducting ground disturbance. Submission and completion of a One-Call request and coordination of any crossing agreements (e.g., pipeline or railroad crossing) is the responsibility of the staff that will be completing the work in the field.

If there is still uncertainty about the exact location of underground utilities and it is not possible to move the proposed well location, a final option may be to hydro-vac the shallow surficial materials to the maximum expected depth of utilities to confirm their absence.

If site accessibility or the underground utilities are complicated, it may be worthwhile to have the drilling contractor and property owner onsite during the utility sweep in case the proposed well location needs to be moved to contend with identified underground utilities. This will allow for all parties to agree upon an exact drilling location.

The results of the BC One-Call and utility sweep of the area must be saved to the project folder.

5.7.2 Drilling Methodologies

There are a number of possible drilling methods, and their selection and use will depend on expected subsurface geological conditions at the proposed location for the new Provincial Observation Well. Possible drilling methods include:

- Hollow and solid stem auger;
- Sonic (**Figure 5-4** – left photo);
- Conventional rotary with water, mud or air;

- Single and dual reverse circulation rotary (**Figure 5-4** – right photo);
- Down-the-hole hammer or air percussion rotary;
- Cored hole or diamond drilling; and
- Cable tool.

The advantages and disadvantages of the various drilling methods are summarized in **Table 5-5**. In general, sonic drilling is preferred as it allows for the collection of continuous subsurface samples with minimal disturbance to assist with development of detailed stratigraphic logs. However, this method may not be available or financially feasible in all parts of the Province or for certain aquifer types / depths. In addition, high resolution stratigraphic logs may not be needed for all drilling projects (e.g., in areas where there are already many detailed well records), in which case a dual rotary drill rig or cable tool rig are the next most common drilling methods for Provincial Observation Wells.

Whenever feasible, drilling practices that do not introduce water or drilling fluids into the borehole should be used. If fluids are needed, select fluids which have minimal impact on the groundwater bearing unit and will not complicate the installation or development efforts. Consult with your selected driller for further information.

Logistical considerations for drilling include:

- Seasonal accessibility to the proposed location;
- Obtaining permits and approval to drill at the site;
- Availability of the necessary equipment and personnel;
- Disposal of cuttings and drilling fluids;
- Experience of the drilling and sampling personnel; and
- Time allocated to complete the drilling program.

Additional drilling considerations include:

- Types and competency of water-bearing units to be drilled and sampled;
- Types and quality of lithologic and other borehole logs required;
- Types and quality of aquifer samples required;
- Minimizing contamination of aquifers via drilling fluid and cross-contamination between aquifers;
- Total depth of drilling anticipated;
- Borehole diameter relative to the well design and construction material;
- Ease of completing the observation well as planned (i.e., ease of installation of the filter pack, grouting and instrumentation);
- Desired stratigraphy resolution (e.g., some drilling methods pulverize or mix the samples which makes it difficult to identify the stratigraphy in detail while other methods provide mostly intact soil cores); and
- Budget availability.

Figure 5-4 Examples of sonic (left) and dual rotary (right) drilling equipment.

Photo source: BC ENV.

Table 5-5 Common drilling methodologies used when drilling Provincial Observation Wells.

Ideal Geologic Formations	Drilling System	Hole Diameter	Maximum Depth	Drilling Process	Advantages	Disadvantages
Unconsolidated	Hollow Stem Auger	160 to 470 mm (6 to 18.5 in)	0 to ~30 m (100 ft)	▪ Equipment is light and easily maneuverable. ▪ The drill head is attached to the first auger flight which is rotated into the ground. Cuttings are rotated up the auger flights to the surface as the borehole is advanced. ▪ To prevent cuttings from entering the “hollow” portion of the auger, a pilot / centre bit is used and held at the cutting face of the augers with drill rods. ▪ Overburden samples can be obtained by removing the pilot / centre bit, attaching a split spoon or thin-wall sampler to the drill rods and lowering them back down through the “hollow” string and into the underlying overburden.	▪ Able to gather relatively undisturbed samples for soil classification purposes. ▪ Allows for well installation through the auger into non-cohesive materials. ▪ Fluids generally do not need to be introduced. ▪ Does not require air or water to advance the borehole. ▪ Well development, water sampling, pumping tests can be done rapidly because little or no drilling fluid is used.	▪ Limited to about 30 metres (100 ft.) in depth. ▪ Cannot penetrate bedrock formations. ▪ If encountered, heaving ground conditions can go inside the hollow portion of the auger and lock it into place or create difficulties when attempting to install instruments through the augers.
Unconsolidated	Solid Stem Auger	80 to 1,370 mm (3 to 36 in)	0 to ~30 m (100 ft)	▪ Equipment is light and easily maneuverable. ▪ The drill head is attached to the first auger flight which is rotated into the ground. Cuttings are obtained from the auger flights. ▪ Samples are collected off the auger flights at a requested interval (e.g., every 1.5 m).	▪ Rapid drilling in shallow applications. ▪ Does not require circulation of fluids. ▪ No casing material required in stable formations. ▪ Easy decontamination. ▪ Smaller rigs than used in hollow-stem. ▪ Well development, water sampling, pumping tests can be done rapidly because little or no drilling fluid is used.	▪ Limited to about 30 metres (100 ft.) in depth. ▪ Cannot penetrate bedrock formations. ▪ Equipment cannot be lowered into the borehole while auger is in the hole. ▪ Limited to stable earth materials which will not collapse when augers are removed from the hole.
Unconsolidated; OR **Weathered / soft bedrock**	Sonic	Up to 300 mm (12 in)	0 to 213 m (0 to 700 ft)	▪ Uses high frequency downward vibration with the addition of a hydraulically powered drill head that applies pressure to the drill stem (working / starter casing).	▪ Drilling in most unconsolidated and soft bedrock (e.g., limestone) formations is rapid. ▪ Allows drilling string to advance quickly through difficult materials including cobbles, boulders and construction debris. ▪ Continuous formation sampling is part of the drilling process and is not an additional cost. ▪ Well development, water sampling, pumping tests can be done rapidly because little or no drilling fluid is used.	▪ Equipment is not readily available and is costly, especially for remote areas. ▪ Equipment may require a large footprint to set-up and operate on. ▪ Cannot be used in hard bedrock (e.g., granite) without potentially damaging the drill string. ▪ Requires addition of drilling fluids for bedrock formations. ▪ Increasingly time-consuming for deeper wells.
Unconsolidated; OR **Weathered / soft bedrock**	Conventional Rotary Drilling (Water or Mud)	70 to 1,200 mm (3 to 24 in)	0 to 9,000 m (0 to 30,000 ft)	▪ Cutting action and bit consist of rotary crush / tri or bi cone. ▪ Continuous rotation of the drill stem (rod) with the bit or cone breaking the formation. ▪ Drilling fluids are forced down the inside of the drill stem to cool the bit and assist with lifting cuttings to surface. ▪ Can drill through both overburden and bedrock.	▪ Penetration rates can be high. ▪ Filter pack and suitable sealant can be readily placed in the hole. ▪ Can drill a deep hole fairly quickly in overburden and bedrock. ▪ Can assist with well control when drilling through gas-bearing formations. ▪ Can adjust drilling fluid viscosity to help maintain borehole integrity when advancing through different formations.	▪ Difficult to drill through boulders or cobbles. ▪ Rig mobility limited to solid ground conditions and large pads for pump and water tanks. ▪ Managing and disposing of drilling fluid can be complicated. ▪ Drilling fluids (water or mud) can be lost or difficult to maintain in fractured bedrock. Can also seal off target formations. ▪ Identifying groundwater bearing zones can be difficult. ▪ Completed well may be difficult to develop because of mud or filter-cake on borehole wall. ▪ Difficult to collect representative soil samples to determine screen slot size.
Unconsolidated; OR **Bedrock**	Dual Rotary / Casing Advancement	70 to 1,020 mm (3 to 40 in)	0 to 400 m (0 to 1,312 ft)	▪ Cutting action and bit consist of rotary cut, rotary crush or rotary percussion. ▪ Casing string is advanced at the same time as the drill string. ▪ Some drill bits have an under-reamer which allows the bit to swing open below the casing and retract into the casing when drilling is complete. ▪ Compressed air is the most common drilling medium used to lift cuttings to surface and cool the drill bit.	▪ Can advance casing at the same time as the drill string. ▪ Borehole stability is not an issue as casing is advanced at the same time as the borehole. ▪ Instruments can be installed inside the casing to reduce the risk of sloughing or caving. Once the instrument is lowered inside the casing, the casing can be removed.	▪ Heaving ground conditions can go inside the casing and lock it into place or create difficulties when attempting to install instruments inside the drill casing (e.g., installing a PVC well casing inside of the outer drill casing). ▪ Slow rate of penetration through bedrock.

Ideal Geologic Formations	Drilling System	Hole Diameter	Maximum Depth	Drilling Process	Advantages	Disadvantages
Unconsolidated; OR **Weathered / soft bedrock**	Cable Tool	100 to 1,200 mm (4 to 48 in)	0 to 1,500 m (0 to 5,000 ft)	▪ Borehole is advanced by repeatedly dropping a heavy string of drill tools and a bit that crushes material at the bottom of the hole. Water is added to the borehole to create a slurry of material that can be pulled out of the borehole with a bailer. ▪ When drilling in overburden, casing is driven into the ground to keep the hole open.	▪ Excellent method when lost circulation of drilling fluid is a problem. ▪ Excellent method for development of well. ▪ Typically, a very good method to detect low yielding groundwater bearing zones.	▪ Slow rate of penetration. ▪ Heavier wall, larger diameter casing than most other methods. ▪ Temporary casing can impact placement of filter pack and sealant (grout). ▪ Heaving of sediment into bottom of casing can be a problem.
Bedrock	Conventional Rotary Drilling (Air)	70 to 750 mm (3 to 30 in)	0 to 1,500 m (0 to 5,000 ft)	▪ Cutting action and bit consist of rotary crush cone, drag bits and pneumatic down hole hammers (rotary percussion). ▪ Compressed air is used as a drilling medium and is forced down the inside of the drill string and lifts groundwater and cuttings up borehole annulus to surface. When using down hole hammers, compressed air is used to activate the piston inside the hammer. ▪ Can drill through unconsolidated material and weathered bedrock but is ideally used in competent bedrock units.	▪ Cuttings are quickly lifted to surface. ▪ High rate of penetration. ▪ Does not require drilling fluid. ▪ Easy to identify at what depth groundwater-bearing intervals are encountered. ▪ Drill string and air compressor can be used to develop the well. ▪ When groundwater bearing intervals are encountered, the yield can be estimated during drilling. ▪ Drilling additives make cleaning the borehole easy prior to the installation of any instrumentation.	▪ Cuttings are ground up into small pieces and can be difficult to identify composition or depth from which they come. Often come to surface as a slurry once groundwater is encountered. ▪ Casing required to keep hole open in the overburden and broken bedrock. ▪ Unless water is misted into the drill string, a lot of dust is produced.
Bedrock	Dual Wall Reverse Circulation	90+ mm (3.5+ in)	0 to 610 m (0 to 2,000 ft)	▪ Cutting action and bit consist of rotary crush or rotary percussion. ▪ Similar to reverse circulation rotary except an additional inner drill pipe is used. ▪ Air is circulated down the inside of the drill pipe between the sample tube and outer wall and cuttings are returned to the surface through the sample tube.	▪ Similar advantages as conventional rotary drilling with air, depending on the application. ▪ Cuttings are quickly lifted to surface. ▪ High rate of penetration. ▪ Does not require drilling fluid. ▪ Easy to identify at what depth groundwater bearing intervals are encountered. ▪ Drill string and air compressor can be used to develop the well. ▪ Can drill larger diameters as less air is required to lift cuttings to surface.	▪ Similar disadvantages as conventional rotary drilling with air. ▪ Cuttings are ground up into small pieces and can be difficult to identify. Often come to surface as a slurry once groundwater is encountered. ▪ Casing required to keep hole open in overburden and broken bedrock. Unless water is misted into the drill string, a lot of dust is produced. ▪ Sample tube and bit can plug easily.
Bedrock	Cored Hole / Diamond Drilling	60 to 120 mm (2.5 to 5 in)	0 to 3,050+ m (0 to 10,000+ ft)	▪ Cutting action and bit consist of a diamond impregnated core bit that is attached onto a core barrel. The core barrel is designed to collect and hold the core until filled, at which point it is lifted to the surface. ▪ Continuous rotation of the drill rod advances the drill string into the formation and cuts around a section of the bedrock that is lifted up inside the core barrel. ▪ Drilling fluids are forced down the inside of the drill stem to cool the bit and assist with lifting cuttings to surface (between the borehole wall and drill string).	▪ Cuttings include a “core” of the bedrock that can show lithological and structural features. ▪ Hydraulic injection testing can easily be completed using the core barrel and drill pipe.	▪ Slower than other drilling methods. ▪ A large volume of water is needed to flush cuttings from the borehole and cool the bit. ▪ Difficult to tell where groundwater is encountered. ▪ Large storage space required for core samples if they are to be retained.

5.8 WELL INSTALLATION

Wells are designed to allow for characterization of the hydrogeologic properties, groundwater levels and / or groundwater quality within a target zone of interest. Field staff overseeing drilling and well installation must be aware of the monitoring well objectives and corresponding design details (e.g., well siting location, target zone or formation, well depths, etc.), but be capable of adapting final well completion details in order to still achieve monitoring objectives if actual real world field observations and conditions are different than expected.

Some well completion considerations which may require adaptation include:

- Well screen depth and / or length:
    - The screened interval may need to be adapted (i.e., placed deeper, shallower, or a shorter interval used) depending on the encountered lithology and groundwater level. This should be adapted so the objective of the Provincial Observation Well can still be achieved and the screened interval will not cross multiple groundwater bearing units.
- Filter pack material:
    - If an unconsolidated formation does not remain open long enough for an artificial filter pack to be placed around the screen interval, the formation should be evaluated if a natural filter pack can be used. If a natural filter pack is suitable, once the screen and PVC casing is lowered into the borehole inside the drill casing, the drill casing can be slowly removed to the top of the screened interval allowing the formation to collapse around the screen.
- Sealant selection and grout mix design:
    - If artesian groundwater conditions are encountered, a thick and heavy grout may need to be used to backfill around the casing. The heavy grout will fill any voids in the borehole wall and will (ideally) stop the flow of groundwater to surface.
    - If borehole stability is an issue in a shallow well, grout is preferred to be used as it can be pumped down inside the drill casing, filling the borehole annular space. Once this is complete, the drill casing can be removed and the grout will be heavy enough that it will stop the formation from collapsing around the PVC casing.

It is important to ensure that upon completion of installation, the casing is extended above the ground surface a minimum of 0.3 m as per the BC GWPR [2022] requirements and to support the installation of the casing extension and any monitoring equipment.

Please refer to the **Borehole Log Field Sheet** (**Appendix A7**) and the **PGOWN MS Teams Channel**) available for use as a template when logging lithology during a drilling operation. The **Well Construction Diagram** template (**Appendix A7** and the **PGOWN MS Teams Channel**) can be used to document the Provincial Observation Well lithology and as-built details; alternatively, there are software applications that can be used to generate the well construction diagram, such as ESlog.

5.8.1 Non-Artesian Well Installation

Upon completion of drilling and prior to constructing the Provincial Observation Well inside the borehole, the following should be considered and confirmed:

- If the drill casing is to be removed prior to installation of the well casing, then the total depth of the completed borehole should be compared against the borehole log. Intervals that are likely to slough during the installation process should be identified and a plan to mitigate this issue discussed (e.g., can a natural filter pack be used instead of an artificial filter pack if the borehole does collapse, can a bentonite seal be placed above the filter pack to seal off the screened interval, etc.).
- The encountered lithology should be compared against the Provincial Observation Well design to determine if the screen and filter pack lengths achieve the required objectives (e.g., do not cross hydrostratigraphic units [Aller, 1991], will be fully submerged regardless of seasonal variation, etc.).
- The borehole annular space can be sealed using the methods selected (i.e., bentonite chips, coated bentonite pellets or grout).

During the installation process, the following steps should generally be followed. It is important to keep in mind these steps should be adapted based upon the final Provincial Observation Well design, drilling methods used, encountered lithology and depth to groundwater. The following steps assume PVC screens and casing will be used to construct the well; however, steel screens and casing would follow similar steps (aside from requiring welding and using a different method for the screen installation). Please note that a qualified well driller should already be familiar with these steps, but **field staff must still take detailed notes** on how the well was constructed (e.g., material types, installation / backfilling depths, other observations, etc.). The general steps when installing a Provincial Observation Well are as follows:

- Confirm the total depth of the borehole. If the borehole is deeper than the desired target screen interval:
  - Use a combination of bentonite chips (i.e., sealant) and sand to backfill the bottom of the hole up to **no closer than 0.3 m** from the bottom of the desired screen depth. If not continuous, ensure that sealant layers are at least 1 m thick, not more than 6 m apart, and are placed adjacent to lower permeability zones to prevent cross flow between upper and lower aquifer units.
  - Ensure an end cap is threaded onto the bottom of the screen and **at least 0.3 m** of filter sand is placed below the bottom of the screen to prevent the screen from settling and to prevent any emplaced bentonite backfill beneath the screen from infiltrating into the bottom of the screen.
- Confirm and record the dimensions of the screen to be installed in the borehole (material, weight and grade, total length, diameter, slot size, etc.) (**Figure 5-5**).
- New sections of PVC are threaded together and lowered down the centre of the borehole. Place a cap on the top of the well riser to prevent inadvertent materials from entering the well.
  - Record installation depths as they are measured.

- Glue and electrical tape should not be used to hold end caps or threaded sections of pipe together. They can contain volatile hydrocarbons which can leach into and contaminate groundwater and alter groundwater quality results.

- Carefully backfill the annulus with a uniformly graded artificial filter pack sand material (e.g., 10/20 filter sand). The filter pack should envelope the screen in the borehole annulus and extend **at least 0.6 m** above the screened interval (GWPR 2022), although **ideally there should be 1 to 2 m** of filter pack above the screen if possible. Record the material types and depths, including the top and bottom range (depth) of the filter pack. If a natural filter pack is to be used, slowly lift the drill casing up to approximately 0.3 m above the top of screen, allowing the material to collapse around the screen.

- A bentonite seal of **at least 1.5 m** is to be located immediately above the filter pack. The seal should be composed of bentonite chips or pellets depending on the water level in the borehole. Record the quantity of materials and depth to the top of the bentonite seal.

- Back-fill the remaining annulus with either bentonite chips or a bentonite-cement grout to the ground surface. If backfilling with grout, allow it to set for a 24-hour period as the grout will shrink and need to be topped up before installing the above ground protective monument (Aller, 1991). Top-up the borehole with either bentonite chips or cement. If the seal will not be continuous to the surface, ensure that sealant layers are **at least 1 m thick**, **not more than 6 m apart**, and are placed adjacent to lower permeability zones to prevent cross flow between upper and lower aquifer units.

- Set an above ground protective monument **at least 0.9 m** into the ground and cement into place. Record the materials used to back-fill the annular space in the borehole (**Figure 5-6**). The protective monument should be able to be locked and, if required, modified to accommodate groundwater level monitoring equipment (**Section 2.4**)

- A surface seal is required to prevent the well to act as a pathway for surface water to enter the ground or aquifer (Aller, 1991). It is required to be **no less than 1 m** in length for monitoring wells. The surface seal may **extend to within 0.3 m** of the ground surface (GWPR 2022).

- Ensure the ground surface surrounding the well is mounded with cuttings to prevent ponding water (GWPR 2022). Do not leave bentonite chips exposed at the surface as they can be a danger to wildlife and create a muddy mess.

- The BC Well Identification Plate Number (tag) should be attached to the protective casing by the driller or field staff (GWPR 2022). This number should be recorded and later added to the well record in GWELLS.

- The protective casing that extends above ground surface should be prepared for installation of groundwater level monitoring equipment (**Section 2.4**).

Figure 5-5 Provincial Observation Well screen with endcap prior to installation.

Photo source: BC ENV.

Figure 5-6 Examples of PVC riser pipe before (left) and after (right) the protective surface casing is installed.

Photo source: BC ENV.

5.8.2 Artesian Well Installation

Installation of Provincial Observation Wells that are artesian follow similar steps when installing non-artesian wells. However, under the BC GWPR (2022), in the event that artesian conditions are encountered when drilling a well, the drilling contractor and field staff must ensure that the artesian flow is stopped or brought under control, and that steps are taken to ensure the flow will be stopped or controlled if the well flows periodically. Artesian flow is considered to be under control when it:

- Is conveyed through the production casing to the well head;
- Can be indefinitely stopped, without leakage into the ground surface or into another aquifer penetrated by the well; and
- Does not pose a risk to property, public safety, or the environment.

Artesian Provincial Observation Wells typically require the installation of a well packer system that will prevent artesian flow out of the well casing while allowing for the installation of a submerged pressure transducer to record water pressure. For more information, please see **Section 5.6.9**.

Review the BC GWPR for further regulatory requirements regarding artesian wells and consult with your Regional Hydrogeologist or Groundwater Protection Officer. If artesian conditions are anticipated, discuss the installation plans with the selected drilling contractor in advance.

5.9 WELL DEVELOPMENT

Well development is required to remove sediment and drilling fluids from the Provincial Observation Well upon completion of drilling and installation. A properly designed and developed Provincial Observation Well should produce groundwater representative of the geological formation with minimal turbidity. There are two main objectives that should be achieved when developing a Provincial Observation Well:

- Remove water, drilling fluids, fine-grained material and any filter cake build-up that could have occurred during drilling and installation; and
- Reduce the amount of fine-grained materials in the formation around the well screen and facilitate collection of representative groundwater samples with reduced turbidity and sediments. This will also minimize potential damage to the pumping equipment.

The following sub-sections discuss the benefits of well development and compare different development methodologies. Refer to the **Well Development SOP** and **Field Sheet** template in **Appendix A7** [**Section A7.2**] (and the **PGOWN MS Teams Channel**) for further instructions for specific development methodologies.

5.9.1 Well Development Criteria

When selecting a method to develop a Provincial Observation Well, the following should be considered:

- Screened interval geology (e.g., overburden vs. bedrock, presence of fine-grained material, etc.);
- Groundwater level recovery;

- Drilling method and accessibility to the Provincial Observation Well;
- Well construction details, including:
    - Diameter and depth of the Provincial Observation Well;
    - Diameter, slot size, and length of the well screen and the filter pack;
- Health and safety requirements for field staff;
- Proper disposal of discharged groundwater; and
- Approvals and regulatory requirements.

5.9.2 Well Development Methods

There are a number of methods that can be used for well development, but the most appropriate method will be based on the factors listed in **Section 5.9.1**. In some cases, multiple techniques may need to be used to develop a well if a single method is not appropriate. Below are common methods of well development utilized in various scenarios. Some methods may be completed using different equipment:

- Bailing (by hand);
- Surging (by hand);
- Surging and bailing (using heavy equipment);
- Pumping and backwashing;
- Air-lifting (surging) and backwashing; and
- Hydraulic jetting.

Figure 5-7 shows a properly developed well screen installed in sand and gravel with a cross-sectional view. By surging water back and forth, a graded zone of sediment is created. Development reduces the amount of fine-grained materials in the immediate proximity of the well screen.

Bedrock Provincial Observation Wells that do not have a well screen still need to be developed. Air rotary drilling methods often cause fine-grained cuttings to be forced into bedrock fractures and not all cuttings are lifted to surface. In addition, fluid (i.e., water and polymer or mud) is injected during drilling to assist with dust suppression, prevent plugging of discharge hoses at the surface and to cool the drill bit. Development is still required to flush this injected fluid and any residual cuttings out of the borehole and intersected fractures.

Table 5-6 compares the advantages and disadvantages of six common well development methods.

Figure 5-7 Cross-section view of a properly developed well screen in an unconsolidated aquifer.

Photo source: BC ENV.

Table 5-6 Advantages and disadvantages of the most common well development methods.

Well Development Technique	Description	Equipment Examples	Advantages	Disadvantages
Hand bailing	The water column is purposefully agitated and removed with a PVC bailer. Any sediment accumulated at the bottom of the well is collected	▪ PVC bailer and string	▪ Able to measure the volume of water purged. ▪ Can be done manually by hand with minimal equipment. ▪ Does not require introduction of foreign fluids. ▪ Works well in low K or fine grained formations and screened intervals. ▪ No potential for damaging the well screen.	▪ Generally, only used in smaller diameter (76 mm / 3 in or less) diameter wells installed at shallow depths. ▪ Can be labour intensive. ▪ May not be aggressive enough to remove all of the fine grained material in the sandpack.
Hand surging	The water column is purposefully agitated with the up-and-down motion of a plunger-like device (i.e., a surge block) attached to the bottom of the Waterra tubing. Water and sediment is lifted up the inside of the Waterra tubing and discharged at surface.	▪ Waterra tubing and surge block.	▪ Able to measure the volume of water purged. ▪ Can be done manually by hand and / or with drilling equipment. ▪ Does not require introduction of foreign fluids. ▪ Water is moved through the screened interval both when lowering the surge block and when removing.	▪ Generally, only used in smaller diameter (76 mm / 3 in or less) diameter wells. ▪ Limited to wells <10 m by hand or <45 m when using a Waterra Hydrolift Pump. ▪ Well screens in fine-grained material may remain turbid. ▪ Not well suited to wells with non-flush casing joints. ▪ Reduced effectiveness if the well has limited water volume.
Surging and wireline bailing	The water column is purposefully agitated with the up-and-down motion of a plunger-like device (i.e., a surge block), and then removing the sediment brought into the well by this action using a bailer.	▪ Wireline surge block. ▪ Bailers.		▪ Excessive pressure differences can damage well screen or casing or cause well failure. ▪ Well screens in fine-grained material may remain turbid. ▪ Not well suited to wells with non-flush casing joints. ▪ Reduced effectiveness if the well has limited water volume. ▪ Should only be completed in wells with steel casing and screens.

Well Development Technique	Description	Equipment Examples	Advantages	Disadvantages
Pumping and backwashing	Pumping the well at a high rate for a brief period, to draw water and formation fines into the well, then shutting off the pump and groundwater inside the pump tubing drops down and into the Provincial Observation Well to break sand bridges in the formation and filter pack.	▪ Uses a higher capacity submersible pump than what will be used during sample collection.	▪ Suits all types of well construction. ▪ Uses simple and readily available equipment. ▪ Does not require the introduction of foreign fluids. ▪ No potential for damaging the well screen.	▪ Preferentially develops high-K zones and / or the zone at the top of the well screen. ▪ Requires heavy / bulky equipment. ▪ Generally, only used in larger (152 mm / 6 in or greater) diameter wells. ▪ Reduced effectiveness if the well has limited water volume.
Air-lifting and backwashing	Pumping the well with an air compressor at a high rate for a brief period. This draws water and formation fines into the screened interval. The air compressor is then shut off to slug the well, loosening up formation fines and breaking sand bridges in the formation and filter pack. As water reaches the surface, it carries the sediment out from the well. One of the most effective techniques to remove fines from within the screened interval (Driscoll, 1986).	▪ Uses an air compressor and tubing or drill pipe to inject air into the screened interval.	▪ Suits all types of well construction. ▪ Uses simple and readily available equipment. ▪ No potential to damage the well screen. ▪ Takes less time. ▪ Is not limited by water volume in the well. ▪ Air surging in combination with air lifting is the most effective technique to remove fines.	▪ Preferentially develops high-K zones and / or the zone at the top of the well screen. ▪ Requires heavy equipment (particularly if an old compressor is used). ▪ Introduces foreign fluids (air) into well. ▪ Can significantly alter the water chemistry in the short-term.
Hydraulic jetting	Forces a high-velocity stream of water through the well screen and into the filter pack and formation to rearrange the grains and flush out fine-grained materials.	▪ Uses a hydraulic jetting tool.	▪ Suited to all types of well construction. ▪ Effective over the entire screen interval. ▪ Works well on open bedrock holes or when drilling mud is used.	▪ High potential for damage to PVC well screens because the water is moving so fast. ▪ Requires the introduction of foreign fluids. ▪ Requires a water source and drilling equipment.

5.10 SUMMARY OF MINIMUM PGOWN WELL DESIGN & INSTALLATION STANDARDS

Below is a summary of the well design and installation standards for Provincial Observation Wells based on the previous sections:

- A BC One-Call and utility sweep must be completed prior to drilling;
- Wells must have an inner diameter of at least 76 mm (3 in);
- If no pumping test is to be performed, wells are typically built with 76 mm Schedule 80 PVC casing with a slotted well screen of a smaller slot size (e.g., 0.254 mm [10-slot]);
- If a pumping test is to be performed, wells are typically built with 152 mm (6 in) steel casing with a continuous slot stainless steel screen and a slot size selected based on the formation material;
- Well screens must not cross confining units and should typically be no more than 3 m (10 ft) in length;
- Wells must have a 10/20 graded filter sandpack or otherwise a natural sand pack produced by developing the well screen;
- There must be least 0.6 m of filter sand or formation material above the well screen prior to applying the sealant, although ideally there should be 1 to 2 m if possible. When using bentonite-cement grout, an intermediate layer of polymer coated bentonite pellets needs to be placed between the filter pack and grout;
- The completed well must comply with the BC GWPR (2022), including but not limited to:
    - There must be a surface seal of at least 1 m in depth and 2.54 cm thick;
    - A locked well cap or wellhead cabinet must be installed on the completed wellhead;
    - The ground surface must be sloped away from the wellhead; and
    - The stick-up must be at least 30 cm high. However, ideally the stick-up should be 90 cm above grade which is a suitable height for the addition of the casing extension and wellhead cabinet (which adds approximately another 30 cm of height).
- Wells must be adequately developed (i.e., developed until purge water runs clear) using a method suitable for the well design and groundwater depth;
- Where multiple wells are to be installed, they should ideally be clustered and not nested; and
- A well packer and pressure gauge or high stick-up must be used for artesian wells (i.e., artesian wells must not overflow the top of the stick-up).

5.11 AQUIFER TESTING

The drilling and installation of a Provincial Observation Well provides an opportunity to complete aquifer hydraulic testing if that is an objective of the drilling project. Please note that if a pumping test is to be completed at a new Provincial Observation Well, this should be taken into consideration during the design process, specifically with regard to the well diameter and well screen.

Depending on the design and construction of the Provincial Observation Well, aquifer hydraulic testing can range from a single well response test (i.e., slug test) to multi-day pumping tests. The collected data (depending on the type of test) can be used to understand aquifer hydraulic parameters (i.e., hydraulic conductivity, transmissivity and storativity) to help inform water availability, support groundwater modelling and / or produce aquifer budgets.

A Provincial Observation Well that has been poorly constructed / developed, or has a plugged well screen, will have a lower well efficiency (i.e., increased artificial head loss associated with water entry into the well screen). These losses and reduced well efficiency will impact the accuracy of any collected aquifer hydraulic parameters that are made from data collected as part of aquifer testing completed on the Provincial Observation Well.

All aquifer testing program design and well specific considerations should be completed in collaboration with the Regional Hydrogeologist and / or Groundwater Monitoring Specialist. Please note that pumping tests are beyond the scope of this manual and are not required, but are completed at some new Provincial Observation Wells if the project manager deems such testing an objective of the installation process.

5.11.1 Hydraulic Conductivity Testing

Occasionally, single well response testing is performed on Provincial Observation Wells that are suspected of functioning at a reduced capacity (**Section 3.2**). Data collected from a single well response test can be used to estimate a hydraulic conductivity (K) value. This value can then be used to assist with determining if a Provincial Observation Well needs to be redeveloped or decommissioned.

Single well response testing typically consists of falling and rising head tests which are completed by rapidly lowering (“slug in”) and (once water levels recover) raising (“slug out”) a solid PVC slug to generate a rapid change in the groundwater level. The displacement or change in groundwater level over time (i.e., the length of time it takes for the groundwater level to return to static) is then measured using a water level tape (manual measurement) and a pressure transducer (continuous measurement). Slug testing is typically only completed for **high K formations**.

Alternatively, a bail down test can be completed for **low K formations** and consists of removing a volume of groundwater from the Provincial Observation Well (i.e., the groundwater level is bailed down), and then measuring the recovery of the groundwater level over time. Bail down tests are completed on low K formations because groundwater level recovery can take a long time (e.g., days) and a slug (if used for a falling head test) must be left in the well and not moved during the test. Conversely, bailing cannot create water displacement fast enough for an accurate test to be conducted on a high K formation; the use of a solid slug (or a pneumatic slug) to create instantaneous water displacement is needed in this case.

Lastly, a pneumatic slug test can be used for highly permeable formations. This type of slug uses compressed air instead of a solid slug.

The detailed **Slug and Bail Testing SOP** for hydraulic conductivity testing, along with a **Hydraulic Conductivity Testing Field Sheet** can be found in **Appendix A7** [**Section A7.3**]. The field sheet can also be found in the **PGOWN MS Teams Channel.**

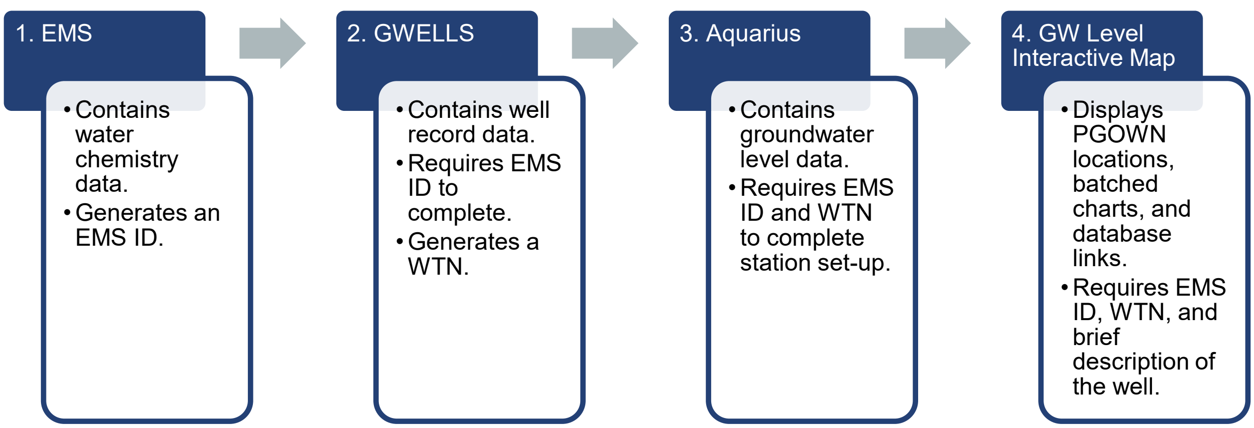
5.12 SAMPLING NEW PROVINCIAL OBSERVATION WELLS

Based on a 2018 PGOWN sampling frequency review, it was decided that all new Provincial Observation Wells (whether newly drilled or adopted), must be sampled at least twice in the first year, including once during the wet season (period of shallowest groundwater levels) and once during the dry season (period of deepest groundwater levels). If there is insufficient groundwater level history, the records for nearby wells may be used as an indicator of groundwater level fluctuation. However, this policy can be relaxed for sites that are only accessible for certain parts of the year. Please see **Section 2.5** for complete sampling information and procedures.

5.13 ADDING A NEW WELL TO PGOWN SYSTEMS

Figure 5-8 shows the databases and sequence that must be followed when adding a new Provincial Observation Well to the network. The exact process is outlined in detail in the **Adding a Well to PGOWN Systems SOP** (**Appendix A8** [**Section A8.1**]) and must be closely followed by staff.

Figure 5-8 Sequence of databases to follow when adding a new well.



5.13.1 Environmental Monitoring System

The EMS database contains the analytical groundwater chemistry data collected from Provincial Observation Wells. Once a Provincial Observation Well is entered into the EMS database, an EMS ID is generated. This EMS ID is used to connect the groundwater chemistry data with the GWELLS and Aquarius databases, as well as the Groundwater Level Data Interactive Map. The EMS ID also allows the analytical lab to upload the groundwater chemistry results directly to this database.

Questions on the EMS database, including setting up access, can be answered by emailing EMSHELP@gov.bc.ca.

5.13.2 GWELLS

The GWELLS database contains well construction records for private, commercial, industrial, and monitoring wells (including Provincial Observation Wells). Field Technicians can log into the GWELLS database to enter well record information from field notes and / or from the well driller's construction record.

Specific training, questions, approval to enter / edit Provincial Observation Well records into the GWELLS database, and to report system issues should be completed by emailing GWELLS@gov.bc.ca.

5.13.3 Aquarius

As discussed in **Section 4.0**, Aquarius is the database that is used to store and process groundwater level data collected from Provincial Observation Wells. When a new observation well is brought into use, a new station needs to be set up in Aquarius by the ENV Water Data Specialist (Aquarius Administrator) who will require the EMS ID and GWELLS WTN. This needs to be completed before any groundwater level data is uploaded to Aquarius.

Aquarius inquires can be made to Aquarius@gov.bc.ca.

5.13.4 Groundwater Level Data Interactive Map

The Groundwater Level Data (PGOWN) Interactive Map is the user-friendly, publicly available interface where groundwater level data and water chemistry data can be accessed. This will be the final database to update when adding a new Provincial Observation Well. This is because it pulls its information directly from EMS, GWELLS and Aquarius in order to generate the new site.

Inquiries about the Interactive Map should be sent to the current Water Data Specialist (Aquarius Administrator) at ENV.

5.14 PROVINCIAL OBSERVATION WELL DRILLING / ADOPTION REPORTS

Reports documenting the addition of a new Provincial Observation Well to the PGOWN must be completed within **1 year** of drilling a new well or adopting an existing one. The reports are an important piece of the well's history and are included as part of the evaluation criteria for the PGOWN funding process.

The intent of these reports is to document a PGOWN expansion project, and outline the following:

- Why a particular location and aquifer was selected for expanded monitoring coverage;
- Provincial Observation Well design and construction rationale;
- Lithology encountered and preliminary data generated to date; and
    - Please note that it is not expected that a detailed and complete understanding of the aquifer's hydrogeological characteristics will be detailed in the report based on the limited period of record of the timeseries data.

- All relevant permits, agreements, initial site conditions, site accessibility, survey results, field notes, etc.

Section 5.14.1 outlines a table of contents and the minimum information that must be included in these reports. Additional information may be included at the report author's discretion.

Once the report is complete and has been reviewed, please email the final version to the Groundwater Monitoring Program Supervisor, who will upload the report to the Ecological Reports Catalogue (EcoCat) and attach it to the respective well record in GWELLS.

5.14.1 Provincial Observation Well Report Table of Contents

Introduction / Background

- Describe the purpose of the Provincial Groundwater Observation Well Network. The following statement can be used and / or adapted:
  - *The Provincial Groundwater Observation Well Network (PGOWN) was established to monitor groundwater levels in BC to support the management, protection, and sustainable use of our groundwater resources and associated ecosystems. The PGOWN is jointly managed by the Ministry of Environment and Parks (ENV) and the Ministry of Water, Land and Resource Stewardship (WLRS) and has been in operation since 1961.*
- Describe the purpose of the project and why this aquifer was targeted for monitoring.

Site Setting

- Site description:
  - Describe the setting, including physical description of the area, geology, aquifer(s), nearby climate stations, Provincial Observation Well location map, site photograph (before drilling if possible), etc.; and
  - Provincial Observation Well location, including physical cross streets, property name (if applicable), and survey results (including survey methodology and margin of error, e.g., handheld GPS, professional surveyor, etc. [attach results in appendix]).
- Describe why this particular site within the aquifer area was selected.
- Site specific challenges / drilling anomalies (e.g., site only accessible outside of winter, artesian part of the year, identify parties who must be notified prior to entering the site, etc.).
- Permits / Land Access Agreement:
  - Describe any permits or legal agreements (attach in appendix) and their **expiry dates**.
- Details of the utility locate (attach results in appendix).

Well Lithology & Construction Details

- Describe the encountered lithology and Provincial Observation Well construction details, including:
    - The depths and description of the encountered lithology;
    - How the lithology determined the well design (screen placement and length, well depth, etc.);
    - Casing material / diameter / depth, screen length / size / depth, and stick-up height;
    - Backfill material and depths (e.g., filter pack and surface seal material types and depths);
    - Well development method, duration, rate, water observations (colour, odour, turbidity before and after, etc.);
    - Static water level after well development, including date / time of measurement and reference point (i.e., m bgs or m btoc);
    - Photograph of the completed Provincial Observation Well;
    - Well construction record and diagram (attach in appendix). Please note that a **Well Construction Diagram** template is located in **Appendix A7**) and the **PGOWN MS Teams Channel**. Alternatively, a software application can be used; and
    - Field notes (attach in appendix).

Provincial Observation Well Set-up & Instrumentation

- General description of instrumentation used (e.g.: "the well was equipped with a vented pressure transducer and satellite telemetry equipment for near real-time data publication").

Provincial Observation Well Testing & Results (if conducted)

- Pumping test methodology, duration, and note-worthy events (e.g., heavy rains, pump issues, etc.).
- Pumping test analysis / results.

Groundwater Quality Sampling & Results

- Describe the groundwater sampling methodology:
    - When and how the sample was collected (including sampling method, use of nitrile gloves, field filtering and preservation, etc.);
    - What sample types were collected (e.g., general chemistry, total nutrients, dissolved nutrients, dissolved metals, etc.);
    - What parameters were field monitored in-situ and what were their results at the time of sampling (e.g., YSI and flow-through cell used to measure pH, DO, ORP, etc.);
    - What QA/QC samples were collected, if any (e.g., duplicate samples); and

        - Describe any events of note (e.g., well dry was pumped dry and then sampled).

- Sampling results:
    - Describe sampling quality assurance assessment (RPD calculations) for duplicate samples, electrical balance (cation / anion balance), and trip / field blanks.
    - Compare chemistry results to Canadian Drinking Water Guidelines (CDWG). Please note that dissolved metals / nutrients typically cannot be directly compared to the CDWG except under certain circumstances.

Summary

- A brief report summary.

References

- Include a list of reference used in the document or use footnotes throughout the report.

Appendices

- Place in order of appearance in the report and divide with appendix title pages:
    - Appendix XX: Survey & Utility Locate Results
    - Appendix XX: Permits & Legal Agreements
    - Appendix XX: Well Construction Record & Diagram
        - Include a scanned copy of field notes.
    - Appendix XX: Photographs of Well Drilling
    - Appendix XX: Pumping Test Data & Results
        - If applicable.
    - Appendix XX: Water Quality Results

It is also strongly recommended to make use of MS Word's cross-referencing and hyperlinking features to ensure correct and automatic updating of numbered items (e.g., figures, tables, appendices, section numbers, etc.).

6.0 WELL REVIEWS & NETWORK CONTRACTION

Provincial Observation Wells within each region should be reviewed by staff every five years, aiming to complete a review for 1/5 of the network each year. This is to assess if:

- Groundwater level data that is collected from each Provincial Observation Well is representative of local aquifer conditions and to identify any required well maintenance (e.g., redevelopment); and
- the Provincial Observation Well is still meeting the intended monitoring objectives.

This review is documented using the **Provincial Observation Well Review Form** and is completed by the Groundwater Monitoring Specialist. Please see the **PGOWN MS Teams Channel** for the latest version of this form.

This review will result in a recommendation of one of the following:

- Make no changes to the Provincial Observation Well;
- Repair or make improvements to the Provincial Observation Well; or
- Decommission and (potentially) replace the Provincial Observation Well.

6.1 WELL CLOSURE / DECOMMISSIONING

In addition to the potential recommendation for Provincial Observation Well decommissioning based on a completed well review, a well may be removed from the PGOWN for a variety of other reasons such as:

- The well has gone dry;
- It is unclear which aquifer the well is screened in;
- It is redundant with other Provincial Observation Wells in the aquifer (i.e., the groundwater level timeseries are nearly identical between locations);
- The well has become damaged and cannot be repaired (e.g., casing has cracked or collapsed);
- The well is in poor hydraulic connection to the adjoining aquifer and cannot be repaired;
- The well was not constructed properly;
- Loss of access to the property;
- There is less of a need to monitor the particular aquifer or the well no longer meets its objective(s); or
- The well has been replaced at a location better suited to the PGOWN.

6.1.1 Well Removal Process

Prior to removing and decommissioning a Provincial Observation Well from the PGOWN, Director-level approval must be obtained, funding approved (if being decommissioned), and the various PGOWN systems updated, as outlined below.

Part 1 – Requesting Director Approval

Director approval is obtained by completing the following steps:

1. Regional staff and / or the Groundwater Monitoring Specialist initiate the recommendation for removal of a Provincial Observation Well. A **Network Reduction Request Form** must be completed and sent for review by the Groundwater Monitoring Program Supervisor and AWSS staff (Senior Hydrogeologist). This form can be found on the **PGOWN MS Teams Channel**. Alternatively, the **Network Well Replacement Request Form** should be completed when replacing an existing well.

2. After review and feedback is provided by CHASM and AWSS staff, the completed form must be sent to the appropriate regional WLRS Director to request approval.

3. The Director will review the form and if they agree with the recommendation, they should provide a signed response (or approve the request in an email). Regional staff initiating the request must ensure that Groundwater Monitoring Program Supervisor also receives a copy of the Director's response and the completed **Network Reduction Request Form**.

Part 2 – Decommissioning

Prior to decommissioning a well, the property owner should be notified as per the established **Land Access Agreement**, or consulted to grant permission for this work if the agreement or permit did not contain procedures regarding well closure and decommissioning. However, it should be noted that in some instances a property owner may wish to assume the responsibility of operating and maintaining the well for their own purposes. In that case, an **Acknowledgement, Release and Indemnity Agreement** must be completed if the Province is the well owner. Contact the Groundwater Monitoring Program Supervisor for a copy of this agreement template.

When a Provincial Observation Well will is going to be decommissioned by the Province, a drilling contractor experienced with decommissioning wells and licensed to conduct this work should be engaged via the established procurement procedures (**Section 5.4**). In addition, if a well is to be decommissioned in a road RoW, park, or other public land, a permit or other legal approval may be required (**Section 5.3**).

Please note that wells that have been closed (monitoring equipment removed and the well is no longer collecting data) must be decommissioned within 5 years as per Part 9 of the BC GWPR (Well Deactivating and Decommissioning; 2022); however, decommissioning should ideally be completed much earlier than this timeframe.

Field Technicians are responsible for ensuring that all monitoring and other related equipment is removed prior to decommissioning (e.g., pressure transducers, telemetry equipment, direct-read cables, wellhead cabinet, etc.). The licensed drilling contractor can assume the role of a qualified professional, which allows them to design and implement a decommissioning program for the Provincial Observation Well, as well as complete and sign-off on the decommissioning paperwork in accordance with the BC GWPR (2022). A copy of the decommissioning report must be saved to the project folder and submitted to the Groundwater Monitoring Program Supervisor.

Part 3 – Updating Applicable Databases

Once a Provincial Observation Well becomes inactive, the Field Technician or the Groundwater Monitoring Specialist should update the various databases (GWELLS, Aquarius, EMS, PGOWN Interactive Map, etc.) to ensure the well status is changed to inactive. The exact process is outlined in detail in the **Removing a Well from PGOWN Systems SOP** (**Appendix A8** [**Section A8.2**]).

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APPENDICES

Appendix A1

Pre & Post-Field Planning

Standard Pre-Field Mobilisation Checklist

#	ITEM	Completed		COMMENTS
		Initial	Date	
1	Determine Provincial Observation Well(s) to visit via tracking spreadsheet.			
2	Obtain keys, permits and / or approvals from property owner, if applicable.			
3	Review Provincial Observation Well(s) history and previous field notes.			
4	Review technical procedures and site access / maps.			
5	Field data sheets (and SOPs) prepared.			
6	Equipment mobilized or shipped to location.			
7	Sample bottles ordered, if needed.			
8	Calibration of meters; keep calibration log up-to-date.			
9	Book vehicle rental, other transport (e.g., ferry) if needed.			
10	Accommodations reserved, if needed.			
11	Complete vehicle inspection.			
12	Field emergency contact form / itinerary completed and shared with supervisors.			
13	Job Hazard Assessment Forms, and / or applicable regional safety procedures completed.			
14	Pre-label bottles and coolers, laboratory requisitions.			
15	Reviewed Equipment Checklist and loaded gear into work vehicle.			

Standard Post-Field Mobilisation Checklist

#	ITEM	Completed		COMMENTS
		Initial	Date	
1	Any repair or equipment needs reported / followed up.			
2	Vehicle refuelled, cleaned and returned.			
3	Samples shipped; confirm lab receipt of samples.			
4	Submit expense claims for trip.			
5	Health and Safety forms scanned and properly stored in project folders.			
6	Field notes / field sheets scanned and properly stored in project folders (electronic and hard copies)			
7	Photos downloaded from computer, labelled, and saved to project folder			
8	Complete and submit any H&S forms for First Aid, near misses, etc.			
9	Update Regional PGOWN Tracking Spreadsheet and PGOWN Equipment & Station Information Spreadsheet (on MS Teams channel) as needed.			

Equipment Checklist

****Ensure all devices / tools are charged, bring spare batteries and all charging cables****

	Field Crew Clothing & PPE		Health & Safety
	Appropriate Field Clothing & Footwear		First Aid Kit & Eyewash (battery safety)
	Rainwear & Rubber Boots		Field Safety Plan (e.g., check-in procedures, safety meeting forms, etc.)
	Sunglasses, Hats, Sunscreen, Bug Protection		Fire Extinguisher Secured to Vehicle
	High Visibility Vest		Bear Spray & Bangers (if applicable for site)
	Safety Glasses		Traffic Cones
	Dust Mask		Vehicle Safety Kit
	Leather Gloves		
	Cell Phone / Car Charger / Sat Phone / SPOT / InReach		
	Water, Food, Clothing		

	General Site Visit	
	Keys for Observation Wells & Gate Access	
	Laptops / iPad / USB stick / Data Device (include necessary cables, e.g., Diver optical reader)	
	Water Level Tape	
	Camera (or cell phone)	
	Pens, Pencils & Permanent Markers (one rite-in-the-rain or weather-proof type)	
	Previous Field Notes & Documentation (e.g., Site Visit Record / Purging & Sampling Record / Instrument & Equipment Manuals / Field Book & Binders / Well Construction Records)	
	Desiccants	
	Industrial (Shop) Papertowels	
	Tap Water / Deionized Water	
	Kevlar String	
	Metal Wire (steel cable), Crimps, Crimper	
	Cordless Drill, Drill Bits (titanium), Step Drill Bit	
	Measuring Tape	
	Field Survey Tape	
	Non-Oil based Lock Lubricant (e.g., WD40)	
	Spare of each piece of equipment to replace an entire monitoring station (e.g., dataloggers [telem & non-telem], 12V battery, well decal, solar panel, antenna, well cap, padlock, etc.)	
	Garbage Bags	
	12-Gauge Extension Cord	
	Electrical Tape, Electrical Multi-Meter, Spare Fuses, Spare Wiring	
	Power Pack / Power Bank	
	Fully Equipped Tool Box (use insulated tools when possible), including: - Screws, nuts, bolts - U-bolts - Cable ties (zap straps) - Wire cutters - Socket set - Wrenches	- Screwdrivers - Duct Tape - Battery Terminal Brush - Scissors - Allen Keys - Hacksaw - Angle Grinder & Discs (cutting & grinding discs) - Hatchet - Etc.
	Ladder / Step Ladder	
	Casing Extension Spray Paint (for metal surfaces)	
	Spare Well ID Plate & Strap (hose clamp)	
	Spare Batteries (A, AAA, C, D, etc.), Baking Soda (to neutralize battery acid) and Vaseline (prevent battery terminal corrosion)	
	Flashlight	
	Shovel	
	Tarp	

	Water Quality Sampling
	Depending on sampling method: - Grundfos Redi-Flo Pump, Pump Controller, Redi-Flo Connector Cables, Reel EZ (60 m of hose), Happy Hose, Generator & Fuel; - Bladder Pump, Controller Box, Auxiliary Air (if required), Discharge Tubing, Battery or Generator & Fuel; and / or - HydraSleeves, Bottom Weights (extra), Tether
	Portable Work Bench (optional)
	YSI Multi-meter, Calibration Fluids, Flow Through Cell
	5-gallon Bucket (to estimate flow while purging)
	Stopwatch (or cell phone)
	Laboratory Sample Collection Bottles (including QA/QC samples & blanks, spare bottles), Preservatives, Bottle Labels, CoC
	Zip Lock Bags (for CoC)
	Disposable Field Filters / Syringes (if required)
	Disposable Nitrile Gloves (appropriate size)
	Coolers, Ice Packs / Zip Lock Bags for Ice Cubes (double bagged), Packing Material for Bottle Shipment (bubble wrap from lab), Duct Tape, Shipping Labels for Coolers

Appendix A2

Groundwater Monitoring

Appendix A2-1

Manual Groundwater Level Measurement SOP

A2.1 MANUAL GROUNDWATER LEVEL MEASUREMENT SOP

This SOP provides instructions for collecting manual groundwater level measurements as part of regular site visits.

A2.1.1 General

Water level tapes have copper wires running down the sides of the tape and into the probe (sensor) at its end. When lowered into water, the electrical conductivity of the water will complete the circuit, causing an alarm to go off and thereby indicating the depth to water.

Manually measured groundwater levels are important as they are required for calibration of pressure transducers at telemetry stations and to assist with correcting collected continuous pressure transducer data.

A2.1.2 Equipment

Task-specific equipment (refer to **Equipment Checklist** in **Appendix A1** for a complete list of recommended equipment for site visits):

- Clipboard with **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]) (or device with electronic field data sheet);
- Field notebook;
- Well depth indicator probe (if available); and
- Water level tape.

At a minimum, tapes must be of appropriate length for the anticipated water level depth and, ideally, should be long enough to measure well bottom depth.

A2.1.3 Procedure

- An initial manual groundwater level measurement should be collected at the beginning of a site visit (along with live datalogger level / pressure readings), prior to making any changes to the Provincial Observation Well and its already-deployed monitoring equipment.
- Turn on the clean, dry water level tape and place in a location, or hold the instrument in a manner, that allows for easy operation.
- Slowly lower the probe into the well until the meter indicates that the probe has contacted the top of the groundwater surface. This will typically be indicated by an audible alarm and light on the front panel.
    - When lowering or raising the tape, make sure to avoid contact between the tape and sharp edges on the well casing or wellhead cabinet.

    - Adjust the “sensitivity” knob on the water level tape higher for low conductivity waters and lower for high conductivity waters.

- When an audible alarm is sounded, hold the graduated side of the tape against the reference point on the well (e.g., bottom of the plexiglass cover or marked point on the well casing) and note the depth to groundwater.

    - The probe should be slightly raised and lowered into the water table a minimum of three times to verify the groundwater level measurement. The final (third) measurement should be recorded to the nearest millimetre (third decimal place), along with the time of the measurement and local time zone (i.e., PST or PDT).

    - Ensure that you record the reading as the meter enters the water, not when it is lifted out.

    - By convention, if no reference point is marked on the well, use the north face of the top of the stick-up to collect your manual measurement (ideally mark that reference point for future site visits using a paint pen or other permanent marker).

- Once per year, after confirming depth to water, commence measurement of total well depth. Start by turning off the instrument or switching the setting to silence the alarm when the probe is in the water.

    - Tracking the well depth over time will help determine if the well is infilling with sediment or if there is an obstruction in the well.

- Lower the probe until the tape becomes slack. Do not bounce the probe on the bottom of the well. Slowly raise the tape until the slack is removed and similarly, hold the water level tape at the reference point and record the total depth measurement.

    - In shallow wells, pull up the water level tape until you feel slight resistance and weight on the tape.

    - In deep wells, the water pressure can make it difficult to feel the resistance, consider this when measuring the bottom of the well.

    - Repeat the total depth measurement three times to ensure correct observation well depth is determined and record the measurement on the **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]) to the nearest centimetre.

    - Alternatively, a well depth indicator probe is available for purchase which can make it easier to measure the well depth, especially for deep wells. Discuss with your Groundwater Monitoring Specialist.

- After recording the measurements, reel the water level tape back in neatly and carefully to avoid snagging the tape on sharp edges. While reeling the water level tape out of the well, use a wet clean cloth or industrial paper towel (shop towel) to clean excess water and any debris that may have accumulated on the instrument during the process.

- Proceed to next step in the site visit (e.g., downloading logger data).

A2.1.4 Miscellaneous

The following subsections will present best practices to consider when collecting manual water level measurements and troubleshooting will present common issues and resolutions.

A2.1.4.1 Best Practice Tips

- Check the recorded manual groundwater level measurement against the historical (typical) groundwater depths from that respective Provincial Observation Well so that any anomalous data / measurements can be verified in the field.
- If an accurate measurement cannot be obtained (e.g., too much nearby pumping interference), the Groundwater Monitoring Specialist should be contacted to discuss the results. It may be necessary to return at a different time, rather than collect an inaccurate measurement which will be used to apply an erroneous offset to the datalogger or to later “correct” data in Aquarius.
- Always raise the water level tape from the well to read the graduated depth (as opposed to lowering) to avoid confusion. For example, if the reading is made at 1.620 m, pull the tape upward to confirm that it is 1.620 and not 2.620 or 0.620 m.
- Decontaminate all equipment between monitoring wells, in accordance with **Section 2.5.8** of the manual.
- Complete periodic water level tape equipment checks, including:
  - Checking the test button;
  - Cleaning the probe;
  - Testing the probe in a clear container with tap water;
  - Ensuring faceplate screws are tight; and
  - Send in for repairs as needed.
  - An **Equipment Calibration Record** is available to track equipment maintenance and repairs in **Appendix A3** [**Section A3.2.5.1**].

A2.1.4.2 Troubleshooting

Observation	Potential Consequences	Potential Causes	Possible Next Steps
No audible signal from water level probe when in water	▪ Unable to record an accurate water level measurement.	▪ Probe sensitivity / volume is set too low. ▪ Probe tip is dirty or damaged. ▪ Probe or wiring is damaged. ▪ Battery is dead. ▪ Electrical conductivity of groundwater is too low (i.e., water does not complete the electrical circuit at the probe / electrode).	▪ Increase probe sensitivity. ▪ Ensure the electrode is clean. ▪ Test probe function in a bucket of tap water. ▪ Replace battery and make sure battery connections are not corroded. ▪ Examine tape for damage that exposes the metal wire. ▪ Measure the conductivity of the groundwater (may be extremely low). ▪ Send in for repairs if needed.
Audible water level signal continues when out of water	▪ Inaccurate water level measurements are collected.	▪ Debris may be lodged around the electrode and cause long-term damage. ▪ Instrument is short circuiting due to exposed or corroded wires or the instrument probe is malfunctioning. ▪ Condensation in the well or along well sides could be triggering the alarm.	▪ Turn down the sensitivity of the instrument. ▪ Check and clean the probe of sediment or other debris around the electrode. ▪ Send in for repairs if needed.
Inconsistent readings	▪ Readings (minimum of three) vary by more than 1 cm. ▪ Low accuracy measurements.	▪ Groundwater level has been disturbed as a result of inserting / removing instrumentation from the well. ▪ Slow recovery after well purging during sampling. ▪ Significant nearby pumping interference. ▪ Problems with water level tape electrical circuit.	▪ If equipment has been removed from the well, wait a bit and allow some time for groundwater levels to equilibrate. ▪ Tighten faceplate screws. ▪ Examine tape for nicks that expose the metal wire. ▪ If possible, wait for water levels in well to recover post-sampling, or return later to collect stable reading.

A2.1.5 Record Keeping

The **Site Visit Data Download & Calibration Field Sheet** should be used to record all groundwater levels during every visit (**Appendix A2** [**Section A2.1.5.1**]). Field data sheets are to be scanned into the project folder upon returning to the office.

Update the **Equipment Calibration Record** (**Appendix A3** [**Section A3.2.5.1**]) every time maintenance / equipment checks are completed (i.e., checking the test button, cleaning the probe, sending for repairs, etc.).

A2.1.5.1 Field Sheet

The applicable field sheet is included on the following page and on the **PGOWN MS Teams channel**.

Site Visit Data Download & Calibration Field Sheet

Obs Well Number: ______________________ **Date:** ______________________

Location: ______________________ **Time (PDT / PST):** ______________________

Weather: ______________________ **Crew:** ______________________

Field Visit Purpose: (*select all that apply*)

❑ Calibration / Download ❑ Maintenance / Repair ❑ Station Upgrade ❑ Sampling (Use GW Sampling Field Sheet plus this one) ❑ Other:

SITE AND WELL HAZARDS

Select relevant hazards and provide comments, mitigations and solutions below:

❑ Hazardous litter (e.g., glass, syringes, etc.) ❑ Traffic ❑ Confined space ❑ Thorned bushes / Heavy vegetation ❑ Hazardous terrain (i.e., uneven ground, steep hills)

❑ Pests ❑ Dangerous wildlife ❑ Working around water ❑ Active construction ❑ Weather ❑ No cell service ❑ Electrical hazards ❑ Other (detail below)

Comments:

MANUAL GROUNDWATER LEVEL MEASUREMENTS

Initial Conditions *(Upon arrival)*

Static Water Level (SWL): ______________ (m btoc)

− Stick-up: ______________ (m ags)

= Calculated SWL: ______________ (m bgs)

Measurement Time: ______________ (PST / PDT)*

Depth to Well Bottom: ______________ (m btoc / m bgs)

Subsequent Measurement *(E.g., when calibrating later, after sampling)*

Static Water Level (SWL): ______________ (m btoc)

− Stick-up: ______________ (m ags)

= Calculated SWL: ______________ (m bgs)

Measurement Time: ______________ (PST / PDT)*

REMINDER: When entering field visits in Aquarius, convert manual measurement times from PST to UTC if Aquarius 'Location Details' is set to UTC.

TRANSDUCER & DATALOGGER INFORMATION

Logger Type: Solinst Van Essen FTS Sutron Other: ______________

Transducer Type: Vented Non-Vented

Live SWL / Pressure (m bgs / mH_2O / Other)	Power / Voltage	Datalogger Date	Datalogger Time (PST / PDT / UTC)	Local Time (PST / PDT)	Pressure Range (mH_2O / PSIG / Other)	Sensor Serial Number	Comments (e.g., PT make/model, anomolies)
Submerged Transducer - Current Conditions							
Barometric Transducer - Current Conditions *(if present)*							
					Not applicable		
					Not applicable		
					Not applicable		

See Reverse Side

Reminder: archive all field sheets into appropriate project folder after site visit.

Site Visit Data Download & Calibration Field Sheet

TELEMETRY OFFSET / CALIBRATION PROCEDURE

If Telemetry:

1. "Start Visit" initiated: ❑ Yes ❑ No *(detail why below)*

2. Drift value (m): ______________________ *= (**Initial** Manual SWL - Well Stickup - **Initial** Live Logger SWL)* ***To be applied as data drift correction in Aquarius.***

3. Instrument calibrated: ❑ Yes ❑ No *(detail why below)*

   a) Old offset value (m): ______________________ *Previously programmed into datalogger.*

   b) New offset value (m): ______________________ *= (Manual SWL - Well Stickup - Live Logger SWL) + Existing Offset* ***To be applied to the datalogger in the field.***

4. Refreshed SWL (m): ______________________ *Compare to manual SWL (must be ± 1mm).*

5. Data log exported: ❑ Yes ❑ No *(detail why below)*

6. "End Visit" initiated: ❑ Yes ❑ No *(detail why below)*

7. Desiccants changed: ❑ Yes ❑ No *(detail why below)*

8. Datalogger s/n: ______________________

NOTES (e.g., well condition / damage, missing well components, in-situ instrumentation, maintenance completed or required, etc.)

Reminder: archive all field sheets into appropriate project folder after site visit.

Appendix A2-2

Telemetry Station Installation SOP

A2.2 TELEMETRY STATION INSTALLATION SOP

This SOP is to be used for installing telemetry continuous groundwater level monitoring equipment into a Provincial Observation Well.

A2.2.1 General

A telemetry station set-up is more complicated than at non-telemetry sites and is comprised of several different pieces of equipment, including power supply, antenna, vented pressure transducer and datalogger.

The following assumptions should be applied when reviewing this SOP:

- The Provincial Observation Well is not artesian;
- The diameter of the surface casing is known and has been used to properly size the green casing extension; and
- Depth to groundwater has previously been measured and is known (to help with determining pressure transducer maximum operating pressure and direct-read cable length).

Please note that a power drill with various sizes of drill bits will be required throughout the installation process in order to secure various parts to the wellhead cabinet, and to secure the wellhead cabinet to the green casing extension. Tip: a stepped drill bit can be a very useful tool for expanding the diameter of drilled holes which is not possible (or safe) with traditional one-size drill bits; in addition, select drill bits that are rated for the material that will be drilled (e.g., aluminum vs. steel). This drilling is not detailed below. Moreover, use of other tools (e.g., angle grinders) may be required but is not detailed here, nor are the necessary safety precautions. Please consult with a Groundwater Monitoring Specialist or Groundwater Network Technology Specialist for further instructions, if needed.

A2.2.2 Equipment

Task-specific equipment (refer to the **Equipment Checklist** in **Appendix A1** for a complete list of recommended equipment for site visits):

- Fully equipment toolbox (e.g., wire cutters, socket set, wrenches, screwdrivers, voltmeter, scissors, miscellaneous hardware);
- Power equipment (e.g., angle grinder with zip disks, drill and drill bits);
- Nuts, bolts (including U-bolts and carriage bolts), washers;
- Field survey tape (long reel measuring tape);
- Measuring tape;
- Field notebook or clipboard with **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]) (or device with electronic field sheet);
- Camera;

- Electrical tape; and
- Ladder or stepladder.

Equipment to be installed:

- Wellhead cabinet with keyhole backplate, and green casing extension that will contain all of the monitoring and telemetry equipment;
- Vented pressure transducer to collect groundwater level data;
  - Tip: it is a good idea to bench test pressure transducers in advance of deployment to avoid installing potentially defective equipment.
- Desiccant packages to minimize any moisture within the pressure transducer vent cable;
- Datalogger to collect groundwater data (either pre-programmed or programmed in the field);
- Power supply:
  - Recently charged 12 V battery to power the datalogger and pressure transducer;
  - Solar panel;
  - Solar regulator (charge controller) to safely charge the battery (if not built into the datalogger); and
  - Necessary wiring and 10 Amp fuses, including datalogger power cable (battery cable).
- Antenna to transmit data to the GOES network (omni or directional / x-yagi antenna);
  - Omni antennas have a built-in GPS antenna to provide an accurate time to transmit the data; however, directional antennas will require a separate GPS antenna to be installed.
- Mast to support GOES antenna and solar panel;
- Padlock to secure wellhead cabinet; and
- Well decal attached to outside of wellhead cabinet door to inform observers of the objective of the station and location of further information (i.e., PGOWN website).

A2.2.3 Procedure

A2.2.3.1 Selecting Operating Pressure and Direct-Read Cable Length

Pressure transducer operating pressures and lengths of direct-read cables should be determined during the equipment procurement process. If it is later discovered that the groundwater level variation or trend will result in the need for a greater pressure rating or longer direct-read cable, a new transducer and cable should be purchased at that time.

If there is low confidence in estimating the water table depth over time in advance, consider installing temporary non-vented pressure transducers of a higher operating pressure than likely necessary on a Kevlar string or steel cable, and collecting one year of data before ordering the permanent vented transducer and direct-read cable. The **Non-telemetry Station Installation SOP** can be found in **Appendix A2** (**Section A2.5**).

Operating Pressure

- Transducer operating pressure rating should be selected based on the expected seasonal groundwater level variation and if any anthropogenic drawdown and long-term groundwater level trends are expected (i.e., is the Provincial Observation Well located in close proximity to pumping wells or in an area experiencing long-term groundwater level decline/rebound). If available, use nearby groundwater level data to inform your decision.
    - Tip: if the seasonal (or anthropogenic) groundwater level variation is expected to be **<5 m**, **choose a 10 m pressure rating** to provide enough of a buffer against current uncertainty and potential future water table changes (trends). If the water level will vary by **>5 m** on an annual basis, **choose a 20 m pressure rating**. It would be highly unusual for groundwater levels to fluctuate by 20 m or more, therefore it should not typically be necessary to select a higher pressure rating.
    - Tip: if the seasonal groundwater level range is completely unknown (no nearby well records or existing water level data), typically a 10 m pressure rating will be sufficient for unconsolidated aquifers as they will often fluctuate by less than a few metres per year; however, seasonal variation is often larger for bedrock aquifers, meaning that a pressure rating of 20 m may be more suitable.
    - Please note there is a trade-off between precision and the transducer operating pressure rating. The pressure rating should be selected to account for current and future water table fluctuations (if possible), but the rating should not be excessively high, as this will lead to less precise pressure readings (i.e., a higher margin of error).

Cable Length

- At a minimum, a manual groundwater level measurement from the new Provincial Observation Well should be obtained. If available, use nearby groundwater level data to help determine the direct-read cable length.
- Account for the following factors when determining the cable length:
    - The impact of the time of year on groundwater levels, i.e., is the current measurement being collected during the high or low groundwater season;
    - Expected seasonal variation for the aquifer type and location;
    - If the aquifer is known to be experiencing long-term decline / rebound; and

- Stick-up height and additional length required in order to secure the direct-read cable to the top of the well.

- A general rule of thumb: estimate the low (deep) season water level, add about 5 m and use that as the cable length. Ensure the selected pressure transducer pressure rating is suitable for this depth.

- Tip: when uncertain, a longer cable than likely necessary may be ordered. However, ordering an excessive amount of extra cable length is not recommended as this can complicate the final set-up and, at telemetry stations, may lead to the build-up of moisture in the cable of the vented pressure transducer. That being said, direct-read cables at telemetry stations can be shortened prior to deployment if a revised shorter length is later determined (discuss with the Groundwater Network Technology Specialist).

A2.2.3.2 Install Wellhead Cabinet

- Confirm the steel well casing is at an appropriate working height and in compliance with the BC GWPR (2022). If necessary, cut down the steel casing (and PVC riser if applicable) with an angle grinder.
  - Collect a manual groundwater level measurement before and after the well stick-up height has been altered.
  - Collect stick-up measurements before and after adjustments to the well height (relative to the original groundwater level measurement reference point, such as the top of the well casing). Follow this formula:

$$\begin{aligned} &New\ Stickup\ Height \\ &\quad = Original\ Stickup\ Height\ (m) - Length\ of\ Removed\ Casing\ (m) \\ &\quad + Length\ of\ New\ Green\ Casing\ Extension\ (m) \end{aligned}$$

  - Record all measurements in field notebook or field data sheet.

- Install the green casing extension and wellhead cabinet over the steel well casing and bolt into place.
  - Carriage bolts should be used to secure the wellhead cabinet to the green casing extension with the bolts tightened from within the cabinet (i.e., nuts are threaded onto the bolts within the cabinet to prevent thieves from unscrewing them).
  - Refer to **Section 3.0** of the **PGOWN Operations Manual and Standard Operating Procedures** for further information on site and wellhead modifications to improve security.

A2.2.3.3 Prepare and Mount the Solar Panel and Antenna

- Cover the solar panel while working on wiring to reduce the risk of damage from a short or electrical shock.

- Verify the polarity of the solar panel wiring (i.e., that the wiring coming from panel is set up properly). Clip insulated test leads from the voltmeter to the solar panel cable, following the colour coding (red to red; black to black). Check that the voltmeter shows (+) voltage when the solar panel is exposed to light. If no voltage is measured, or the meter reads (-) voltage, take corrective action before proceeding (see **Section A2.2.4.1**).
    - If solar panel cable ends with a bayonet connector, use voltmeter probes in the terminals (holes) of the bayonet connector to check voltage / functionality of solar panel.
    - Tip: bring a spare solar panel in case of manufacturing defect or accidental damage to original solar panel during installation.
- Temporarily wrap the bare ends of the wires from the solar panel (if present) with electrical tape to prevent electrical contact during assembly.
- At this point you will be attaching the solar panel to the mounting bracket and then mounting the assembly to the mast. Use the brackets, U-bolts, and hose clamps provided to mount the solar panel and bracket on the mast as per the supplied instructions with the mounting bracket. The solar panel should typically be set at a 45° angle relative to the mast. Once the mast is secured to the wellhead cabinet (discussed below) the panel should be facing south (or southeast / southwest if solar coverage will be more optimal in those directions due to trees or other obstructions).
    - Tip: if solar coverage and / or snowy conditions is a concern, mount the solar panel vertically. If the problem is vegetation cover, consider hiring a landscaper to remove trees and other high vegetation (ideally before they grow too large), provided approval is granted by the property owner and / or necessary permits are obtained.
- The GOES antenna can then be attached to the mast using the supplied brackets and U-bolts.
    - For omni antennas, the most ideal placement would be to simply bolt the antenna to the outside top of the wellhead cabinet, or to attach it to the top of the mast. In either case, the omni antenna should typically be pointed vertically. An internal GPS antenna is already part of the omni antenna.
    - For directional (x-yagi) antennas, place near the top of the mast. The antenna can generally be oriented southwards with an inclination of 30°. Moreover, a separate GPS antenna will need to be installed. The GPS antenna can simply be secured to the outside top of the wellhead cabinet.
    - Ensure that the antenna is not placed such that it will cast a shadow on the solar panel. Conversely, ensure that the solar panel is not placed such that it could block the signal from the antenna (e.g., by placing the panel just above the antenna).
- Before the mast is mounted onto the wellhead cabinet, thread the solar panel power cable through the mast, as well as the antenna cable if it is secured to the mast.
    - Drill a hole near the bottom of the mast and then another hole on the side of the wellhead cabinet where the mast will be secured. Feed the antenna (if secured to mast) and solar

panel cables through the mast and out this side hole near the bottom, directly into the wellhead cabinet, to minimize exposure of cables (potential vandalism point).

- Mount the mast to the wellhead cabinet by using two U-bolts.
- The final result should be similar to the figures below. The station in the left-side image uses a directional antenna while the station on the right side uses an omni directional antenna attached to the top of the well cabinet (although it can be attached to the top of the mast if preferred).

Figure A2-2.1 Examples of telemetry stations.

Photo credit: BC ENV.

A2.2.3.4 Install Internal Components

During this step, it is important to ensure that **none** of the wires or cables are connected to the battery or datalogger unless explicitly indicated in the steps below. All bare wires should be taped or restrained away from conductive objects to avoid any shorts or shocks, especially from the walls of the aluminum wellhead cabinet.

- Install the keyhole backplate to the rear of the inside of the wellhead cabinet.
- Install the datalogger on the keyhole backplate.
    - Tip: prior to installation of the telemetry system, it is recommended that the datalogger be programmed at the office to minimize tasks in the field. Instructions for programming of the FTS datalogger can be found in the **FTS Datalogger Programming SOP** (**Appendix A2** [**Section A2.3**]).
    - Tip: install the datalogger in the top left corner area of the keyhole backplate to later on keep wiring better organized and avoid working directly over the opening of the well casing.
    - Install a solar regulator on the backplate prior to installing the backplate in the wellhead cabinet if the datalogger does not contain an internal regulator.

- Record the serial number and make / model of the datalogger.

- Using a voltmeter, check and record the battery voltage. It should read at least 12 V. Do not install batteries that have not been fully charged in advance of installation.
- While the battery is still in the transport box, wrap the red (+) battery terminal completely in electrical tape to insulate in case of accidental contact with any conducting material.
- Place the battery inside the wellhead cabinet at least an inch from the cabinet walls to allow for airflow around the battery.
  - Record the manufacturing year of the battery.

A2.2.3.5 Wire Internal Components

- The datalogger power cable (battery cable) from the battery to the datalogger must be fused with a 10 Amp fuse. On new installations, both the red (+) and black (-) wires should ideally have inline fuses.
  - The FTS datalogger power cable is manufactured as a unit. Previous designs of the power cable will have an inline fuse in the red (+) wire (see red arrow in the left image in **Figure A2-2.2**). Newer power cables are designed with red and black wires fused separately.
  - The datalogger end of the power cables terminates in an insulated bayonet connector (right image in **Figure A2-2.2**).
- To help avoid accidentally shorting the datalogger, the power cable must be connected to the battery first, then to the datalogger. However, connection of the power cable to the datalogger will occur at a later step, detailed below in **Section A2.2.3.7**.

Figure A2-2.2 Components of an FTS datalogger power cable.

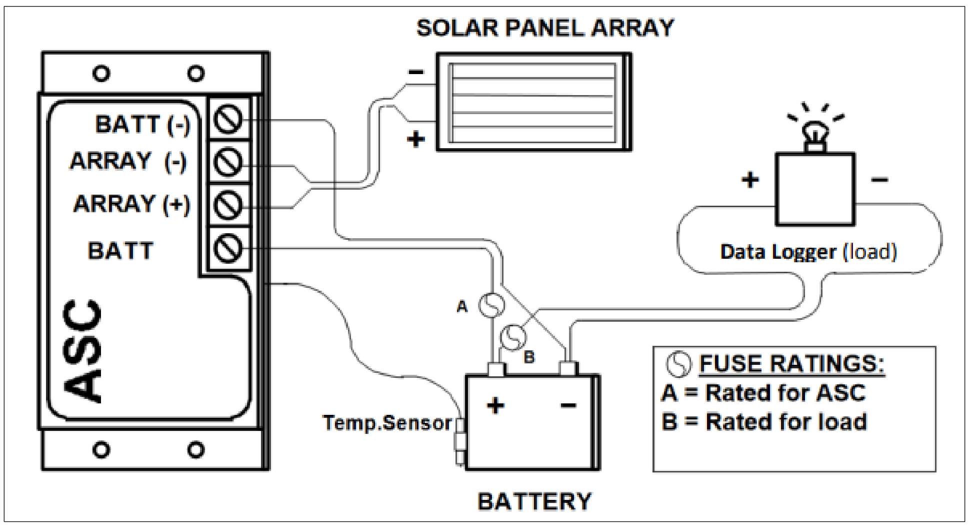
- If using an **external solar regulator** (i.e., H1R FTS datalogger):
  - Remove the tape from the red (+) battery terminal. Use insulated tools to connect the red (+) wires from the solar regulator and datalogger power cable to the red (+) battery terminal. When finished, cover the (+) battery terminal with the red insulating cap provided on the power cable and cover the unattached end of the solar regulator (+) wire with electrical tape.

- Use insulated tools to connect the black (-) wires from the solar regulator cable and datalogger power cable to the (-) battery terminal. Cover the (-) battery terminal and unattached end of the solar regulator (-) wire.

- Taking care not to short bare wires or touch them to the wellhead cabinet, remove the electrical tape from the solar panel wire ends one by one, and connect the wires from the solar panel to the solar regulator. Connect the red (+) wire first, then the black (-) wire. Repeat for the covered wires from the battery terminals to the solar regulator.

- **Figure A2-2.3** shows a schematic of the sequencing between the solar panel, external solar regulator, battery and datalogger. For external solar regulators, it is recommended that the cables from the regulator to the battery terminals include appropriately sized fuses.

Figure A2-2.3 Schematic of telemetry wiring using an external solar regulator.



- If using an **internal solar regulator** (i.e., H1RS FTS datalogger):

  - Remove the tape from the red (+) battery terminal. Use insulated tools to connect the red (+) wire from the datalogger power cable to the red (+) battery terminal. When finished, cover the (+) battery terminal with the red insulating cap provided on the power cable.

  - Use insulated tools to connect the black (-) wire from the datalogger power cable to the (-) battery terminal. Cover the (-) battery terminal with the black insulating cap provided on the power cable.

  - **DO NOT** connect either the solar panel bayonet connector or the power cable to the datalogger yet.

- If there is a battery temperature sensor, tape it to the top of the battery using electrical tape.

- Review and check all connections, especially the polarity of the wires (red (+); black (-)).

A2.2.3.6 Install Vented Pressure Transducer

- Record the serial number, make / model, cable length, and pressure range of the deployed pressure transducer.
  - The pressure range and make / model of the transducer is required when determining data grading to apply to reviewed data in Aquarius.
- It is important to ensure that the full weight of the pressure transducer and direct-read cable is not borne by the desiccant enclosure at the top of the cable. This could result in the cable wiring being pulled out of the desiccant enclosure, changing the cable length (impacting groundwater level data), and potentially damaging the pressure transducer, or resulting in the entire transducer and cable falling into the well. Install a strain relief cable every time to support the weight of the direct-read cable and transducer. Typically, strain relief cables are made using Kevlar string and electrical tape. Prepare these materials prior to lowering the transducer into the well. Contact the Groundwater Network Technology Specialist or Groundwater Monitoring Specialist on how to prepare a strain relief cable.
- Prior to lowering the pressure transducer, tighten the desiccant enclosure gland (plastic nut on the outside of the enclosure) around the direct-read cable to ensure a tight fit. If this is not properly done, the cable may be pulled out of the enclosure, changing the cable length and potentially damaging the equipment.
- Carefully lower the transducer and attached direct-read cable to the desired monitoring depth.
  - **DO NOT** allow the cable to bend or kink as this could damage the airline inside of the cable.
  - Vented pressure transducers do not have memory inside them and will be programmed after all the connections are made (see **FTS Datalogger Programming SOP**, **Appendix A2** [**Section A2.3**]).
  - Tip: consider programming and deploying non-telemetry pressure transducers as backups for remote sites (especially for sites not accessible over the winter) in the event of a telemetry station power failure.
- While not ideal, if there is excess direct-read cable length, carefully wrap the excess around the datalogger and secure with cable ties (zap-straps) within the wellhead cabinet.
  - Coiling the excess direct-read cable can create a heat differential between the wellhead cabinet and the submerged pressure transducer which can impact the data and, as such, should be avoided where possible.
  - If possible and necessary, have the cable shortened in advance of deployment in the field. Contact the Groundwater Network Technology Specialist on how to complete this procedure.
- Secure a strain relief cable to the direct-read cable at the desired point **below** the desiccant enclosure.
- Plug the direct-read cable connector into the datalogger.

A2.2.3.7 Connect Power and Remaining Cables to Datalogger

- Connect the bayonet end of the power cable into the datalogger.
    - Be mindful for sparks, smoke, and heat while connecting power to the datalogger.
- For dataloggers with an internal solar regulator: plug solar panel bayonet cable into datalogger.
    - Note: the solar panel should have arrived with a bayonet connector already attached at the end of its cable. If not, contact the Groundwater Network Technology Specialist for an adaptor.
- Connect the GOES and GPS antenna cables to the datalogger.
    - For all excess lengths of cables, carefully wrap around the datalogger and secure with cable ties as needed to keep cabinet space organized.
- Check the voltage at the battery when all the connections are complete. Check again five minutes later to ensure battery is charging, although this may not be the case during a cloudy day. The battery voltage should drop very slowly if the solar panel is not receiving sufficient light. The battery voltage should rise slowly if the solar panel is getting sufficient light. A small change in battery voltage is normal, but a major change in battery voltage is not expected within a few minutes of connecting the circuit. For charging issues, see **Section A2.2.4.1**.
- Follow the **FTS Datalogger Programming SOP** (**Appendix A2** [**Section A2.3**]) to program the transducer using the FTS datalogger interface.
- The final set-up inside the wellhead cabinet should resemble **Figure A2-2.4**.

Figure A2-2.4 Inside the telemetry station wellhead cabinet (datalogger, desiccant enclosure, vented direct-read cable, battery).

Photo credit: BC ENV.

A2.2.4 Miscellaneous

Common troubleshooting issues and potential causes and resolutions are presented in the following section.

A2.2.4.1 Troubleshooting

Observation	Potential Consequences	Potential Cause	Possible Next Steps
No power to datalogger	▪ Datalogger and pressure transducer will be unable to collect, store and transmit data.	▪ Battery disconnected from datalogger. ▪ Battery is no longer holding a charge. ▪ Fuse has blown.	▪ Check battery voltage and replace if not reading at least 12 V. ▪ Check status of in-line fuse; replace with spare fuse if needed. ▪ Check for proper wiring and connections from battery to datalogger.
Solar panel not charging battery	▪ Battery may eventually die, leading to shutdown of datalogger and data gaps.	▪ Improper solar panel connections. ▪ Inadequate orientation of panel. ▪ Poor solar coverage. ▪ Weather conditions.	▪ If there is adequate solar coverage (sky view) but installation is occurring on a cloudy / dark day, lack of solar charging may be result of weather conditions and, therefore, temporary. ▪ Check for proper wiring connections between solar panel, solar regulator, and battery. ▪ Check if the solar panel is working properly by disconnecting from regulator / datalogger and checking voltage and current readings. ▪ Reorient solar panel to a more optimal position (e.g., vertically). ▪ Replace wiring, replace solar panel, and / or solar regulator. ▪ Consider using a larger solar panel (e.g., 50W).

Note: Using a voltmeter to check power throughout the station should be one of your primary actions when troubleshooting a station with power issues. This will indicate where, if any, there is power loss throughout the station and will help narrow down corrective actions.

Additional telemetry troubleshooting tips can be found in the **Groundwater Level Data Downloading SOP** and the **FTS Datalogger Programming SOP** (**Appendix A2** [**Sections A2.4** and **A2.3**]). Contact the Groundwater Network Technology Specialist or a Groundwater Monitoring Specialist for further assistance.

A2.2.5 Record Keeping

During installation of the telemetry station, it is important to document all details of the installation. This includes at a minimum documenting and recording:

- Make, model and serial numbers of the datalogger and pressure transducer;
- The maximum operating pressure of the transducer;
- Depth the pressure transducer is deployed;
- Revised stick-up height (if applicable);
- Manufacture's date of the battery; and
- Any other relevant details.

This information should be recorded in the field notebook as well as any complications or issues that arose during the installation process. Your **Regional PGOWN Tracking Spreadsheet** and the **PGOWN Equipment & Station Information Spreadsheet** (on the **PGOWN MS Teams Channel**) should be updated with the recorded equipment details (serial numbers, operating pressure of transducer, battery age, etc.). This is necessary for tracking the deployment and age of equipment, as well as planning for its eventual replacement:

- Dataloggers and pressure transducers will need to be replaced approximately every 10 years as per the manufacturer's recommendations.
- The 12 V battery should be replaced approximately every 5 years.

Photos of the installation process should also be taken and all field notes, or field data sheets, and photos should be scanned / saved to the project folder upon returning to the office.

A2.2.5.1 Field Sheets

There is no specific field sheet for installation of telemetry stations.

Appendix A2-3

FTS Datalogger Programming SOP

A2.3 FTS DATALOGGER PROGRAMMING SOP

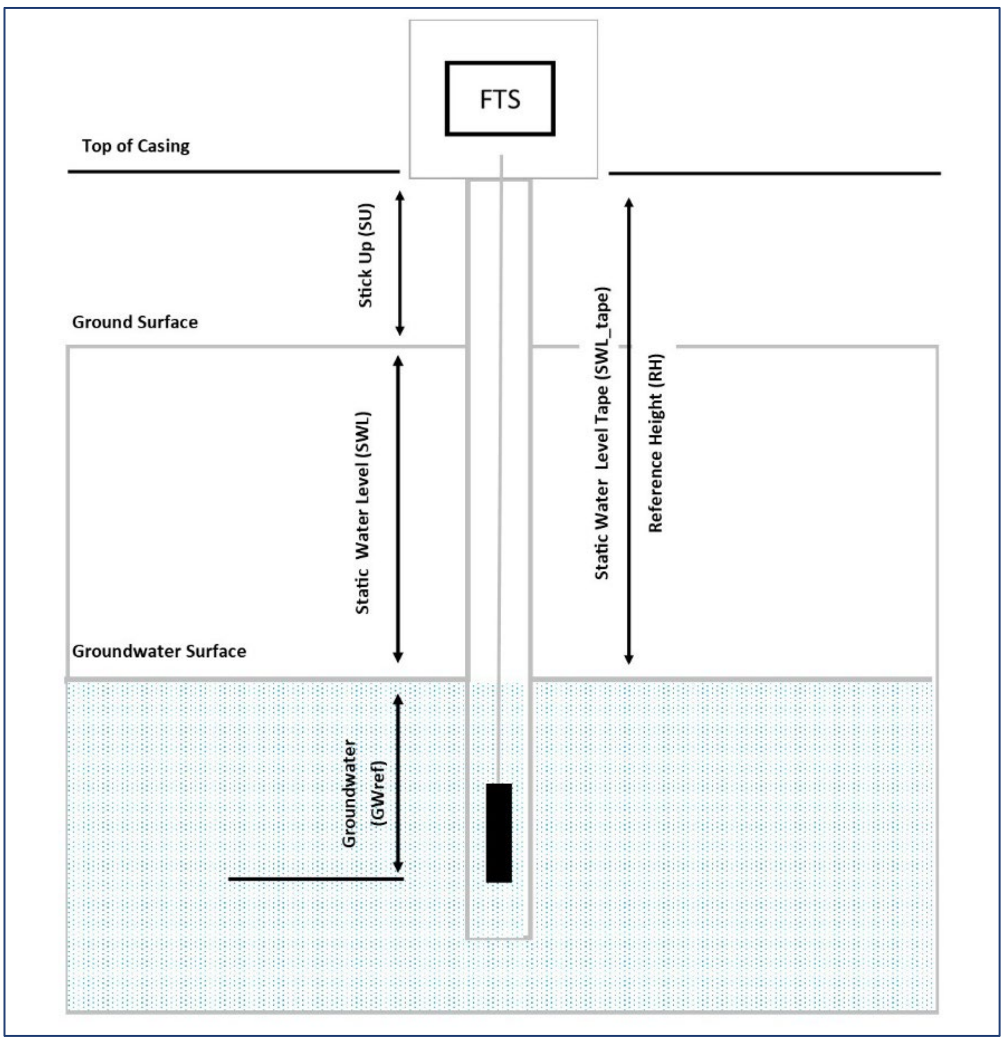
This SOP provides instructions for programming FTS dataloggers at the time of telemetry installation or if dataloggers need to be switched out from a station.

A2.3.1 General

The following procedure outlines the steps required to properly program an FTS datalogger which will then allow for the generation of a “Site Visit Report” (i.e., data package that is downloaded during a site visit). Each step in this document is to be completed in the order that it is presented. Each step is critical and extra care should be taken to avoid making any errors or entering incorrect information. Incorrect information or missed steps can result in the datalogger being unable to successfully record and / or transmit data.

Parameters that need to be measured / known for input into the datalogger during programming are shown in **Figure A2-3.1**.

Figure A2-3.1 FTS Datalogger H1RS parameters.



A2.3.1.1 Equipment

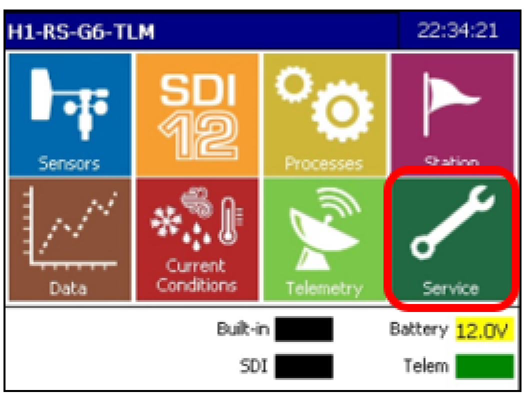
Task-specific equipment (refer to the **Equipment Checklist** in **Appendix A1** for a complete list of recommended equipment for site visits):

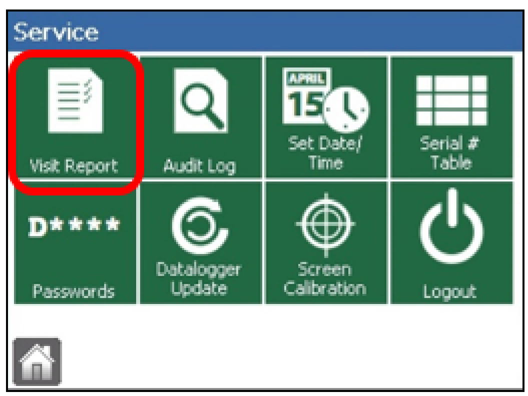
- USB drive;
- Measuring tape;
- Water level tape; and
- Field notebook.

A2.3.2 Procedure

A2.3.2.1 Initial Steps

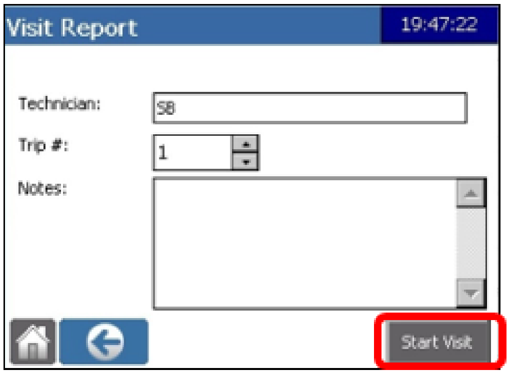
- Prior to going into the field, load the Standard Configuration File onto the USB stick that will be used to program the datalogger. As there are multiple versions of this file, depending on the type of pressure transducer used, please contact the Groundwater Network Technology Specialist for the correct and latest version.
  - In addition, obtain a NESID as this information will be required to program the datalogger and allow it to transmit. Moreover, ensure all newly deployed FTS dataloggers have the most recent software and firmware updates. Contact the Groundwater Network Technology Specialist for instructions and the latest updates, as well as to obtain a NESID.
- Insert the USB stick into the datalogger.
- From the Home screen, select '*Service*' → '*Visit Report*'. See screenshots below.

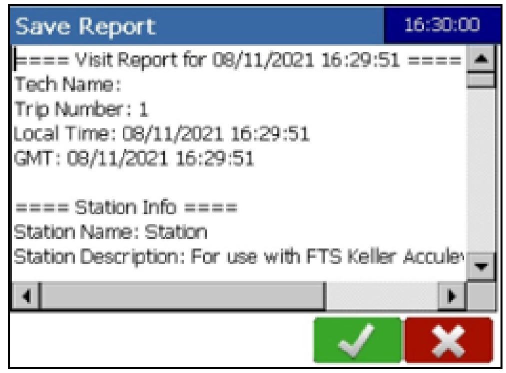




  - Enter the Field Technician's initials.
  - The Trip # will automatically increment.

- Press '*Start Visit*'. A new screen will pop up showing the report which you can review. See screenshots below.

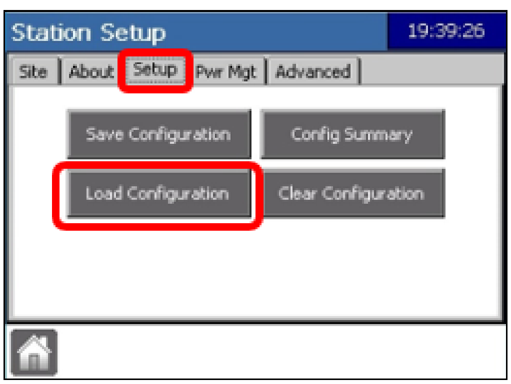


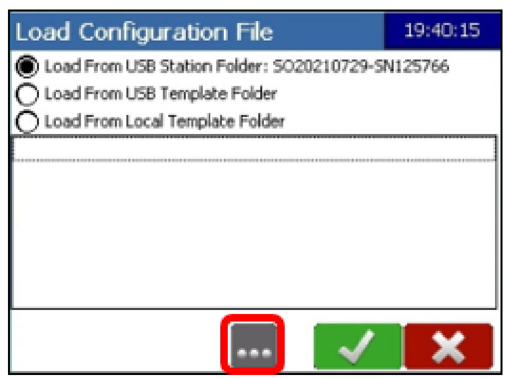


- Press the '*green check mark'* button, which will return you to the Visit Report screen. Return to the Home screen by selecting the '*house*' icon in the bottom left corner. **Do not** press '*End Visit'*.

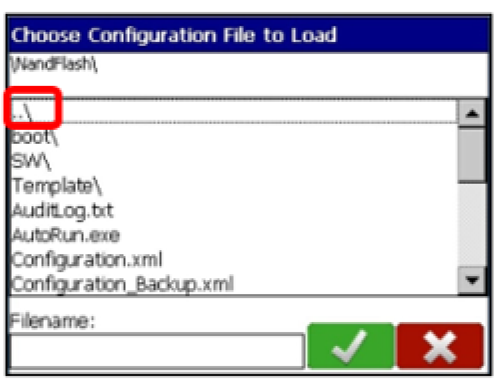
A2.3.2.2 Load Configuration File

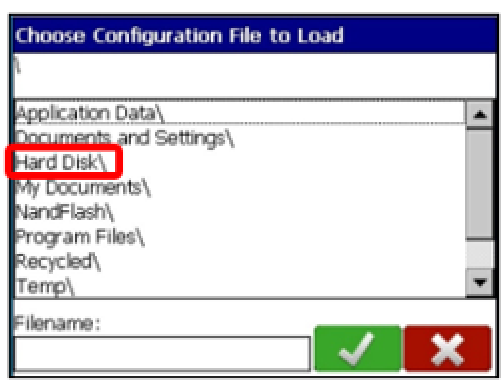
- From the Home screen, select '*Station'* → '*Set-up'* tab → '*Load Configuration'* button→ Triple dots *'(…)'*. See screenshots below.





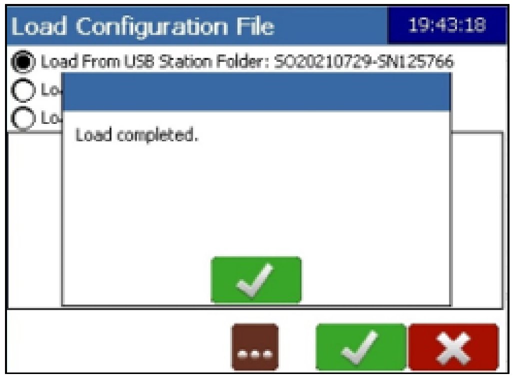
- Press the *'..\'* button → '*Hard Disk'* (i.e., the USB stick). See screenshots below.





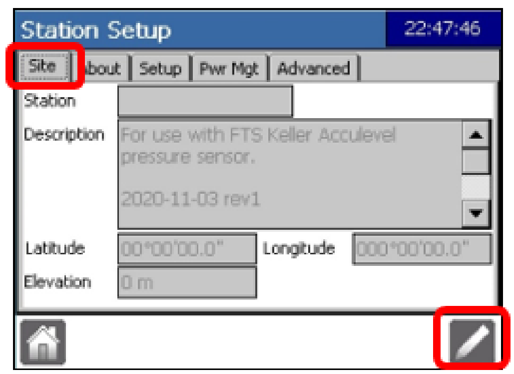
- Select the appropriate configuration file.

- Press the '*green check mark'* button once the "Load completed" message appears. See screenshot below.



A2.3.2.3 Update Station Information

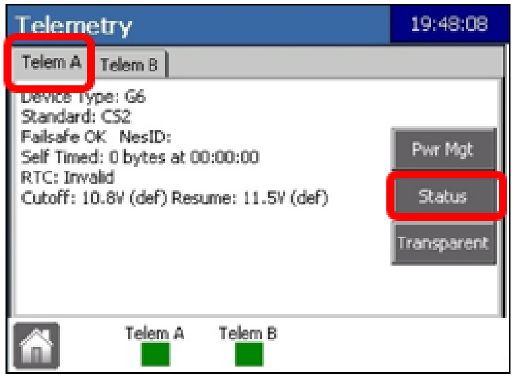
- To program the station name, select *'Station'* → *'Site'* tab → *'edit'* (stylus icon in the bottom right corner) and enter the station (Site) name in the following format: "**OW# Location Name**" (e.g., "OW296 Merritt"). See screenshot below.

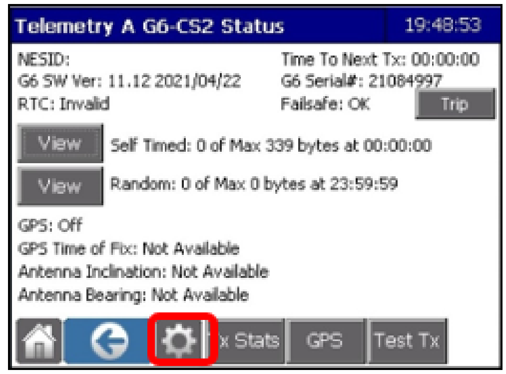


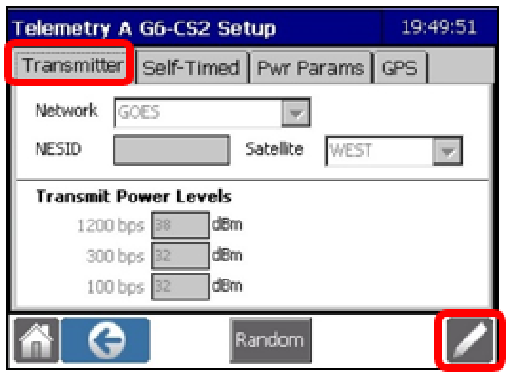
  - The Provincial Observation Well latitude and longitude are automatically updated by the GOES system transmitter once a GPS position is acquired. These parameters will not populate until the GPS position has been acquired, which may take up to 30 minutes.
  - Return to the Home screen.

A2.3.2.4 Enter Telemetry Information

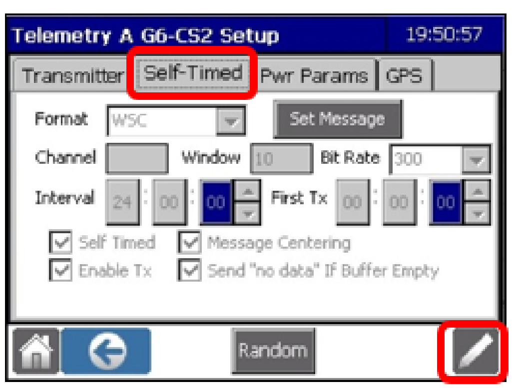
- Press *'Telemetry'* → *'Telem A'* tab → *'Status'* button → *'gear'* button at the bottom → *'edit'* button (stylus graphic, bottom right). See screenshots below.







- ○ Under the *'Transmitter'* tab enter the NESID and select either the East or West satellite depending on the information provided by the Groundwater Network Technology Specialist with the NESID (generally the West satellite is used).
- ○ Increase the 300bps field from 32 dBm to a **maximum** of 38 dBm for **omni directional antennas only**. This is done for sites with trees or other obstacles to improve signal strength.
- ○ Select the *'Self-Timed'* → *'edit'* button. Enter Channel, Interval, First Tx (transmission) details. See screenshot below.

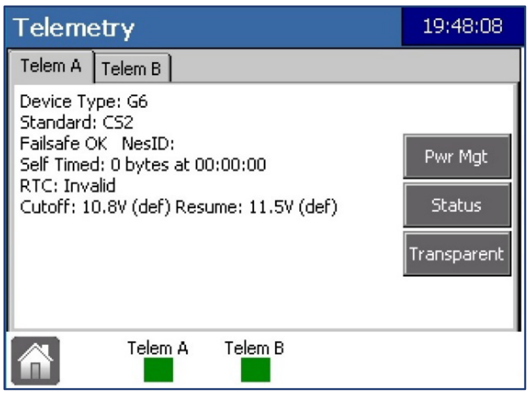


- ○ **Double-check that all edited parameters are correct**. Return to the Home screen.

A2.3.2.5 Antenna Orientation

If using an omni directional antenna with a clear sky view, you may skip this step as the antenna can simply be fixed vertically, otherwise, follow the steps below.

- Retrieve the Antenna Inclination and Antenna Bearing by pressing the *'Telemetry'* icon. → Port A's *'Status'* button. See screenshots below.
  - ○ If 'GPS Time of Fix' says 'Not Available', wait for GPS antenna to confirm a fixed location. This may take up to 30 minutes once the datalogger is powered on and the GPS antenna has been attached.



  - ○ Once GPS has a fixed location, record Antenna Inclination and Antenna Bearing in the field notebook. For example: 196° True, 178° Compass (use Compass value and set the antenna direction). **Do not** add the magnetic declination to 178°.
  - ○ Adjust the antenna inclination and direction as needed and tighten the bolts.
  - ○ Return to the Home screen.

A2.3.2.6 Map Pressure Transducer

- From the Home screen, press the *'SDI12'* icon. Under the Vendor/Serial column, newly detected sensors will be shown with a red background.
  - ○ Press on the red field and the sensor mapping window will appear.

- In the drop-down list, select either *'Stage'*, *'SDI-PT'* or *'Acculevel'* (only one should be listed in the drop-down) → *'green check mark*'. The background should now be yellow. See screenshots below.

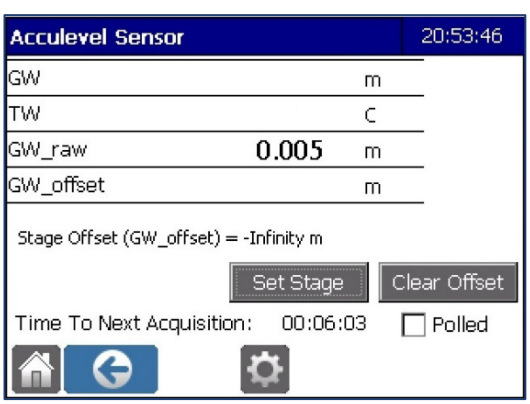
- If the number in the right address column is red, repeat the steps above by pressing the address column instead. The address should be mapped to 0.

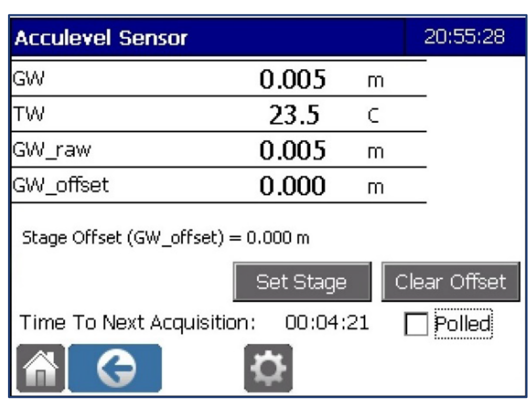
- Return to the Home screen.

A2.3.2.7 Clear Offset

- From the Home screen, press the *'Sensors'* icon → *'Stage'* → '*SDI-PT'* or '*Acculevel'* icon (both TW and GW fields will be blank on the following screen).

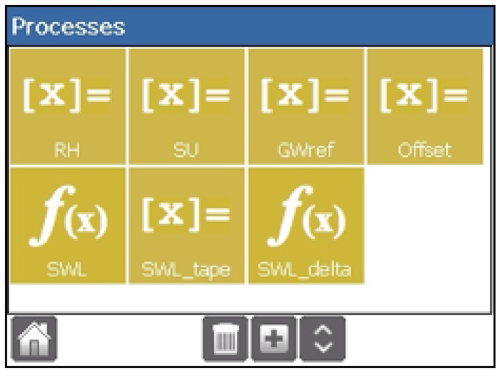
- Press the *'Clear Offset'* button in the lower right corner of the screen to set the stage offset to zero. See screenshots below.





A2.3.2.8 Enter Groundwater Level Information

- In the *'Processes'* menu from the Home screen, the following parameters must be entered to calibrate the pressure transducer (see screenshot below):
    - Stick-up (SU);
    - Groundwater Reference (GWref);
    - Static Water Level Tape (SWL_tape); and
    - Reference Height (RH).



- **SU** – Stick-up is a site-specific value representing the height of the measurement (reference) point above local ground surface that will be used when collecting manual groundwater level measurements (see **Manual Groundwater Level Measurement SOP**, **Appendix A2** [**Section A2.1**]). This value is unique and does not change unless the wellhead (stick-up height) is later modified by field staff.
    - From the Home screen, enter the *'Processes'* menu → *'SU'* icon ➔ *'Set'*. Enter the stick-up value that was measured during the station installation.
    - Set the entered value as the Default Power Up Value when prompted.
- **GWref** – Groundwater Reference is the height of the water column above the top of the pressure transducer; also occasionally referred to as "GW".
    - To populate the GWref value, the pressure transducer must be 'polled' to acquire a current value. The pressure transducer is automatically polled every 15 minutes; however, it is possible to force a measurement by following the steps listed below.
    - From the Home screen, select the '*Sensor'* icon → '*PT*' → '*Set Stage'*. A number will be displayed, often to several (>5) decimal places.
    - Select the '*Cancel'* button. An updated GWref value will be displayed. Record this value to 3 decimal places.
    - Repeat this step to ensure groundwater level is stable (e.g., no nearby pumping interference is currently occurring). If the static groundwater level is not changing, the GWref value will not change.

- From the Home screen, select the '*Processes'* icon → '*GWref*' icon → '*Set'* button and enter the GWref value recorded earlier.

- Be sure to set the entered value as the Default Power Up Value when prompted. By setting the Default Power Up Values, in the case of a loss of power, the logger does not need to be reprogrammed when it regains power.

- **SWL_tape** – Static Water Level Tape and Reference Height (RH) are the same groundwater level measurement measured to the reference point established in the telemetry cabinet (i.e., enter the "m btoc" groundwater level value). This value must be entered into the datalogger twice due to programming nuances.

  - Take a manual water level measurement to the nearest millimeter (see **Manual Groundwater Level Measurement SOP**, **Appendix A2** [**Section A2.1**]).

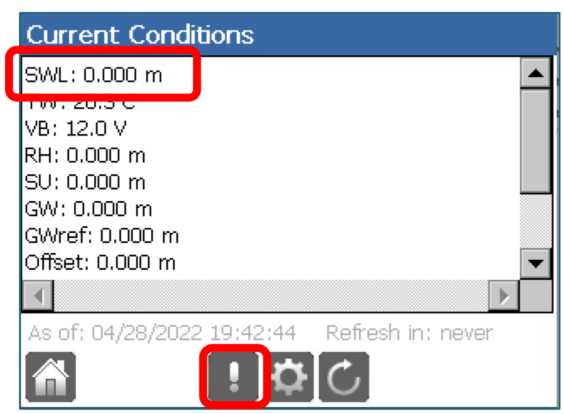
  - From the '*Processes*' menu, press on the '*SWL_tape*' icon. Enter the manual groundwater level measurement.

  - Do not subtract the stick-up from the manual groundwater level measurement when entering the SWL_tape and RH values as the datalogger will already account for this.

  - Set the entered value as the Default Power Up Value when prompted.

  - Repeat the above steps for RH.

- The '*Offset'* value in the *'Processes'* menu is set to zero as a default. This value should be left at zero when setting up a new datalogger or reprograming an existing station. The offset is calculated and entered during subsequent site visits to correct for sensor drift.



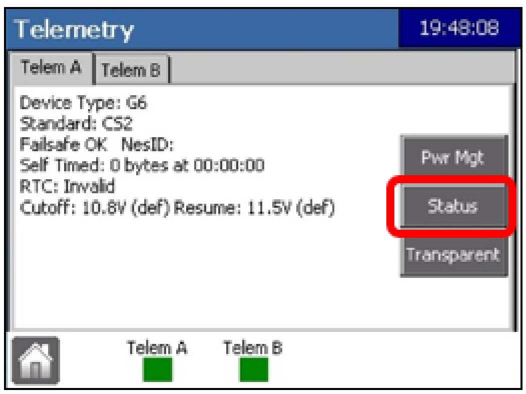
- To ensure that the groundwater level measurement is calculating properly, click on the '*Current Conditions'* icon on the Home screen. Hit the refresh button (*!*) and scroll back up to check the SWL value. See screenshot above.

  - Assuming only minimal time has passed since the manual groundwater level measurement was collected and input into the datalogger, the SWL value should match the manual groundwater level measurement minus the stick-up height (+/- 0.001 m). The SWL value is displayed as ‘m bgs’. If the values are different by greater than 0.001 m, double check that all parameters were entered correctly in the ‘Processes’ menu. If this does not resolve the issue, collect another GWref value and a manual water level measurement and program those into the ‘Processes’ menu.

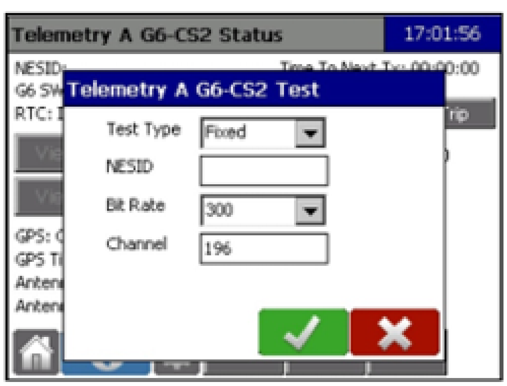
- For Provincial Observation Wells experiencing significant tidal influence or pumping interference from nearby production wells, the SWL may change quickly, making it difficult to program the datalogger and input the manual groundwater level measurement before the SWL changes. **DO NOT** complete programming of the datalogger when the water levels are unstable. Instead, return later to reprogram the SWL and delete the intervening, inaccurate data.
  - Tip: collect the manual water level reading and GWref value as close in time as possible to help avoid fluctuations in the groundwater levels.

A2.3.2.9 Test Transmission

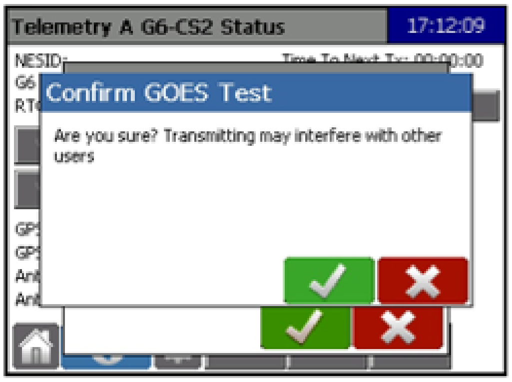
- From the Home screen, select *‘Telemetry’* → *‘Status’* button. See screenshot below.



- Select ‘*Test Tx’* and in the ‘Channel’ field enter “195” for GOES East or “196” for GOES West (the datalogger will likely default to the correct value already). The ‘NESID’ field will also likely already be pre-populated after previously entering the telemetry information (as per sections above). Press the ‘*green check mark*’. See screenshot below.



- A popup window will appear. Press the '*green check mark*' to confirm the test. A Test Transmission screen will pop up, indicating that a transmission is being sent. See screenshot below.



- When the Test Transmission is finished press the '*green check mark*'. The transmission signal strength is provided in the results (pop-up window). Ideally the signal strength should be a minimum of 40 dBm and anything below 37 dBm is less than ideal. See troubleshooting section below.

- Return to the Home screen.

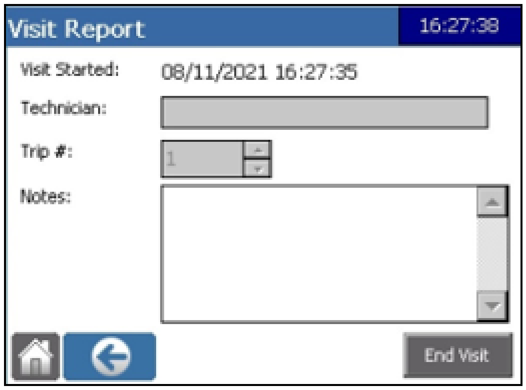
If in an area that has a cellular signal, it is important to check if the test transmission was successful (received by the satellite). Occasionally it can take several minutes for the test transmission to be uploaded to the test website (https://dcs4.noaa.gov/Account/FieldTest or https://sutronwin.com/dcpmon).

- On the USGS EDDN website, enter the NESID / GOES ID under *'DCP Address'*. Enter 24 hours in the *'back'* field. You should be able to see the test transmission results. If no results appear, the signal was not successfully received by the satellite.

- Checking station transmission results on the USGS EDDN website can be incredibly useful for troubleshooting stations. Please contact the ENV Groundwater Network Technology Specialist for information on accessing this website and how to read the transmission results.

A2.3.2.10 End Site Visit

- To end the Visit Report, select *'Service'* → *'Visit Report'* → *'End Visit'*. A screen will pop up showing the report which you can scroll through. See screenshot below.



  - In the following pop-up, press the '*green check mark'* to return to the *'Visit Report'* screen.

- Remove the USB stick.

A2.3.3 Miscellaneous

Common troubleshooting issues and potential causes and resolutions are presented in the following section.

A2.3.4 Troubleshooting

Observation	Potential Consequences	Potential Causes	Possible Next Steps
Weak test transmission signal (<37 dBm)	▪ Collected groundwater level data may not be transmitted, leading to telemetry feed data gaps (between site visits).	▪ Antenna direction not set properly (for directional antennas). ▪ Output power not high enough (for omni antennas).	▪ Check antenna orientation and inclination (if using a directional antenna). ▪ Adjust transmission output power (omni antennas only), if needed, to a maximum of 38 dBm.
Station will not transmit and / or test transmission failure	▪ Collected groundwater level data will not be transmitted, leading to telemetry feed data gaps (between site visits).	▪ Antenna disconnection from the datalogger or not properly programmed. ▪ Antenna not aimed properly / interference. ▪ Issues with GOES network.	▪ Check telemetry information was entered correctly into datalogger (e.g., NESID, East / West network, etc.). ▪ Check antenna connections on antenna and datalogger ends. ▪ Check antenna orientation and inclination (if using a directional antenna). ▪ Check for potential interference sources (e.g., solar panel installed too closely over antenna). ▪ Check transmission status of other stations on the network in case they are transmitting at the same time. ▪ Contact CHASM to ensure correct NESID is used.
Unable to detect transducer	▪ Cannot complete programming of datalogger.	▪ Transducer is disconnected or malfunctioning. ▪ Datalogger unable to identify transducer type (e.g., SDI-PT, Acculevel, etc.).	▪ Check connection of transducer to datalogger. ▪ Open desiccant enclosure at top of transducer cable and check that wiring has not come loose (reattach and tighten if needed). ▪ Go to sensor mapping window (Home screen→*'SDI12'*). Ensure address number is the same under both address columns. Attempt to map sensor.

Additional telemetry troubleshooting tips can be found in the **Groundwater Level Data Downloading SOP** and the **Telemetry Station Installation SOP** (**Appendix A2** [**Sections A2.4** and **A2.2**). Contact the Groundwater Network Technology Specialist or your Groundwater Monitoring Specialist for further assistance.

A2.3.5 Record Keeping

At the end of programming the FTS datalogger, the Field Technician will have the following on the USB memory stick:

- A copy of the logger's XML configuration file for the station;
- A copy of the Telemetry Log and Audit Log (includes records any offset changes); and
- A copy of the FTS Site Visit Report which includes:
    - Station and datalogger information;
    - Sensor / equipment serial number table; and
    - Telemetry configuration.

All field notes and data files should be scanned and saved to the project folder upon returning to the office. The NESID information should be saved to the **Regional PGOWN Tracking Spreadsheet**.

A2.3.6 Field Sheets

There is no specific field sheet for the programming of telemetry stations.

Appendix A2-4

Groundwater Level Data Downloading SOP

A2.4 GROUNDWATER LEVEL DATA DOWNLOADING SOP

This SOP provides instructions for continuous groundwater level data collection / data downloading at Provincial Observation Wells.

A2.4.1 General

Prior to downloading data at a Provincial Observation Well, the following steps should be followed for **every** site visit (whether or not the station has telemetry):

- A manual water level measurement should be the **first task** that is completed at the beginning of a site visit prior to any work at the well that could potentially alter the cable length of the pressure transducer or water levels in the well (e.g., maintenance inside the wellhead or sampling of the well). All field notes should be recorded on the **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]) or onto an electronic field form.

- The date and time of the manual groundwater level measurement should be recorded on the field sheet (also see the **Manual Groundwater Level Measurement SOP** for supplemental details in **Appendix A2** [**Section A2.1**]). In addition, the datalogger current date / time and the local date / time should be recorded, as well as the power level of the datalogger (battery percentage or voltage).

- A **live** groundwater level / pressure reading should be collected close in time to the manual water level measurement to allow for accurate determination of the pressure transducer drift. Sensor **drift** is calculated as follows:
    - $\boldsymbol{Drift} = Manual\ SWL - Well\ Stickup\ Height - Live\ Datalogger\ SWL$
        - All units should be converted to metres;
        - SWL = Static Water Level (recorded to the nearest millimeter);
        - All manual measurements should be in metres below top of casing (m btoc) and then subtract off the previously established well stick-up height to convert to metres below ground surface (m bgs);
        - The live datalogger SWL for non-vented transducers would first need to be compensated by a live barometric reading and converted to ‘m toc’;
        - Keep negative / positive signs for the calculated drift; and
        - Provincial Observation Well stick-up is determined at the time of installation and should remain unchanged unless the wellhead has been altered. Refer to **Regional PGOWN Tracking Spreadsheet** which should compile all information regarding the well.

- Be aware of the time of the next pressure transducer measurement. If it is close to the hourly mark, wait until after the next data point (groundwater level) is logged.

A2.4.2 Equipment

Task-specific equipment (refer to **Equipment Checklist** in **Appendix A1** for a complete list of recommended equipment for site visits):

- Water level tape;
- Clipboard with **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]) (or device with electronic field sheet);
- Field laptop or iPad, with appropriate up-to-date logger software installed;
- Appropriate laptop-datalogger interface cables (e.g., optical data downloading cable); and
- USB drive.

A2.4.3 Data Download Procedures

The following is a step-by-step guide for downloading data from both non-telemetry and telemetry dataloggers.

A2.4.3.1 Non-Telemetry Stations

Solinst Leveloggers / Barologgers

- Connect the Levelogger to a laptop or iPad containing the most recent Levelogger software. There are two ways to connect:
  - If not using a direct-read cable, connect through an optical reader (**Figure A2-4.1**, left images). If this method is used, the Levelogger needs to be pulled out of the Provincial Observation Well first. After removal, dry off the Levelogger with a clean paper towel to prevent moisture from interfering with the optical reader, unscrew the Levelogger cap and place the Levelogger in the optical reader as shown below.
    - Note: the cable that suspends the Levelogger should be set up such that it will not change length when the Levelogger is retied / redeployed in the well. See **Non-Telemetry Station Installation SOP** (**Appendix A2** [**Section A2.5**]).
  - If a direct-read cable (**Figure A2-4.1**, right images) is used, the Levelogger remains in the Provincial Observation Well and does not need to be removed as part of the data collection process. A USB-PC interface cable is used to connect the computer and the top of the direct-read cable.

Figure A2-4.1 Solinst optical reader (left) and direct-read cable (right).

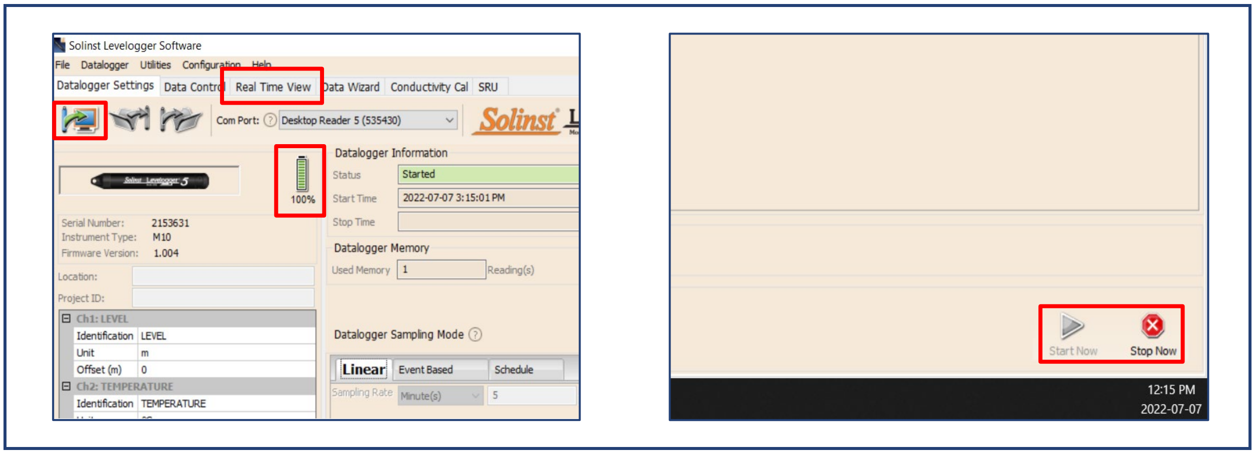
Programming Leveloggers (if not already programmed)

Programming Solinst Leveloggers follows the same steps as the downloading process. This is discussed in the next section below.

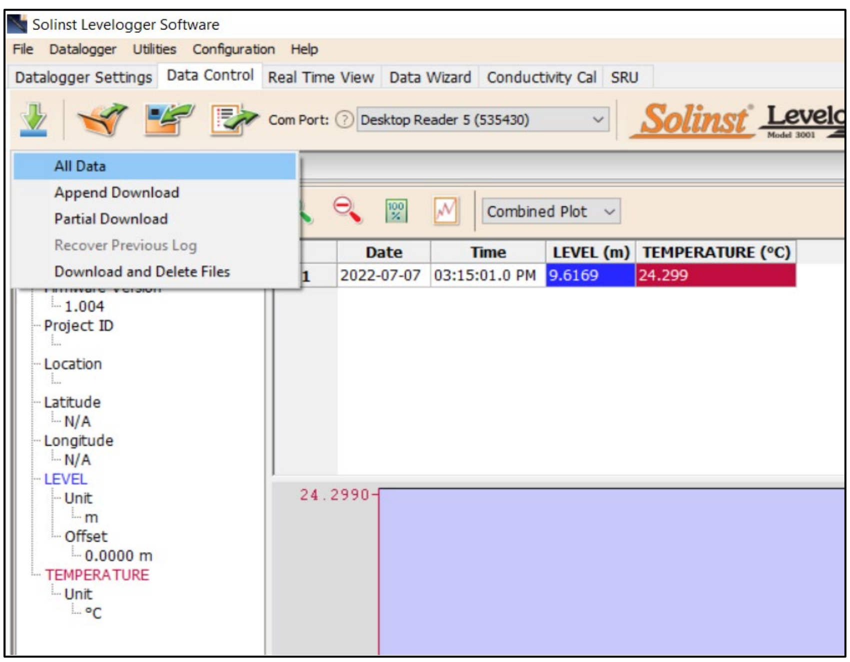
Downloading Leveloggers

- Once connected, start the Solinst program (Levelogger Software) and retrieve the Levelogger current conditions by pressing the icon showing an arrow pointing into the computer, as shown below. In your field notes, make note of the current conditions of the pressure transducer:
  - The logger time and computer time;
  - The logger power level; and

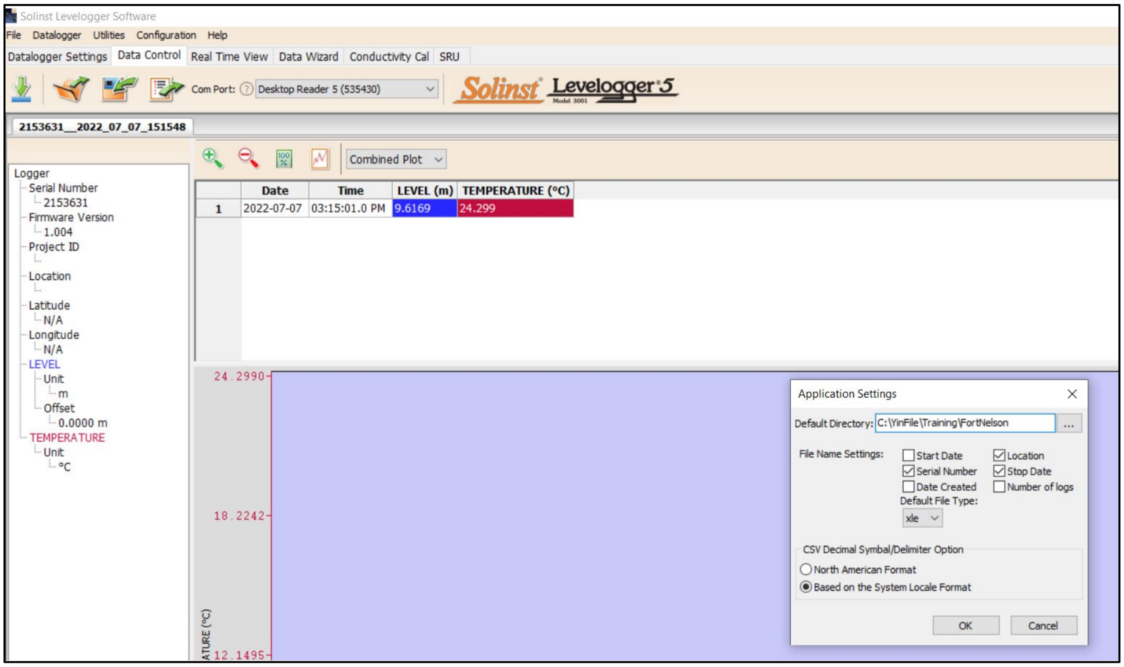
- The live pressure reading (including units) of the logger by selecting *'Real Time View'* and hitting the *'Start'* button (if a dialogue pop-up warns that doing so will delete existing data, then you are on the wrong tab; click the *'Real Time View'* tab and start / stop live data readings there). Please note that you can only collect live pressure readings for a Levelogger that is connected to a direct-read cable and remains in the well at the time of the pressure reading.



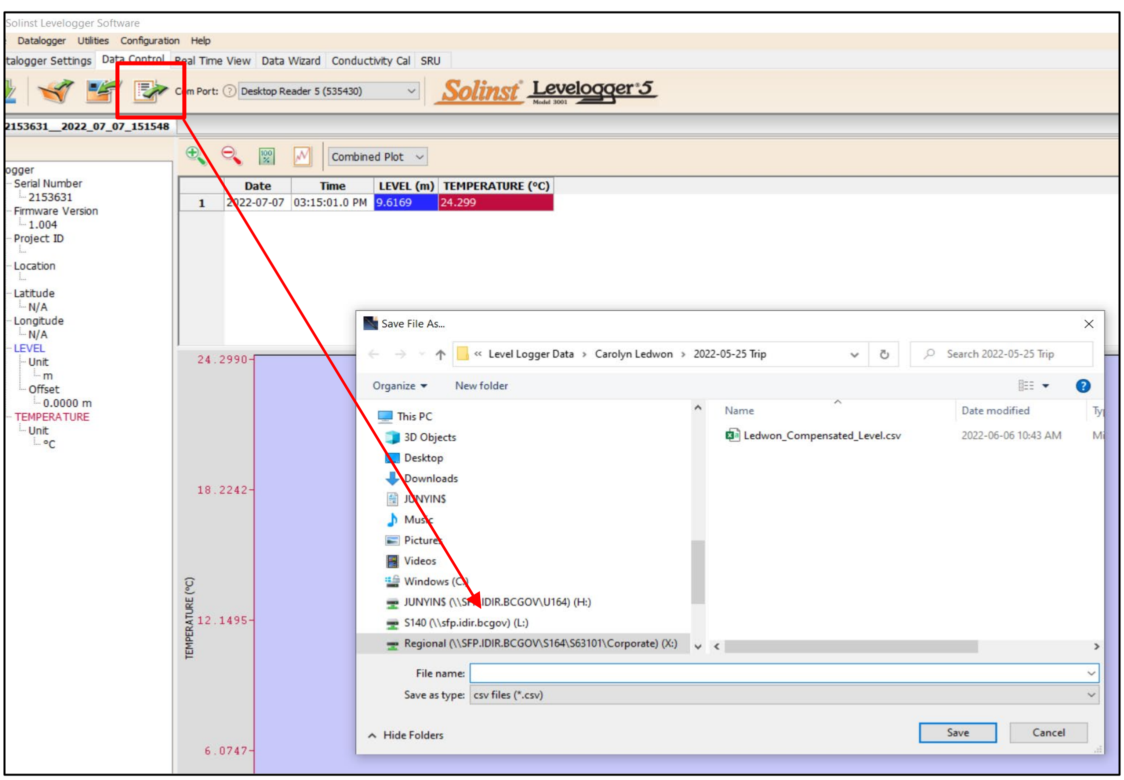
- To download, select the *'Data Control'* tab → '*Download Data*' → *'All Data'*.



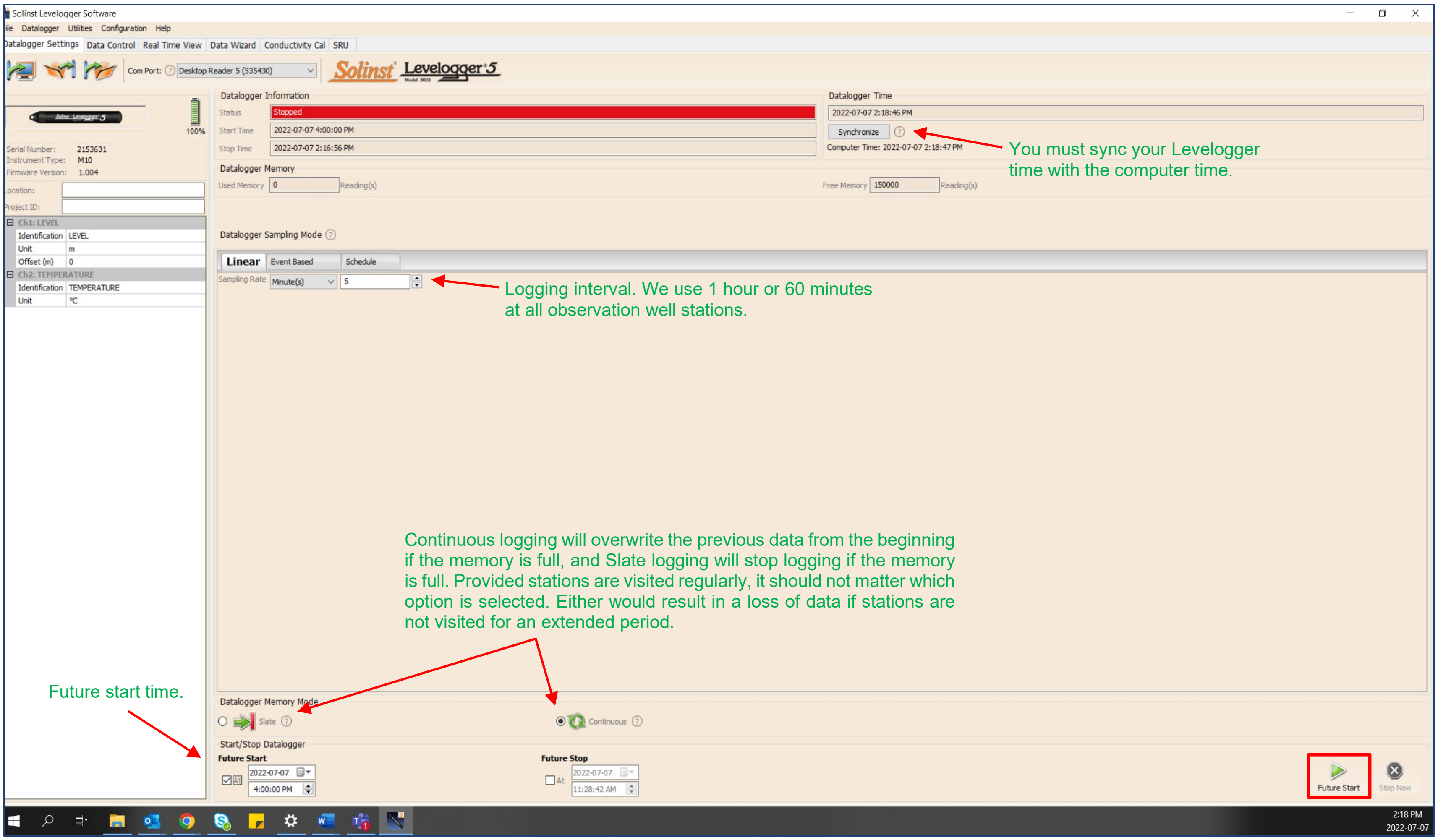
- A plot of the downloaded data should appear when you have completed the data downloading. The saved data directory can be seen and edited through *'Configuration'* (dropdown menu) → *'Application Settings'*.

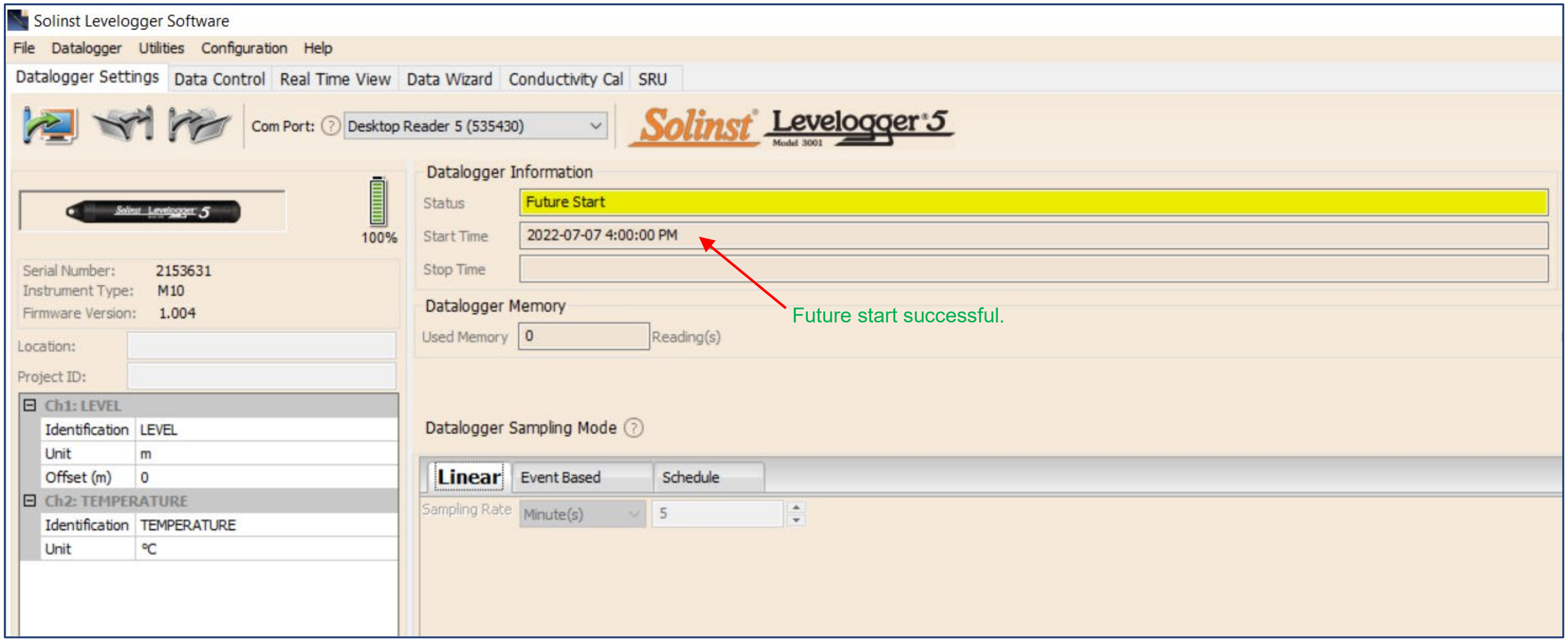


- Data can also be saved as a .csv file through *'Export Data'* → *'Data'* (screenshot below). The downloaded default data format is an .xle file which requires the Levelogger software to open and view the data. Save a copy of the data as a .csv file which will later be uploaded to Aquarius. All downloaded data files should be saved using a consistent naming convention.
    - The file naming convention should consist of the unique Provincial Observation Well identifier number, the transducer type / compensation status, and the date the data was downloaded (e.g., ***OBS273_UNCOMP_23Nov2022*** and ***OBS273_BARO_23Nov2022***).



- Once the data has been downloaded successfully (i.e., open the .csv file and confirm the start and end date of the dataset), stop the Levelogger by going to the *'Datalogger Settings'* tab and selecting the '*Stop*' button. Then restart the Levelogger to synchronize the logger time with the computer time as the logger time can drift (hit the *'Synchronize'* button). Select *'Future Start'* so the datalogger begins collecting groundwater level measurements again at the top of the next hour (e.g., Future Start: 11:00:00 PDT).




Solinst Levelogger Software
File Datalogger Utilities Configuration Help
Datalogger Settings Data Control Real Time View Data Wizard Conductivity Cal SRU
Com Port: Desktop Reader 5 (535430)
Solinst Levelogger 5
100%
Serial Number: 2153631
Instrument Type: M10
Firmware Version: 1.004
Location:
Project ID:
Ch1: LEVEL
Identification LEVEL
Unit m
Offset (m) 0
Ch2: TEMPERATURE
Identification TEMPERATURE
Unit °C
Datalogger Information
Status Future Start
Start Time 2022-07-07 4:00:00 PM
Stop Time
Datalogger Memory
Used Memory 0 Reading(s)
Future start successful.
Datalogger Sampling Mode
Linear Event Based Schedule
Sampling Rate Minute(s) 5

- Once completed, clean and lower the datalogger back into the Provincial Observation Well if the optical reader was used. Check all the connections so the datalogger will not be dropped into the well. If a direct-read cable was used, check that the cable is secured and will not shift (change length) between site visits.
- Repeat the same procedure above for the Barologger. The Barologger should be programmed to collect an atmospheric pressure measurement on the hour, consistent with the Levelogger.

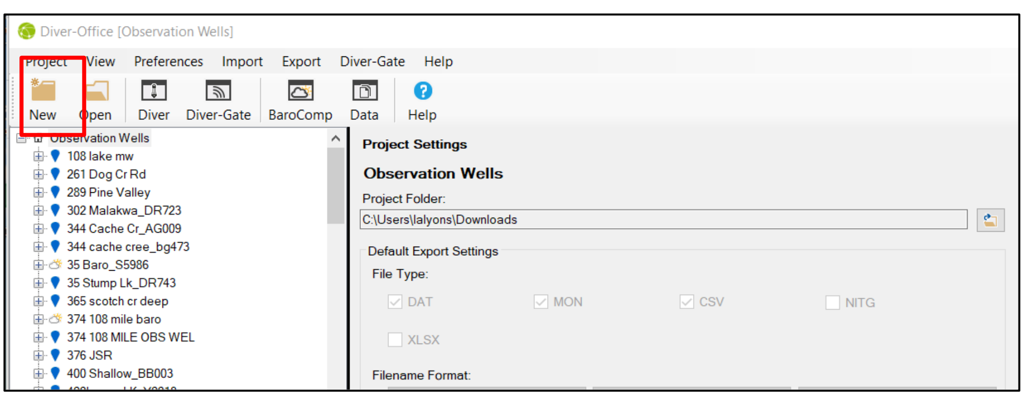
Van Essen Divers / Baros

- Connect the Van Essen Diver to a laptop or iPad containing the most recent Diver software. There are two types of connection cables: the optical reader or direct-read cable (see **Figure A2-4.2**).

Figure A2-4.2 Van Essen optical reader (left) and direct-read cable (right).

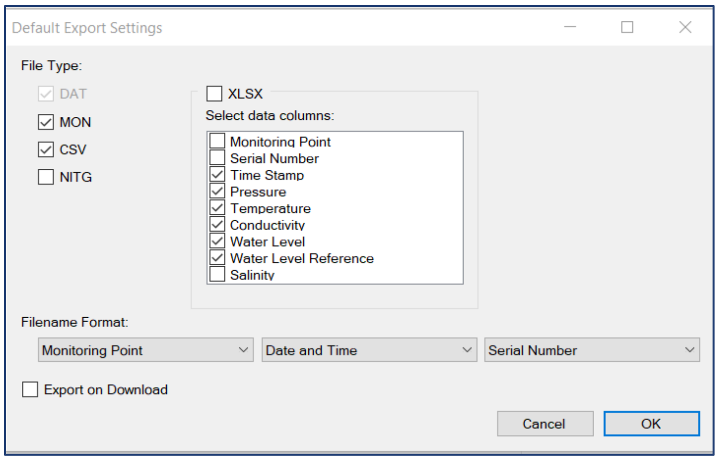
Programming Divers (if not already programmed)

- Launch Diver Office software and create a New Project by hitting the *'New'* button.



- Set-up the project settings as shown in the table below:

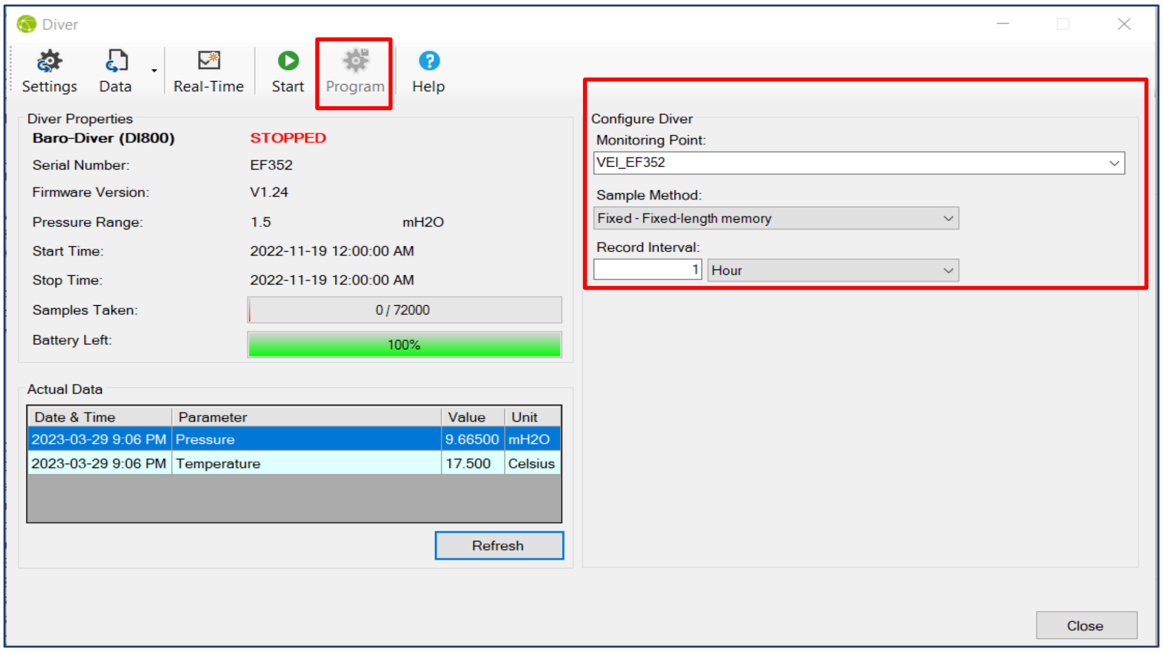
Project folder	▪ C:\ or H:\ drive.
Default Export Settings	▪ Select 'CSV'.
File name format	▪ See screenshot below table on next page. ▪ Suggested: 'Monitoring Point', 'Date and Time' and 'Serial Number'.
Project Time Settings	▪ Select 'Standard Time'.
Vertical Reference Datum	▪ Select 'Mean Sea Level'.
Merge Time Series	▪ Select 'Manual'.



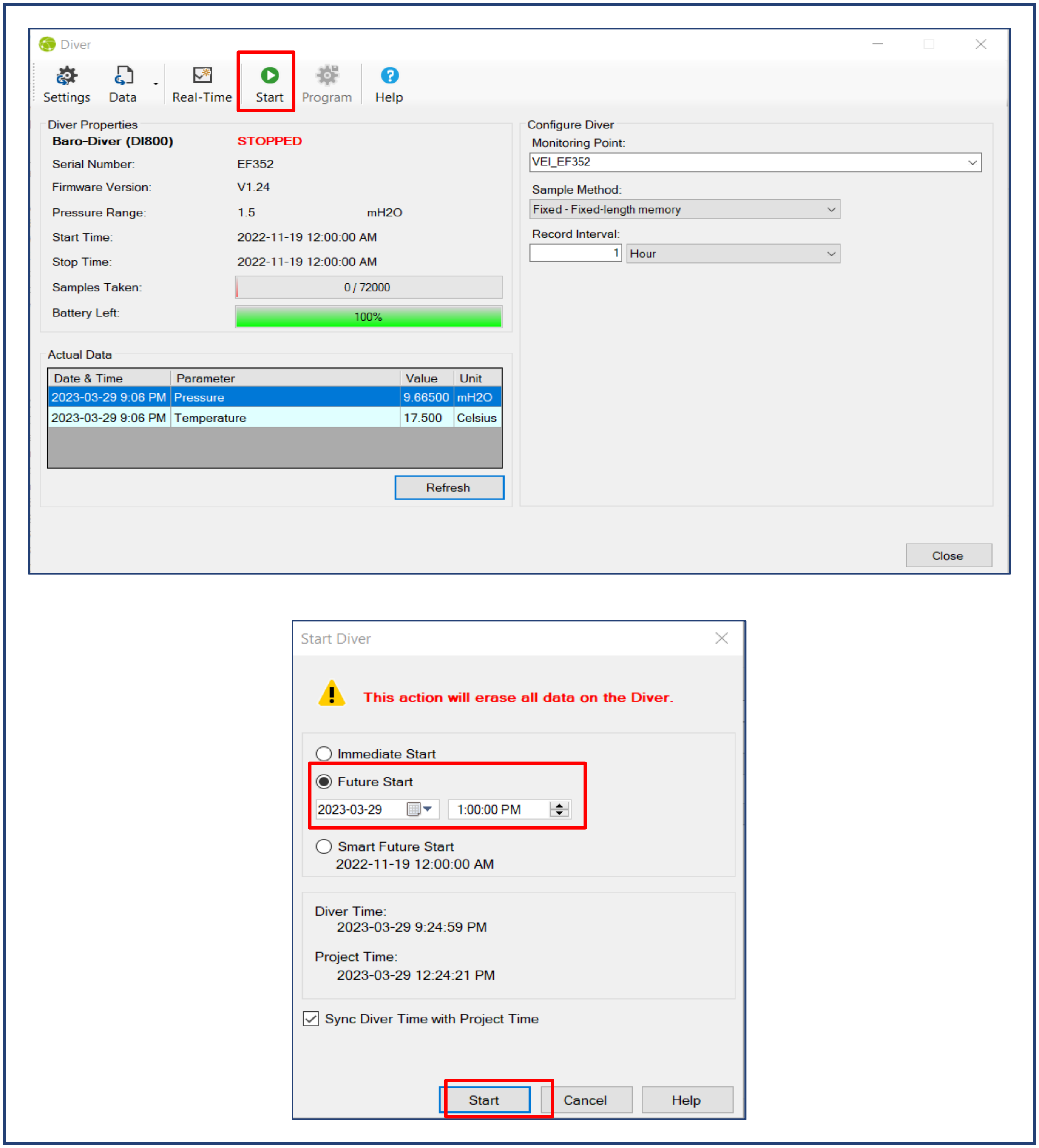
- Place Diver in the optical reader. **Figure A2-4.2** shows the two types of connection cords available (optical reader and direct-read cable). Yellow and green transmitting and receiving lights will flash on optical reader, and Diver user screen will open on computer.
    - Please note that bright sunlight can occasionally make it difficult for optical readings made from translucent plastic to properly read the Diver (or Baro).

- Select the *'Diver'* button on the main screen, which will open a pop-up window. Complete the configuration settings as per the table below and hit the *'Program'* button:

Monitoring Point	▪ Provincial Observation Well name
Sample Method	▪ Fixed – Fixed-length memory
Record Interval	▪ 1 hour



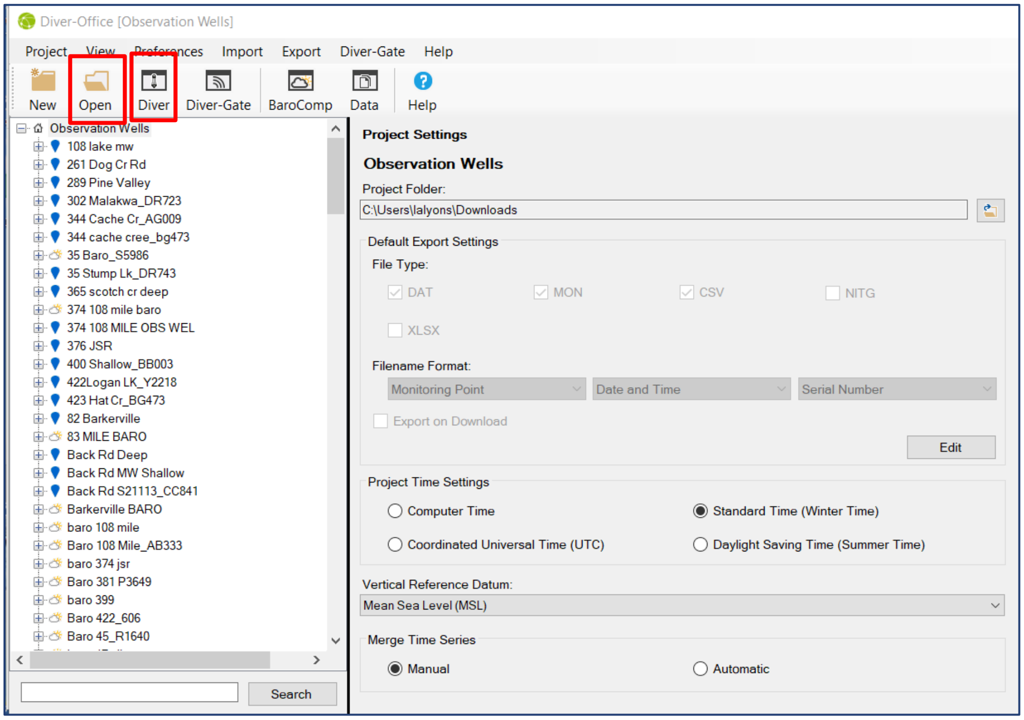
- To start the Diver, press *'Start'* and a new screen will pop-up. Enter the Future Start settings. Ensure the time is set to record on the hour (e.g., 1:00:00 PM). Check off (✓) the *'Sync Diver Time with Project Time'* option. Press '*Start*'.



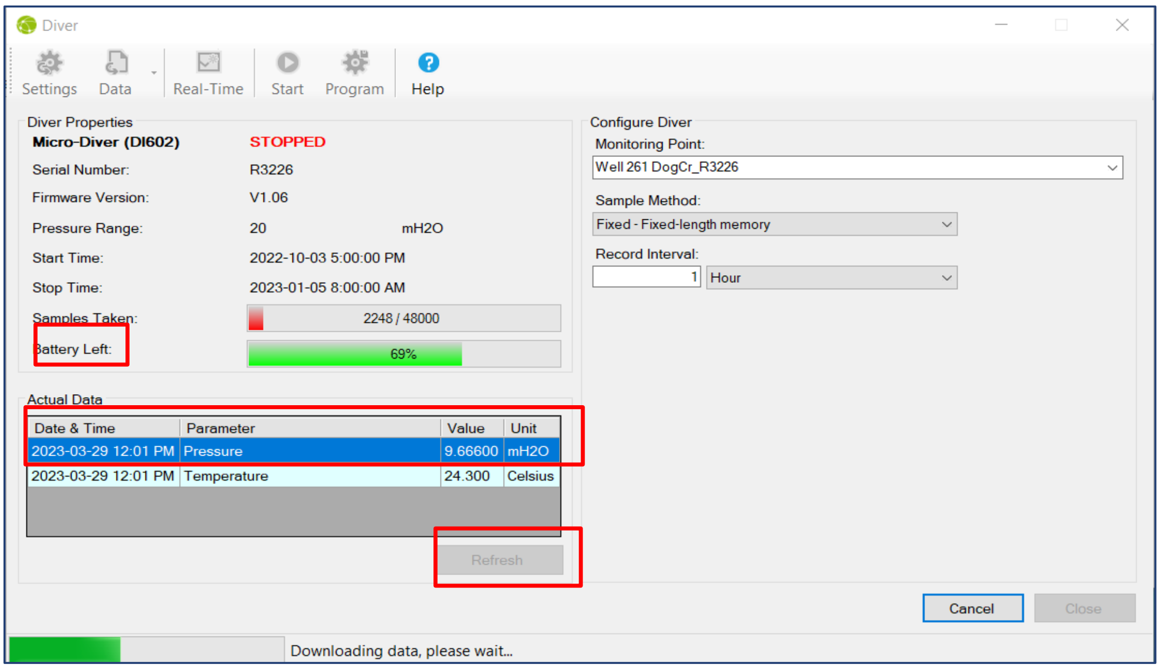
- Repeat the same procedure above for the Baro. The Baro should be programmed to collect an atmospheric pressure measurement on the hour, consistent with the Diver.

Downloading Divers

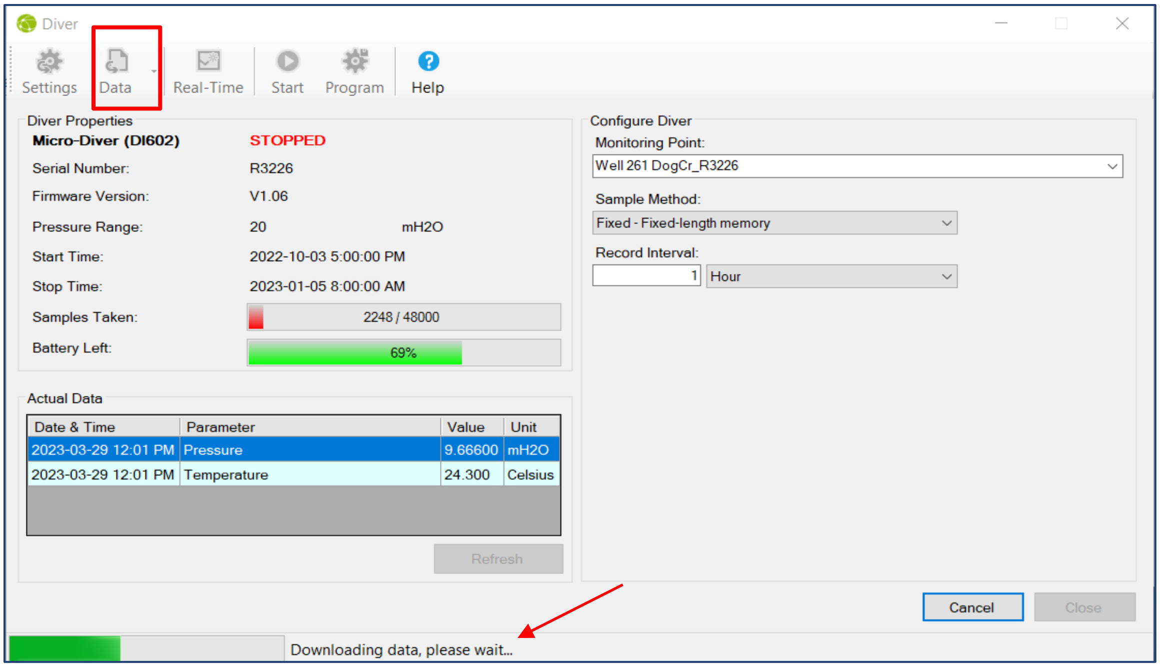
- Connect to the Diver using the direct-read cable or optical reader (if using an optical reader, retrieve the Diver from the well and connect it to the reader). Launch the Diver Office software and open to the correct project folder by clicking the *'Open'* button and then selecting the correct Provincial Observation Well (double check that you have selected the correct well folder). Then select the '*Diver*' button and a pop-up window (Diver settings screen) will open.



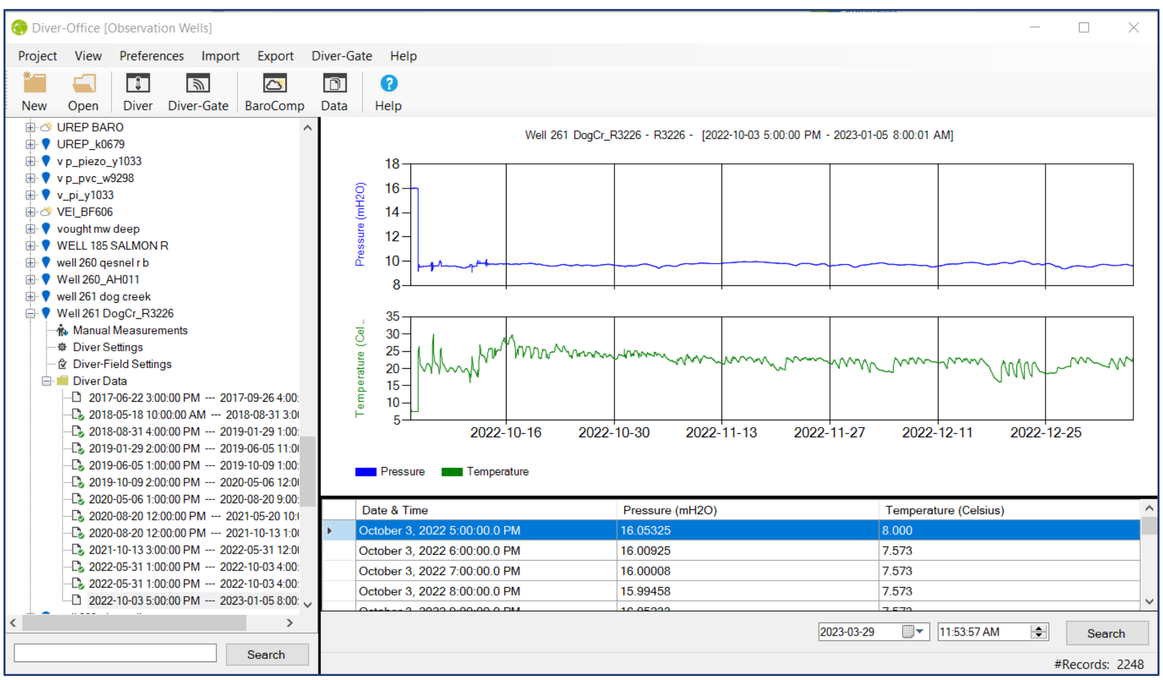
- In the Diver settings screen, hit the *'Refresh'* button. In your field notes, record the Diver current conditions shown, including:
    - The logger time and computer time;
    - The logger power level; and
    - The live pressure reading (including units) of the logger. Please note that you can only collect live pressure readings for a Diver that is connected to a direct-read cable and remains in the well at the time of the pressure reading.



- To begin downloading data, select the *'Data'* button to begin the process, and a green download bar will appear at the bottom of the screen.

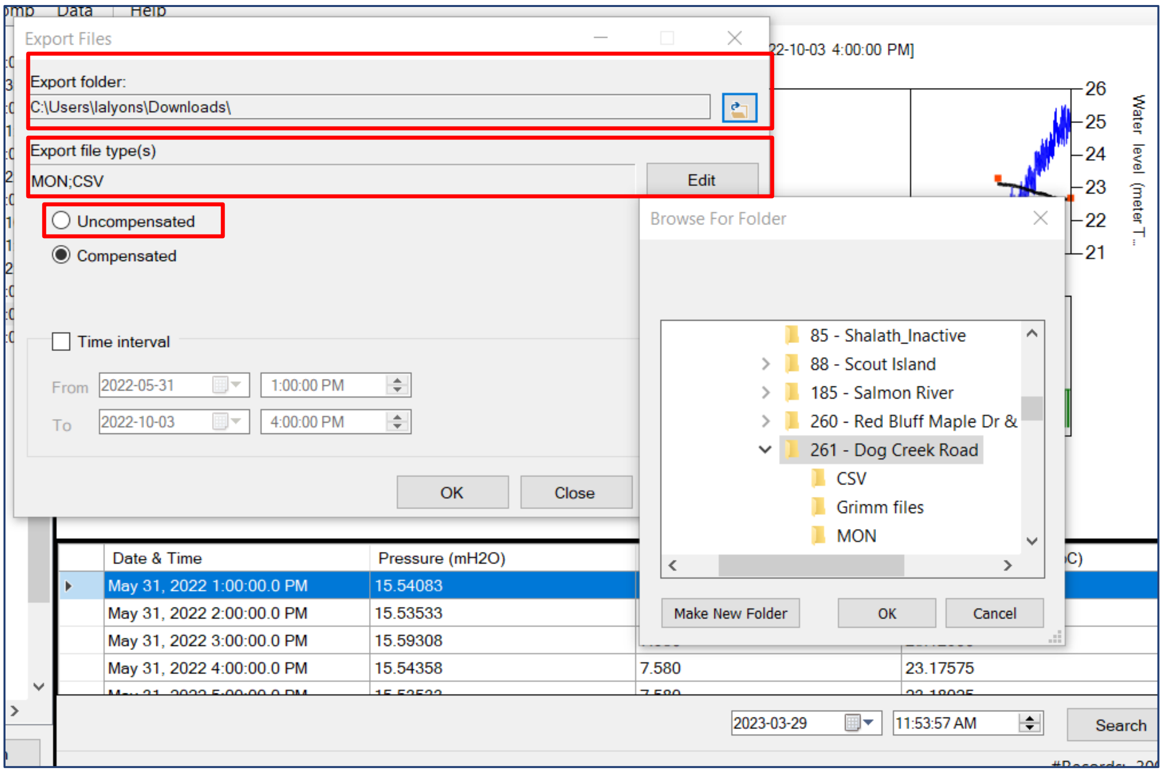


- When the download is completed, a pop-up of the downloaded data will appear, as shown below.



- The Diver time must now be synchronized to the computer time. To do so, return to the Diver settings by selecting the *'Diver'* button at the top of the screen. Then select the *'Stop'* button (assuming the data was downloaded as per the previous steps). A pop-up will ask if the data has been downloaded before continuing to the next step (or else the data will be lost). Select *'Yes'*.

- To start the Diver recording again, select *'Start'*. This will synchronize the logger time with the computer time.
- In the left-side navigation, select the data file of interest to export (i.e., the just downloaded Diver file [which will be labelled with the download date stamp]). Right click on the data file and select *'Export'* from the drop-down menu. Select *'Browse'* to navigate to desired location and select *'OK'.* Ensure the Export file type is set to 'CSV' and select *'Uncompensated'*. Select '*OK'.*



- The final step is to navigate to the folder where the file was saved and name the exported file. These raw logger files will later be appended to Aquarius for data processing.
    - The file naming convention should consist of the unique Provincial Observation Well identifier number, the transducer type / compensation status, and the date the data was downloaded (e.g., ***OBS273_UNCOMP_23Nov2022*** and ***OBS273_BARO_23Nov2022****)*.
- Once completed, clean and lower the datalogger back into the Provincial Observation Well, if the optical reader was used. Check all the connections so the datalogger will not be dropped into the well. If a direct-read cable was used, check that the cable is secured and will not shift (change length) between site visits.
- Repeat the same procedure above for the Baro. The Baro should be programmed to collect an atmospheric pressure measurement on the hour, consistent with the Diver.

A2.4.3.2 Telemetry Stations

The following procedure outlines the steps required to download groundwater level data from a telemetry station that is equipped with an FTS datalogger. The steps are to be completed in the order presented.

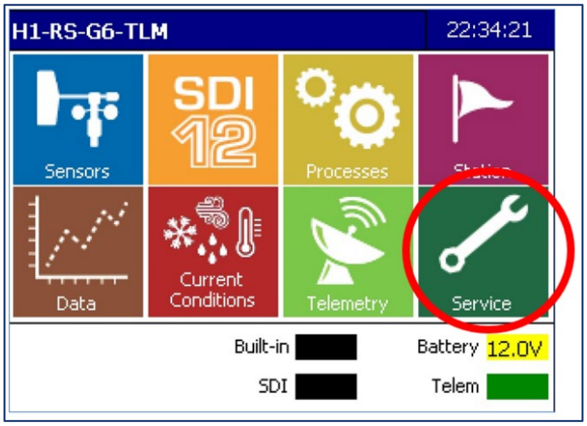
Please note the following:

- The **data download should only occur when the datalogger offset is ready to be applied** so as to avoid "orphaned" datapoints that will later need to be manually offset in Aquarius. In other words, you do not want another hourly data point to be logged between when the datalogger offset is applied to the FTS and when the data is downloaded as this will create confusion later on in Aquarius and at the next site visit.
- **If there is to be no well maintenance or sampling** that could potentially impact the pressure transducer cable length or water levels, then the manual water level measurement, data logger current conditions, datalogger offset, and data download, should be completed at the start of the site visit. Keep in mind that another data point will be logged on the hour.
- **If well maintenance or sampling is to be conducted**, then a manual water level measurement and datalogger current conditions should be collected at the start of the site visit to accurately determine the **drift** correction value (which will later be applied in Aquarius to the downloaded data since the last site visit). After the maintenance or sampling is completed (and water levels have stabilized), another manual measurement should be collected and compared to the datalogger live water level reading in order to calculate and apply the **offset** value to the datalogger in the field, and the groundwater level data can then be downloaded.
    - If the well groundwater levels are likely to **recover quickly** after sampling, complete data download and datalogger offset **after** sampling. The same procedure is required if the submerged transducer must be removed during sampling as the cable length could change during redeployment; or
    - If the well groundwater levels are likely to **recover slowly**, and the pressure transducer does not need to be removed during sampling, complete the data download and datalogger offset **before** sampling. Alternatively, return to the site in the following days once groundwater levels have stabilized (as may be the case for slow recovering bedrock wells); however, the intervening data between the sampling event and offset application must be later be deleted from the 'Working' dataset in Aquarius.

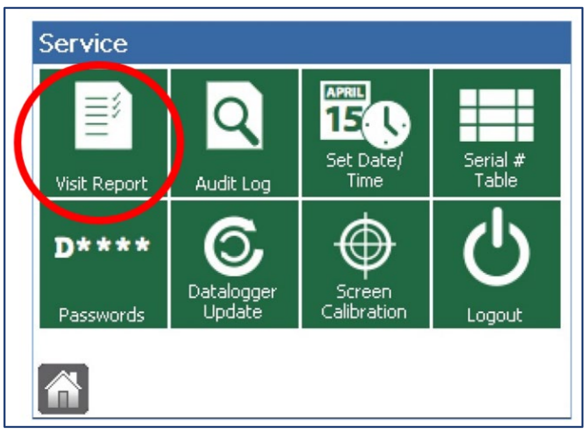
All field notes should be recorded on the **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]) or onto an electronic field form.

Downloading FTS Dataloggers & Applying Offsets

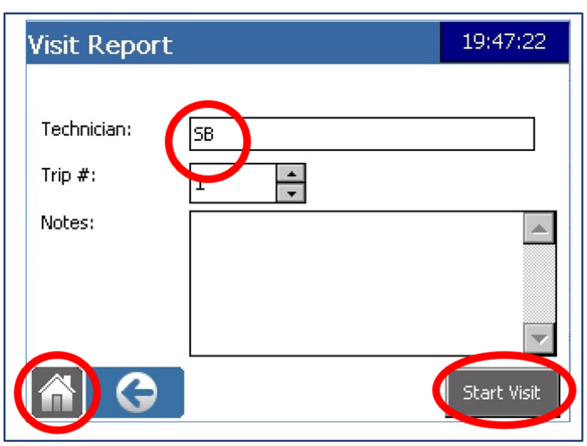
- Plug in the USB drive into the datalogger. Tap the datalogger display screen and then select the *'Service'* button.



- Select '*Visit Report*' to start a field visit log to capture any changes made to the FTS datalogger and to automatically create a folder where the data will be saved on the USB drive.

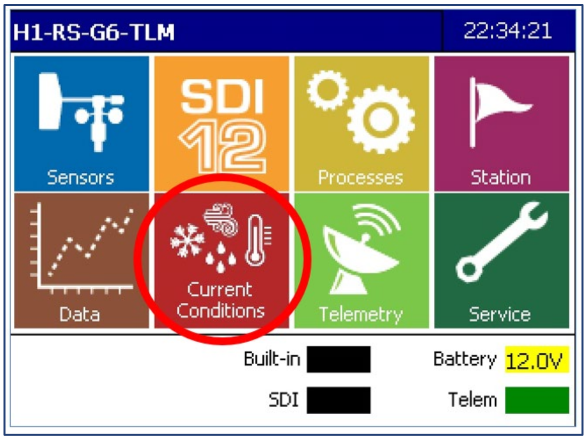


- Enter your initials in the 'Technician' field and select '*Start Visit*'. Accept any pop-up windows. Select the *'House'* icon to return to the 'Home Screen'.

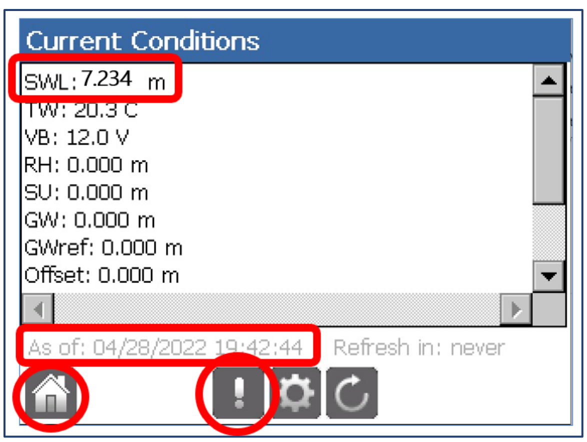


To calculate and apply the datalogger **offset** value (sensor drift), follow the instructions below:

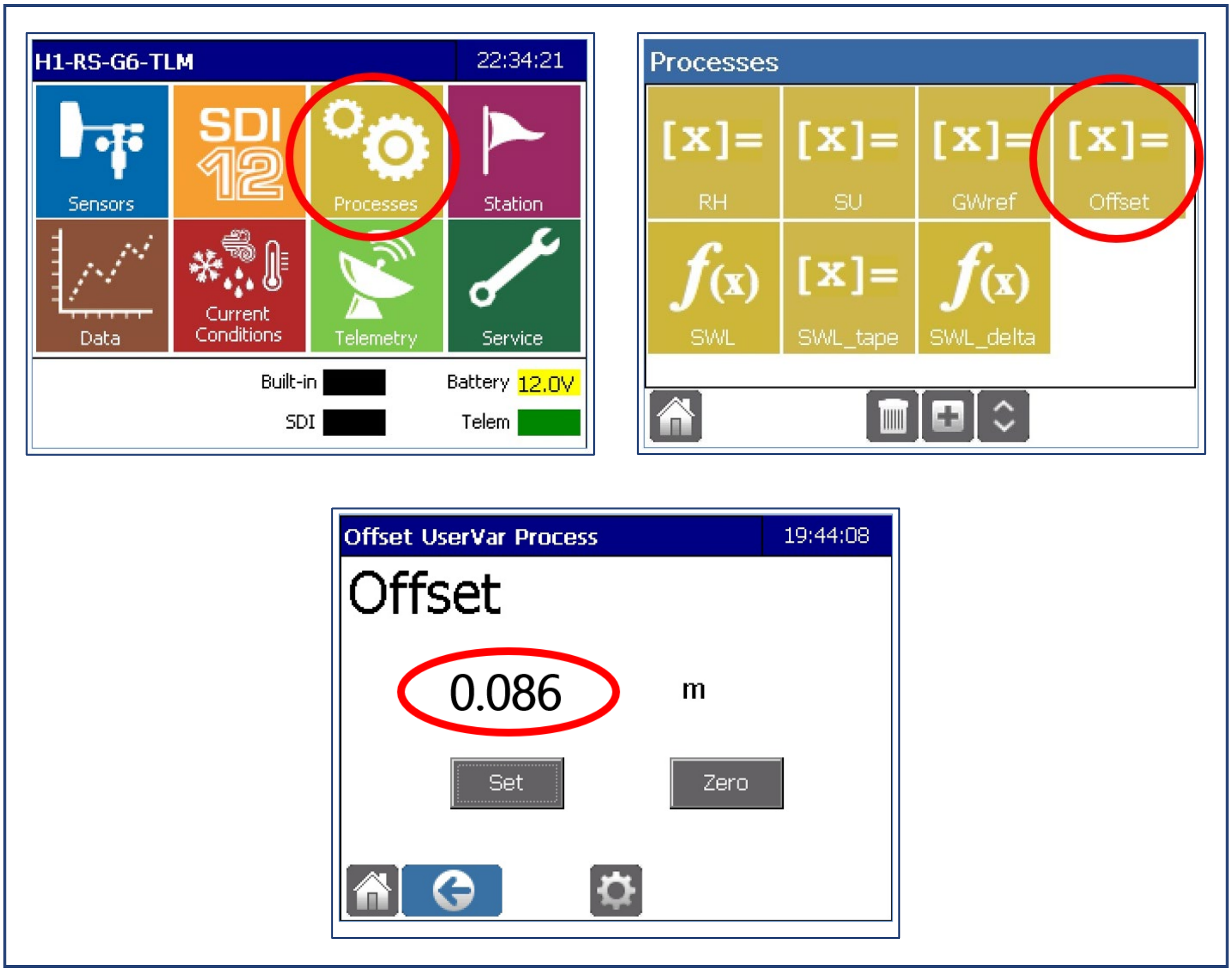
- Select the *'Current Conditions'* icon. Select the *'!'* icon to refresh the current conditions screen (ignore / accept warning pop-up window).



- Record the date, time (UTC and local time), static water level (SWL), and battery voltage (VB) as shown on the datalogger display screen using the **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]). In addition, collect a manual groundwater level measurement and record the date and time of collection on your field sheet. Select the *'House'* icon to return to the 'Home Screen'.



- Retrieve the current datalogger offset value by selecting the ‘*Processes*’ icon → ‘*Offset*’ icon.



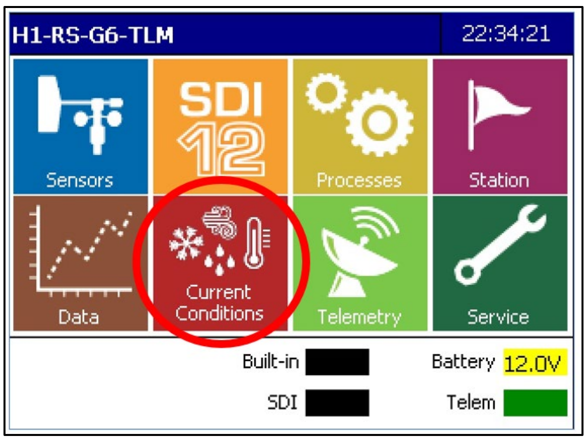
- Record the displayed offset shown on the screen onto the **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]). Calculate and apply a **new offset** using the following equation:
    - $\boldsymbol{New\ FTS\ Offset} = (Manual\ SWL - Well\ Stickup\ Height - Live\ FTS\ SWL) + Existing\ Offset$
        - All units are in metres;
        - SWL = Static Water Level (recorded to the nearest millimeter);
        - All manual measurements should be in ‘m btoc’ and then subtract off the previously established well stick-up height to convert to ‘m bgs’;
        - The datalogger SWL is already expressed as metres below ground surface (m bgs);
        - Keep negative / positive signs;

- Provincial Observation Well stick-up is determined at the time of installation and should remain unchanged unless the wellhead has been altered. Refer to the **Regional PGOWN Tracking Spreadsheet** which should compile all information regarding the well.

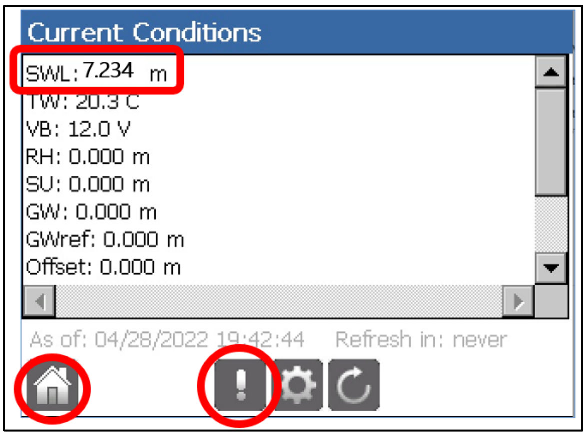
- Select *'Set'* and enter the newly calculated offset value. Accept the new offset (ignore / accept warning pop-up window) and return to 'Home Screen'.

Next, to confirm that the offset has worked as intended, follow these steps:

- From Home Screen → *'Current Conditions'* → *'!'* to refresh station conditions (ignore / accept warning pop-up window).

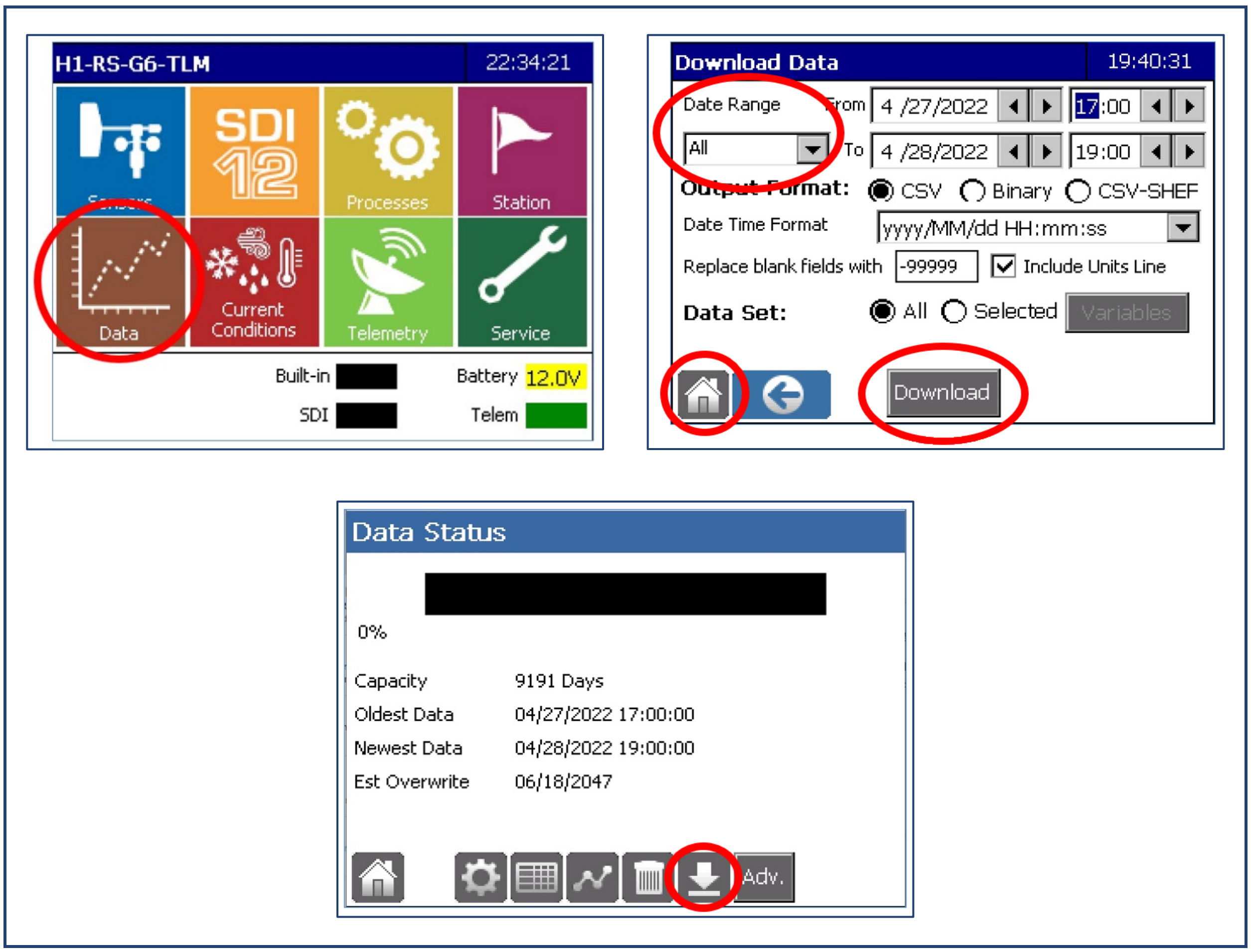


- Compare the new SWL value (in 'm bgs') shown on the datalogger screen to the manual groundwater level measurement minus the well stick-up height (to convert the manual measurement to 'm bgs').
    - If the difference between the two measurements is ±0.001 m, no further offset correction is needed.
    - If the difference between both measurements is greater than 0.001 m, double check your calculations and the entered offset. Should that not identify the issue, then repeat the offset process, including collecting another manual water level measurement. Once the value is accepted, return to the 'Home Screen'.



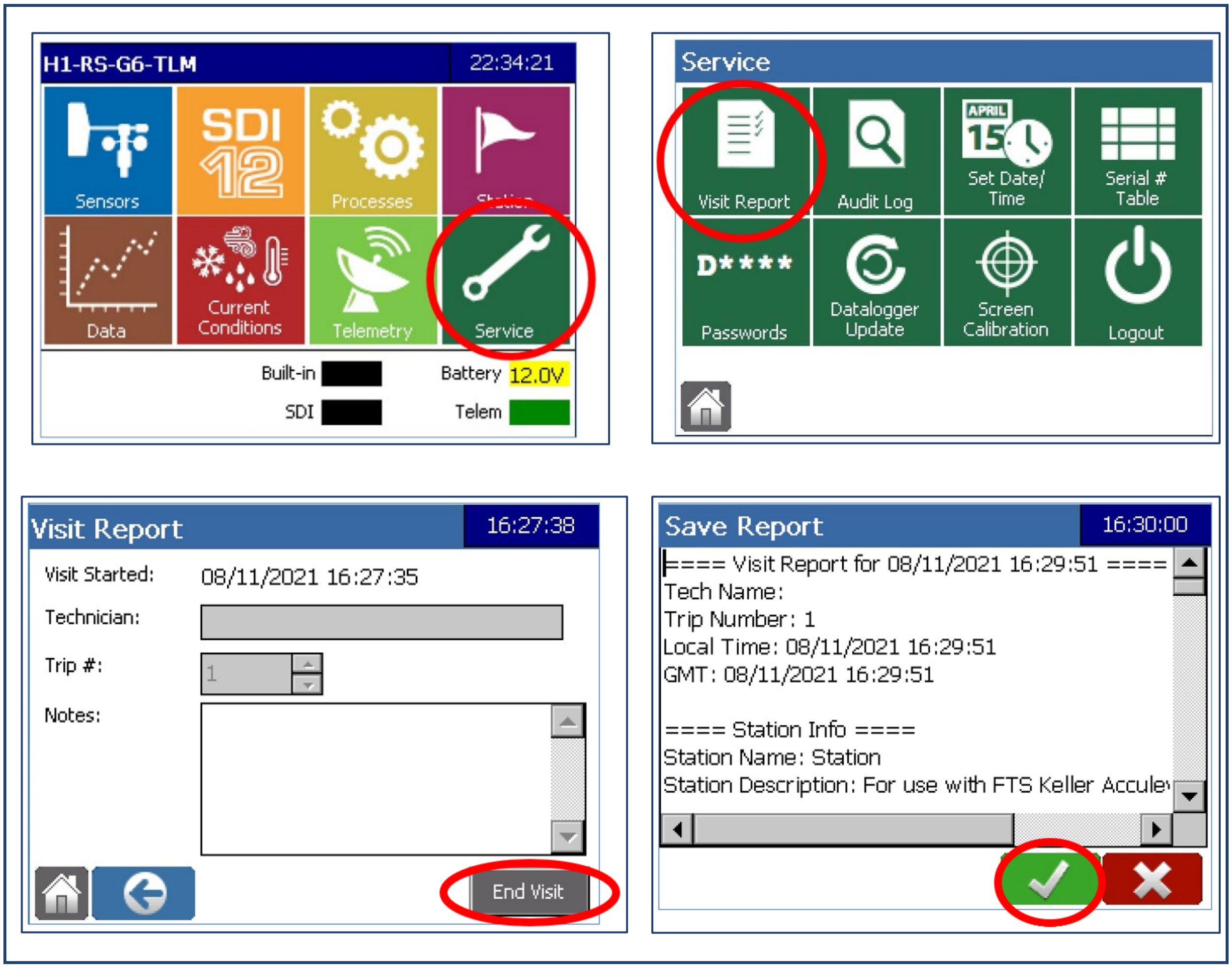
After applying the offset, download the data that has been logged since the previous site visit:

- From 'Home Screen', → *'Data'* → *'Download'* icon to initiate downloading of the data. You will be able to select a date range, including 'Since Last Visit' or 'All', on this screen. Once you have confirmed your selection, select *'Download'*. Wait until your data has downloaded; this can take several minutes to occur. Once the download process is completed, return to 'Home Screen'.
    - Please note that even though FTS will default to your previous date range option, you will need to re-select this option from the 'Date Range' dropdown menu in order for FTS to update the selected period of record.
    - Tip: if you click *'Variables'* and limit which variables are downloaded (select 'SWL' and 'VB' at the minimum), the download speed will increase greatly.



- End the site visit by selecting *'Service'* → *'Visit Report'*. You may record any necessary comments in the notes section of the log (e.g., issues applying offset corrections, initial and final manual groundwater level measurements, etc.). Select *'End Visit'* and the '*green checkmark'* to save.

- You may record any necessary comments in the notes section of the log (e.g., issues applying offset corrections, initial and final manual groundwater level measurements, etc.). Select *'End Visit'* and the '*green checkmark'* to save.



- Remove the USB drive and continue on with the remaining tasks to be completed during the site visit.

A2.4.4 Miscellaneous

This section provides supplemental information that was not included in the above step-by-step guide, including a Troubleshooting section of common issues.

A2.4.4.1 User Manual

If additional information is required, review the applicable equipment user manual (i.e., Solinst Levelogger, Van Essen Diver or FTS H1S), or consult one of the Groundwater Monitoring Specialists or Groundwater Network Technology Specialist.

A2.4.4.2 Troubleshooting

Observation	Potential Consequences	Potential Causes	Possible Next Steps
Non-Telemetry Stations			
Issues communicating with datalogger (e.g., 'Check Com Port' error message)	▪ Inability to download data and data loss.	▪ Loose or damaged connection cords (e.g., direct-read cable). ▪ Dead datalogger / pressure transducer battery. ▪ Software not recognizing a connection. ▪ Missing USB driver.	▪ Ensure the correct connection cord for the brand of pressure transducer is used. ▪ Examine the communication cords and optical lenses are debris-free, dry, clean and properly connected. ▪ Restart the computer and connect USB device *before* starting software. ▪ Check the Communication Port settings within the software (i.e., ensure it is pointing to the correct USB port). ▪ Verify software is up-to-date prior to site visit. ▪ Plug in all necessary cables (e.g., optical readers) to the laptop while an internet connection is available so that drivers are properly downloaded for new cables. ▪ Test an alternate direct-read cable or pressure transducer. Replace if needed. ▪ Data from dead non-telemetry dataloggers can be retrieved by technicians at the respective supplier. Contact local supplier for shipping instructions.
Telemetry Stations			
Cannot connect USB to datalogger	▪ Visit Report cannot be initiated and data cannot be downloaded.	▪ Poor connection from USB to datalogger or issue with datalogger port. ▪ USB drive is corrupt.	▪ Use different (spare) USB. ▪ Try different USB port on datalogger. ▪ Contact FTS tech support and discuss. If necessary, replace datalogger (send original datalogger in for assessment / repairs).

Observation	Potential Consequences	Potential Causes	Possible Next Steps
Corrosion of battery terminals	▪ Difficulty charging battery / power failure, leading to data gaps.	▪ Battery overcharging / undercharging.	▪ Clean battery terminals with wired brush (first disconnect battery from datalogger, remove cable connections from battery terminals, then clean all battery terminal connections, and reassemble). Follow applicable safety procedures (consult Groundwater Monitoring Specialist or Groundwater Network Technology Specialist). ▪ Apply Vaseline or similar product to battery terminals (keeps out oxygen and prevents corrosion). ▪ If necessary, install new battery / power cable and / or replace battery.
After offset applied, refreshed pressure transducer reading does not match manual water level measurement (i.e., difference is >0.001 m)	▪ Low precision of data recordings.	▪ Mistake made in calculating offset. ▪ Using incorrect stick-up height in calculations (notes) or programmed into FTS datalogger. ▪ Comparing 'm bgs' reading to 'm btoc' measurement. ▪ Water level still recovering after sampling event or nearby pumping interference is causing water levels to change faster than manual measurement / offset can be completed. ▪ Faulty pressure transducer.	▪ Double check offset calculation stick-up height (both in field notes and programmed into FTS logger). ▪ Collect another manual water level measurement and apply the newly calculated offset. Record this value in field notebook or data sheet. ▪ Collect a series of manual measurements a few minutes apart to confirm that water levels are indeed stable. If they are not, wait for them to stabilize or return to the site later if needed to collect a stable reading and apply a new offset. DO NOT apply an offset if you are unable to collect a stable groundwater level reading. ▪ Replace pressure transducer. Temporarily deploy non-telemetry pressure transducers if a spare vented transducer is not available to avoid a data gap.

Observation	Potential Consequences	Potential Causes	Possible Next Steps
		All Station Types	
Recent change in hydrograph behaviour (i.e., recent hydrograph results clearly vary from historical pattern) **May also observe large drift between pressure transducer and manual measurements**	▪ Potential low precision of data recordings.	▪ New nearby productions well(s). ▪ Faulty pressure transducer.	▪ Review hydrograph results for signs of pumping interference (i.e., recovery curves). If new nearby production wells are causing pumping interference, data can be considered valid, provided drift values are acceptable. ▪ For telemetry stations: Apply a datalogger offset as usual and return to the observation well in the following weeks to confirm that no significant drift has occurred (i.e., < 0.02 m). If a large drift value is found after recently calibrating the pressure transducer, replace it with a new one. Temporarily deploy non-telemetry pressure transducers if a spare vented transducer is not available to avoid a data gap. ▪ For non-telemetry stations: Replace the pressure transducers or deploy a spare set for comparison of the data between the new and old transducers after the next site visit.

Additional telemetry troubleshooting tips can be found in the **FTS Datalogger Programming SOP** and **the Telemetry Station Installation SOP**, both in (**Appendix A2** [**Sections A2.3** and **A2.2**]). Contact the Groundwater Network Technology Specialist or the Groundwater Monitoring Specialist for further assistance.

A2.4.4.3 Data Download Field Quick Guide

Data download quick guides for telemetry and non-telemetry stations are included below and on the **PGOWN MS Teams Channel**.

Non-Telemetry Station Data Download - Field Quick Guide

Equipment

	Appropriate Field Clothing		Measuring Tape		Well Keys
	High-Vis. Vest & Safety Glasses		Water Level Tape		Camera
	Field Safety Plan		Transducer Connection Cords		Communication Device
	Vehicle Safety Kit		Tool boxes		Laptop or iPad
	First Aid Kit		Field Sheets (electronic or paper)		Charging Cords for electronics
	Wildlife Deterrents		Field Notebook		Garbage Bags
	Spare Batteries		Pens, Pencils & Markers		
	Water Jug & Shop Towels		Spare Monitoring Instrumentation		

General Steps

1) Record all site visit information in field notebook and enter data into Data Downloading & Calibration Field Sheet.
2) Take photos around, outside and inside the well and note any issues in the field notebook.
3) Collect and record static water level (SWL) to the nearest mm (as close as possible to just after the top of the hour if no direct-read cable).
4) All measurements to be made relative to reference point, typically top of well casing or bottom inside of aluminum wellhead cabinet, if present.
5) Connect to the loggers (water and barometric pressure transducers) and download data.

a) Optical Reader. Remove logger from the well, unscrew and attach to optical reader.

b) Direct-Read Cable. If the well is set up with one, connect the cable to laptop using the direct-read cable.

6) Verify data downloads are complete and data looks reasonable.
7) Save the data onto the field laptop or iPad as a .csv file.
8) Reprogram (restart) the logger to "Future Start" at the top of the next hour in Pacific Standard Time (PST) or (-08:00 UTC) at an hourly frequency.
9) If sampling, refer to the Sampling Quick Guide.
10) Complete any necessary instrument or station maintenance.
11) Double check all data sheets are fully filled out, update field notebook.
12) Clean up area around well site as well, and the outside and inside of the wellhead cabinet. Ensure all tools, cables are collected. Lock up the well.

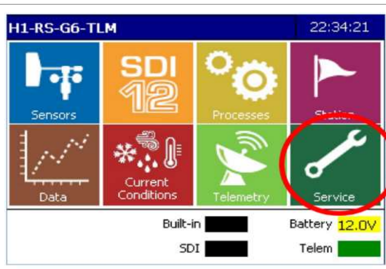
Telemetry Station Data Download - Field Quick Guide

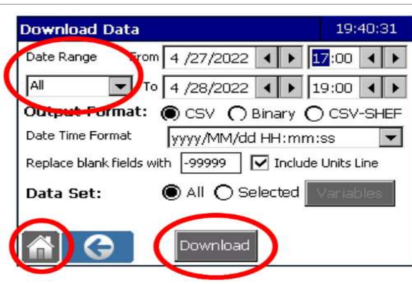
Equipment

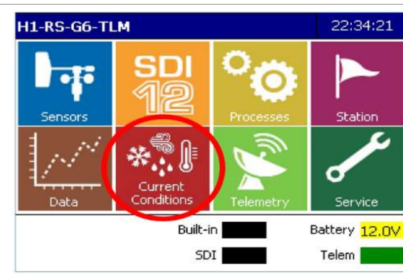
	Appropriate Field Clothing		Measuring Tape		Well Keys
	High-Vis. Vest & Safety Glasses		Water Level Tape		Camera
	Field Safety Plan		Transducer Connection Cords		Communication Device
	Vehicle Safety Kit		Spare Desiccants		Tool Boxes
	First Aid Kit		USB to download data		Field Sheets (hardcopy or electronic)
	Wildlife Deterrents		Step Ladder / Regular Ladder		Spare Monitoring & Telem. Instrumentation
	Water Jug & Shop Towels		Field Notebook		Garbage bags
	Spare Batteries		Pens, Pencils & Markers		
	Laptop or iPad and USB Stick		Garbage Bags		

General Steps

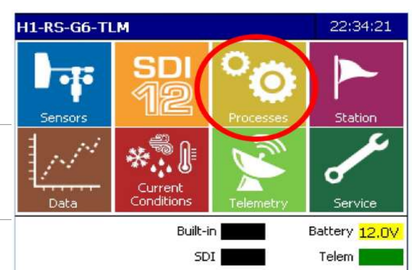
1) Record all site visit information in field notebook and enter data into Data Downloading & Calibration Field Sheet.
2) Take photos around, outside and inside the well and note any issues in the field notebook.
3) Collect and record static water level (SWL) to the nearest mm.
4) All measurements to be made relative to reference point, typically top of well casing or bottom inside of aluminum wellhead cabinet, if present.
5) Put the USB into the datalogger and start a "Visit Report" within the "Service" menu.
6) In the "Data" menu, select the date range or "Since last visit" and download the data.
7) In the "Current Conditions" menu, compare the measured SWL to the live datalogger SWL. Record the information in the field notebook / Field Sheet. Manual SWL measurement should be collected close in time to live datalogger reading to avoid large differences between the datalogger and manual SWL.







8) In the "Processes" menu, apply newly calculated offset using the formula:
   New offset =
   (Manual SWL - Well stickup - 'Live' datalogger SWL) + Existing programmed offset



9) Return to "Current Conditions" menu, hit refresh "**!**" and verify the offset was applied correctly. The value should be within ±0.001 m of the manual SWL. If not, recheck or redo steps above.
10) To close out the data download, return to "Service" menu, and "End Visit" within the "Visit Report" option.
11) If sampling, refer to the Sampling Quick Guide.
12) Complete telemetry station specific site maintenance to equipment, such as:
    - Replace the desiccant packages.
    - All datalogger, battery and solar regulator connections are tight and secure.
    - Check battery voltage and swap if necessary.
    - Clean / adjust solar panel.
    - Wipe down inside and outside of wellhead cabinet.
13) Double check all data sheets are fully filled out, update field notebook.
14) Clean up area around well site as well, and the outside and inside of the wellhead cabinet. Ensure all tools are collected. Lock up the well.

A2.4.5 Record Keeping

The **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]) should be used to record all groundwater levels during every visit. Field data sheets are to be scanned into the project folder upon returning to the office.

In addition, all downloaded logger files should be saved to the respective regional Provincial Observation Well project folder prior to being uploaded to Aquarius.

A2.4.5.1 Field Sheets

The applicable field sheet is included in **Section A2.1.5.1** and on the **PGOWN MS Teams Channel**.

Appendix A2-5

Non-Telemetry Station Installation SOP

A2.5 NON-TELEMETRY STATION INSTALLATION SOP

This SOP is to be used for installing non-telemetry continuous groundwater level monitoring equipment into a Provincial Observation Well.

Behold, this is the third 'hidden' paragraph! If you have found the first two, then you are surely reading this manual carefully. Do let the Groundwater Monitoring Program Supervisor know of its discovery and the section number.

A2.5.1 General

The following assumptions should be applied when reviewing this SOP:

- The Provincial Observation Well is not artesian;
- The diameter of the surface casing is known and has been used to size the green casing extension or locked well cap; and
- Depth to groundwater has previously been measured and is known (to help with determining pressure transducer maximum operating pressure and direct-read cable length).

Please note that a power drill with various sizes of drill bits will be required throughout the installation process in order to secure various parts to the wellhead cabinet, and to secure the wellhead cabinet to the green casing extension. Tip: a stepped drill bit can be a very useful tool for expanding the diameter of drilled holes which is not possible (or safe) with traditional one-size drill bits; in addition, select drill bits that are rated for the material that will be drilled (e.g., aluminum vs. steel). This drilling is not detailed below. Moreover, use of other tools (e.g., angle grinders) may be required but is not detailed here, nor are the necessary safety precautions. Please consult with a Groundwater Monitoring Specialist or the Groundwater Network Technology Specialist for further instructions, if needed.

A2.5.2 Equipment

Task-specific equipment (refer to the **Equipment Checklist** in **Appendix A1** for a complete list of recommended equipment for site visits):

- Fully equipped toolbox (e.g., wire cutters, socket set, wrenches, screwdrivers, scissors, miscellaneous hardware);
- Power tools (e.g., angle grinder with disks, drill and drill bits);
- Nuts, bolts (including U-bolts and carriage bolts), washers;
- Field survey tape (long reel measuring tape);
- Measuring tape;
- Field notebook or clipboard with **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]) (or device with electronic field sheet);

- Field laptop or iPad, with appropriate up-to-date logger software installed;
- Appropriate laptop-datalogger interface cables (e.g., optical data downloading cable); and
- Camera.

Equipment to be installed:

- Wellhead cabinet and green casing extension or lockable well cap to house all of the supporting equipment;
- Well decal attached to the outside of wellhead cabinet door or top of well cap to inform observers of the objective of the station and location of further information (i.e., PGOWN website).
- Submerged pressure transducer (i.e., a Diver or Levelogger) and a direct-read cable to collect groundwater level data; and
  - A Kevlar string or stainless-steel aircraft cable may be used in place of a direct-read cable only if the installation will be **temporary** (e.g., a telemetry system will be installed in the following months). If this is the case, the installation procedure will be the same unless indicated otherwise.
- A barometric pressure transducer to collect barometric pressure data.
  - Tip: it is a good idea to bench test both pressure transducers in advance of deployment to avoid installing potentially defective equipment.

A2.5.3 Procedure

A2.5.3.1 Selecting Operating Pressure and Direct-Read Cable Length

Pressure transducer operating pressures and lengths of direct-read cables should be determined during the equipment procurement process. If it is later discovered that the groundwater level variation or trend will result in the need for a greater pressure rating or longer direct-read cable, a new transducer or cable should be purchased at that time.

If there is low confidence in estimating the water table depth over time in advance, consider temporarily installing a submerged pressure transducer of higher operating pressure than likely necessary on a Kevlar string or steel cable, and collecting one year of data before ordering the permanent direct-read cable and pressure transducer.

Operating Pressure

- Transducer operating pressure rating should be selected based on the expected seasonal groundwater level variation and if any anthropogenic drawdown and long-term groundwater level trends are expected (i.e., is the Provincial Observation Well located in close proximity to pumping wells or in an area experiencing long-term groundwater level decline/rebound). If available, use nearby groundwater level data to inform your decision.

- Tip: if the seasonal (or anthropogenic) groundwater level variation is expected to be **<5 m**, **choose a 10 m pressure rating** to provide enough of a buffer against current uncertainty and potential future water table changes (trends). If the water level will vary by **>5 m** on an annual basis, **choose a 20 m pressure rating**. It would be highly unusual for groundwater levels to fluctuate by 20 m or more, therefore it should not typically be necessary to select a higher pressure rating.
- Tip: if the seasonal groundwater level range is completely unknown (no nearby well records or existing water level data), typically a 10 m pressure rating will be sufficient for unconsolidated aquifers as they will often fluctuate by less than a few metres per year; however, seasonal variation is often larger for bedrock aquifers, meaning that a pressure rating of 20 m may be more suitable.
- Please note there is a trade-off between precision and the transducer operating pressure rating. The pressure rating should be selected to account for current and future water table fluctuations (if possible), but the rating should not be excessively high, as this will lead to less precise pressure readings (i.e., a higher margin of error).

- A barometric pressure transducer from the same manufacturer of the submerged transducer must also be installed. However, there is no need to select a pressure rating for the barometric transducer as it comes with a standard rating suitable for all atmospheric conditions.

Cable Length

- At a minimum, a manual groundwater level measurement from the new Provincial Observation Well should be obtained. If available, use nearby groundwater level data to help determine the direct-read cable length.
- Account for the following factors when determining the cable length:
  - The impact of the time of year on groundwater levels, i.e., is the current measurement being collected during the high or low groundwater season;
  - Expected seasonal variation for the aquifer type and location;
  - If the aquifer is known to be experiencing long-term decline / rebound; and
  - Stick-up height and additional length required in order to secure the direct-read cable to the top of the well.
- A general rule of thumb: estimate the low (deep) season water level, add about 5 m and use that as the cable length. Ensure the selected pressure transducer pressure rating is suitable for this depth.
- Tip: when uncertain, a longer cable than likely necessary may be ordered. However, ordering an excessive amount of extra cable length is not recommended as this can complicate the final set-up and, at telemetry stations, may lead to the build-up of moisture in the cable of the vented pressure transducer. That being said, direct-read cables at telemetry stations can be shortened

prior to deployment if a revised shorter length is later determined (discuss with the Groundwater Network Technology Specialist).

A2.5.3.2 Install Wellhead Cabinet

While a non-telemetry station does not require a wellhead cabinet and a well cap could be used instead, a wellhead cabinet allows for greater space to securely install direct-read and barometric pressure transducer cables. Well caps (depending on the design) can sometimes prove difficult to install these cables in a way that ensures they will not move (change length) during site visits. However, well caps can be used at non-telemetry sites, provided they are designed specifically to securely suspend cables inside of the well.

- Confirm the steel well casing is at an appropriate working height and in compliance with the BC GWPR (2022). If necessary, cut down the steel casing (and PVC riser if applicable) with an angle grinder.
  - Collect a manual groundwater level measurement before and after the well stick-up height has been altered.
  - Collect stick-up measurements before and after adjustments to the well height (relative to the original groundwater level measurement reference point, such as the top of the well casing). Follow this formula:

$$\begin{aligned} New\ Stickup\ Height \\ &= Original\ Stickup\ Height\ (m) - Length\ of\ Removed\ Casing\ (m) \\ &+ Length\ of\ New\ Green\ Casing\ Extension\ (m) \end{aligned}$$

  - Record all measurements in field notebook or field data sheet.
- Install the green casing extension and wellhead cabinet over the steel well casing and bolt into place.
  - Carriage bolts must be used to secure the wellhead cabinet to the green casing extension with the bolts tightened from within the cabinet (i.e., nuts are threaded onto the bolts within the cabinet to prevent thieves from unscrewing them).
  - Refer to **Section 3.0** of the **PGOWN Operations Manual and Standard Operating Procedures** for further information on site and wellhead modifications to improve security.

A2.5.3.3 Programming Pressure Transducers

- Use the appropriate Solinst or Van Essen software to program both pressure transducers to record at hourly intervals at the top of every hour (see **Groundwater Level Data Downloading SOP** (**Appendix A2** [**Section A2.4**]) or appropriate software manual for additional information on programming).
- It is recommended that the pressure transducers should be programmed at the office to minimize completing these tasks in the field. Excess data (i.e., if logging commences prior to deployment of transducers), can later be deleted.

A2.5.3.4 Deploying Submerged and Barometric Pressure Transducers

- When deploying a non-vented pressure transducer temporarily, or if a site suffers from significant pumping interference, it is good practice to manually measure and record the direct-read cable length from the diaphragm of the attached submerged pressure transducer to the cable suspension point (i.e., the point where the cable will be suspended). Measure and mark the suspension point on the cable using a paint pen or other visible (bright coloured) permanent marker.
    - If Kevlar string is used instead of a direct-read cable (which should only be done on a temporary basis), then to achieve the desired length to suspend the pressure transducer will require the cable to be stretched out and the length measured.
    - The cable length value should be recorded as it, along with manual water level readings, will be used to compensate the data from non-telemetry stations.
    - The height from the cable suspension point to the manual water level measurement reference point (i.e., top of well casing) should be measured and subtracted from the measured cable length in order to determine the final cable length value that will be used in data compensation calculations.
- Attach the pressure transducer to the direct-read cable and deploy the transducer into the Provincial Observation Well.
    - It is critical that the direct-read cable be attached in such a way that it avoids the potential for the cable length to change at each site visit as a result of handling the cable when downloading the data. This could be accomplished by using a strain-relief cable, for example, or using plexi-glass secured to the bottom inside of the well cabinet with properly sized holes to restrain the top of the direct-read cable as shown in **Figure A2-5.1**.

Figure A2-5.1 Suggested direct-read cable set-up to avoid changes in cable length.

- In the event the well is not open to the atmosphere (i.e., has a sealed well cap), create a V-notch in the PVC side or drill a hole into the well casing to create an opening in order to avoid air pressure build up in the enclosed airspace (BC FSM 2013).

- After installation, at approximately the same time the transducer is programmed to record a measurement (i.e., on the hour), a second manual groundwater level measurement should be taken and recorded in the field notebook or data sheet.
  - Please note that if a direct-read cable is used, then live pressure readings from the submerged pressure transducer and the barometric transducer (via an optical read cable) can instead be collected immediately.
  - These measurements will add confidence to the compensated data when the data is eventually downloaded from the site for the first time.
- If the groundwater level is deep enough (**>3 m bgs in cold regions** or **>2 m in warm regions**), the barometric pressure transducer should be suspended on Kevlar string inside the Provincial Observation Well.
  - Ideally, the barometric pressure transducer will be situated approximately 2 to 3 m bgs so as to avoid large temperature differences between the barometric and submerged pressure transducers.
  - If the groundwater level is shallow, a barometric well should be constructed beside the Provincial Observation Well to avoid being submerged. Ideally, the barometric well should be constructed using solid 51 mm diameter PVC pipe and should extend 2 m bgs. A contractor may be required for this installation. The barometric pressure transducer should be suspended on Kevlar string above the bottom of the barometric well. Slits or holes, cut / drilled on an angle, should be installed at the top of this PVC pipe to ensure the barometric pressure transducer remains under atmospheric conditions. Alternatively, a solid PVC pipe (25 mm) may be installed within the existing well casing, provided the PVC pipe has a properly sealed bottom and can be securely attached to the well casing wall. This may reduce the potential for vandalism occurring that could exist with an external barometric well. In this case, the PVC pipe should still extend to about 2 m bgs and no cap would be required as it would already be sheltered from any rainwater.

A2.5.4 Miscellaneous

Not Applicable

A2.5.5 Record Keeping

During installation of the non-telemetry station, it is important to document all the details of the installation. This includes, at a minimum, documenting and recording:

- Make, model and serial numbers of the submerged and barometric pressure transducers;
- The maximum operating pressure of the submerged transducer;

- Depth the submerged and barometric transducers were deployed;
- Length of the direct-read cable (if measured);
- Revised stick-up height (if applicable); and
- Any other relevant details.

This information should be recorded in the field notebook, as well as details surrounding encountered complications, if any arose during the installation process.

Photos of the installation process should also be taken and all field notes, or field data sheets, and photos should be scanned / saved to the project folder upon returning to the office. Your **Regional PGOWN Tracking Spreadsheet** should be updated as well with the recorded details (serial numbers, operating pressure of transducer, etc.).

A2.5.5.1 Field Sheets

There is not a specific field sheet for installation of non-telemetry stations.

Appendix A3

Groundwater Sampling

Appendix A3-1	Groundwater Sampling SOP
Appendix A3-2	Groundwater Sampling Multiparameter Meter Calibration, Maintenance, and Storage SOP
Appendix A3-3	Quality Assurance and Quality Control for Groundwater Sampling SOP

Appendix A3-1

Groundwater Sampling SOP

A3.1 GROUNDWATER SAMPLING SOP

This SOP will cover purging, passive and no purge groundwater sampling methods. This SOP provides an overview of industry best-practices to assist with collecting samples that are representative of groundwater quality (chemistry) conditions.

A3.1.1 General

The objective of any groundwater quality sampling event is to collect representative samples that can be used to provide an indication of current groundwater quality conditions at a particular location in the aquifer. While collection of groundwater quality samples is not a primary objective for Provincial Observation Wells, it is still important that groundwater samples be collected to reflect representative conditions and utilize standardized and repeatable protocols.

A3.1.2 Equipment

Task-specific equipment (refer to the **Equipment Checklist** in **Appendix A1** for a complete list of recommended equipment for site visits):

- Sample collection equipment:
  - Grundfos Redi-Flow Pump, pump controller, tubing reel with controller cable, and connector cables, generator and fuel, pump tubing; or
  - Bladder pump, pump controller, auxiliary air, pump and air tubing, power supply (battery or generator); or
  - HydraSleeves with additional weights and tether line.
- Portable work bench;
- Water quality multiparameter meter (YSI) with flow-through cell;
- Turbidity meter (if available);
- Water quality meter calibration solutions;
- Water level tape;
- Bucket (20 L);
- Laboratory-supplied bottle set, preservatives, coolers, frozen icepacks, and deionized water;
- Phosphate-free detergent;
- Paper towels or shop towels;
- Disposable high-capacity field filters and / or syringes (if required);
- Disposable nitrile gloves;
- Camera;
- Lab requisition (chain-of-custody) documents;
- Clipboard with **Groundwater Sampling Field Sheet** (**Appendix A3** [**Section A3.1.5.1**]) (or device with electronic field sheet); and
- Field notebook.

A3.1.3 Procedure

A3.1.3.1 Pre-Sampling Tasks

- In advance of preparing equipment for the field, ensure that the preservatives to be used have not expired. If they have, order new preservative vials from the laboratory.
- After arriving to the site, but **prior to deploying sampling equipment**, collect a manual groundwater level reading and live water level reading from the datalogger (or pressure readings if at a non-telemetry station with a direct-read cable). Record all notes in the **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]).
- Additional requirements at telemetry stations:
  - Use the field sheet to calculate the drift value (based on the initial manual water level measurement) which will later be applied in Aquarius.
  - If the well groundwater levels are likely to **recover quickly** after sampling, complete data download and datalogger offset **after** sampling. This post-sampling calibration will be completed using an offset calculated based on a new (second) manual water level measurement. The same procedure is required if the submerged transducer must be removed during sampling as the cable length could change during redeployment; or
  - If the well groundwater levels are likely to **recover slowly**, and the pressure transducer does not need to be removed during sampling, complete the data download and datalogger offset **before** sampling. Alternatively, return to the site in the following days once groundwater levels have stabilized (as may be the case for slow recovering bedrock wells); however, the intervening data between the sampling event and offset application must be later be deleted from the 'Working' dataset in Aquarius.
- Ensure the YSI water quality meter (and turbidity probe, if available) is calibrated, if calibration was not completed earlier. Update your **Equipment Calibration Record** with the calibration results (**Appendix A3** [**Section A3.2.5.1**]).

Refer to the following SOPs for further details regarding the aforementioned tasks:

- **Manual Groundwater Level Measurement SOP** (**Appendix A2** [**Section A2.1**]);
- **Groundwater Level Data Downloading SOP** (**Appendix A2** [**Section A2.4**]); and
- **Groundwater Sampling Multiparameter Meter Calibration, Maintenance and Storage SOP** (**Appendix A3** [**Section A3.2**]).

A3.1.3.2 Purge Sampling

The following procedures describe groundwater sampling using a submersible pump (e.g., Grundfos Redi-Flow pump).

Calculate Purge Volume

- Using the water level tape, measure and record the depth to bottom of well from top of casing. Refer to the **Manual Groundwater Level Measurement SOP** (**Appendix A2** [**Section A2.1**]) for detailed instructions.

- Calculate the volume of groundwater in the well (i.e., the well casing volume) to be purged using the following equation, and reference **Figure A3-1.1**:

  - $\boldsymbol{Purge\ Volume}\ (\boldsymbol{V}) = Well\ Radius^2[m]\ x\ \pi\ x\ (Total\ Well\ Depth[m\ btoc] - Static\ Water\ Level\ [m\ btoc])$

- Alternatively, you could use the following equation and the pre-determined volume of groundwater per linear metre of the well (as shown below in **Table A3-1.1**):

  - $\boldsymbol{Purge\ Volume}\ (\boldsymbol{V}) = Volume\ of\ Groundwater\ per\ metre\ \left(\frac{L}{metre}\right) x\ (Total\ Well\ Depth\ [m\ btoc] - Static\ Water\ Level\ [m\ btoc])$

Figure A3-1.1 Well volume measurements.

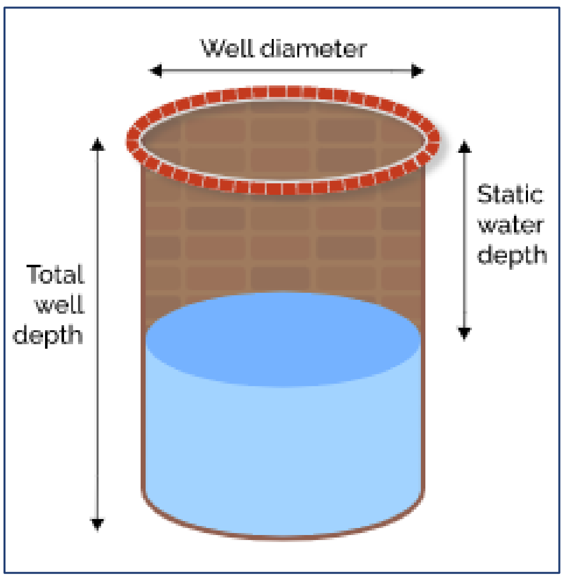


Table A3-1.1 Well groundwater volume per metre of the submerged well casing.

Well Diameter (mm)	Volume of groundwater (L/metre)
51 (2”)	2.0
76 (3”)	4.5
102 (4”)	8.2
127 (5”)	12.7
152 (6”)	18.1
203 (8”)	32.4

Deploy Pump and Start Purging

- Safely connect all components of the submersible pump and tubing that will be lowered into the well.

- At smaller diameter wells (i.e., inside well diameter is 51 mm [2 in]), pressure transducers will need to be removed to minimize tangling of cables and to fit the pump into the well.

- Lower the submersible pump into the well. The pump should ideally be placed a few feet above the well screen to reduce the chances of sediment from damaging the pump and to pull 'fresher' water from the well screen (as opposed to placing the pump higher in the well where the water would be older / stagnant). If the well screen is too deep for this, the pump should be lowered as deep as possible into the well. Lock the tubing reel in place so the depth of the submersible pump will not change.

    - Tip: if deploying most of the length of the pump down the well, use equipment (e.g., toolbox or 12V battery) to weigh down the pump to prevent it from moving towards the well due to the weight of the water in the hose. Alternatively, use a rope (not Kevlar string) to secure the pump reel to the steel well casing, a nearby tree, or another heavy, secure object.

- Connect the pump controller to the submersible pump cable and plug the pump controller into the generator. Then connect the submersible pump discharge tubing flow tee to the pump reel. The discharge tubing flow tee is then connected to the YSI flow-through cell (**Figure A3-1.2**). Ensure both valves in the discharge tubing flow tee are fully open so that water will properly discharge from hose end when the pump is later started. Having these valves closed when starting the well will prevent water from pumping to the surface which could overpressure and damage the submersible pump.

Figure A3-1.2 Typical groundwater purge sampling set-up.

Photo source: BC ENV.

- Prior to starting the pump, ensure the pumping direction is set to forward. Check that the pump speed on the controller is set to the off-setting (i.e. pump speed is set to 0 Hz.). Turn on the pump and slowly increase the pump speed to between 250 to 400 Hz, at which point water should be discharging to surface through the discharge tubing flow tee. Be sure to record the time that purging began.
    - If the pump speed is increased too quickly or too high for the generator to handle, the pump will shut off.
- Once water is discharging through the flow tee and out the large tubing, slowly close the large bypass valve just a bit to direct water towards smaller tubing and into the YSI flow-through cell (**Figure A3-1.3**). Only partially close the large bypass valve as having too much flow going over the YSI probes can damage them.
    - Water should be exiting the flow-through cell at a slow rate (~ 0.5 L/min) in order to collect accurate readings from the YSI. Moreover, exceeding this rate could pressurize the flow-through cell and damage the YSI sensors.

Figure A3-1.3 Water quality multiparameter meter (YSI) and flow-through cell.

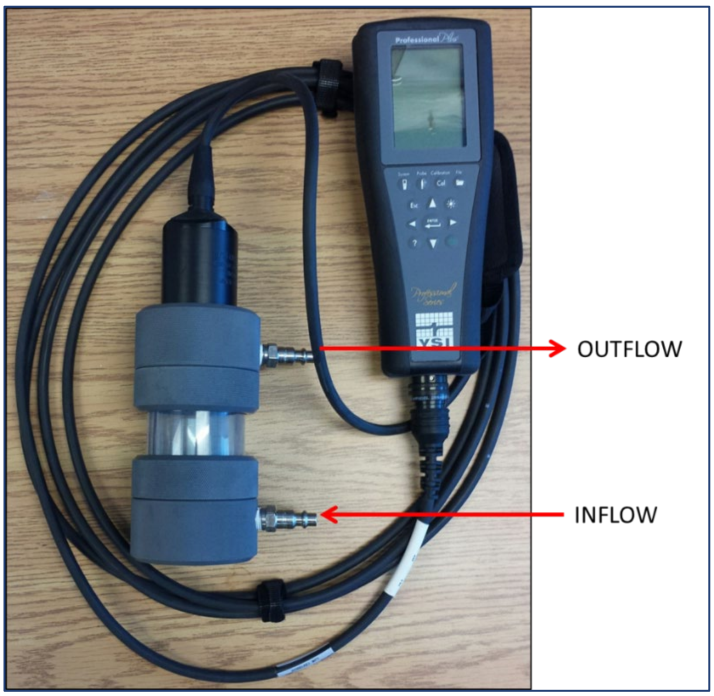


Photo credit: BC ENV.

- Before starting to record and monitor groundwater quality parameters, make sure the flow-through cell is completely filled and there are not any air pockets inside the unit (groundwater that has come into contact with the atmosphere can result in unrepresentative readings); gently tap the flow through cell on an angle to dislodge any build-up of air bubbles and wait one minute before reading the YSI results. Record the initial groundwater quality parameters using the YSI (and turbidity meter, if available) in the **Groundwater Sampling Field Sheet** (**Appendix A3** [**Section A3.1.5.1**]).

- Collect occasional groundwater level measurements during well purging using the water level tape (or live readings from telemetry dataloggers if the pressure transducer remains in the well). It is important to make sure that the groundwater level does not drop below the bottom of the pump intake which could result in the pump cavitating and potentially seizing. In addition, these pumps are water-cooled and will overheat if allowed to run dry.

- Once the pump and YSI are running, you should measure the flow rate and estimate the purge time. To do this, open the bypass valve and close the valve to the flow-through cell (directing all purged groundwater away from the YSI and onto the ground). Use a 20 L (5 gallon) bucket and determine the time it takes to fill the bucket (i.e., determine the purging rate). This can then be used to estimate how long it will take to purge one well volume (a minimum of three well volumes should ideally be purged prior to sampling). This can be determined by using the following two equations:

    - $Flow\ Rate\ (L/min) = \frac{18.9\ L}{Total\ time\ to\ fill\ the\ bucket\ (seconds)}\ x\ 60$
    - $Purge\ Time\ for\ One\ Well\ Volume\ (min) = \frac{One\ well\ casing\ volume\ (L)}{Flow\ rate\ (L/min)}$

- Carefully re-open the valve to the flow-through cell. Continuously monitor the water quality parameters of the purge water (i.e., water in the flow-through cell). Record the water quality readings at predetermined intervals (typically every 10 to 15 min). Reminder to dislodge any accumulated bubbles from under the YSI probes.

- Groundwater purging should continue until at least **three** well volumes have been purged and stabilization of groundwater quality parameters has been achieved. Groundwater quality stabilization parameter criteria are specified below in **Table A3-1.2**.

    - If three well volumes cannot be achieved (e.g., well purged dry or time constraints due to large well volume), the Groundwater Monitoring Specialist should be contacted and an alternative plan discussed on how the well should be sampled.

    - Wells that remain turbid and / or for which water quality parameters do not stabilize after purging greater than three well volumes, should be noted on the field data sheet. If turbidity does not stabilize after three well volumes, stop purging and allow suspended solids to settle for approximately 1 to 3 hours. Once suspended solids have had time to settle, collect a sample.

Table A3-1.2 Stabilization criteria for in-situ parameters (BC MOECCS 2021).

Parameters	Stabilization Criteria
pH	+/- 0.1 pH units
Conductivity	+/- 3% of the reading
Dissolved Oxygen	+/- 10% of the reading, or +/- 0.2 mg/L, whichever is greater
Turbidity	< 50 NTU and +/- 10%
Redox Potential (ORP or eH)	+/- 10 mV

Sample Collection

- Make sure all sample bottles are labeled using a permanent marker. Ideally, label the bottles in advance to allow the labelling to dry as the label can otherwise rub off, or label them inside your work vehicle prior to completion of well purging. Labels should include the following information:
    - EMS ID (Sample ID);
    - Sampler Name (Client);
    - Observation Well Number (Project);
    - Date and time (24-hour clock) of collection; and
    - Analysis (including type of field preservative and if field filtering was completed).
- The laboratory bottle order sheet will provide instructions on which bottles are to be field filtered and require preservatives to be added or which bottles have been pre-charged with preservatives. That being said, the standard suite of parameters analyzed at Provincial Observation Wells include one bottle for each of the following:
    - General chemistry (not filtered, not preserved);
    - Total nutrients (not filtered, **sulfuric acid** preservative);
    - Dissolved nutrients (**filtered**, **sulfuric acid** preservative); and
    - Dissolved metals (**filtered**, **nitric acid** preservative).
- Prior to collecting the groundwater samples, take a final groundwater quality parameter measurement using the YSI (and turbidity meter if available).
- Open the large bypass valve on the discharge tubing flow tee and slowly close the small bypass valve to the flow-through cell.
- Put on new and clean nitrile gloves.
- Start by filling sample bottles that do not require field-filtering, adding preservatives as required (check that bottles have not already been pre-charged [already filled] with preservative by the lab). Be sure not to overflow bottles as this will dilute the preservative.
    - If bottles are overfilled or the preservative is washed out from a pre-charged bottle, use a new sample bottle. If new sample bottles are not available, collect an unfiltered and unpreserved sample and ask the lab to filter and preserve the sample. This is not an ideal scenario but can be used in an emergency situation.
    - For samples where no headspace should remain (i.e., volatiles), fill bottles so that the water mounds at the rim to ensure no air bubbles are trapped (please note that Provincial Observation Wells are not typically sampled for volatiles).
- Then collect filtered samples by following these steps:

- Use a new inline high-capacity field filter (**Figure A3-1.4**) and insert the barbed end of the field filter into the discharge tubing. It is critical to allow water to flow over the field filter for **1 to 2 minutes** to rinse away any impurities that may exist in the filter as a result of the manufacturing process;
- Add preservatives to the sample bottles requiring them, following the guidance above; then
- Fill the sample bottles that required field-filtering.

Figure A3-1.4 High-capacity inline field filter.

Photo source: Waterra 2022b.

Post-Sampling

- Place samples in a clean and cold cooler (with icepacks, bagged ice, or old sample bottles filled with frozen tap water and labelled with “ICE”).
  - Package bottles such that they are upright. Glass bottles should be separated from each other by bubble wrap or sleeves (may be requested from the analytical laboratory).
- Shut down the pump and remove from the well.
  - Any sampling equipment shared between wells (e.g., pump and YSI), should be cleaned with water and phosphate-free detergent solution in a clean bucket.
- If removed, redeploy the pressure transducer(s) into the well.
  - Ensure removed pressure transducers are redeployed to same depth as previously set; and
  - As previously mentioned for fast-recovering wells with telemetry, calibration of the pressure transducer and data downloading should be completed after sampling is completed and water levels have stabilized. The same is true at telemetry stations any time the submerged transducer must be removed from the well. Record all related data to the **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]).
- Review field notes and field sheets for completeness.

- Complete the lab requisition form(s) (chain-of-custody) for each Provincial Observation Well sampled (see **Table A3-1.3** for tips and example form in **Figure A3-1.5**). Cross-check samples with requisition forms to ensure that samples are properly labelled and match what is written on the forms (e.g., names, number and type of containers, sampling times, etc.). The requisition forms should be enclosed in a sealed plastic bag and placed inside the cooler. If multiple wells are sampled and there are multiple coolers, enclose the forms with the associated wells within the same cooler.

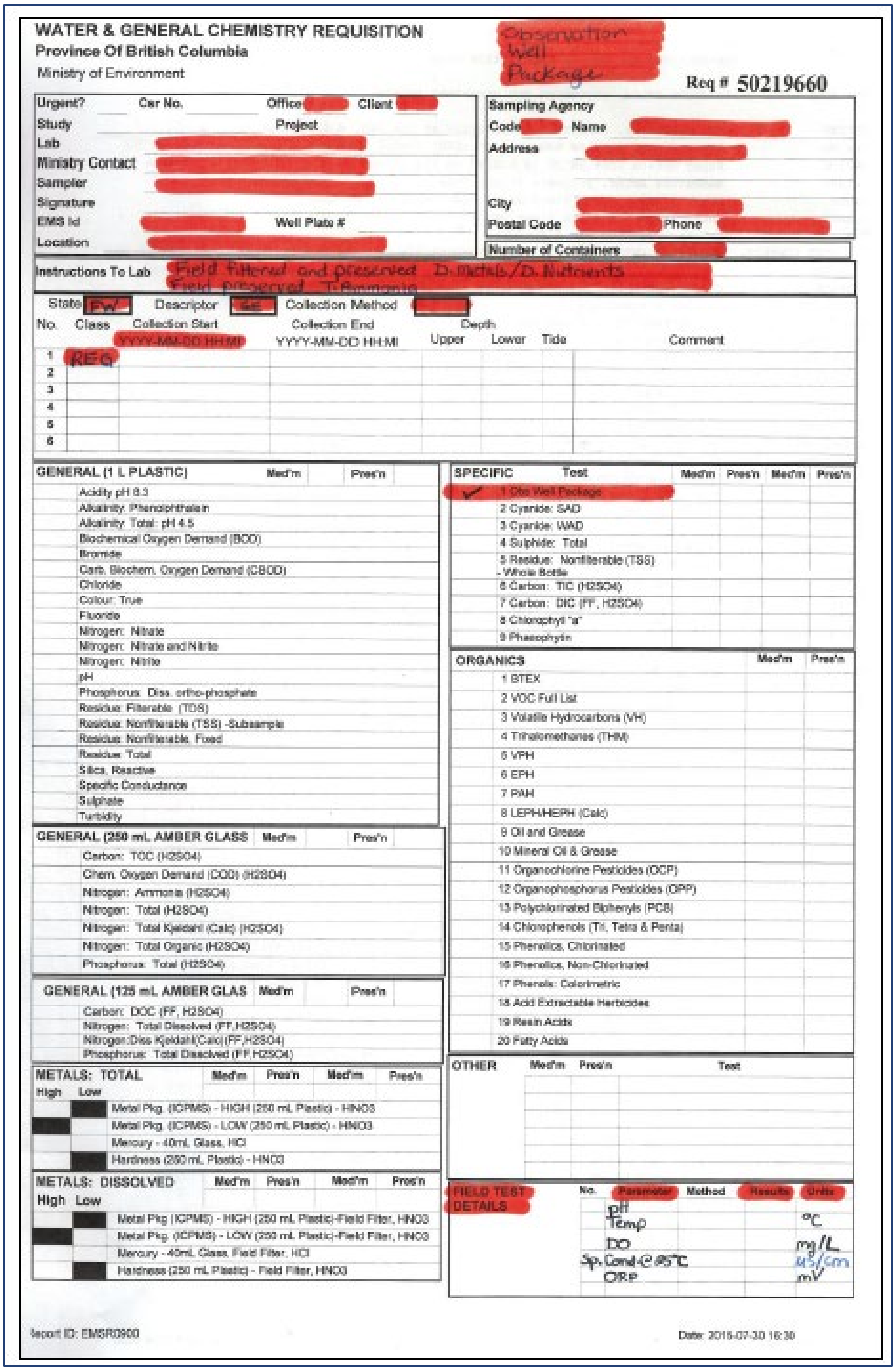
- Prepare the coolers for shipment by sealing the coolers with heavy duty packing tape and attach a shipping address label to their tops (lab address is provided below for reference). Ensure samples are received by the laboratory as soon as possible. Certain analyses must be completed by the lab within 72 hours of sample collection (therefore samples should arrive within 24 to 48 hours of sample collection time).

    - ALS Lab address:
      ALS Burnaby Lab
      8081 Lougheed Highway
      Burnaby BC
      V5A 1W9

Table A3-1.3 Mandatory information to include for EMS laboratory requisition form.

Category	Information to Include
Office	Office number code selected through EMS when setting up sampling site.
Client	▪ Nanaimo (GW) ▪ Surrey (DM) ▪ Penticton (GO) ▪ Kamloops (GK) ▪ Prince George (and Dawson Creek (G1) ▪ Smithers (WD)
Lab	ALS Environmental
Ministry Contact	Contact Name (if lab has questions about the samples)
Sampler	Full name of sampler
EMS ID	EMS site ID where samples collected
Location	Name and location of Provincial Observation Well (e.g., Obs Well 374 – 108 Mile Subdivision)
Instructions to Lab	Record which samples were field filtered / field preserved. List any special instructions to lab (e.g., return coolers)
Code	Same number as 'Office', see above.
Name	Name of Office
Address / City / Postal Code / Phone	Office address and sampler work phone number
Number of Containers	Number of containers submitted for analysis relevant to the well on the form
Class Code	'REG' for all samples, ''BLF' for field or trip blanks.
State	'FW' for all samples.
Descriptor	'GE' for all samples
Collection Method	'GRB' for all samples
Collection Start	Format: yyyy-mm-dd / hh:mm
Specific Test	"Obs Well Package"
Field Test Details	List field parameter values at the time of sample collection (i.e. stabilized/last field reading) for pH, temperature, Specific Conductivity @ 250C, DO, Redox and the respective units.

Figure A3-1.5 Sample laboratory requisition form indicating mandatory fields.



WATER & GENERAL CHEMISTRY REQUISITION
Province Of British Columbia
Ministry of Environment

Observation Well Package

Req # 50219660

Urgent? Car No. Office Client
Study Project
Lab
Ministry Contact
Sampler
Signature
EMS Id Well Plate #
Location

Sampling Agency
Code Name
Address
City
Postal Code Phone
Number of Containers

Instructions To Lab: Field filtered and preserved D-Metals/D-Nutrients; Field preserved T-Ammonia

State FW Descriptor GE Collection Method

No.	Class	Collection Start YYYY-MM-DD HH:MI	Collection End YYYY-MM-DD HH:MI	Depth Upper	Lower	Tide	Comment
1	REG						
2							
3							
4							
5							
6							

GENERAL (1 L PLASTIC)	Med'm	Pres'n
Acidity pH 8.3		
Alkalinity: Phenolphthalein		
Alkalinity: Total: pH 4.5		
Biochemical Oxygen Demand (BOD)		
Bromide		
Carb. Biochem. Oxygen Demand (CBOD)		
Chloride		
Colour: True		
Fluoride		
Nitrogen: Nitrate		
Nitrogen: Nitrate and Nitrite		
Nitrogen: Nitrite		
pH		
Phosphorus: Diss. ortho-phosphate		
Residue: Filterable (TDS)		
Residue: Nonfilterable (TSS) -Subsample		
Residue: Nonfilterable, Fixed		
Residue: Total		
Silica, Reactive		
Specific Conductance		
Sulphate		
Turbidity		

GENERAL (250 mL AMBER GLASS)	Med'm	Pres'n
Carbon: TOC (H2SO4)		
Chem. Oxygen Demand (COD) (H2SO4)		
Nitrogen: Ammonia (H2SO4)		
Nitrogen: Total (H2SO4)		
Nitrogen: Total Kjeldahl (Calc) (H2SO4)		
Nitrogen: Total Organic (H2SO4)		
Phosphorus: Total (H2SO4)		

GENERAL (125 mL AMBER GLAS	Med'm	Pres'n
Carbon: DOC (FF, H2SO4)		
Nitrogen: Total Dissolved (FF,H2SO4)		
Nitrogen:Diss Kjeldahl(Calc)(FF,H2SO4)		
Phosphorus: Total Dissolved (FF,H2SO4)		

METALS: TOTAL High	Low		Med'm	Pres'n	Med'm	Pres'n
		Metal Pkg. (ICPMS) - HIGH (250 mL Plastic) - HNO3				
		Metal Pkg. (ICPMS) - LOW (250 mL Plastic) - HNO3				
		Mercury - 40mL Glass, HCl				
		Hardness (250 mL Plastic) - HNO3				

METALS: DISSOLVED High	Low		Med'm	Pres'n	Med'm	Pres'n
		Metal Pkg (ICPMS) - HIGH (250 mL Plastic)-Field Filter, HNO3				
		Metal Pkg. (ICPMS) - LOW (250 mL Plastic)-Field Filter, HNO3				
		Mercury - 40mL Glass, Field Filter, HCl				
		Hardness (250 mL Plastic) - Field Filter, HNO3				

SPECIFIC Test	Med'm	Pres'n	Med'm	Pres'n
✓ 1 Obs Well Package				
2 Cyanide: SAD				
3 Cyanide: WAD				
4 Sulphide: Total				
5 Residue: Nonfilterable (TSS) - Whole Bottle				
6 Carbon: TIC (H2SO4)				
7 Carbon: DIC (FF, H2SO4)				
8 Chlorophyll "a"				
9 Phaeophytin				

ORGANICS	Med'm	Pres'n
1 BTEX		
2 VOC Full List		
3 Volatile Hydrocarbons (VH)		
4 Trihalomethanes (THM)		
5 VPH		
6 EPH		
7 PAH		
8 LEPH/HEPH (Calc)		
9 Oil and Grease		
10 Mineral Oil & Grease		
11 Organochlorine Pesticides (OCP)		
12 Organophosphorus Pesticides (OPP)		
13 Polychlorinated Biphenyls (PCB)		
14 Chlorophenols (Tri, Tetra & Penta)		
15 Phenolics, Chlorinated		
16 Phenolics, Non-Chlorinated		
17 Phenols: Colorimetric		
18 Acid Extractable Herbicides		
19 Resin Acids		
20 Fatty Acids		

OTHER	Med'm	Pres'n	Test

FIELD TEST DETAILS	No.	Parameter	Method	Results	Units
		pH			
		Temp			°C
		DO			mg/L
		Sp. Cond @ 25°C			uS/cm
		ORP			mV

Report ID: EMSR0900 Date: 2015-07-30 16:30

Photo source: BC ENV.

A3.1.3.3 Low-Flow Sampling

The procedures for low-flow purging and sampling are similar to the purge and sample method using a submersible pump outlined above in **Section A3.1.3.2** with the following exceptions:

- The pump intake should be placed in the middle of the well screen or fraction formation;
- The purging and sampling rate should begin at 0.1 L/min and be adjusted depending on groundwater level drawdown;
- Groundwater levels must be continuously monitored during purging; and
    - Drawdown should not be more than 0.1 m. Groundwater stabilization indicates that the rate of pumping equals the rate of groundwater inflow into the well screen during purging. If groundwater levels do not stabilize, consult with a Groundwater Monitoring Specialist.
- The minimum purge volume is **one well screen volume** (i.e., volume of a cylinder based on length of well screen), and purging should continue until groundwater levels are stable (in addition to stabilization of other in-situ water quality parameters, listed in **Table A3-1.2** above). Samples can then be collected.

Set-up of a double-valve or bladder pump is very similar to a submersible pump. However, instead of an electrical cable to activate the pumping mechanism and lift groundwater to the surface, pumping is driven by compressed gas (i.e., nitrogen and oxygen) via a gas injection line / tube. Refer to the instrumentation operation manual of the respective pump in use.

In comparison, a peristaltic pump uses silicone tubing and an adaptor kit that is fed through the pump head and is connected to the sample tubing. The sample tubing is lowered inside the well and a variable dial is used to control the rate of flow out of the pump. Please note that these pumps are only suitable for use in shallow wells where there is a maximum groundwater lift of about 7 to 8 m. The peristaltic pump operation manual should be consulted prior to use of this equipment.

A3.1.3.4 Passive (No Purge) Sampling

HydraSleeves (**Figure A3-1.6**) can be used at Provincial Observation Wells as a somewhat easier sampling method or when other sampling methods are not suitable (e.g., when a water table is too deep for most submersible or low-flow pumps). Refer to the instrumentation operation manual for the HydraSleeve for additional detailed instructions.

Figure A3-1.6 Example of a no-purge method: HydraSleeve.

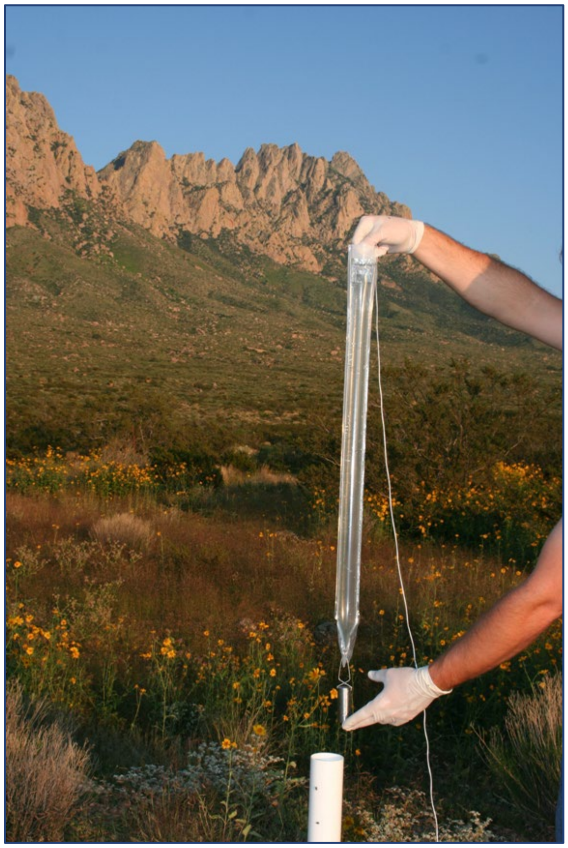


Photo source: HydraSleeve, 2023.

HydraSleeve Deployment

- It is recommended that the HydraSleeve Field Manual (**Appendix A4**) be reviewed.
- Remove the pressure transducer(s) from the well, as the line will most likely become tangled with the HydraSleeve tether.
- Attach a suspension tether line to the top and a weight to the bottom of an empty sampler (HydraSleeve).
    - A discharge straw for sampling will come with the HydraSleeve. Put this off to the side in a clean, secure place for later.
- Carefully lower the HydraSleeve down to the bottom of the screened interval and secure the tether. Ensure that the tether does not run against the top (rim) of the well casing as it may cut the line.
- Leave the HydraSleeve for at least 24 hours to allow the disturbed water column to equilibrate prior to retrieval, however an ideal wait period of 48 hours would guarantee ample time for equilibration.

Sample Collection

- Follow the bottle labeling, field-filtration and field-preservation guidance provided in the Sample Collection portion of **Section A3.1.3.2**, with the exception being that a syringe attached with a filter will be required, as opposed to the standard high-capacity in-line filter. Syringe filters can be ordered from the analytical laboratory.

- The HydraSleeve is pulled upward through the sample zone (screened interval) at one foot per second or faster.

    - When pulling up on the HydraSleeve, the reed-valve at the top of the sleeve opens, allowing the sleeve to fill with water.

    - Technicians should pull up the HydraSleeve in a smooth continuous motion, so the sleeve properly and fully opens, and fills up with water from within the screened portion of the well. Take care to not damage the HydraSleeve or snag it on anything inside the well.

    - Once the sample sleeve is full, the self-sealing reed-valve closes, preventing loss of the sample, the entry of extraneous fluid, and mixing of the captured grab sample with the overlying water column.

- At the surface, the HydraSleeve is punctured with the pointed discharge straw. Rinse the straw with a minimum of 50 mL of sample water, then begin to fill the bottle set.

    - Prior to filling sample bottles, put on new and clean nitrile gloves.

    - Tip: puncture the HydraSleeve at the top end and then roll the sleeve up from the bottom to force water out of the straw, thereby allowing greater control while collecting samples.

- If there is extra water in the HydraSleeve, it can used to fill up the YSI cup to measure in-situ field parameters.

- Follow the Post-Sampling steps outline in **Section A3.1.3.2**.

A3.1.4 Miscellaneous

The following troubleshooting section covers common issues and their respective potential causes and potential resolutions, followed by a brief QA/QC discussion.

A3.1.4.1 Troubleshooting

Observation	Potential Consequences	Potential Causes	Possible Next Steps
Parameters not stabilizing	▪ Collecting a non-representative sample.	▪ Pumping method is affecting water quality. ▪ Insufficient purge volume removed from well (**Table A3-1.1**). ▪ Well is not properly developed.	▪ Continue purging. ▪ Re-evaluate the position of the pump (particularly with the purge method). Ensure pump is not too close to bottom of the well which can induce turbulent sediment. For low-flow sampling, ensure pump is in middle of well screen. ▪ If at least 3 well volumes have been purged, proceed with sample collection and note on field data sheets and notebook. ▪ If unable to purge adequately due to time constraints, consider alternative sampling method for next visit (e.g., no purge sampling).
Sample is very turbid	▪ Could bias certain parameters (i.e., a non-representative result).	▪ Pumping method is affecting water quality. ▪ Pump may be too close to bottom of well. ▪ Well is not properly developed.	▪ Adjust pump deployment depth (place shallower in the well). ▪ Stop purging and allow suspended solids to settle for approximately 1 to 3 hours before attempting to collect sample. ▪ Consider well redevelopment.
Pump not starting	▪ Unable to purge and collect samples.	▪ Loose / damaged connections in pump set-up. ▪ Insufficient pump speed for deployed depth. ▪ Clogged pump impeller.	▪ Unplug the unit and re-connect after 1-2 minutes. ▪ Check the cable for damage and connections along the whole system assembly. ▪ Try to increase pump speed setting if the pump is submerged under a lot of water. ▪ Clean-out the impeller by soaking in water and trying to remove debris (mud, dirt, or sand).

Observation	Potential Consequences	Potential Causes	Possible Next Steps
Water stops discharging from hose	▪ Unable to purge and collect samples. ▪ Pump may overheat / burn out.	▪ Insufficient power to pump. ▪ Pumping rate exceeds inflow rate of well (water level falls to below pump).	▪ Immediately shut off pump. ▪ Check that groundwater level has not fallen to within 1 m of pump depth in the well. If so, allow well to recharge and collect sample at that point, or if possible, restart pump at slower purge rate that does not exceed inflow rate. ▪ If water levels have not fallen to pump depth, lift pump up and down ~1 m (to dislodge potential build-up of bubbles [off-gassing]), restart pump at lower speed and very slowly increase speed so as to not overwhelm the generator. Consider using a more powerful generator next time.
Water levels continue decreasing / not stabilizing	▪ Purge method: may lower water level down to pump depth, causing pump to overheat / burn out. ▪ Low-flow method: may result in mixing of stagnant and fresh formation water, thus collecting an unrepresentative sample.	▪ The pump speed is not correct and causing too much drawdown. ▪ Well screen is poorly constructed / developed, or well is installed in low-yield formation.	▪ Lower the pump speed. ▪ For a low-yield well, purge dry, allow to recharge and then collect sample. Consider well redevelopment or other well modifications in the future (e.g., deepening the well into more porous material / higher-yield bedrock fractures).

Note: See instrumentation operation manuals for detailed troubleshooting support.

A3.1.4.2 Quality Assurance and Quality Control

Below are several measures that should be taken during field visits to control / eliminate sampling errors:

- Collect QA/QC samples, including duplicate, field blanks, and / or trip blank samples;
- Record information / data on field sheets; and
- Collect complete, unambiguous and clearly legible field notes and pictures.

Refer to **QA/QC for Groundwater Sampling SOP** (**Appendix A3** [**Section A3.3**]) for further information.

A3.1.4.3 Groundwater Sampling Field Quick Guide

The applicable quick guides are included on the following page and on the **PGOWN MS Teams Channel**.

Groundwater Sampling Field Quick Guide – Submersible Pump

Required Equipment

	Appropriate Field Clothing		Redi-Flo Pump & Controller / Connector Cables / Reel EZ (60 m of tubing) / Generator / Fuel
	High-Vis. Vest & Safety Glasses		YSI Multimeter / flow-through Cell / Spare Battery
	Field Safety Plan		Turbidity Meter
	Vehicle Safety Kit		Calibration Fluids (pH 4, 7, 10, EC 1413, Zobell)
	First Aid Kit		Laboratory Sample Bottles / Preservatives / Coolers / Ice Packs / Bubble Wrap
	Wildlife Deterrents		Tap Water / Deionized Water
	Spare Batteries		Disposable Field Filters (high and low capacity) and Syringes (if required)
	Communication Device		Disposable Nitrile Gloves in appropriate size
	Camera		Well Keys
	Tool Box		"Groundwater Sampling" and "Data Download Field Sheets" (electronic or paper) and CoCs (requisitions)
	Garbage Bags & Paper Towels		Field Notebook
	Charging Cords for Electronics		Pens, pencils and markers
	Timing device		5-gallon Bucket (to estimate flow while purging)

Pre-Field Considerations

Do you expect low well recharge?
- Purge well dry, wait for recharge, collect sample.
- Discuss future sampling with the Groundwater Monitoring Specialist.

Do you expect high purge volumes / time?
- Consider low-flow or no-purge sampling instead, if possible. Or contract out the sampling.
- Start early and plan accordingly. Do not bother sampling if it is not feasible to follow proper procedures (sample representativeness is critical).

Is groundwater turbidity and filtering expected to be an issue?
- High capacity vs low capacity depending on groundwater turbidity.

Is sample preservation required?
- Some labs have bottles pre-charged with preservatives (i.e., are ready to be filled).
- Some bottle sets require preservatives to be added in the field. Be sure to understand which preservatives are used for each sample, check the bottle order for specific instructions.

Groundwater Sampling Procedure

Pre-Sampling

- Collect manual water level and total depth measurements, and live pressure / water level readings from loggers (see SOP and / or other quick guides for manual groundwater level measurements and downloading of pressure transducers / dataloggers).
- Set up and calibrate YSI probe and turbidity meter if not already completed.
- Label sample bottles using appropriate site specific naming conventions.

Sample Collection

- Calculate the well volume by multiplying the height of the water column by the well volume calculation factor (see Note section below for common sized well diameters). The well volume should be multiplied by 3 to calculate the minimum purge volume.
- Connect all components of the submersible pump and carefully lower the pump such that the pump is placed a few feet above the screened interval, or as deep as possible.
- Lock the tubing reel in place or secure the tubing to the top of the well, open both valves in the discharge tubing flow tee.
- Ensure pump direction is forward and start the pump on the lowest setting.
- Turn on pump and increase slowly until 250 to 400 Hz. Record the time purging began.
- Partially close the bypass valve to direct water to the YSI multi-parameter meter and flow-through cell at a rate of ~0.5 L/min. Fill the flow-through cell completely (i.e., no air pockets)
- During purging, collect water quality field parameters at a consistent pre-determined interval (e.g., every 10 to 15 minutes).

- Estimate the pumping / purging rate (e.g., measure the time it takes to fill a 20 L (5 Gallon) bucket).
  Flow rate (L/min) = [18.9 L / Total time to fill the buckets (seconds)] * 60
  Purge time to one well volume (min) = One well volume / Flow rate
- Continue purging groundwater until a minimum of three well volumes have been removed AND water quality parameters of the purged well water have stabilized for at least 3 consecutive readings.

- If it is not possible to purge the minimum number of well volumes or the well is purged dry, record if this occurs on the groundwater sampling sheet and contact the Groundwater Monitoring Specialist. Allow dry wells to recharge and then collect sample.
- If the well remains turbid and / or water quality parameters do not stabilize after purging three well volumes, if time, continue purging until parameters stabilize.

- Put on clean and new nitrile gloves, and reduce the pumping speed to collect representative groundwater samples.
- Collect samples, ensuring that preservatives have been added. Filter (where necessary) using a new filter. Attach the filter to the end of the tubing and allow purge water to run for 1 - 2 minutes through the filter.
- Collect field water quality parameter readings at the time of sampling using the multi-parameter probe and turbidity meter.
- Download pressure transducers / dataloggers, apply offset based on new manual groundwater level reading (see Non-Telemetry or Telemetry Quick Guide or SOPs).
- Decontaminate all equipment used.

Sample Packaging and Transport

- Wrap glass bottles with laboratory supplied bubble wrap.
- Place sealed bottles in a clean, cold (with ice packs or ice) cooler.
- Fill out Chain of Custody (COC) forms with sample and analysis information.
- Transport to the laboratory within acceptable holding times. A summary of common hold times are listed below.

Groundwater Sample Hold Time

Routine parameters (including alkalinity, anions and physical parameters)	3 - 28 days	**Nitrogen species**	3 days
Total metals	28 days	**Microbiology**	24 hours
Dissolved metals	28 days	**Hydrocarbons**	14 days

References: ALS Western Canada Sampling/Handling Guide (https://www.alsglobal.com)

Notes

Well Volume Calculation Factors		*Stabilized Water Quality Field Parameter Values*	
1" Well	0.5 L/m	**pH**	± 0.1
1.5" Well	1.1 L/m	**Specific Conductivity**	± 5 % mS/cm
2" Well	2.0 L/m	**Temperature**	± 0.5°C
3" Well	4.6 L/m	**ORP**	± 5 % mV
4" Well	8.1 L/m	**Turbidity** Note: Turbidity is generally last parameter to stabilize	± 5% NTU (and less than 50 NTU)

Groundwater Sampling Field Quick Guide – Bladder Pump

Required Equipment

	Appropriate Field Clothing		Bladder Pump / Controller Box / Auxiliary Air (if required) / Injection and Discharge Tubing / Battery or Generator (including fuel)
	High-Vis. Vest & Safety Glasses		YSI Multimeter / flow-through Cell / Spare Battery
	Field Safety Plan		Turbidity Meter
	Vehicle Safety Kit		Calibration Fluids (pH 4, 7, 10, EC 1413, Zobell)
	First Aid Kit		Laboratory Sample Bottles / Preservatives / Coolers / Ice Packs / Bubble Wrap
	Wildlife Deterrents		Tap Water / Deionized Water
	Spare Batteries		Disposable Field Filters (high and low capacity) and Syringes (if required)
	Communication Device		Disposable Nitrile Gloves in appropriate size
	Camera		Well Keys
	Tool Box		"Groundwater Sampling" and "Data Download Field Sheets" (electronic or paper) and CoCs (requisitions)
	Garbage Bags & Paper Towels		Field Notebook
	Charging Cords for Electronics		Pens, pencils and markers
	Timing device		5-gallon Bucket (to estimate flow while purging)

Pre-Field Considerations

Is groundwater turbidity and filtering expected to be an issue?
- High capacity vs low capacity depending on groundwater turbidity.

Is sample preservation required?
- Some labs have bottles pre-charged with preservatives (i.e., are ready to be filled).
- Some bottle sets require preservatives to be added in the field. Be sure to understand which preservatives are used for each sample, check the bottle order for specific instructions.

Groundwater Sampling Procedure

Pre-Sampling

- Collect manual water level and total depth measurements, and live pressure / water level readings from loggers (see SOP and / or other quick guides for manual groundwater level measurements and downloading of pressure transducers / dataloggers).
- Set up and calibrate YSI probe and turbidity meter if not already completed.
- Label sample bottles using appropriate site specific naming conventions.

Sample Collection

- Calculate the well volume by multiplying the height of the water column by the well volume calculation factor (see Note section below for common sized well diameters). The well volume should be multiplied by 3 to calculate the minimum purge volume.
- Connect all components of the bladder pump, including kevlar string. Carefully lower the pump with the kevlar string and tubing such that the pump is placed in the middle of the screened interval.
- Secure the kevlar string once pump is in place. Attach the sample line to the YSI flow-through cell and the drive line to the control unit.
- Turn on pump and set the vent time to be 2 to 4 times the drive time (vent time increases with depth and slower well recharge). Record the time purging began.
- Fill the flow-through cell completely (i.e., no air pockets).
- During purging, collect water quality field parameters at a consistent pre-determined interval (e.g., every 10 to 15 minutes).

- Estimate the pumping / purging rate (e.g., measure the time it takes to fill a 20 L (5 Gallon) bucket).
  Flow rate (L/min) = [18.9 L / Total time to fill the buckets (seconds)] * 60
  Purge time to one well volume (min) = One well volume / Flow rate
- Continue purging groundwater until a minimum of one well volume has been removed AND water quality parameters of the purged well water have stabilized for at least 3 consecutive readings.
  - If the well remains turbid and / or water quality parameters do not stabilize after purging one well volume, if time, continue purging until parameters stabilize.
- Put on clean and new nitrile gloves and reduce the pumping speed to collect representative groundwater samples.
- Collect samples, ensuring that preservatives have been added. Filter (where necessary) using a new filter. Attach the filter to the end of the tubing and allow purge water to run for 1 - 2 minutes through the filter.
- Collect field water quality parameter readings at the time of sampling using the multi-parameter probe and turbidity meter.
- Download pressure transducers / dataloggers, apply offset based on new manual groundwater level reading (see Non-Telemetry or Telemetry Quick Guide or SOPs).

- Decontaminate all equipment used.

Sample Packaging and Transport

- Wrap glass bottles with laboratory supplied bubble wrap.
- Place sealed bottles in a clean, cold (with ice packs or ice) cooler.
- Fill out Chain of Custody (COC) forms with sample and analysis information.
- Transport to the laboratory within acceptable holding times. A summary of common hold times are listed below.

Groundwater Sample Hold Time

Routine parameters (including alkalinity, anions and physical parameters)	3 - 28 days	**Nitrogen species**	3 days
Total metals	28 days	**Microbiology**	24 hours
Dissolved metals	28 days	**Hydrocarbons**	14 days

References: ALS Western Canada Sampling/Handling Guide (https://www.alsglobal.com)

Notes

Well Volume Calculation Factors

1" Well	0.5 L/m
1.5" Well	1.1 L/m
2" Well	2.0 L/m
3" Well	4.6 L/m
4" Well	8.1 L/m

Stabilized Water Quality Field Parameter Values

pH	± 0.1
Specific Conductivity	± 5 % mS/cm
Temperature	± 0.5°C
ORP	± 5 % mV
Turbidity Note: Turbidity is generally last parameter to stabilize	± 5% NTU (and less than 50 NTU)

Groundwater Sampling Field Quick Guide – HydraSleeve

Required Equipment

	Appropriate Field Clothing		HydraSleeves / Bottom Weights (extra) / Tether
	High-Vis. Vest & Safety Glasses		YSI Multimeter / flow-through Cell / Spare Battery
	Field Safety Plan		Turbidity Meter
	Vehicle Safety Kit		Calibration Fluids (pH 4, 7, 10, EC 1413, Zobell)
	First Aid Kit		Laboratory Sample Bottles / Preservatives / Coolers / Ice Packs / Bubble Wrap
	Wildlife Deterrents		Tap Water / Deionized Water
	Spare Batteries		Disposable Field Filters (high and low capacity) and Syringes (if required)
	Communication Device		Disposable Nitrile Gloves in appropriate size
	Camera		Well Keys
	Tool Box		"Groundwater Sampling" and "Data Download Field Sheets" (electronic or paper) and CoCs (requisitions)
	Garbage Bags & Paper Towels		Field Notebook
	Charging Cords for Electronics		Pens, pencils and markers
	Timing device		Kevlar or other suitable tether line

Pre-Field Considerations

Is the HydraSleeve lost in the well?
- Return with downhole camera (includes attachable hook) and retrieve from well.

Does the HydraSleeve have the volume to fill the sample suite?
- Consider 2 L HydraSleeve / Supersleeve options.
- Consider connecting two HydraSleeves and deploying together (if target zone is large enough).
- Speak to the lab and Groundwater Monitoring Specialist to understand priority analysis and minimum sample volumes.

Has the HydraSleeve been deployed in the well?
- Deploy the correct size HydraSleeve and weight assembly for the diameter of the well. Inside diameter of PVC is different between Schedule 40 and Schedule 80.
- In deep wells, a heavier than normal weight is recommended. This reduces the time required for the HydraSleeve to drop through the water column.

Is groundwater turbidity and filtering expected to be an issue?
- High capacity vs low capacity depending on groundwater turbidity.

Is sample preservation required?
- Some labs have bottles pre-charged with preservatives (i.e., are ready to be filled).
- Some bottle sets require preservatives to be added in the field. Be sure to understand which preservatives are used for each sample, check the bottle order for specific instructions.

Groundwater Sampling Procedure

Pre-Sampling

- Collect manual water level and total depth measurements, and live pressure / water level readings from loggers (see SOP and / or other quick guides for manual groundwater level measurements and downloading of pressure transducers / dataloggers).
- Set up and calibrate YSI probe and turbidity meter if not already completed.
- Label sample bottles using appropriate site specific naming conventions.

Deploying a HydraSleeve

- Measure enough tether line to comfortably reach the targeted depth plus an adequate amount to secure the tether from falling into the well.
- Attach weight(s) and a tether to the HydraSleeve.
- Slowly lower the HydraSleeve to the bottom of the targeted depth and be sure NOT to pull up on the tether at all. Pulling up on the tether will cause the sleeve to open and fill with water.
- Allow the HydraSleeve to equilibrate for a minimum of 1 hour.
- Continue with the steps below when the well is ready to sample.

Retrieving a Deployed HydraSleeve

- Pull up on the HydraSeleeve in a continuous motion, at a rate of one foot per second for a length of between 0.3 to 1 m until you have cleared the length of the well screen.
- Once at the surface, discard the small volume of water in the HydraSleeve above the check valve. Pinch the top of the HydraSleeve under the stiffeners and dump the water out.
- Put on clean and new nitrile gloves.
- Using the straw provided with the HydraSleeve, puncture the bag and collect samples, ensuring that preservatives have been added. Use syringe to filter samples requiring filtering.
- If there is sufficient volume left in the HydraSleeve, pour into a suitable container and collect field water quality parameter readings using the multi-parameter probe and turbidity meter.
- Download pressure transducers / dataloggers, apply offset based on new manual groundwater level reading (see Non-Telemetry or Telemetry Quick Guide or SOPs).

- Decontaminate all equipment used.

Sample Packaging and Transport

- Wrap glass bottles with laboratory supplied bubble wrap.
- Place sealed bottles in a clean, cold (with ice packs or ice) cooler.
- Fill out Chain of Custody (COC) forms with sample and analysis information.
- Transport to the laboratory within acceptable holding times. A summary of common hold times are listed below.

Groundwater Sample Hold Time

Routine parameters (including alkalinity, anions and physical parameters)	3 - 28 days	**Nitrogen species**	3 days
Total metals	28 days	**Microbiology**	24 hours
Dissolved metals	28 days	**Hydrocarbons**	14 days

References: ALS Western Canada Sampling/Handling Guide (https://www.alsglobal.com)

Notes

1" Well	0.5 L/m	**pH**	± 0.1
1.5" Well	1.1 L/m	**Specific Conductivity**	± 5 % mS/cm
2" Well	2.0 L/m	**Temperature**	± 0.5°C
3" Well	4.6 L/m	**ORP**	± 5 % mV
4" Well	8.1 L/m	**Turbidity** Note: Turbidity is generally last parameter to stabilize	± 5% NTU (and less than 50 NTU)

A3.1.5 Record Keeping

All collected data during the site visit should be recorded using field sheets (i.e., the **Groundwater Sampling Field Sheet** [**Section A3.1.5.1**] and the **Site Visit Data Download & Calibration Field Sheet** in **Appendix A2** [**Section A2.1.5.1**]) and / or field notebooks.

Photos of the sampling process should also be taken and all field notes, or field data sheets, and photos should be scanned / saved to the project folder upon returning to the office.

A3.1.5.1 Field Sheets

The applicable field sheet is included on the following page and on the **PGOWN MS Teams Channel**.

Groundwater Sampling Field Sheet

Obs Well Number: ______________________ **Date:** ______________________

Location: ______________________ **Time (PDT / PST):** ______________________

Weather: ______________________ **Crew:** ______________________

PURGING/SAMPLING

Method: ❑ Waterra ❑ Bailer ❑ Peristaltic ❑ Submersible ❑ No Purge ❑ Bladder ❑ Other: ______________________

Static Water Level (SWL): ______________ (m btoc) Calculated Well Volume*: ______________________ (L)

–

Stick-up: ______________ (m ags) Calculated Purge Volume: ______________________ (L)

=

Calculated SWL: ______________ (m bgs) Water Intake Depth: ______________ (m btoc)

Measurement Time: ______________ (PST / PDT) Flow Rate: ______________ (L/min)

Depth to Well Bottom: ______________ (m btoc) ***Refer to well volume calculation factors and formula on third page.***

Time	SWL (m btoc / m bgs)	Est. Purge Volume (L)	pH	Temp. (°C)	Specific Cond. (µS/cm)	DO (mg/L)	ORP (mV)	Turbidity (NTU)	Comments
		-	-	-	-	-	-	-	Start of purging.

See Reverse Side

Reminder: archive all field sheets into appropriate project folder after site visit.

Groundwater Sampling Field Sheet

Time	SWL (mbtoc)	Est. Purge Volume (L)	pH	Temp. (°C)	Specific Cond. (μS/cm)	DO (mg/L)	ORP (mV)	Turbidity (NTU)	Comments

Logged By: ______________________________ **Signature:** ______________________________

WATER DESCRIPTION (AT END OF PURGE)

Odour: Y / N Description:

Sheen: Y / N Description:

Sediment: Y / N Description:

Colour: Y / N Description:

Well Yield (Good / Moderate / Poor):

Clarity: Relative scale, indicate start and end value:

1 2 3 4 5 6 7 8

Start: End:

Other:

SAMPLE INFORMATION

Sample ID: Sample Date: Sample Time:

Notes:

QA/QC Sample ID: Sample Date: Sample Time:

Notes:

QA/QC Sample ID: Sample Date: Sample Time:

Notes:

See Next Page

Reminder: archive all field sheets into appropriate project folder after site visit.

Groundwater Sampling Field Sheet

NOTES (e.g., pump problems, sampling issues / observations, recommendations for future sampling events, etc.)

Well Volume Calculation Factors

1" Well	0.5 L/m
1.5" Well	1.1 L/m
2" Well	2.0 L/m
3" Well	4.6 L/m
4" Well	8.1 L/m
4.5" Well	10.3 L/m
6" Well	18.2 L/m
8" Well	32.4 L/m

Formula for One Well Casing Volume (L)

$$Purge\ Volume = Well\ Volume\ Calculation\ Factor\left(\frac{L}{metre}\right)\ x\ (Total\ Well\ Depth\ [m\ btoc]\ -\ Static\ Water\ Level\ [m\ btoc])$$

Stabilized Water Quality Field Parameter Values

pH	± 0.1	
Specific Conductivity	± 5 % mS/cm	
Temperature	± 0.5°C	
ORP	± 5 % mV	
Turbidity	± 5% NTU (and less than 50 NTU)	Note: Generally last parameter to stabilize.

Groundwater Sample Hold Time

Routine parameters*	3 - 28 days	**Nitrogen species**	3 days
Total metals	28 days	**Microbiology**	24 hours
Dissolved metals	28 days	**Hydrocarbons**	14 days
Dissolved organic carbon	3 days		

* Including alkalinity, anions and physical parameters.

References: BC MOE Sample Preservation and Holding Time Requirements (https://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/monitoring/emre/manuals/environmental-lab-manual/2023-09-18-bc-env-sample-preservation-holding-time-requirements.pdf)

Reminder: archive all field sheets into appropriate project folder after site visit.

Appendix A3-2

Groundwater Sampling Multiparameter Meter Calibration, Maintenance, and Storage SOP

A3.2 GROUNDWATER SAMPLING MULTIPARAMETER METER CALIBRATION, MAINTENANCE AND STORAGE SOP

This SOP provides guidance for Field Technicians on calibrating, maintaining, and storing multi-parameter meters (YSI). Prior to using any multiparameter meter to measure groundwater quality field parameters (e.g., pH, specific conductivity [EC], temperature, dissolved oxygen [DO] or redox potential [ORP]), the instrument must be calibrated.

A3.2.1 General

If multiparameter meters are not calibrated, are incorrectly calibrated, or are calibrated using expired solutions, the measurements obtained may not be representative of groundwater conditions. As such:

- Calibration of the instrument should be completed at the start of each day the instrument is used under operating conditions (i.e., in the field);
- Where possible, multi-point calibrations are preferred over single point calibrations for improved accuracy for most parameters (Nielsen 2007);
- Calibration solution bottles should remain sealed with the cap on when not being used and stored in climate-controlled environments (e.g., storage cabinets located somewhere where the calibration solution will not freeze);
- Expiration dates and batch numbers for calibration solutions should be documented, and any expired solution should be disposed of appropriately (or used only as a rinse prior to calibrating with fresh calibration solution); and
- Expired pH 4 calibration buffer solution can be kept and used for short-term probe storage.

A3.2.2 Equipment

As part of calibrating a multiparameter meter, the following equipment is needed:

- Calibration cups (ideally one designated calibration cup should be used for each calibration solution), or use the multiparameter meter plastic storage sleeve;
- Clean / new nitrile gloves;
- Calibration solutions:
    - pH buffer solutions (pH 4,7 and 10);
    - Conductivity solution (1413 µS/cm);
    - ORP Solution (Zobell);
- Deionized (DI) water;
- Phosphate-free cleaning solution (e.g., Liquinox); and
- Multiparameter meter (YSI).

A3.2.3 Procedure

A3.2.3.1 Probe Set-Up

- Set up the calibration solutions near a sink. Rinse each calibration cup (or the plastic storage sleeve if that is being used) with the respective calibration solution to remove any residual debris or solution from a prior calibration event.
    - Expired calibration solutions can be saved and used for rinsing the calibration cups.
- Remove the plastic storage sleeve from the YSI probes and pour the storage solution into a temporary container.
- Rinse the YSI probes with DI water to remove any residual storage solution.
- Turn on the YSI.

A3.2.3.2 pH Probe Calibration Procedure

- Select the pH 4 buffer (calibration) solution to start and rinse the probe with a bit of the selected buffer first (rinse solution can be poured down the sink while the tap is running).
- Fill the plastic storage sleeve (or designated cup) with just enough of the selected buffer solution to cover the bulb of the pH probe. Insert the YSI probes into the storage sleeve.
- Press *'Cal'*, highlight "pH Probe" and press *'Enter'*.
- Wait for the "Actual Value" displayed on the screen to stabilize.
- Look at the temperature displayed on the YSI screen and compare that to the pH buffer solution bottle to determine what the "Calibration Value" should be. Highlight "Calibration Value" and press *'Enter'* to input the temperature-dependant value listed on the pH bottle.
- Highlight "Accept Calibration" and press *'Enter'* **once**. You should see "Ready for Calibration ##" at the bottom of the screen.
    - If the screen shows that the calibration is out-of-range, **do not** accept the calibration. Replace the pH probe before proceeding. The same is true for all other calibrations to follow.
- Rinse probe with DI water and repeat steps above for the next pH buffer solution (pH 10 followed by pH 7). Rinse the YSI probes with a small amount of the buffer solution that will be used next.
    - The order of the pH calibration solutions should ideally be such that the pH of the final solution would be closest to the expected pH that will be encountered at the well (which is typically pH 7).
- Once you have completed these steps for all three pH buffer solution, press *'Cal'* to finalize the calibration.

Calibration Check

- Remove the YSI from the storage sleeve and rinse with DI water. Place the probe back in the pH 4 solution and allow probe to equilibrate.
- Record the pH value given by the YSI and compare to the pH calibration solution (account for the temperature and compare to bottle pH value).
- pH should stabilize within the acceptable range of **± 0.1 pH units** around the pH calibration solution value. If the pH probe does not stabilize within this range, the calibration process should be repeated. If the pH probe will not calibrate after multiple attempts, the probe may need to be replaced.
- Rinse the YSI probes with DI water and prepare for calibration of the next probe.

A3.2.3.3 Conductivity Probe Calibration Procedure

- Rinse the probes with conductivity calibration solution (similar to the initial pH calibration step).
- Insert the YSI into the calibration cup filled with 1413 µS/cm conductivity calibration solution and ensure there is enough solution to completely submerge the sensor portion of the probe.
- Press *'Cal'*, highlight "Conductivity Probe" and press *'Enter'*.
- Choose "Specific Conductance @ 25°C" and press *'Enter'*.
- Wait for the "Actual Value" displayed on the screen to stabilize.
- Highlight "Calibration Value" and change to "1413 µS/cm" if necessary. Press *'Enter'*.
- Highlight "Accept Calibration" and press *'Enter'*. Press *'Cal'* to finalize calibration.

Calibration Check

- Remove the YSI from the storage sleeve and rinse with DI water. Place the probe back in the 1413 µS/cm calibration solution and allow probe to equilibrate.
- Record the conductivity reading given by the YSI probe. The probe should measure a conductivity value within **± 0.5% of 1413 µS/cm** (i.e., ± 7 µS/cm). If the conductivity probe does not stabilize within this range, the calibration should be repeated. If the conductivity probe will not calibrate after several attempts, the probe may need to be replaced.
- Rinse probe with DI water and prepare for calibration of the next probe.

A3.2.3.4 ORP Probe Calibration Procedure

- Successful calibration of the pH probe must be completed prior to attempting to calibrate the ORP probe as the YSI relies on an accurate pH reading when determining the ORP.
- Rinse the YSI probes with ORP calibration solution.

- **ATTENTION**: ORP calibration solution is toxic to aquatic life and **must not** be disposed of down a sink. Please collect all used or expired ORP solution into a jug container for proper disposal once full. Contact Hoskin Scientific Ltd. to dispose of the stored ORP waste solution.

- Insert the YSI into the storage sleeve filled with ORP calibration solution. Ensure there is enough calibration solution covering the bottom of the ORP probe.
- Press *'Cal'* button, highlight "ORP Probe" and press *'Enter'*.
- Wait for the "Actual Value" displayed on the screen to stabilize.
- Compare the temperature value displayed on the YSI screen with the ORP calibration solution bottle to determine the "Calibration Value". If necessary, highlight "Calibration Value" and press *'Enter'* to input the temperature-dependant value listed on the ORP bottle.
- Highlight "Accept Calibration" and press *'Enter'*. Press *'Cal'* to finalize calibration.

Calibration Check

- Remove the YSI from the storage sleeve and rinse with DI water. Place probe into ORP solution and allow probe to equilibrate.
- Record the ORP reading given by the YSI and compare to the expected value listed on the ORP solution bottle based on the displayed temperature.
- The ORP value should be **within ± 20 mV**. If the measured value is not within the acceptable range, calibration of the ORP probe should be repeated. If the probe will not calibrate after several attempts, the probe may need to be replaced.
- Rinse the probe with DI water and prepare for calibration of the next probe.

A3.2.3.5 Dissolved Oxygen Probe Calibration Procedure

- If available, place a small, moistened sponge at the bottom of the storage sleeve. Alternatively, pour a small volume of water (~1 cm) into the storage sleeve.
- Screw the probe into the storage sleeve by only 1 or 2 threads so the probe is not isolated from the atmosphere while ensuring the air inside the storage sleeve will become saturated.
- Press *'Cal'*, highlight "DO probe" and press *'Enter'*.
- Highlight "DO%" and press *'Enter'* .
  - DO concentrations can be reported in DO%, mg/L or ppm. The YSI Pro Plus DO probe should be calibrated in DO%, which will simultaneously calibrate the probe for mg/L and ppm.
- Let the YSI equilibrate for approximately 10 minutes. The DO% should stabilize close to the values in **Table A3-2.1**, below, which depend on your location elevation. If the DO% is deviating **more than 10%** from the respective value in **Table A3-2.1** and the probe does not stabilize, consider the following trouble shooting options:

- Clean the sensor cap;
- Replace the DO membrane;
- Double check the barometer is reading correctly (weather service readings are corrected to sea level, so consider the following formula: True BP in mmHg = Corrected BP in mmHg – [2.5 * (Local Altitude in ft. above sea level/100); or
- Replace the DO probe.

- Once the DO% stabilizes, highlight "Accept Calibration" and press *'Enter'*.

Table A3-2.1 Calibration values for various atmospheric pressures and altitudes.

PRESSURE			ALTITUDE		CALIBRATION VALUE
Inches Hg	mm Hg	Millibars	Feet	Meters	Percent Saturation
30.23	768	1023	-276	-84	101
29.92	760	1013	0	0	100
29.61	752	1003	278	85	99
29.33	745	993	558	170	98
29.02	737	983	841	256	97
28.74	730	973	1126	343	96
28.43	722	963	1413	431	95
28.11	714	952	1703	519	94
27.83	707	942	1995	608	93
27.52	699	932	2290	698	92
27.24	692	922	2587	789	91
26.93	684	912	2887	880	90
26.61	676	902	3190	972	89
26.34	669	892	3496	1066	88
26.02	661	882	3804	1160	87
25.75	654	871	4115	1254	86
25.43	646	861	4430	1350	85
25.12	638	851	4747	1447	84
24.84	631	841	5067	1544	83
24.53	623	831	5391	1643	82
24.25	616	821	5717	1743	81
23.94	608	811	6047	1843	80
23.62	600	800	6381	1945	79
23.35	593	790	6717	2047	78
23.03	585	780	7058	2151	77
22.76	578	770	7401	2256	76
22.44	570	760	7749	2362	75
22.13	562	750	8100	2469	74
21.85	555	740	8455	2577	73
21.54	547	730	8815	2687	72
21.26	540	719	9178	2797	71
20.94	532	709	9545	2909	70
20.63	524	699	9917	3023	69
20.35	517	689	10293	3137	68
20.04	509	679	10673	3253	67
19.76	502	669	11058	3371	66

A3.2.3.6 Storage

When not in use, YSI probes should be kept submerged in a storage solution such as pH 4 calibration buffer solution. Storage solution should be periodically changed. It is important to ensure that YSI probes do not dry out and are not allowed to freeze. In addition, DI water should never be used as a storage solution for a multiparameter meter probe as this can damage the probes and result in calibration issues.

When storing the YSI probes for long periods of time, ensure the storage sleeve (**Figure A3-2.1**) is secured and standing upright so storage solution cannot leak out. In addition, batteries should be removed to prevent any corrosion.

Figure A3-2.1 YSI Multi-Parameter Probe with storage sleeve.

Photo source: BC ENV.

A3.2.3.7 Probe Maintenance

Multiparameter meter probes will need to be replaced periodically with the approximate working life of each probe summarized in **Table A3-2.2**.

Table A3-2.2 YSI probes working lifespans (YSI 2009).

Probe	Approximate Working Lifespan
pH	1 year
Conductivity and Temperature	5+ years
DO	2 to 4 years
DO membrane	30 to 60 days
ORP	1 year

Prior to completing maintenance or replacing malfunctioning probes, consult the YSI user manual or the supplier (e.g., Hoskin Scientific Ltd.).

A3.2.4 Miscellaneous

Not applicable.

A3.2.5 Record Keeping

Calibration events should be documented in the **Equipment Calibration Record** (**Appendix A3** [**Section A3.1.5.1**]). These records should be saved to the appropriate folder upon completion of each calibration event.

A3.2.5.1 Field Sheet

A calibration record template is included on the following page and on the **PGOWN MS Teams Channel**.

Equipment Calibration Record

GROUNDWATER MULTI-METER

Make:	**Manufacturer:**											
		Serial #:										
		Date:										
		Technician:										
Calibration	Lot #	Exp. Date	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
pH 4												
pH^2 7												
pH^2 10												
Sp. EC 1413 µS/cm												
ORP (mV)												
DO (%)	n/a	n/a										
Additional Comments:												

WATER LEVEL TAPE

Make: **Manufacturer:**					
Serial #:					
Date:					
Technician:					
Battery Test Button					
Sensor Check					
Clean Senor *(and tape, if required)*					
Additional Comments:					

See Reverse Side

Equipment Calibration Record

TURBIDITY METER												
Make:		**Manufacturer:**										
		Serial #:										
		Date:										
		Technician:										
Standard/Units	Lot #	Exp. Date	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Additional Comments:												

OTHER EQUIPMENT												
Make:		**Manufacturer:**										
		Serial #:										
		Date:										
		Technician:										
Standard	Lot #	Exp. Date	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Additional Comments:												

Notes:

[1] Calibration record from manufacturer may be used in lieu of this form on the first day in the field.

[2] pH calibration should be performed using at least two buffers that bracket the expected groundwater pH range.

Equipment calibration should be completed each morning on-site before beginning field work.

If possible, keep calibration solutions on hand while in the field in case you notice equipment readings drifting during the day.

Appendix A3-3

Quality Assurance and Quality Control for Groundwater Sampling SOP

A3.3 QUALITY ASSURANCE AND QUALITY CONTROL FOR GROUNDWATER SAMPLING SOP

This SOP outlines the approach to collect QA/QC samples in the field and an overview of data analysis once the QA/QC analytical results have been received.

A3.3.1 General

QA/QC procedures are a key part of the overall management of a sampling program to ensure representative (unbiased) and accurate data are collected and used during interpretation. Although some natural variability can be expected, it is important to confirm that no significant bias (e.g., sample contamination or alteration) is introduced during sample collection and lab analysis.

A3.3.2 Equipment

In addition to the standard equipment required for groundwater sample collection (see **Groundwater Sampling SOP** in **Appendix A3** [**Section A3.1**]), task-specific equipment includes:

- Additional unfilled laboratory-supplied bottle sets (for duplicate or field blank samples); and
- Filled (deionized water) laboratory-supplied bottle sets (for trip blank samples).

There is no task-specific equipment required for the desktop-review evaluation which will occur after analytical results are received by the lab.

A3.3.3 Procedure

A3.3.3.1 QA/QC Sample Collection

- The collection of QA/QC samples should follow standard sample collection and handling procedures, as outlined in the **Groundwater Sampling SOP** in **Appendix A3** [**Section A3.1**]), including:
  - Proper labelling of sample bottles;
  - Wearing new and clean nitrile gloves prior to filling sample bottles; and
  - Storing samples, once collected, in a cooler with icepacks.
- **Field duplicates** are collected concurrently with the parent sample to obtain the precision for each analyte analyzed within the two samples (BC MOECCS 2013). When collecting a field duplicate, the sampler will fill the parent bottle approximately half full, then the duplicate bottle by half, and continue until both sample bottles are filled. There should be a corresponding duplicate bottle for each parent bottle collected.
  - The correct bottle set for duplicate samples is the full analytical suite, including **general chemistry**, **dissolved metals**, **dissolved** and **total nutrients**.

    - Field duplicate samples should be field-filtered and preserved in the same manner as the regular (parent) samples.

- **Field blanks** are collected in the same environment as groundwater quality samples. The Field Technician will fill a bottle set in the field at a Provincial Observation Well location with deionized (DI) water and add preservatives (if sample bottles do not already contain preservative from the lab). Best practices for DI water handling include recording the date of opening a new DI water bottle, never using DI water that was opened more than 2 months ago, and not using DI water that has expired (even if the bottle is sealed).
    - The correct bottle set for field blanks is **general chemistry** and **total ammonia**.
    - Total ammonia is not filtered but is preserved with **sulfuric acid**.
- **Trip blanks** are sample bottles that come already pre-filled directly the laboratory and are obtained prior to the start of a sampling event. The bottle set is carried with the other regular bottle sets and handled in a similar fashion throughout the sampling program (e.g., stored in the same cooler).
    - The correct bottle set for field blanks is **general chemistry** and **total ammonia**.
    - Total ammonia is not filtered but is preserved with **sulfuric acid**.
- See **Groundwater Sampling SOP** (**Appendix A3** [**Section A3.1**]) for instructions on delivery and shipping of water quality samples.

A3.3.3.2 QA/QC Sample Identification

Quality control samples such as duplicates or blanks may be submitted to the laboratory using a blind or plain naming convention. Typically, blind naming is preferable to minimize the potential for bias at the analytical laboratory.

Requisition Naming Convention

Blind naming is the practice of assigning a random or anonymous name to prevent bias during analysis by the analytical laboratory. There is no sample name associated on lab requisitions for Provincial Observation Wells as they use EMS IDs. Samples collected at designated EMS sites are named using the appropriate "Class Codes" as follows:

- **Regular and duplicate samples**: class code is "**REG**", and the samples will be differentiated by documenting the duplicate sampling time as **one minute later** from the regular sample.
- **Field or trip blanks**: class code "**BLF**".

Field Technicians will identify analytical results (i.e., which Provincial Observation Well is being reported) based on the EMS ID reported on the results and field notes which should list where duplicate, and field or trip blanks were collected.

A3.3.3.3 Desktop-Review of QA/QC Results

Desktop QA/QC procedures are completed when analytical results are received from the laboratory. These procedures should be completed as soon as the results are received to assist with identifying issues, determine if reanalysis of any parameters is required and to confirm the analytical results are representative of groundwater conditions.

- The **ionic balance** provided in the received analytical results from the lab must be reviewed as it can provide an indication of potential analytical issues (e.g., missing analytes which contribute to the ionic balance). Water quality samples are acceptable when the **ionic balance is within a ±10% range** and requires investigating if the balance is outside of this range.
- **Field** and **trip blank** results are reviewed to determine if the field or transport environment caused contamination to the samples. The results are reviewed to identify any elevated concentrations and are considered acceptable if **analyte concentrations are less than twice their corresponding reportable / method detection limit** (2 x RDL/MDL).
- For **field duplicates**, the Field Technician must first calculate the relative percent difference (RPD) which measures the overall precision of sampling plus heterogeneity in the environment. The RPD can identify samples which are outside of the acceptable range and indicate a potential problem or non-representative samples. The RPD compares the duplicate result to the original parent result and quantifies the variability.

  Calculate the RPD as follows:

  - $\% \boldsymbol{RPD} = \frac{(Sample\ Result - Duplicate\ Result)}{\left(\frac{Sample\ Result + Duplicate\ Result}{2}\right)}\ x\ 100$
  - Please note that the RPD **should only be calculated** when the analytical results are 5x the reported detection limit for the given analyte.
  - When the sample result is at/below the lab detection limit, use half the detection limit (divide the detection limit by 2) as the assumed concentration when calculating RPD. This approach is applicable when one sample is 5x the DL and the other sample is at or below DL.
  - Set up a spreadsheet template to copy / paste analytical results into with the RPD formula entered into a separate column to allow for automatic calculation and flagging of RPD values. Contact the Groundwater Monitoring Program Supervisor for a template. Alternatively, a new column with the necessary RPD formula could be entered directly into the lab results.

  The RPD results are screened against the following criteria:

  - **Less than 20%** is considered **acceptable**;
  - **Greater than 20%** indicate a **potential problem** (e.g., sample contamination, sampling method bias, media heterogeneity, etc.); and
  - **Greater than 50%** are considered to indicate a **definite problem** (BC MOECCS, 2013).

Elevated RPD values (i.e., above 20%) must be evaluated to determine potential causes and the significance of the poor replication.

- Lastly, check that the results have been properly uploaded by the lab to EMS, including checking for transcription errors with the reported field parameters (i.e., the YSI groundwater chemistry parameters recorded on the lab requisition by the Field Technician during sampling).

Notify the laboratory as soon as possible if issues are identified with the QA/QC results so that the lab can investigate (e.g., rerun samples) prior to samples being disposed. Discuss with your Groundwater Monitoring Specialist for further follow-up actions. In some cases, a Provincial Observation Well may need to be resampled and the previous analytical results removed from Provincial databases if the representativeness of the samples is called into question.

A3.3.4 Miscellaneous

This section provides supplemental information that is relevant to QA/QC but not part of the procedure, including a Troubleshooting section of common issues, including potential causes and resolutions.

A3.3.4.1 QA/QC Sample Frequency

Quality control of samples can evaluate the precision of the sampling method, the analytical procedure or the local heterogeneity in the environment. It is recommended that field duplicates are collected at a 10% rate (1 in every 10 samples), whereas field blanks and trip blanks are collected at a 5% rate (1 in every 20 samples), or **at least once per sampling event**, whichever is greater. A sampling event is when several Provincial Observation Wells are sampled as part of the same program. This can occur over several days (e.g., four groundwater quality samples are collected from Provincial Observation Wells over a three-day period). The QA/QC sampling requirements are summarized in **Table A3-3.1** below.

Table A3-3.1 Quality control sample types (BC MOECCS 2013).

Sample Type	Sample Frequency	Intended Use
Field Duplicates	1 every 10 samples **or** 1 per sampling event if <10 samples are collected	Analytical results of the duplicate samples are compared, and the RPD is calculated.
Field Blanks	1 per 20 samples **or** 1 per sampling event if <20 samples are collected	Identify if any analytical results are detectable.
Trip Blanks	1 per 20 samples **or** 1 per sampling event if <20 samples are collected	To identify if cross-contamination may occur during handling, storage or shipment of collected samples.

A3.3.4.2 Troubleshooting

Observation	Potential Consequence	Potential Cause	Possible Next Steps
Well does not have sufficient water volume for a duplicate sample	▪ Lab may be unable to analyze sample bottles with insufficient sample volume.	▪ Slow recharge due to aquifer materials or degraded well integrity.	▪ Collect a limited sample (prioritize metals and ammonia bottles, and fill minimums of sample bottles, where possible). ▪ Allow the well to rest until sufficiently recharged, will vary depending on well.
Field or trip blanks are outside acceptable limits	▪ Collecting a non-representative sample. ▪ Uncertainty in quality of the analytical sample result.	▪ Cross-contamination / mishandling of samples in the field or transport environment.	▪ Review field sampling data sheets and notes to identify possible sources of cross contamination. ▪ Have the lab reanalyze the parent and duplicate samples. ▪ If necessary, ask lab to remove the analytical results from EMS and resample the well. Discuss with your Groundwater Monitoring Specialist first.
Field duplicate RPDs or ionic balance results are outside acceptable limits	▪ Collecting a non-representative sample. ▪ Uncertainty in quality of the analytical sample result.	▪ Sample heterogeneity; ▪ Sample contamination; ▪ Sampling method bias; or ▪ Media heterogeneity.	▪ Review field sampling data sheets and notes to identify possible sources of cross contamination. ▪ Have the lab reanalyze the parent and duplicate samples. ▪ If necessary, ask lab to remove the analytical results from EMS and resample the well. Discuss with your Groundwater Monitoring Specialist first.

A3.3.5 Record Keeping

The **Groundwater Sampling Field Sheet** (**Appendix A3** [**Section A3.1.5.1**]) and field notebook should be used to document field QA/QC samples that are collected should be scanned and saved to the respective project folders.

Any desktop evaluation of analytical lab results should be documented in a database or spreadsheet that can be reviewed as needed.

A3.3.5.1 Field Sheets

The **Groundwater Sampling Field Sheet** can be found in the **Groundwater Sampling SOP** (**Appendix A3** [**Section A3.1.5.1**]).

Appendix A4

Equipment & Instrumentation User Manuals

Appendix A4-1

Telemetry

Axiom Datalogger Technical Specifications

Hardware

Display/touchscreen:	• Graphical color touch screen display, 3.65” (diagonal), QVGA (320x240 pixels). • Display is transflective (readable in low light and outdoors in bright daylight) • Displays system status, configuration, stored data (graphical and tabular) and provides system configuration and troubleshooting diagnostics. • Displays voltage and current separately for battery and solar panel and battery temperature. • Supports troubleshooting, configuration and programming.
CPU:	• Two (2) CPUs total, both low-power RISC. • Main CPU is 200MHz 32-bit ARM.
Memory/storage:	• 64MB RAM • 256MB fixed physical, non-volatile flash memory for data and program storage. • Data is stored in a circular 10MB buffer (oldest data overwritten by newest when buffer full). • Based on NFDRS logging criteria, 7,575 days (about 20 years) of data can be stored.
Device ports:	• 2 waterproof USB 2.0 host ports, 1.5Mbps and 12 Mbps, support for flash memory and other USB-compliant devices. • 1 waterproof USB 2.0 12 Mbps device port with automatic PC detect. • Supports USB keyboard and mouse. • GOES RF output (for models with an integrated GOES transmitter): N-type jack • GPS RF input (for models with an integrated GOES transmitter): SMA jack

Sensor ports:	• Waterproof, color-coded, military-style connectors.
	• Dedicated ports (F6):
	  ◦ wind speed (frequency input)
	  ◦ wind direction (potentiometer input)
	  ◦ rain gauge (counter)
	  ◦ temperature & humidity (thermistor, 0-1.0V)
	  ◦ fuel stick (thermistor, 0-1.0V)
	• Dedicated ports (H2):
	  ◦ rain gauge (counter)
	• 2 (F6 and H1) or 4 (H2) independent SDI-12 V1.3 ports, expandable using external expansion modules to support up to 62 digital sensors.
	• SDI ports each support up to 500mA and are electrically isolated.
	• Optional, configurable analog-to-SDI expansion module (SDI-AM) to connect legacy analog sensors (terminal strips).

Serial ports:	• Either:
	  ◦ 2 ports factory configured as internal GOES transmitter and one external, waterproof, military style bayonet connector
	  ◦ 2 external, waterproof, military-style bayonet connectors
	  ◦ One external, waterproof, military style bayonet connector
	• Signal levels: RS232C
	• Signals: TXD, RXD, RTS, CTS, DCD, DTR, RI

Environmental sealing, size, weight:	• Waterproof to IP67, O-ring sealed, cast aluminum & stainless steel hardware, engineered resin bezel • Dimensions: 10” W x 8” H x 6” D • Weight: approx. 8 lbs.

Power supply:	• Internal, temperature compensated charge regulator • Waterproof, military style bayonet connectors for solar panel and battery. • Sensing of battery voltage, battery current, battery temp, solar voltage and solar current. • 9.6VDC to 20VDC operating voltage.

Software

Station identification:	The station's name, NESID and GOES data can be easily identified on the touchscreen display.
Programming:	• All programming done through intuitive graphical user interface (GUI) without writing code. • No laptop required; GUI accessed through integrated touchscreen. • Unlimited setup configurations are stored directly on the datalogger; different configurations can be selected or a new one created with the GUI.

Electronic service reports:	• All of the data recorded by field techs during a service call can be captured electronically in the Axiom and saved to a USB memory stick.
	• Data includes:
	  ◦ a list of sensor serial numbers before and after the service trip.
	  ◦ Audit log.
	  ◦ datalogger program version.
	  ◦ latitude, longitude, elevation.

Datalogger performance verification:	• Graph sensor data and diagnostic parameters. • Battery load tests; view voltage before and after (requires dummy load on battery). • View current sensor readings. • View historical data. • View GPS performance stats. • View forward and reflected power stats to check GOES antenna performance.
Rain count:	• Custom NFDRS rain GUI allows users to quickly test tipping buckets each year by viewing manual tip measurement in real-time and quickly removing the test tips from memory (F6). • User can select a rain reset date if desired and set the action on power failure (rain total can be set to return to previous values or reset to zero).
One-touch current conditions:	• Users can customize the Current Conditions screen so that all sensors' real-time data are viewable with one button press, extremely handy when validating wind quadrants or simply validating each sensor as it is replaced. • The electronic service report automatically captures the current conditions at the start (pre-swap) and after (post-swap).
Data transfer via USB memory stick:	• Data, Programs and Firmware updates can be transferred to and from datalogger via a conventional USB memory stick. • Historical data download is fast: approximately 5 seconds for 1 year of data including logger and telemetry records. • Data downloaded in universal .CSV (comma-separated values) format; importable into Excel and many other software.

GOES Transmitter (Optional)

Manufacturer:	• FTS
Supported baud rates:	• 100 bps • 300 bps • 1,200 bps
Operating supply voltage:	• 10.8 VDC to 16 VDC
Supply current (at 12VDC):	• Idle: <3 mA • Transmitting: <2.6 A • GPS ON: <50 mA

Output power:	**GOES** • 300 bps: 14W max • 1,200 bps: 14W max **METEOSAT** • 100 bps: 14 W max
EIRP:	• 40-45 dBm
Compatible antennas:	• Power: 14W Max • Polarization: Right hand circular • Connector: N-Type Female • **Recommended antenna:** FTS EON 2 with GPS
Frequency range:	**GOES** • 401.701 MHz – 402.09850 MHz **METEOSAT** • 402.0355 – 402.4345 MHz
Frequency stability:	• Initial accuracy +/- 20Hz synchronized to GPS • GPS Schedule: 1 fix at power up, 1 fix per day thereafter
Channel bandwidth	• 100 bps: 3KHz • 300 bps: 750 Hz • 1,200 bps: 1.5 KHz
Time-keeping:	• < 100 µsec initial accuracy, automatically synchronized to GPS • < 10 ms per day drift without GPS • 28 day operation without GPS signal (after initial GPS synchronization)

Interface Serial Ports

Command port:	• N/A
SDI-12 port:	• N/A

User Interaction

User interface:	• Always-present status indicator of GPS time, data received by transmitter, success of transmission. • Number of satellites in view, average signal strength and other GPS status information available.
Forced transmissions:	• User can select any channel and time to force a test GOES transmission.

Resolution, Accuracy and Stability

I/O accuracy (with optional SDI-AM Analog interface module):

Input ranges	Accuracy
5 V	± 1.5 mV
2.5 V	± 0.75 mV
1 V	± 0.3 mV
100 mV	± 0.1 mV
55 mV	± 0.055 mV
25 mV	± 0.0375 mV

Analog-to-digital resolution:	• 24 bits
Sampling rates:	• Sampling rates are user-defined and can be as frequent as 1 second. • Sampling can be done on a timed basis or conditionally. • Sampling can be increased whenever a specific condition is met, for example if relative humidity drops below a certain percent, logging frequency can increase to every 15 minutes. • Multiple sampling routines can be set and stored. • Special "burn day" function allows logging data every 5 minutes during prescribed burning for higher resolution data.

GPS (Models with GOES transmitter only):	• Internal 12-channel GPS receiver. • SMA connector for 3V active patch GPS antenna. • Periodic time synchronization to UTC. • Latitude, longitude, elevation to full GPS accuracy.

Environmental Protection

Operational moisture range:	• 0-100% RH, condensing
Operational temperature range:	• Display operation: -20°C to +60°C • Datalogger operation: -40°C to +60°C • Storage: -55°C to +70°C

Lightning protection:	• Three-stage protection circuit offers superior protection:
	  ◦ Stage 1: transient earth clamp.
	  ◦ Stage 2: series impedance.
	  ◦ Stage 3: high speed shunt diode.

UV resistance:	• Excellent, as minimal plastics are used. Cable housing and omnidirectional GOES antenna are UV-stable.
Electronics protection:	• Core electronics sealed from moisture and dust in waterproof housings, completely isolated from environment and user. • All non-telemetry data exchange (firmware upgrades, report downloads) performed through waterproof USB port. • Battery overcharge protection.
IP code rating:	• IP67

Power Consumption

Datalogger current:	• Idle: 2-3mA (no integrated GOES transmitter), 7-8mA (with integrated GOES transmitter) • Active (collecting data): 7.5mA (no integrated GOES transmitter), 12mA (with integrated GOES transmitter) • Touchscreen backlight on: 60mA • GOES transmit: 2.6A. • GPS on: <50mA
Power status:	• Datalogger measures and logs solar panel voltage, solar panel current, battery voltage, battery current and battery temperature. • Status indicators (always visible) allow techs to identify if the system is charging correctly or not. • This data is also part of the Current Conditions screen call and are captured in the electronic service report.

Appendix A4-2

Groundwater Sampling

ROYAL Eijkelkamp
Meet the difference

Submersible pump Grundfos MP 1 / Redi-Flo2

User manual

Royal Eijkelkamp
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I royaleijkelkamp.com

M-1227E

Contents

Warning! This MP 1/Redi-Flo2 pump does not contain motor cooling fluid. Fill the motor as directed in these instructions.

1. Information on this manual

☞ **If the text follows a mark (as shown on the left), this means that an important instruction follows.**

⚠ **If the text follows a mark (as shown on the left), this means that an important warning follows relating to danger to the user or damage to the apparatus. The user is always responsible for its own personal protection.**

Text **Italic indicated text indicates that the text concerned appears in writing on the display or the apparatus (or must be typed).**

2. General description

⚠ **Prior to installation, read these installation and operating instructions (also read the separate manual on the frequency converter). Installation and operation must comply with local regulations and accepted codes of good practice.**

The Grundfos MP 1/Redi-Flo2 submersible pump is specially designed for the purging and sampling of (contaminated) groundwater in monitoring wells with an internal diameter of at least 50 mm. The pump is powered via an adjustable converter in the 25 to 400 Hz frequency range. At 400 Hz, the pump provides a flow rate of 1 m^3/h at 74 metres head.

⚠ **The pump must always be powered via the converter. See fig. 1.**

Fig. 1 Submersible pump Grundfos MP 1/Redi-Flo2 and frequency converter

Pump and converter (motor) form a complete unit that can easily be dismantled for cleaning and servicing. The Teflon power cable is available in different lengths.

2.1 Applications

The Grundfos MP 1/Redi-Flo2 pump is designed for sampling of groundwater. The maximum sand content of the water must not exceed 50 g/m^3. A larger sand content will reduce the life of the service parts and increase the risk of blocking of the pump. The water temperature at which the pump can be used is +1 °C to +30 °C.

All parts of the pump are made of materials that do not release foreign substances into the pumped liquid. This ensures that the pump does not affect or alter the sample taken. Only for PFAS-substances this may not apply and it is recommended to perform a blank sampling with demi water.
It is possible to use the same pump for sampling in different monitoring wells if the risk of cross-contamination can be eliminated by observing a cleaning procedure or by renewing the tubing at each monitoring well.

⚠ **The MP 1/Redi-Flo2 pump is not designed for the pumping of concentrated oils, chemicals or explosive liquids.**

☞ **When the MP 1/Redi-Flo2 pump is used, the regulations covering the handling of hazardous material and possible local regulations must be observed.**

⚠ **The MP 1/Redi-Flo2 pump is not designed for continuous operation like for instance remedial pumping. Continuous operation may reduce the life of the pump.**

2.2 Technical specifications

Marking:	The MP 1/Redi-Flo2 sampling pump system is CE-marked.

Submersible pump Grundfos MP 1/Redi-Flo2:

Power input:	1.3 kW
Voltage:	3 x 220 V, 400 Hz
Maximum current:	5.5 A
Motor protection:	Built-in thermal switch
Water temperature:	0 °C to +35 °C
Discharge port:	Rp 3/4
Continuous operation:	Maximum 500 hours
Net weight:	2.5 kg

Frequency converters:

Supply voltage:	1 x 200-240 V (+/- 10%), 50/60 Hz
Minimum generator size:	With voltage control: • 3.0 kVA (suitable for non-linear loads, minimal value) • 4.5 kVA (suitable for non-linear loads, recommended value) • 7.5 kVA (not suitable for non-linear loads)
Nominal input current:	12.9 A
Nominal output current:	7.0 A

Supply voltage:	1 x 110-115 V (+/- 10%), 50/60 Hz
Minimum generator size:	With voltage control: • 2.2 kVA (suitable for non-linear loads, minimal value) • 3.3 kVA (suitable for non-linear loads, recommended value) • 5.5 kVA (not suitable for non-linear loads)
Nominal input current:	21.9 A
Nominal output current:	5.8 A

Fuse:	10 A
Power factor:	0.65
Connecting cable:	3 x 1.5 mm^2, 3 m with plug.
Output voltage:	3 x 15.4 V, 25 Hz, to 3 x 235 V, 400 Hz
Motor protection:	Built-in overcurrent protection, set to 6.1 A
Acceleration time:	0 to 400 Hz: Maximum 6 sec
Deceleration time:	400 to 0 Hz: Maximum 6 sec
Enclosure class:	IP66 Outdoor
Ambient temperature:	–10 °C to +40 °C
Relative air humidity:	Maximum 95 %
Weight:	8.0 kg (incl. case).

3. Safety

3.1 Safety precautions

During handling, operation, storage and transportation, the environmental regulations covering the handling of hazardous material must be observed.
When the pump is taken out of operation, care must be taken to ensure that the pump contains no material that might be injurious to human health or to the environment.
The motor is <u>not</u> factory-filled with liquid (the user has to fill approx. 25 ml demineralised water). During operation, this liquid is wholly or partly replaced by the eventually contaminated water. Therefore, there is a risk of coming into contact with pollutants.

3.1.1 Explosion hazard

The pumping system is not approved as explosion-proof. Local authorities and regulations should be consulted if there is any doubt about its suitability for a certain application.

3.1.2 Personal safety equipment

When pumping water containing hazardous material, personal safety equipment must be used.

3.1.3 Warranty

Pumps installed in accordance with these instructions and accepted codes of good practice are covered by the warranty.
Any constructional change of the pumping system will invalidate the warranty. Royal Eijkelkamp cannot be held responsible for possible consequential damage.

3.1.4 Electrical connection

When lowering/pulling out the pump, take care not to damage the motor (power) cable. The electrical connections should be carried out in accordance with local regulations.

Never fit or remove the motor cable plug from the converter unless the electricity supply to the converter has been switched off.

3.1.5 Service

Only pumps that can be certified as uncontaminated, i.e. pumps containing no contaminated material, may be returned to Royal Eijkelkamp for servicing.

See section 9.2 Service.

4. Transportation and storage

4.1 Delivery

4.1.1 MP 1/Redi-Flo2 pump

After production, the pump has been ultrasonically cleaned and packed into a polyethylene bag. This means that the pump has not been in contact anymore with other substances after cleaning and it is untouched by persons.

4.1.2 Converter

The converter should not be exposed to unnecessary shocks and should be handled like sensitive electronic equipment.

4.2 Storage

The pumping system should be stored in a clean and dry area.

4.2.1 MP 1/Redi-Flo2 pump

Storage temperature: –20 °C to +50 °C.
If the pump has to be stored after use, it must be cleaned thoroughly before storing. See section 9. Maintenance and service.

4.2.2 Converter

The converter should be stored in a clean and dry area. Storage temperature: –10 °C to 45 °C.

5. Installation

5.1 Assembly

The pump can be installed either horizontally or vertically. The pump discharge port should never fall below the horizontal plane. See fig. 2.

During operation, the pump must always be completely submerged in the liquid.
The pump performance is controlled by changing the frequency. The installation of a valve in the discharge line is not necessary and is not recommended. Otherwise, the heat produced will cause the pump to switch off.
Otherwise the heat generated will cause the pump to stop.

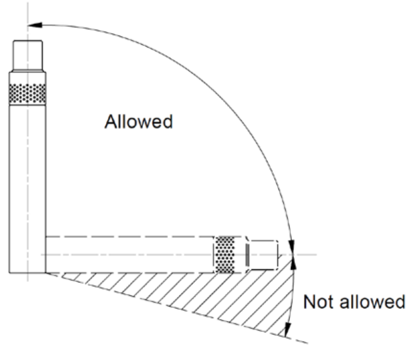


Fig. 2 Positional requirements

5.2 Monitoring well diameter

The inside diameter of the sampling monitoring well must be at least 50 mm. If the borehole diameter is larger than 80 mm, the pump must be fitted in a cooling jacket/flow sleeve to prevent unintended pump cut-outs. See fig. 3.

5.3 Water level

The dynamic water level (depth to the water level in the borehole during operation) must not exceed 80 metres.

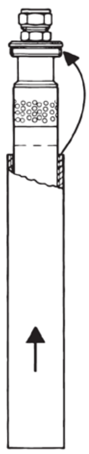


Fig. 3 MP 1/Redi-Flo2 in cooling jacket (flow sleeve)

5.4 Checking of liquid in motor

The level of the liquid in the motor should be checked before the pump is installed.

1. Place the pump and motor in a vertical position with the discharge port pointing downwards (i.e. the bottom of the motor is uppermost), and remove the filling screw. See fig. 4.

2. If the water stands up to the edge of the threaded hole, no filling is required.
   If not, fill demineralised water into the motor.
   To enable all air to escape, insert your finger in the pump discharge port and lift the shaft a few times.
   Recheck the liquid level.

3. Replace and tighten the filling screw.

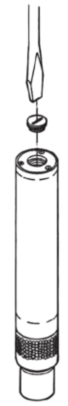


Fig. 4 Removal of filling screw

The pump is now ready for use.

5.5 Pipe connection

Pump discharge port: Rp 3/4.
A pipe or a hose must be connected to the pump.
Whenever a hose is fitted, a compression coupling must be used.
See fig. 5.
Tighten the union nut using fingers only and then give it 1 1/4 turns with a tool.

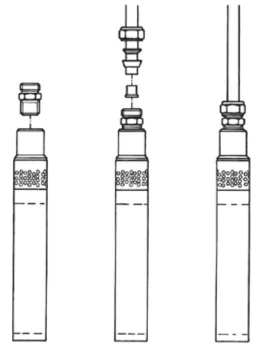


Fig. 5 Use of compression coupling

It is recommended that a stainless steel lifting wire be attached at all times to lower and raise the pump.

Secure the lifting wire to the pump with a wire holder. See fig. 6.

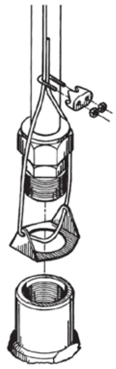


Fig. 6 Fitting the lifting wire

5.6 Lowering the pump

Lower the pump into the monitoring well, taking care not to damage the motor cable.

⚠ **Do not lower or lift the pump by the motor cable. Use the lifting wire or include all components (hose, lifting wire and motor cable).**

5.7 Installation depth

During operation, the pump must be completely submerged (cooling) to prevent it from overheating and seizing up.
If the pump pumps more water that the well can yield, there is a risk that the water level falls below the level of the pump inlet and that air is therefore sucked into the pump.

⚠ **Long time of operation with water containing air may damage the pump and cause insufficient cooling of the motor.**

6. Converter

6.1 Position of the converter

⚠ **Place the converter with cabinet (case) in such a way that water cannot enter into the cabinet.**
Do not close the cabinet during operation.

The converter must be installed vertically to ensure free air circulation around the unit. See fig. 7.
Make sure that the cabinet/converter is in a stable position.

Fig. 7 Vertical installation of the converter

6.2 Converter keypad

Before they leave the factory, Royal Eijkelkamp has programmed the converters for use with the MP 1 (converter art . no. 12274601) and for use with the Redi-Flo2 (converter art. no. 12274701) pump. The rest of the functions are blocked by a password and can only be changed by Eijkelkamp.
That is why **only 3** buttons are used to operate the MP 1/Redi-Flo2 pump.

Switch 1: to start the convertor, after connecting it to the power supply (switch turns hard).

Switch 2: to set the direction of rotation to Forward (>>) (Function Rewind (<<) is disabled by Eijkelkamp, because this will damage the pump).

Switch 3: to set the speed from 0 to 400 Hz.

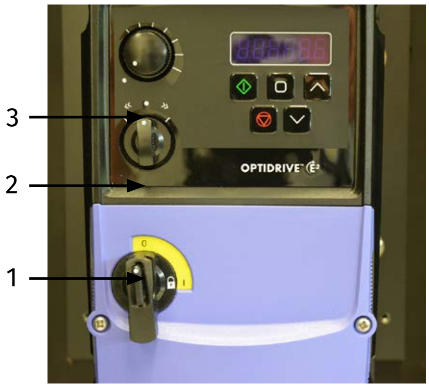


Fig. 8a Pump operation switches

Fig. 8b Switch 1 set to ON

Fig. 8c Switch 2 set to >> forward

Fig. 8d Switch 3 set to 200 Hz

Fig. 8e Switch 3 set to the max 400 Hz

7. Electrical connection

Before starting work on the pump, make sure that the electricity supply has been switched off and that it cannot be accidentally switched on.

Ensure a stable voltage, when working with a generator, before the converter and MP1 pump is connected.

7.1 Connection of the MP 1/Redi-Flo2 pump to the converter

Connect the power (motor) cable from the pump with the power/motor cable of the converter.

Never fit or remove the motor cable plug from the converter unless the electricity supply to the converter has been switched off.

Power / motor cable

Mains supply

Fig. 9 Converter connections

8. Start-up and operation

8.1 Start-up

Switch on the electricity supply when the pump has been installed and connected to the converter.

- Turn switch 1 to ON to start the converter
  The display shows: StoP (see fig. 8b)
- Turn switch 2 to >> (forward)
  The display shows: H 00 (see fig 8c)

8.1.1 Speed control

- Turn switch 3 to in- or decrease the speed.
  The display shows the actual speed (see fig. 8d and 8e)

The MP 1/Redi-Flo2 pump is not designed for continuous operation like for instance remedial pumping. Continuous operation may reduce the life of the pump.

8.2 Operation

The MP 1/Redi-Flo2 pump is not designed for continuous operation like for instance remedial pumping. Continuous operation may reduce the life of the pump.

8.2.1 Setting of pump performance

When the pump speed has been changed, wait a while to let the speed settle at the set level. Afterwards, the pump capacity can be adjusted again.

8.2.2 Minimum flow

To ensure the necessary cooling of the motor, the pump should never be set so low that it gives no water.
If the flow rate suddenly falls, the reason might be that the pump is pumping more water than the monitoring well can yield. The pump performance must immediately be reduced or the pump must be stopped to avoid damage to the pump.

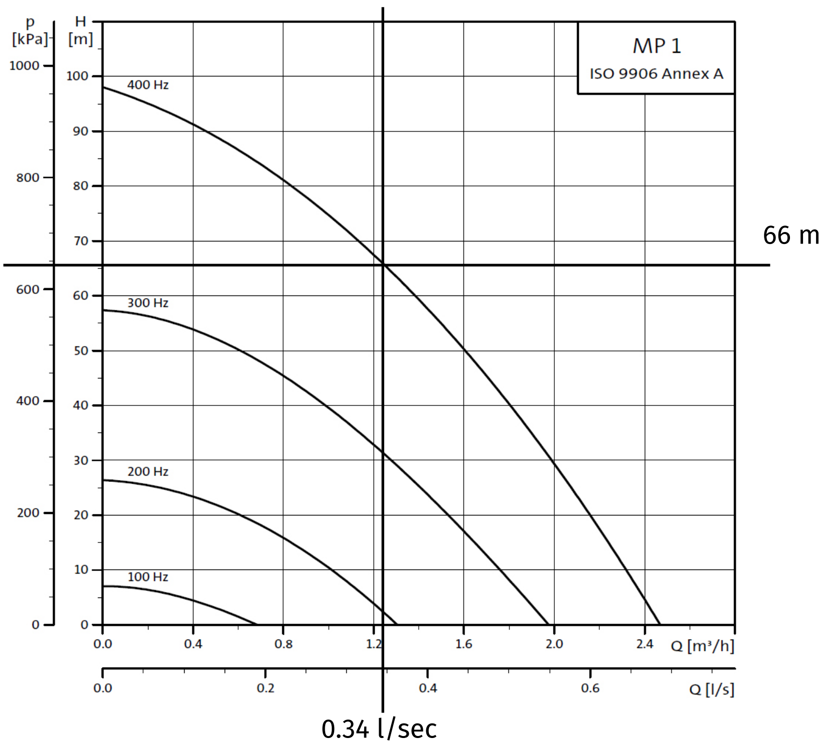
8.2.3 After use

After use, switch off the electricity supply to the converter **before** the motor cable is disconnected from the converter.

8.3 Performance curves MP 1 / Redi-Flo2 pump

Example

When the static head is 66 m, discharge of the pump will be 0,34 l/s.
In practice the discharge/pressure will be less because of losses.
At a frequency of 300 Hz or lower, the pump does not deliver water at this head.



9. Maintenance and service

9.1 Maintenance

If the pump is used alternately in several monitoring wells, it must be decontaminated before every sampling event or before possible storing. Clean the pump, cable, straining wire, etc. on the outside. Then dismantle the pump. Thoroughly clean the pump components before reassembling the pump. See section 10. Dismantling and assembly.
As the demineralised water (approx. 25 ml) in the motor may have been wholly or partly replaced by the (contaminated) groundwater, it is necessary to refill the motor with demineralised water. See section 5.4 Checking of liquid in motor.
For the replacement of wear parts including impellers, see fig. 10, a service kit (art. no.: 12274301) is available. Replace the wear parts including impellers as shown in section 10. Dismantling and assembly.
In addition, a service kit (product number 12274311) is available. This kit includes wear parts for two pumps, i.e. 4 washers, pos. 285, and 4 seals, pos. 207. See fig. 10.

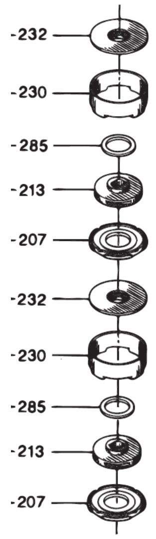


Fig. 10 Wear parts MP 1 pump

The rinsing water from the decontamination and the motor liquid must be collected and disposed of in accordance with local regulations

9.2 Service

The MP 1/Redi-Flo2 pump is specially designed for the sampling of possibly contaminated groundwater. As a precaution, Royal Eijkelkamp cannot undertake to service the pump.

Only pumps that have been thoroughly cleaned, i.e., pumps that do not contain contaminants, can be sent to Royal Eijkelkamp for maintenance. Use the registration form for service/repair. See also our website under Customer Service.
To protect the health of our staff and the environment, this document should be added with a statement that the pump has been cleaned.
Eijkelkamp may refuse to service the pump. Any costs for returning the product are for the customer.

If the converter is defective, please contact your nearest Royal Eijkelkamp distributor.

10. Dismantling and assembly

10.1 Description and overview of the MP 1/ Redi-Flo2 sampling pump system

Components

Pos.	Designation
1	Motor with suction interconnector
74	Filling screw
74a	O-ring for filling screw
200	Service kit: wear parts including impellers
201a	Chamber/pump housing
207	Seal
213	Impeller
215	Strainer
215a	Screw
230	Intermediate ring
232	Guide vanes
285	Washer
A	Pump with motor
B	Converter

A

B

Fig. 11 Pump with converter

All work on the electric parts of the MP 1/Redi-Flo2 sampling pump system must be carried out by a qualified service engineer.

If the motor, motor cable, converter or converter cable is defective, please contact your nearest Royal Eijkelkamp distributor.

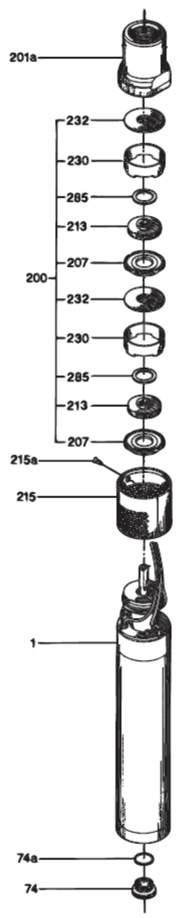


Fig. 12 Pump components

10.2 Dismantling the pump

Procedure (see fig. 12):
1. Place the pump in upright position with the discharge port on top.
2. If the pump is fitted with hose and fittings, remove these.
3. Slacken and remove the screw (pos. 215a).
4. Remove the strainer (pos. 215).
5. Screw (right-hand thread) the pump housing (pos. 201a) off the suction interconnector on the motor (pos. 1).
6. Pull the pump housing and the wear parts including impellers (pos. 200) off the motor shaft. Push the wear parts including impellers out of the pump housing from the discharge side.
7. Dismantle the wear parts including impellers (pos. 200).
8. Clean the holes in the suction interconnector.
9. Clean and check all parts. See section 10.3 Checking of components.

For assembly of the pump, see section 10.4 Assembling the pump.

10.3 Checking of components

When the pump has been dismantled, all parts must be cleaned and checked for fractures, corrosion and wear. Apart from the visual inspection, it is necessary to measure the following parts:

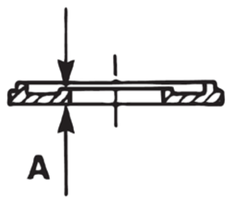


Fig. 13 Seal (pos. 207) - A = minimal 1.5 mm

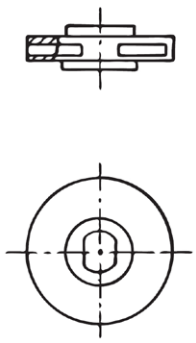


Fig. 14 Impeller (pos. 213) - no measurable wear

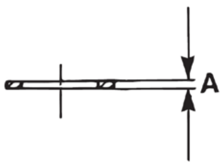


Fig. 15 Washer (pos. 285) - A = minimal 1.0 mm

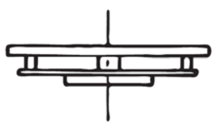


Fig. 16 Guide vanes (pos. 232) - no measurable wear

10.4 Assembling the pump

Procedure (see fig. 17):

1. Fit the seal (pos. 207) to the intermediate ring (pos. 230). The dogs of the intermediate ring must engage with the seal.
2. Position the intermediate ring and the seal on the motor with suction interconnector (pos. 1).
3. Fit the impeller (pos. 213) to the shaft and push it against the seal (pos. 207). The skirt of the impeller must fit into the hole of the seal.
4. Fit the washer (pos. 285) to the impeller.
5. Fit the guide vanes (pos. 232) to the intermediate ring.

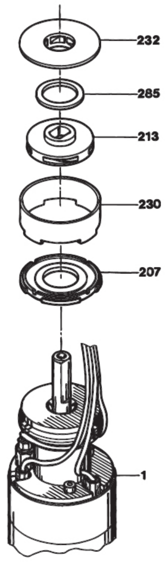


Fig. 17 Assembling the pump

6. Repeat the procedure with seal, intermediate ring, impeller, washer and guide vanes.
7. Push the pump housing (pos. 201a) over the wear parts including impellers (pos. 200) and screw it on the suction interconnector on the motor (pos. 1). See fig. 12.
8. Position the cable along the pump housing (in the recess).
9. Push the strainer (pos. 215) over the pump housing, and press it against the motor. Turn the strainer to the right so that the hole of the strainer and that of the pump housing are in the same position.
10. Fit and tighten the screw (pos. 215a).

The pump is now assembled and it can be tested.

11. Trouble shooting

11.1 Fault code messages

Fault Code	No.	Description	Suggested remedy
no-FLt	00	No fault	Not required
O I-b	01	Brake channel over current	Check external brake resistor condition and connection wiring
OL-br	02	Brake resistor overload	The drive has tripped to prevent damage to the brake resistor
O-I	03	Output Over Current	Instantaneous Over current on the drive output. Excess load or shock load on the motor.
I_t-trP	04	Motor Thermal Overload (I2t)	The drive has tripped after delivering >100% of value in P-08* for a period of time to prevent damage to the motor.
PS-trP	05	Power stage trip	Check for short circuits on the motor and connection cable
O-Volt	06	Over voltage on DC bus	Check the supply voltage is within the allowed tolerance for the drive. If the fault occurs on deceleration or stopping, increase the deceleration time in P-04* or install a suitable brake resistor and activate the dynamic braking function with P-34*
U-Volt	07	Under voltage on DC bus	The incoming supply voltage is too low. This trip occurs routinely when power is removed from the drive. If it occurs during running, check the incoming power supply voltage and all components in the power feed line to the drive.
O-t	08	Heatsink over temperature	The drive is too hot. Check the ambient temperature around the drive is within the drive specification. Ensure sufficient cooling air is free to circulate around the drive. Increase the panel ventilation if required. Ensure sufficient cooling air can enter the drive, and that the bottom entry and top exit vents are not blocked or obstructed.
U-t	09	Under temperature	Trip occurs when ambient temperature is less than -10°C. Temperature must be raised over -10°C in order to start the drive.
P-dEF	10	Factory Default parameters loaded	
E-trIP	11	External trip	E-trip requested on digital input 3. Normally closed contact has opened for some reason. If motor thermistor is connected check if the motor is too hot.
SC-ObS	12	Optibus comms loss	Check communication link between drive and external devices. Make sure each drive in the network has its unique address.
FLt-dc	13	DC bus ripple too high	Check incoming supply phases are all present and balanced
P-LOSS	14	Input phase loss trip	Check incoming power supply phases are present and balanced
h O-I	15	Output Over Current	Check for short circuits on the motor and connection cable
th-FLt	16	Faulty thermistor on heatsink	Check the analog input connection(s)
dAtA-F	17	Internal memory fault. (IO)	Press the stop key. If the fault persists, consult you supplier
4-20F	18	4-20mA Signal Lost	Check the analog input connection(s)
dAtA-E	19	Internal memory fault. (DSP)	Press the stop key. If the fault persists, consult you supplier
F-Ptc	21	Motor PTC thermistor trip	Connected motor thermistor over temperature, check wiring connections and motor
FAn-F	22	Cooling Fan Fault (IP66 only)	Check / replace the cooling fan
O-hEAt	23	Drive internal temperature too high	Drive ambient temperature too high, check adequate cooling air is provided
AtF-01	40	Autotune Fault	The motor parameters measured through the autotune are not correct Check the motor cable and connections for continuity Check all three phases of the motor are present and balanced
AtF-02	41		
AtF-03	42		
AtF-04	43		
AtF-05	44		

SC-F01	50	Modbus comms loss fault	Check the incoming Modbus RTU connection cable Check that at least one register is being polled cyclically within the timeout limit set in P-36 Index 3*
SC-F02	51	CANopen comms loss trip	Check the incoming CAN connection cable Check that cyclic communications take place within the timeout limit set in P-36 Index 3*

* See separate manual of the converter

12. Disposal

This product or parts of it must be disposed of in an environmentally sound way:
1. Use the public or private waste collection service.
2. If this is not possible, contact the nearest Royal Eijkelkamp company/distributor.

Supplement to Installation and Operating Instructions

1. Replacement/shortening of motor cable

The submersible drop cable must be complete and without cable joint from the motor to the converter.

A previously connected cable must be fitted with a new cable kit before it can be reused. See 3. Shortening of motor cable.
A video instruction can be found at www.eijkelkamp.com and on the YouTube channel of Royal Eijkelkamp.

2. Replacement of motor cable

Slacken and remove the screw, pos. 215a, together with the strainer, pos. 215. See fig. 1.

Screw the pump housing, pos. 201a, (right-hand thread) off the suction interconnector, pos. 214. Pull the pump housing and the impeller assembly, pos. 200, off the motor shaft.

Push the impeller assembly out of the pump housing from the discharge side.

Slacken the screw, pos. 20k, for the earth lead and pull it off the screw, pos. 222a, together with the earth lead and the washers, pos. 20d and 20f.

Slacken and remove the screws, pos. 222 and 222a

Pull the suction interconnector, pos. 214, off the motor.

Slacken and remove the screws, pos. 20b, holding the motor cable.

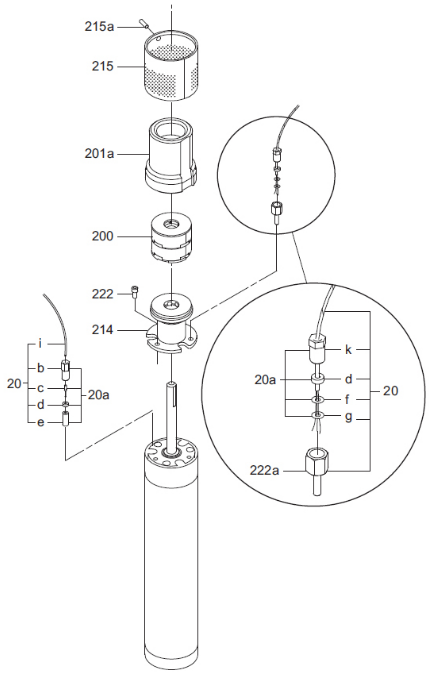


Fig. 1 MP 1/Redi-Flo2 pump components

Pull the motor cable off the motor.

Screw positions 20d and 20e out of the motor using a small screwdriver and precision electronic pliers.

Before fitting the motor cable, clean the holes in the motor.

Pull positions 20b, 20d and 20e on the three leads (phases) of the motor cable. On the earth lead (yellow/green), the order is pos. 20k, 20d and 20f. See fig. 1.

Bend the stripped end of the earth lead. See fig. 1.

When fitting the plugs in the motor, the first plug can be fitted arbitrarily. Then it is very important that the colour sequence is correct. Clockwise the order is black - blue - brown. See fig. 2.

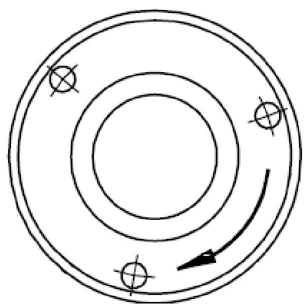


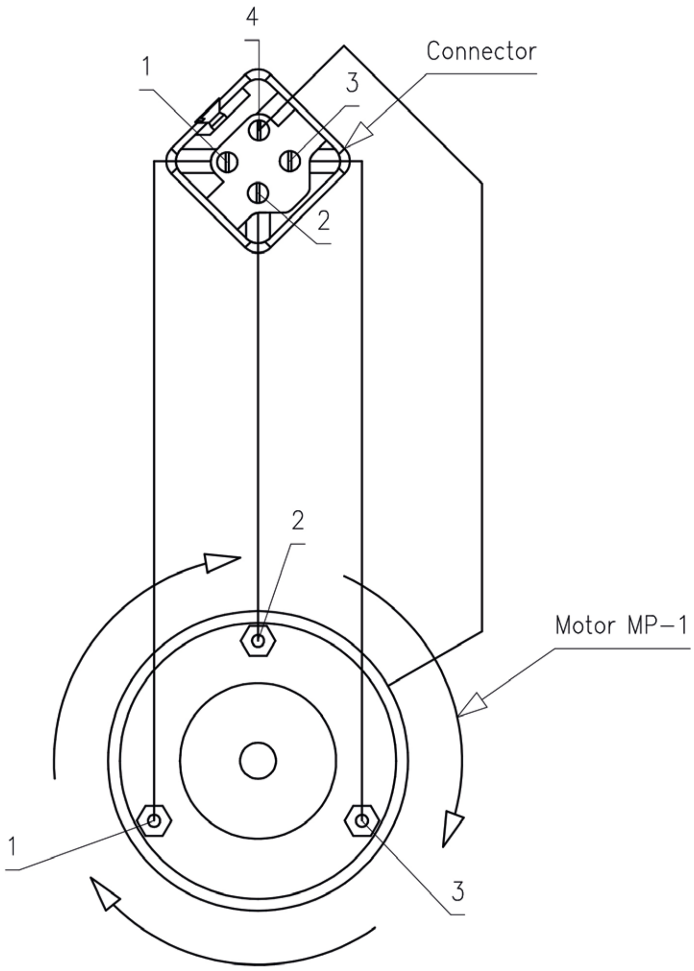
Fig. 2 Colour sequence

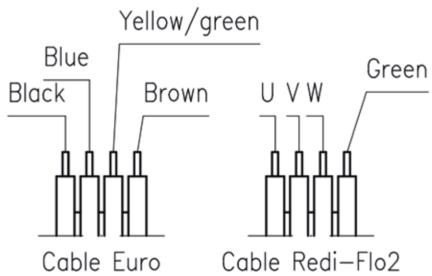
Push the plug of the lead into the plug of the stator. Then press positions 20e and 20d around the lead and tighten by means of the screw, pos 20b.

Fit the suction interconnector, pos. 214, to the shaft and secure it to the motor with the screws, pos. 222 and 222a. Position the washer pos. 20g, on the screw, pos. 222a. Hold the earth lead against the washer while the screw, pos. 20k, is tightened.

Position the cable along the pump housing (in the recess). Push the strainer, pos. 215, over the pump housing and press it against the motor. Turn the strainer to the right so that the hole of the strainer and that of the pump housing are in the same position. Fit and tighten the screw, pos. 215a.

Check the direction of rotation, see 3.2 Checking of direction of rotation





Connector	Motor	Cable Euro	Cable Redi-Flo2
1	1	Blue	Blank – U
2	2	Brown	Blank – V
3	3	Black	Blank – W
4	Housing	Yellow/green	Green

3. Shortening of motor cable

Motor cables with a common plastic sheath <u>cannot</u> be repaired or shortened. See fig. 3.

Motor cables with a plastic sheath for each lead (new type of cable) can be repaired or shortened. See fig. 4.

Cut the cable (new type), separate and strip the leads. See fig. 5.

Cable to motor:
L = 72 mm, L1 = 4 mm.
Cable to frequency converter: L = 45 mm, L1 = 6 mm.

Deburr the individual leads. See fig. 6

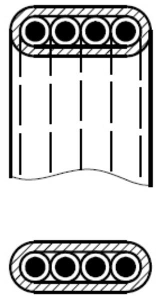


Fig. 3 Cables with common plastic sheath

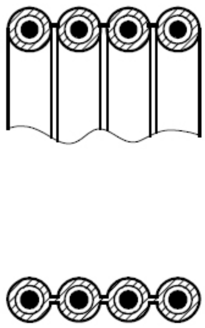


Fig. 4 Cables with plastic sheath for each lead

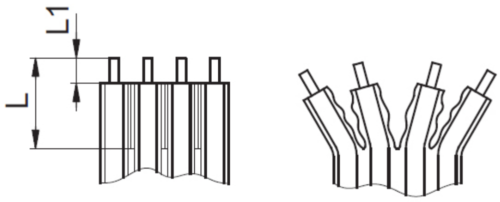


Fig. 5 Cut the cable and separate and strip the leads

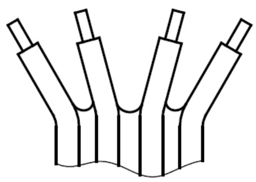


Fig. 6 Deburr the leads

3.1 Cable end to motor

Fit plug pins on the black, blue and brown leads. See fig. 7.

Press home the plug pin and fix it firmly by means of the crimping tool, part no. SV 03 74. See fig. 8.

Fit the cable in the motor. See 2. Replacement of motor cable.

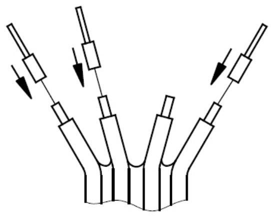


Fig. 7 Fit plug pins

3.2 Checking of direction of rotation

Observe the movement of the pump shaft when the electricity supply is switched on for a short period. The correct direction of rotation is indicated by an arrow on the side of the motor.

Fit the fittings and the hose to the pump. The pump is now reassembled and can be tested.

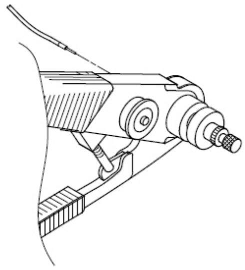


Fig. 8 Fixing the plug pin

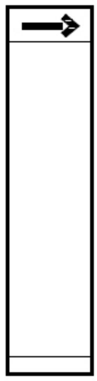
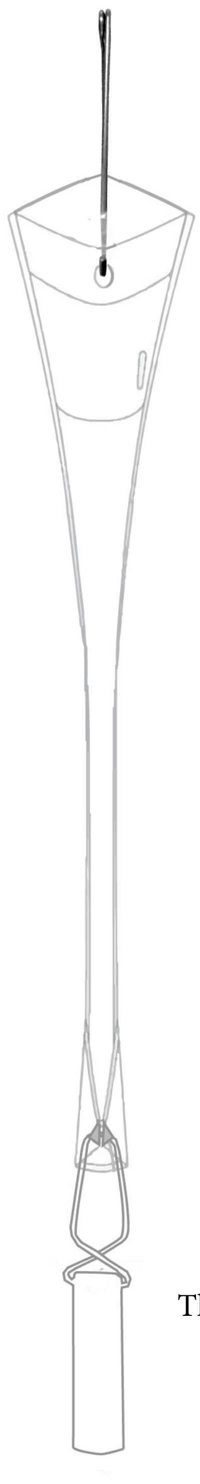


Fig. 9 Checking direction of rotation

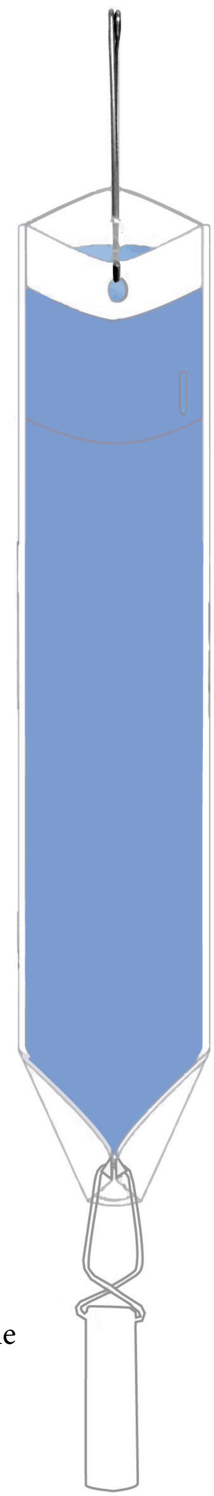
HYDRASleeve™

Simple by Design

US Patents No. 6,481,300; No. 6,837,120; others pending



Field Manual



The HydraSleeve is a simple tool. In keeping with the Simple by Design motto, these are the basic instructions. Please call if you have any questions.
800-996-2225

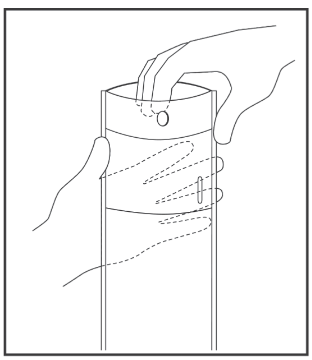
Introduction

Please read the manual in its entirety before sampling with HydraSleeve.

The HydraSleeve groundwater sampler can be used to collect a representative sample for most physical and chemical parameters without purging the well. It collects a whole water sample from a user-defined interval (typically within the well screen), without mixing fluid from other intervals. One or more HydraSleeves are placed within the screened interval of the monitoring well, and a period of time is allocated for the well to re-equilibrate. Hours to months later, the sealed HydraSleeve can be activated for sample collection. (Note: the new SpeedBags can be immediately deployed and recovered.) When activated by rapid upward motion, the check value opens and the HydraSleeve collects a sample with no drawdown and minimal agitation or displacement of the water column. Once the sampler is full, the one-way reed valve collapses, preventing mixing of extraneous, non-representative fluid during recovery. HydraSleeves go in flat and closed and come out full and closed.

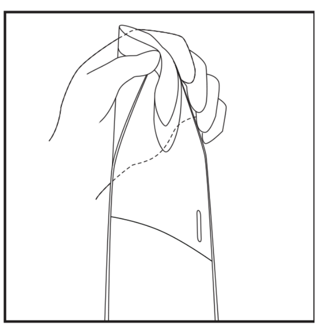
Assembly

Assembling the HydraSleeve is simple, and can be done by one person in the field, taking only a minute or two.



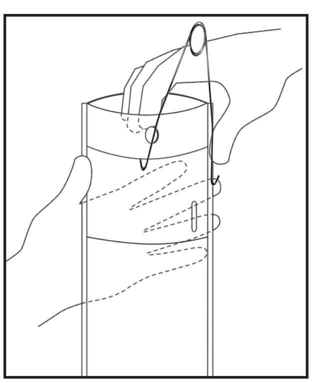
1

Remove HydraSleeve from package and grasp top to "pop" open.
Remember to save the discharge tube for later.



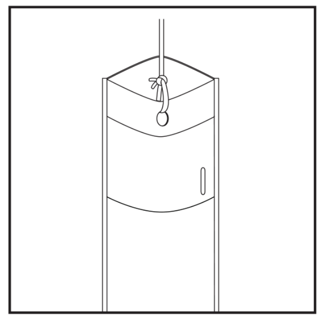
2

Squeeze side fins together at top to bend reinforcing strips outward. Crimp the corners to remain open



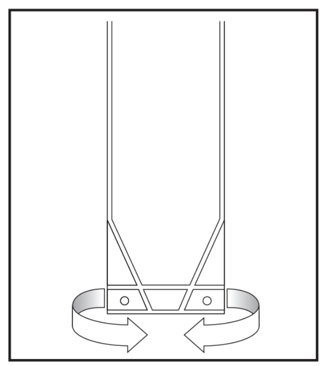
3 Preferred

Attach the tethered spring clip (see separate spring clip instructions); or



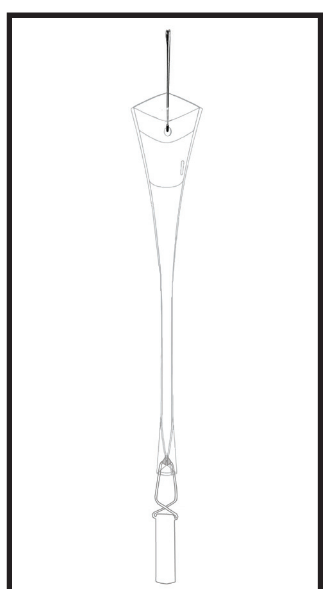
4 Option B

Alternatively attach the line to one side of the HydraSleeve if spring clips are not being used. Be sure the top is sharply crimped open.



5

Align the two holes at bottom of HydraSleeve together and attach weight with the weight clip.



6

Sampler is ready to be placed in the well.

Placing the HydraSleeve(s)

To collect a representative groundwater sample without purging, the well usually needs to be allowed time to equilibrate after placement of the sampler. When any device is lowered into a well, some mixing of the water column occurs. The diameter of the device, how tightly it fits in the well, and its shape greatly affect the degree of mixing. The flat cross-section of the empty HydraSleeve minimizes the disturbance to the water column as the sampler is lowered into position, reducing the time needed for the well to return to equilibrium. Using a SpeedBag HydraSleeve eliminates equilibration time for most wells.

There are several methods for holding a HydraSleeve in position as the well equilibrates.

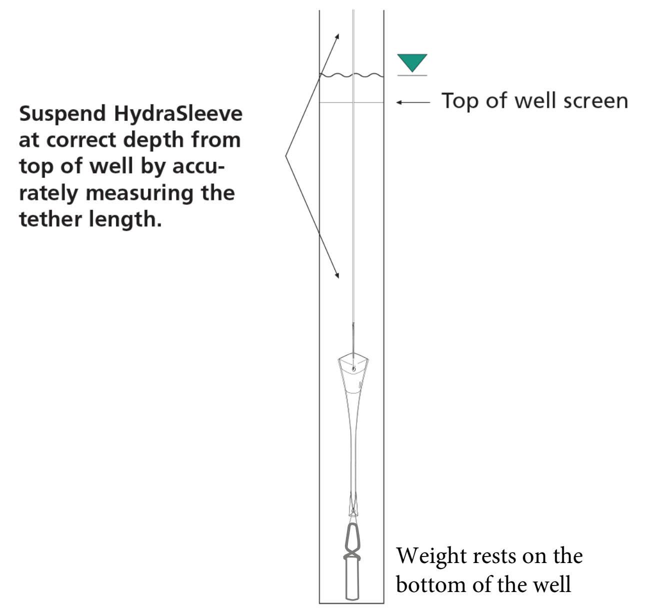
Most HydraSleeves and SuperSleeves are 3-5 feet long. The weight will go to the bottom of well but sample will come from upper half of well; because the sleeve will be suspended ~3-5 feet from the bottom up.

Most Common
TOP DOWN DEPLOYMENT (Figure 1)

Measure the correct amount of suspension line needed to "hang" the top of the HydraSleeve(s) at the desired sampling depth (in most cases, this will be at the bottom of the sampling zone). The upper end of the tether can be connected to the well cap to suspend the HydraSleeve at the correct depth until activated for sampling.

Note: For deep settings, it may be difficult to accurately measure long segments of suspension line in the field. Using our optional calibrated tether (marked sequentially in feet) will help solve this problem.

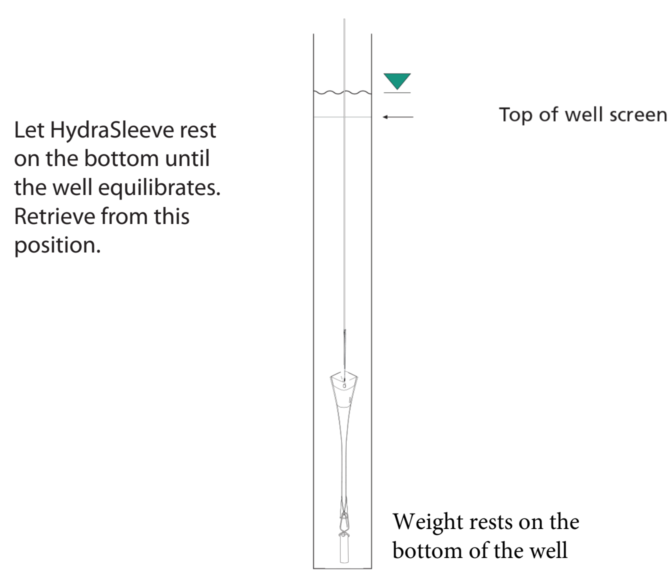
Figure 1



BOTTOM DEPLOYMENT (Figure 2)

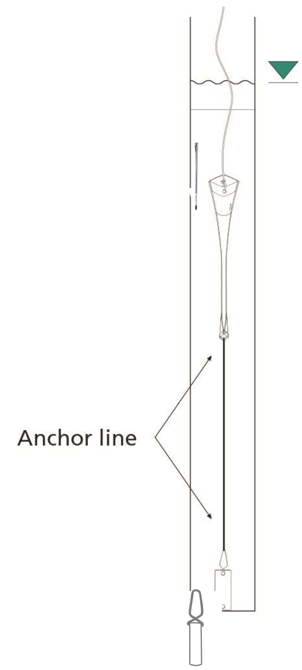
Sound the well to determine the exact depth. Lower the weighted HydraSleeve into the well and let it rest on the bottom. The HydraSleeve sits suspended off the bottom & typically sample will be collected from the area directly above the top of the sleeve at this point without adjustment. Attach the suspension line to the top of the well to suspend it at this depth. (It is often easier to measure a few feet from the bottom of the well up to the sample point, than it is to measure many feet from the top of the well down.)

Figure 2



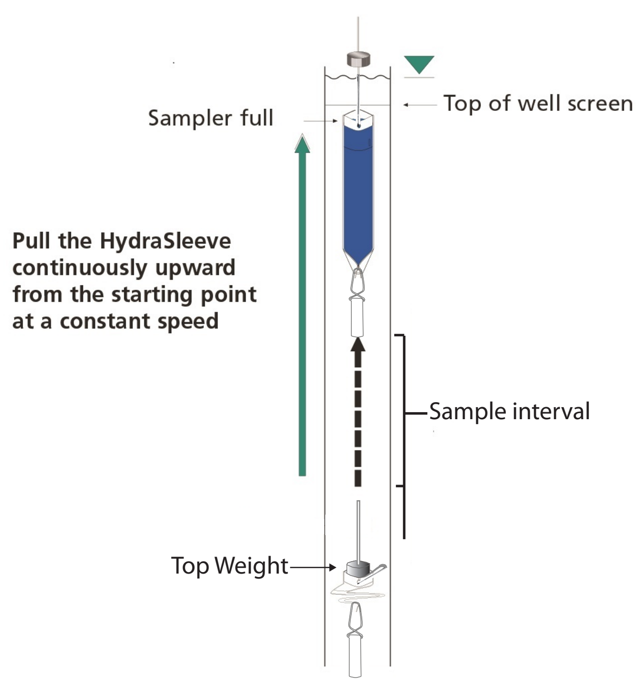
BOTTOM ANCHOR (Figure 3)
Determine the exact depth of the well. Calculate the distance from the bottom of the well to the desired sampling depth. Attach an appropriate length anchor line between the weight and the bottom of the sampler and lower the assembly until the weight rests on the bottom of the well, allowing the top of the sampler to float at the correct sampling depth.

Figure 3



TOP WEIGHTED ASSEMBLIES (Figure 4)
Using a top weight for short water collumns will compress the HydraSleeve into the bottom of the well. This allows for sample collection to begin at the lowest point possible. It provides for more saturated screen above the check valve from which to collect the sample. Insert the top wighted assembly into the well. Allow it to reach the bottom. Be sure to leave enough slack (at least the length of the sampler) so that there is enough tether to allow the HydraSleeve to compress over a period of time. The length of time and compression area are determined by the type and size of HydraSleeve being used.

Figure 4



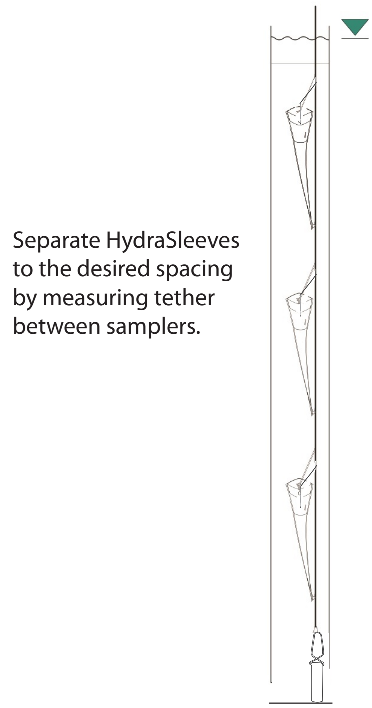
Multiple Interval Deployment

There are 3 basic methods for placing multiple HydraSleeves in a well to collect samples from different levels simultaneously.

ATTACHED TO A SINGLE TETHER (Figure 5)
To use 3 or more samplers simultaneously, we recommend attaching them all to a tether for support to prevent the sampling string from pulling apart. The weight is attached to a single length of suspension line and allowed to rest on the bottom of the well. The top and bottom of each HydraSleeve are attached to the tether at the desired sample intervals. Cable tie or stainless steel clips (optional) work well for attaching the HydraSleeves to the line. Simply push one end of the clip between strands of the rope and tie a knot at the desired point before attaching the clip to the HydraSleeve.

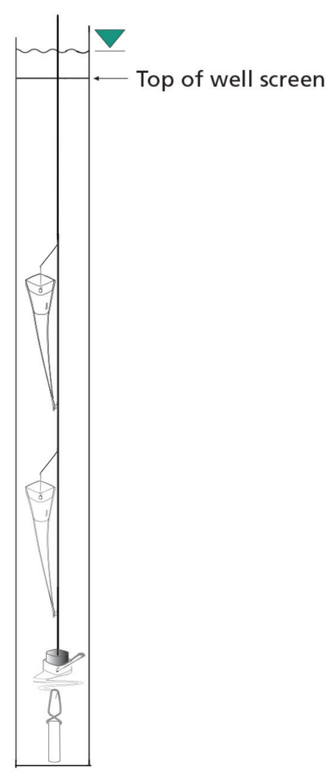
Note: if many HydraSleeves are attached to a tether, more bottom weight will be required than with a single sampler.

Figure 5



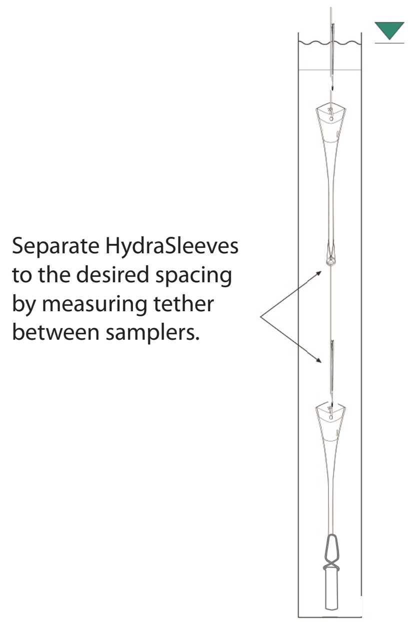
ATTACHED TO A SINGLE TETHER WITH A TOP WEIGHT ON THE BOTTOM (Figure 6)
Attach the HydraSleeves in the same manner as figure 5 but put a top weight on the bottom HydraSleeve. Remember to leave enough slack in the tether (at least the length of the bottom sleeve) so the assembly can be compressed into the bottom of the well.

Figure 6



ATTACHED END TO END (Figure 7)
To place 2 stacked HydraSleeves for vertical profiling, use one of the methods described above to locate where you want to place the bottom sampler. Attach the bottom of the top sampler to the top of the following HydraSleeve with a carefully measured length of suspension cable. Connect the weight to the bottom sampler. Heavier bottom weight will be required for this application.

Figure 7



NOTE: If multiple sleeves are being used soley to provide additional sample volume, consider a single longer (often top-weighted) custom sleeve instead of multiple shorter sleeves. It's simpler and more reliable.

Sample Collection

The HydraSleeve must move upward at a rate of one foot per second or faster (about the speed a bailer is usually pulled upward) for water to pass through the check valve into the sample sleeve. For most applications the HydraSleeve will fill within the length of the sampler. For example, a 30-inch HydraSleeve needs a total upward movement of 30 inches to fill.

There are times when the total upward distance the check valve must travel to fill the sample sleeve is longer. When using a smaller sleeve diameter in a larger diameter well the pull-to-fill distance will be longer. The upward motion can be accomplished using one of several variations of cycling or long continuous pull or any combination that moves the check valve the required distance within the saturated screen zone in the open position.

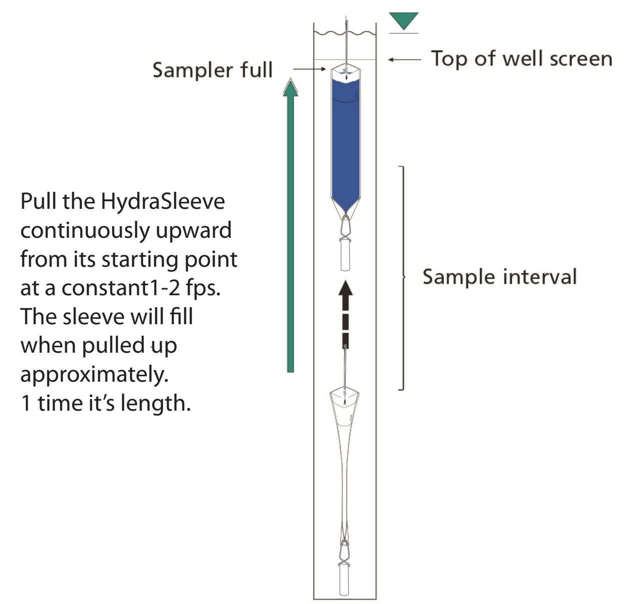
To ensure the Hydrasleeve is full and check valve closed we recommend one of the cycling methods is followed see below.

CONTINUOUS PULL (Figure 8)

Pull the HydraSleeve continuously upward from its starting point at a constant 1 to 2 feet per second until full. This method is analogous to coring the water column from the bottom up.

Note: When using this method, the screen interval must be long enough so the sampler fills before exiting the top of the screen. Fill rate is dependent on the sleeve being sized for the well diameter. 2-inch sleeves for 2-inch wells. 4-inch sleeves for 4-inch wells. If using undersized sleeves please use a cycling method to assure the sleeve fills in the screened interval.

Figure 8

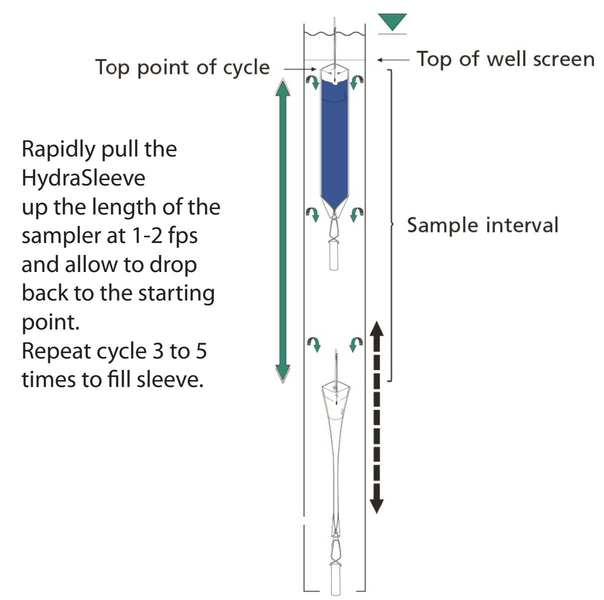


CYCLING THE SLEEVE (Figure 9)

Pull the sampler upward at about 1 to 2 feet or the length of the sampler and let it drop back to the starting point. Repeat the cycle 3 to 5 times.

This method provides a shorter sampling interval than the continuous pull method (above), and usually reduces the turbidity levels of the sample below that of numerous rapid, short cycles. The sample comes from between the top of the cycle and the top of the check valve at its resting point.

Figure 9



Sample Discharge

The best way to remove a sample from the HydraSleeve with the least amount of aeration and agitation is with the short plastic discharge tube (included).

First, squeeze the full sampler just below the top to expel water resting above the flexible check valve. **(Fig. 10, top right)** Fold the stiffeners over to make sure all of the water is off the top of the check valve.

Then, push the pointed discharge tube through the outer polyethylene sleeve as desired but at least 3-4 inches below the white reinforcing strips. **(Fig. 11, middle right)**

Note: For some contaminants (VOC's/sinkers) the best location for discharge is the middle to bottom of the sampler. This would be representative of the deeper portion of the well screen.

Discharge the sample into the desired container.**(Fig. 12, bottom right)**

Raising and lowering the bottom of the sampler or pinching the sample sleeve just below the discharge tube will control the flow of the sample. The sample sleeve can also be squeezed, forcing fluid up through the discharge tube, similar to squeezing a tube of toothpaste. With a little practice, and using a flat surface to set the sample containers on, HydraSleeve sampling becomes a one-person operation.

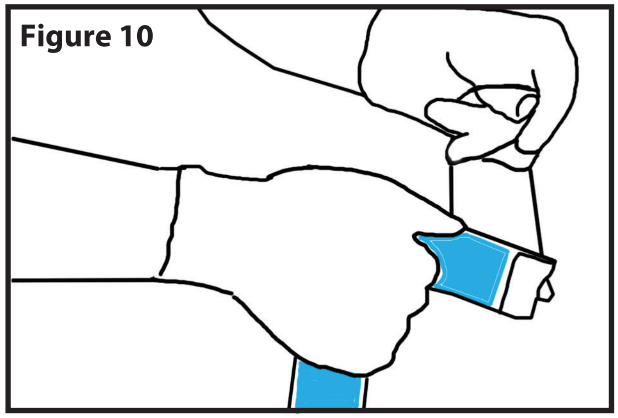


Figure 10

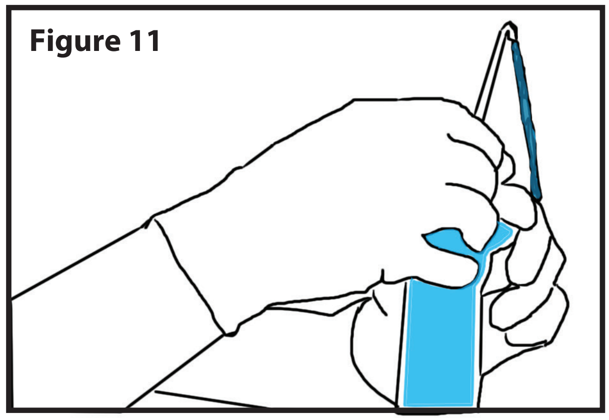


Figure 11

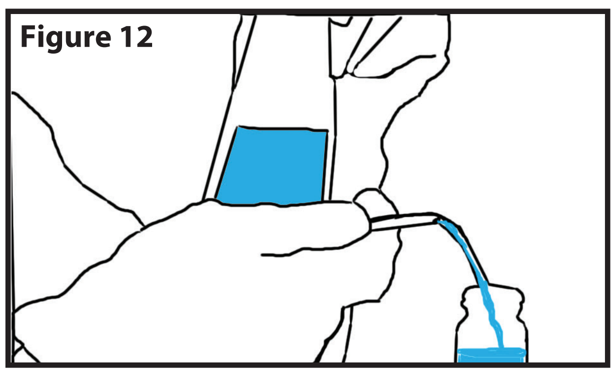


Figure 12

GeoInsight

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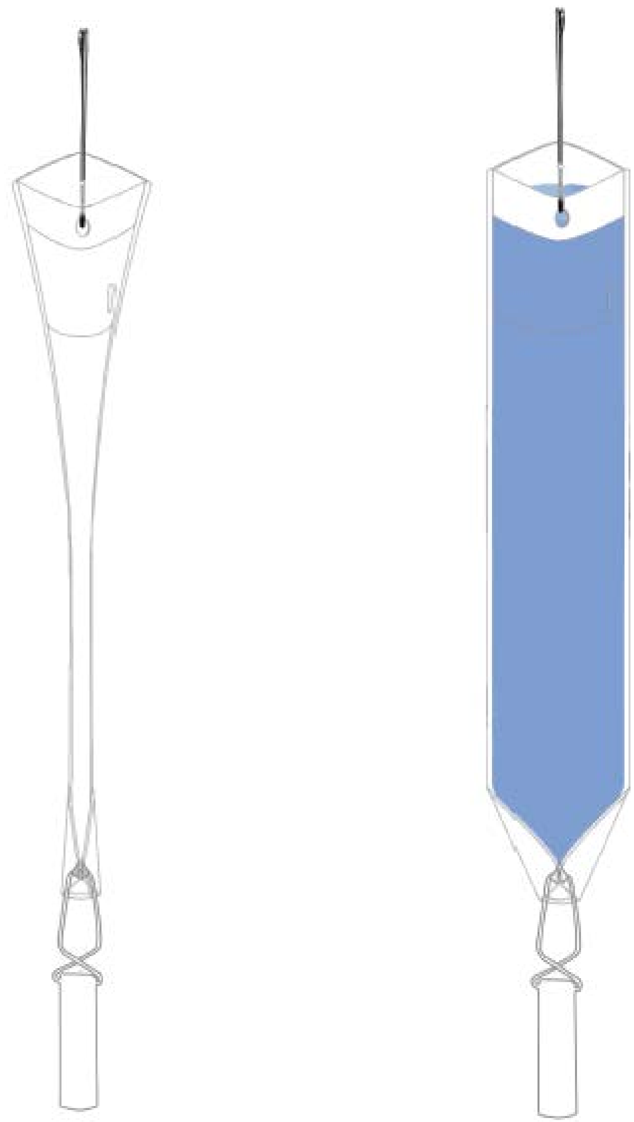
www.hydrasleeve.com info@hydrasleeve.com

HYDRASleeve™

Simple by Design

US Patent No. 6,481,300; No. 6,837,120; No. 9,726,013; others pending

Standard Operating Procedure:
Sampling Groundwater with a HydraSleeve



This guide should be used in addition to field manuals and instructions appropriate to the chosen sampling device (i.e., HydraSleeve, SpeedBag or Super/Skinny Sleeve and W3 HybridSleeve).

Find the appropriate field manual and instructions on the HydraSleeve website at http://www.hydrasleeve.com.

For more information about the HydraSleeve, or if you have questions, contact:
GeoInsight, P.O. Box 1266, Mesilla Park, NM 88047
800-996-2225, info@hydrasleeve.com.

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Introduction

The HydraSleeve is classified as a no-purge (passive) grab sampling device, meaning that it is used to collect groundwater samples directly from the screened interval of a well without having to purge the well prior to sample collection. When it is used as described in this Standard Operating Procedure (SOP), the HydraSleeve causes no drawdown in the well (until the sample is withdrawn from the water column) and only minimal disturbance of the water column, because it has a very thin cross section and it displaces very little water (<100 ml) during deployment in the well. The HydraSleeve collects a sample from within the screen only. It excludes water from any other part of the water column in the well through the use of a self-sealing check valve at the top of the sampler. It is a single-use (disposable) sampler that is not intended for reuse, so there are no decontamination requirements for the sampler itself.

The use of no-purge sampling as a means of collecting representative groundwater samples depends on the natural movement of groundwater (under ambient hydraulic head) from the formation adjacent to the well screen through the screen. Robin and Gillham (1987) demonstrated the existence of a dynamic equilibrium between the water in a formation and the water in a well screen installed in that formation, which results in formation-quality water being available in the well screen for sampling at all times. No-purge sampling devices like the HydraSleeve collect this formation-quality water as the sample, under undisturbed (non-pumping) natural flow conditions. Samples collected in this manner generally provide more conservative (i.e., higher concentration) values than samples collected using well-volume purging, and values equivalent to samples collected using low-flow purging and sampling (Parsons, 2005).

Applications of the HydraSleeve

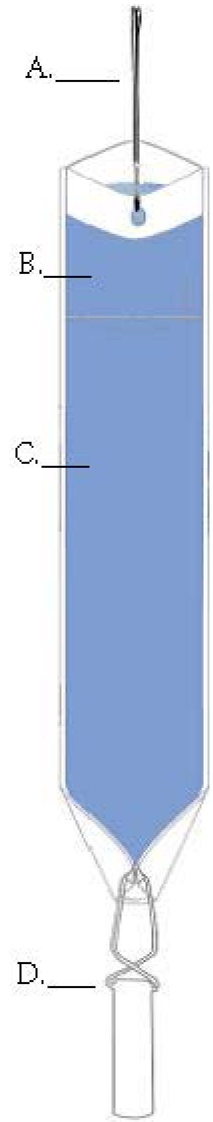
The HydraSleeve can be used to collect representative samples of groundwater for all analytes (volatile organic compounds [VOCs], semi-volatile organic compounds [SVOCs], common metals, trace metals, major cations and anions, dissolved gases, total dissolved solids, radionuclides, pesticides, PCBs, explosive compounds, and all other analytical parameters). Designs are available to collect samples from wells from 1" inside diameter and larger. The HydraSleeve can collect samples from wells of any yield, but it is especially well-suited to collecting samples from low-yield wells, where other sampling methods can't be used reliably because their use results in dewatering of the well screen and alteration of sample chemistry (McAlary and Barker, 1987).

The HydraSleeve can collect samples from wells of any depth, and it can be used for single-event sampling or long-term groundwater monitoring programs. Because of its thin cross section and flexible construction, it can be used in narrow, constricted or damaged wells where rigid sampling devices may not fit. Using multiple HydraSleeves deployed in series along a single suspension line or tether, it is also possible to conduct in-well vertical profiling in wells in which contaminant concentrations are thought to be stratified.

As with all groundwater sampling devices, HydraSleeves should not be used to collect groundwater samples from wells in which separate (non-aqueous) phase hydrocarbons (i.e., gasoline, diesel fuel or jet fuel) are present because of the possibility of incorporating some of the separate-phase hydrocarbon into the sample.

Description of the HydraSleeve

The basic HydraSleeve (Figure 1) consists of the following components*:



- A suspension line or tether (A.), attached to the spring clip or directly to the top of the sleeve to deploy the device into and recover the device from the well. Tethers with depth indicators marked in 1-foot intervals are available from the manufacturer.
- A long, flexible, 4-mil thick lay-flat polyethylene sample sleeve (C.) sealed at the bottom (this is the sample chamber), which comes in different sizes, as discussed below with a self-sealing reed-type flexible polyethylene check valve built into the top of the sleeve (B.) to prevent water from entering or exiting the sampler except during sample acquisition.
- A reusable stainless-steel weight with clip (D.), which is attached to the bottom of the sleeve to carry it down the well to its intended depth in the water column. Bottom weights available from the manufacturer are 0.75" OD and are available in a variety of sizes. An optional top weight may be attached to the top of the HydraSleeve to carry it to depth and to compress it at the bottom of the well (not shown in Figure 1);
- A discharge tube that is used to puncture the HydraSleeve after it is recovered from the well so the sample can be decanted into sample bottles (not shown).
- Just above the self-sealing check valve at the top of the sleeve are two holes which provide attachment points for the spring clip and/or suspension line or tether. At the bottom of the sample sleeve are two holes which provide attachment points for the weight clip and weight.

*Other configurations such as top weighted assemblies, Super/SkinnySleeves, Speedbags, and W3 Hybrids are available.

> **Note:** The sample sleeve and the discharge tube are designed for one-time use and are disposable. The spring clip, weight and weight clip may be reused after thorough cleaning. Suspension cord is generally disposed after one use although, if it is dedicated to the well, it may be reused at the discretion of the sampling personnel.

Selecting the HydraSleeve Size to Meet Site-Specific Sampling Objectives

It is important to understand that each HydraSleeve is able to collect a finite volume of sample because, after the HydraSleeve is deployed, you only get one chance to collect an undisturbed sample. Thus, the volume of sample required to meet your site-specific sampling and analytical requirements will dictate the size of HydraSleeve you need to meet these requirements.

Table 1. Dimensions and Volumes of HydraSleeve Models.

Diameter	Volume	Length	Lay-Flat Width	Filled Dia.
2-Inch HydraSleeves				
Standard 600 mls HydraSleeve	~600mls	30”	2.5”	1.4”
Standard 1-liter HydraSleeve	~1 Liter	38”	3”	1.9”
Super/SkinnySleeve 1-liter	~1 Liter	38”	2.5"	1.5”*
Super/SkinnySleeve 1.5-liter	~1.5 Liters	52”	2.5”	1.5”*
Super/SkinnySleeve 2-liter	*~2Liters*	*66"*	*2.5"*	*1.5"**
4-Inch HydraSleeves				
Standard 2.5 liter	~2 Liters	38”	4”	2.7”

* outside diameter on the Heavy Duty Universal Super/SkinnySleeves is 1.5" however when using with schedule 40 hardware the O.D. of the assembly will be 1.9"

It's also recommended that you size the diameter of the HydraSleeve according to the diameter of the well (i.e. use 2-inch HydraSleeves in 2-inch wells). Using smaller sleeves in larger diameter wells (i.e. 2-inch HydraSleeves in 4-inch wells) will result in a longer fill rate and will require special retrieval instructions (explained later).

The volume of sample collected by the HydraSleeve varies with the diameter and length of the HydraSleeve. Dimensions and volumes of available HydraSleeve models are detailed in Table 1.

HydraSleeves can be custom-fabricated by GeoInsight in varying diameters and lengths to meet specific volume requirements. HydraSleeves can also be deployed in series (i.e., multiple HydraSleeves attached to one tether) to collect additional sample to meet specific volume requirements, as described below.

If you have questions regarding the availability of sufficient volume of sample to satisfy laboratory requirements for analysis, it is recommended that you contact the laboratory to discuss the minimum volumes needed for each suite of analytes. Laboratories often require only 10% to 25% of the volume they specify to complete analysis for specific suites of analytes, so they can often work with much smaller sample volumes that can easily be supplied using a HydraSleeve.

HydraSleeve Deployment

Information Required Before Deploying a HydraSleeve

Before installing a HydraSleeve in any well, you will need to know the following:

- The inside diameter of the well
- The length of the well screen
- The water level in the well
- The position of the well screen in the well
- The total depth of the well

The inside diameter of the well is used to determine the appropriate HydraSleeve diameter for use in the well. The other information is used to determine the proper placement of the HydraSleeve in the well to collect a representative sample from the screen (see HydraSleeve Placement, below), and to determine the appropriate length of tether to attach to the HydraSleeve to deploy it at the appropriate position in the well.

Most of this information (with the exception of the water level) should be available from the well log; if not, it will have to be collected by some other means. The inside diameter of the well can be measured at the top of the well casing, and the total depth of the well can be measured by sounding the bottom of the well with a weighted tape. The position and length of the well screen may have to be determined using a down-hole camera if a well log is not available. The water level in the well can be measured using any commonly available water-level gauge.

HydraSleeve Placement

The HydraSleeve is designed to collect a sample directly from the well screen. It fills by pulling it up through the screen a distance equivalent to the length of the sampler when correctly sized to the well diameter. This upward motion causes the top check valve to open, which allows the device to fill. To optimize sample recovery, it is recommended that the HydraSleeve be placed in the well so that the bottom weight rests on the bottom of the well and the top of the HydraSleeve is as close to the bottom of the well screen as possible. This should allow the sampler to fill before the top of the device reaches the top of the screen as it is pulled up through the water column, and ensure that only water from the screen is collected as the sample. In short-screen wells, or wells with a short water column, it may be necessary to use a top-weight on the HydraSleeve to compress it in the bottom of the well so that, when it is recovered, it has room to fill before it reaches the top of the screen.

Example

2" ID PVC well, 50' total depth, 10' screen at the bottom of the well, with water level above the screen (the entire screen contains water).

Correct Placement (figure 2): Using a standard HydraSleeve for a 2" well (2.5" flat width/1.5" filled OD x 30" long, 600 ml volume), deploy the sampler so the weight (a 5 oz., 2.5" long weight with a 2" long clip) rests at the bottom of the well. The top of the sleeve is thus set at ~34" above the bottom of the well. When the sampler is recovered, it will be pulled upward approximately 30" before it is filled; therefore, it is full (and the top check valve closes) at approximately 64" (5.3 feet) above the bottom of the well, which is well before the sampler reaches the top of the screen. In this example, only water from the screen is collected as a sample.

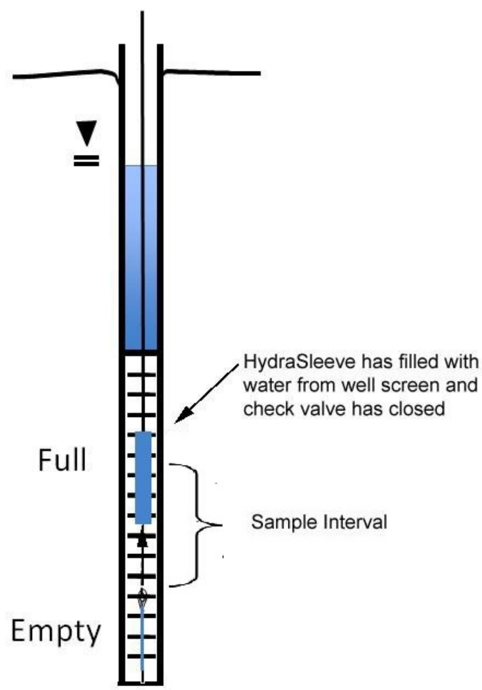


Figure 2. Correct Placement of HydraSleeve.

Incorrect Placement (figure 3): If the well screen in this example was only 5' long, and the HydraSleeve was placed as above, it would not fill before the top of the device reached the top of the well screen, so the sample would include water from above the screen, which may not have the same chemistry.

The solution? Deploy the HydraSleeve with a top weight, so that it is collapsed to within 6" of the bottom of the well. When the HydraSleeve is recovered, it will fill within 36" (3 feet) from the bottom of the well, or 2-feet before the sampler reaches the top of the screen, so it collects only water from the screen as the sample.

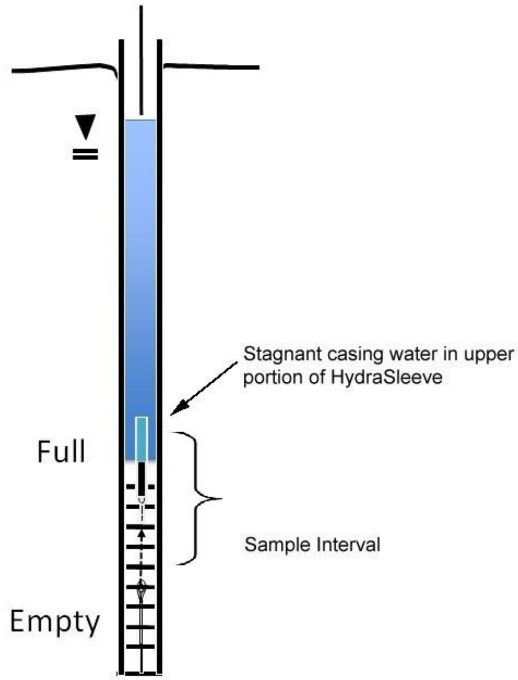


Figure 3. Incorrect placement of HydraSleeve.

This example illustrates one of many types of HydraSleeve placements. More complex placements are discussed in a later section.

NOTE: Using smaller diameter HydraSleeves (2-inch) in larger diameter wells (4-inch) causes a slower fill rate. Special retrieval methods are necessary if this is your set up (shown later in this document).

Procedures for Sampling with the HydraSleeve

Collecting a groundwater sample with a HydraSleeve is usually a simple one-person operation.

> **Note:** Before deploying the HydraSleeve in the well, collect the depth-to-water measurement that you will use to determine the preferred position of the HydraSleeve in the well. This measurement may also be used with measurements from other wells to create a groundwater contour map. If necessary, also measure the depth to the bottom of the well to verify actual well depth to confirm your decision on placement of the HydraSleeve in the water column.
>
> Measure the correct amount of tether needed to suspend the HydraSleeve in the well so that the weight will rest on the bottom of the well (or at your preferred position in the well). Make sure to account for the need to leave a few feet of tether at the top of the well to allow recovery of the sleeve.

> **Note:** Always wear sterile gloves when handling and discharging the HydraSleeve.

I. Assembling the Basic HydraSleeve*

1. Remove the HydraSleeve from its packaging, unfold it, and hold it by its top.
2. Crimp the top of the HydraSleeve by folding the hard polyethylene reinforcing strips at the holes.
3. Attach the spring clip to the holes to ensure that the top will remain open until the sampler is retrieved.
4. Attach the tether to the spring clip by tying a knot in the tether.

> **Note: Alternatively, if spring clips are not being utilized, attach the tether to one (NOT both) of the holes at the top of the Hydrasleeve by tying a knot in the tether.**

5. Fold the flaps with the two holes at the bottom of the HydraSleeve together to align the holes and slide the weight clip through the holes.
6. Attach a weight to the bottom of the weight clip to ensure that the HydraSleeve will descend to the bottom of the well.

*See Super/SkinnySleeve assembly manual and HydraSleeve Field Manual for other assembly instructions.

II. Deploying the HydraSleeve

1. Using the tether, carefully lower the HydraSleeve to the bottom of the well, or to your preferred depth in the water column

   During installation, hydrostatic pressure in the water column will keep the self-sealing check valve at the top of the HydraSleeve closed, and ensure that it retains its flat, empty profile for an indefinite period prior to recovery.

> **Note:** Make sure that it is not pulled upward at any time during its descent. If the HydraSleeve is pulled upward at a rate greater than 0.5'/second at any time prior to recovery, the top check valve will open and water will enter the HydraSleeve prematurely.

2. Secure the tether at the top of the well by placing the well cap on the top of the well casing and over the tether.

> **Note:** Alternatively, you can tie the tether to a hook on the bottom of the well cap (you will need to leave a few inches of slack in the line to avoid pulling the sampler up as the cap is removed at the next sampling event).

III. Equilibrating the Well

The equilibration time is the time it takes for conditions in the water column (primarily flow dynamics and contaminant distribution) to restabilize after vertical mixing occurs (caused by installation of a sampling device in the well).

- Situation: The HydraSleeve is deployed for the first time or for only one time in a well

  The basic HydraSleeve is very thin in cross section and displaces very little water (<100 ml) during deployment so, unlike most other sampling devices, it does not disturb the water column to the point at which long equilibration times are necessary to ensure recovery of a representative sample.

  In some cases, like when useing the SpeedBags, the HydraSleeve can be recovered immediately (with no equilibration time) or within a few hours. In regulatory jurisdictions that impose specific requirements for equilibration times prior to recovery of no-purge sampling devices, these requirements should be followed.

  NOTE: If using top weights additional equilibration time is needed to allow the top weight time to compress the HydraSleeve into the bottom of the well.

- Situation: The HydraSleeve is being deployed for recovery during a future sampling event.

  In periodic (i.e., quarterly, semi-annual, or annual) sampling programs, the sampler for the current sampling event can be recovered and a new sampler (for the next sampling event) deployed immediately thereafter, so the new sampler remains in the well until the next sampling event.

Thus, a long equilibration time is ensured and, at the next sampling event, the sampler can be recovered immediately. This means that separate mobilizations, to deploy and then to recover the sampler, are not required. HydraSleeves can be left in a well for an indefinite period of time without concern.

IV. HydraSleeve Recovery and Sample Collection

1. Hold on to the tether while removing the well cap.
2. Secure the tether at the top of the well while maintaining tension on the tether (but without pulling the tether upwards)
3. Measure the water level in the well.
4. Use one of the following 3 retrieval methods. In all 3 scenarios, when the HydraSleeve is full, the top check valve will close. You should begin to feel the weight of the HydraSleeve on the tether and it will begin to displace water. The closed check valve prevents loss of sample and entry of water from zones above the well screen as the HydraSleeve is recovered.

   a. In one smooth motion, pull the tether up 30”-60" (the length of the sampler) at a rate of about 1 foot per second (or faster). The motion will open the top check valve and allow the HydraSleeve to fill (it should fill in about 1:1 ratio or the length of the HydraSleeve if the sleeve is sized to fit the well). This is analogous to coring the water column in the well from the bottom up.

   b. There are times it is recommended that the HydraSleeve be oscillated in the screen zone to ensure it is full before leaving the screen area. Pull up 1-3 feet, let the sleeve assembly drop back down and repeat 3-5 times before pulling the sleeve to the surface. The collection zone will be the oscillation zone. ***When in doubt use this retrieval method.***

   c. SpeedBags require check valve activation and oscillation during recovery: When retrieving the SpeedBag, pull up hard 1-2 feet to open the check valve; let the assembly drop back down to the starting point; REPEAT THIS PROCESS 4 TIMES; and then quickly recover the SpeedBag through the well sceen to the surface.

5. Continue pulling the tether upward until the HydraSleeve is at the top of the well.
6. Discard the small volume of water trapped in the Hydrasleeve above the check valve by pinching it off at the top under the stiffeners (above the check valve).

v. Sample Discharge

NOTE: Sample collection should be done immediately after the HydraSleeve has been brought to the surface to preserve sample integrity.

Be sure you have discarded the water sitting above the check valve – see step #6 above.

1. Remove the discharge tube from its sleeve.
2. Hold the HydraSleeve at the check valve
3. Puncture the HydraSleeve at least 3-4 inches below the reinforcement strips with the pointed end of the discharge tube. NOTE: For some contaminants (VOC's/sinkers) the best location for discharge is the middle to bottom of the sampler. This would be representative of the deeper portion of the well screen.
4. Discharge water from the HydraSleeve into your sample containers. Control the discharge from the HydraSleeve by either raising the bottom of the sleeve, by squeezing it like a tube of toothpaste, or both.
5. Continue filling sample containers until all are full.

Measurement of Field Indicator Parameters

Field indicator parameter measurement is generally done during well purging and sampling to confirm when parameters are stable and sampling can begin. Because no-purge sampling does not require purging, field indicator parameter measurement is not necessary for the purpose of confirming when purging is complete.

If field indicator parameter measurement is required to meet a specific non-purging regulatory requirement, it can be done by taking measurements from water within a HydraSleeve that is not used for collecting a sample to submit for laboratory analysis (i.e., a second HydraSleeve installed in conjunction with the primary sample collection HydraSleeve [see Multiple Sampler Deployment below]).

Alternate Deployment Strategies

Deployment in Wells with Limited Water Columns

For wells in which only a limited water column needs to be sampled, the HydraSleeve can be deployed with an optional top weight in addition to a bottom weight. The top weight will collapse the HydraSleeve to a very short (approximately 6" to 24") length, depending on the length and volume of the sampler. This allows the HydraSleeve to fill in a water column only 3' to 10' in height (again) depending on the sampler size. Note the SuperSleeves accomplish the same thing but provide greater sample volume at a lower per sample cost.

Multiple Sampler Deployment

Multiple sampler deployment in a single well screen can accomplish two purposes:

1. It can collect additional sample volume to satisfy site or laboratory-specific sample volume requirements.
2. It can be used to collect samples from multiple intervals in the screen to allow identification of possible contaminant stratification.

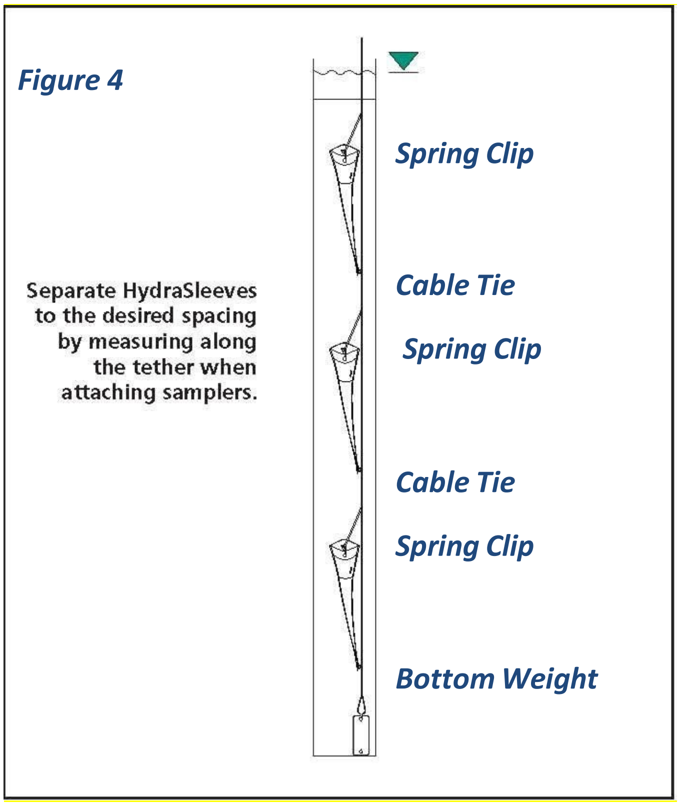


Figure 5. Multiple HydraSleeve deployment

If there is a need for only 2 samplers, they can be installed as follows. The first sampler can be attached to the tether as described above, a second attached to the bottom of the first using your desired length of tether between the two and the weight attached to the bottom of the second sampler (figure 6). This method can only be used with 2 samplers; 3 or more HydraSleeves in tandem need to be attached as described above.

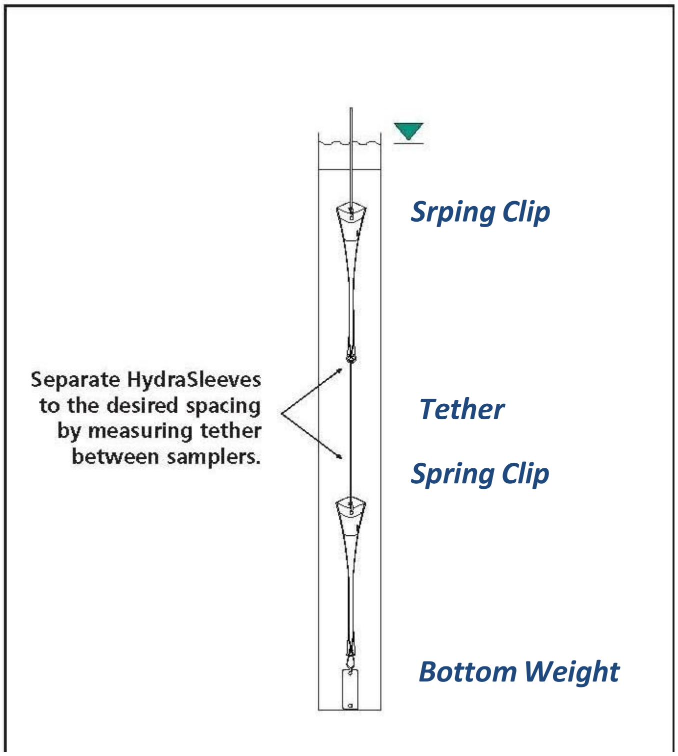


Figure 5. Alternative method for deploying multiple HydraSleeves.

In either case, when attaching multiple HydraSleeves in series, more weight will be required to hold the samplers in place in the well than would be required with a single sampler. Recovery of multiple samplers and collection of samples is done in the same manner as for single sampler deployments.

Post-Sampling Activities

The recovered HydraSleeve and the sample discharge tubing should be disposed as per the solid waste management plan for the site. To prepare for the next sampling event, a new HydraSleeve can be deployed in the well (as described previously) and left in the well until the next sampling event, at which time it can be recovered.

The weight and weight clip can be reused on this sampler after they have been thoroughly cleaned as per the site equipment decontamination plan. The tether may be dedicated to the well and reused or discarded at the discretion of sampling personnel.

References

McAlary, T. A. and J. F. Barker, 1987, Volatilization Losses of Organics During groundwater Sampling From Low-Permeability Materials, groundwater Monitoring Review, Vol. 7, No. 4, pp. 63-68

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Robin, M. J. L. and R. W. Gillham, 1987, Field Evaluation of Well Purging Procedures, groundwater Monitoring Review, Vol. 7, No. 4, pp. 85-93

Professional Plus

USER MANUAL

Item # 605596
Rev D
Drawing # A605596
March 2009

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WARRANTY

The YSI Professional Plus Instrument (Pro Plus) is warranted for three (3) years from date of purchase by the end user against defects in materials and workmanship, exclusive of batteries and any damage caused by defective batteries. Pro Plus field cables are warranted for two (2) years from date of purchase by the end user against defects in material and workmanship (6 months for non-field rugged cables*). Pro Plus sensors (pH, ORP, pH/ORP combo, Polarographic DO) are warranted for one (1) year from date of purchase by the end user against defects in material and workmanship (6 months for ammonium**, nitrate**, chloride**, and Galvanic DO). Pro Plus systems (instrument, cables & sensors) are warranted for 90 days from date of purchase by the end user against defects in material and workmanship when purchased by rental agencies for rental purposes. Within the warranty period, YSI will repair or replace, at its sole discretion, free of charge, any product that YSI determines to be covered by this warranty.

To exercise this warranty, call your local YSI representative, or contact YSI Customer Service in Yellow Springs, Ohio at +1 937 767-7241, 800-897-4151 or visit www.YSI.com (Support tab) for a Product Return Form. Send the product and proof of purchase, transportation prepaid, to the Authorized Service Center selected by YSI. Repair or replacement will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days from date of repair or replacement.

LIMITATION OF WARRANTY

This Warranty does not apply to any YSI product damage or failure caused by:

1. failure to install, operate or use the product in accordance with YSI's written instructions;
2. abuse or misuse of the product;
3. failure to maintain the product in accordance with YSI's written instructions or standard industry procedure;
4. any improper repairs to the product;
5. use by you of defective or improper components or parts in servicing or repairing the product;
6. modification of the product in any way not expressly authorized by YSI.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. YSI's LIABILITY UNDER THIS WARRANTY IS LIMITED TO REPAIR OR REPLACEMENT OF THE PRODUCT, AND THIS SHALL BE YOUR SOLE AND EXCLUSIVE REMEDY FOR ANY DEFECTIVE PRODUCT COVERED BY THIS WARRANTY. IN NO EVENT SHALL YSI BE LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES RESULTING FROM ANY DEFECTIVE PRODUCT COVERED BY THIS WARRANTY.

* The warranty period for the non-field rugged cables (605107, 605177, 605108, 605178, 605109, 605179) is listed as 6 months. However, the true "working life" of these sensors may be 3-9 months depending on storage and usage in solutions other than clean aqueous samples.

** The warranty for the ammonium, nitrate, and chloride sensors (605104, 605105, 605106) is listed as 6 months. However, the true "working life" of these sensors may be 3-9 months depending on storage and usage in solutions other than clean aqueous samples.

INTRODUCTION

Thank you for purchasing the YSI Professional Plus (Pro Plus). The Pro Plus features a waterproof (IP-67) case, backlit display and keypad, user-selectable cable options, USB connectivity, large memory with extensive site list capabilities, and a rugged, rubber over-molded case.

Reading the entire manual before use is recommended for an overall understanding of the instrument's features.

GETTING STARTED

INITIAL INSPECTION

Carefully unpack the instrument and accessories and inspect for damage. Compare received parts with items on the packing list. If any parts or materials are damaged, contact YSI Customer Service at 800-897-4151 (+1 937 767-7241) or the authorized YSI distributor from whom the instrument was purchased.

BATTERY INSTALLATION

The Pro Plus requires (2) alkaline C-cell batteries which are included with the purchase of a new instrument. Battery life depends on parameters and usage. Under normal conditions, battery life is approximately 80 hours for continuous use at room temperature. To install or replace the batteries:

1. Turn the instrument over to view the battery cover on the back.
2. Unscrew the four captive battery cover screws.
3. Remove the battery cover and install the new batteries, ensuring correct polarity alignment on the instrument or the removed cover. (Figure 1)
4. Replace the battery cover on the back of the instrument and tighten the four screws. Do NOT over-tighten.

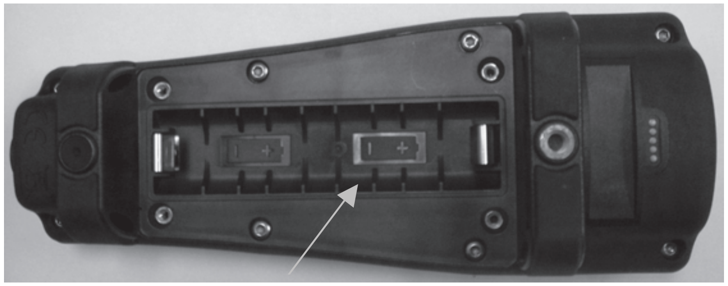


Figure 1. Pro Plus with battery cover removed. Notice battery symbols indicating polarities.

> ⓘ *Batteries must be installed in the instrument even if powering the unit via the USB connection. This will retain the correct date and time if the PC is turned off. If the USB power is disconnected and there are no batteries in the instrument, the date and time will need to be reset upon subsequent power on.*

NOTE - On subsequent battery changes you will have approximately 2 minutes to change the batteries before the clock resets. If the clock resets, the instrument will automatically bring up the Date/Time menu the next time it is powered on in order to update this information. This is important, especially if you intend to log data!

SETUP

The Pro Plus instrument has several compatible field-rugged cable/sensor options, each with temperature:

Cable:	Available Sensors:
Cable number 60520-x	DO/temp (605780 for lab BOD)
Cable number 60530-x	Conductivity/temp
Cable number 60510-x	ISE*/temp
Cable number 6051010-x	ISE*/ISE*/temp
Cable number 6051020-x	ISE*/DO/temp
Cable number 6051030-x	ISE*/conductivity/temp
Cable number 6052030-x	DO/conductivity/temp
Cable number 605790-x	DO/conductivity/ISE*/ISE*/temp (Quatro**)

*ISE (Ion Selective Electrode) notates a port that can accept pH, ORP, Ammonium, Nitrate, Chloride, and, in <u>some</u> cases, a pH/ORP combination sensor.

**Cable 605790 will be referred to as a Quatro cable throughout this manual.

All cables come in standard lengths of 1, 4, 10, 20, and 30-meters (3.28, 13, 32.8, 65.6, and 98.4-feet) with options for special order lengths up to 100-meters (328-feet) on the 60520-x cables. Contact YSI or your local representative for additional information.

In addition there are several cable options with built in sensors for the measurement of pH and ORP that are not considered field-rugged (non-replaceable sensors, less rugged single-junction sensors). These cables are

recommended for lab use or controlled conditions where a more rugged, field cable is not necessary. These cables include:

Cable number 605107	1-meter cable; single-junction pH sensor
Cable number 605177	4-meter cable; single-junction pH sensor
Cable number 605108	1-meter cable; single-junction ORP sensor
Cable number 605178	4-meter cable; single-junction ORP sensor
Cable number 605109	1-meter cable; single-junction pH/ORP sensors
Cable number 605179	4-meter cable; single-junction pH/ORP sensors

STANDARD PRO SERIES SENSOR INSTALLATION

Throughout the manual, the term "sensor" refers to the removable portion or electrode sensing portion of the cable assembly. For example, the DO sensor or pH sensor is the part that can be removed from a field cable and replaced with a new sensor. The conductivity sensor is not removable from a non-Quatro cable but still refers to the "sensing" portion and will be referred to as a sensor. This section covers most of the sensor installations on a Professional Series cable bulkhead including the following sensors:

2003 - Polarographic DO (black)	1001 - pH	1003 - pH/ORP	1005 - Chloride
2002 - Galvanic DO (gray)	1002 - ORP	1004 - Ammonium	1006 - Nitrate

See the next section of this manual for installation instructions for the Quatro cable's Conductivity/Temperature sensor.

Dual sensor bulkhead ports are numbered 1 and 2, see figure to the left. Please refer to the following tables to determine correct sensor installation into each port of a two port cable.

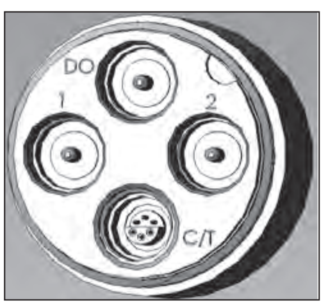
	Port 1 Options	Port 2 Options
1010 dual cable	pH	pH
	ORP	ORP
	pH or pH/ORP*	pH or pH/ORP*
	ammonium	ammonium
	chloride	chloride
	nitrate	nitrate
		none (port plug)

* If using a 6051010 cable, a sensor must be installed in port 1 for correct operation. If you install a pH/ORP combo sensor into a 6051010 cable, ORP will not be measured. It is not recommended to use a pH/ORP combo sensor on a 6051010 cable.

	Port 1 Options	Port 2 Options
1020 dual cable	pH	Polarographic DO
	ORP	Galvanic DO
	pH or pH/ORP	none (port plug)
	ammonium	
	chloride	
	nitrate	
	none (port plug)	

If using a 1020 cable, install a pH, ORP, pH/ORP, Ammonium, Nitrate or Chloride sensor in port 1 and a DO sensor in port 2.

ⓘ *If using a 605103 pH/ORP combination probe on a 6051020 or 6051030 cable you can report both pH and ORP. However, it is recommended to set ISE1 as pH and ISE2 as ORP in the Sensor Setup menu.*



The Quatro cable bulkheads are labeled 1, 2, DO, and CT, see figure to the left. All sensors except the Conductivity/Temperature sensor can be installed following the Standard Pro Series Sensor Installation instructions. Conductivity/Temperature sensor installation is described in the next section. For ease of installation, YSI recommends that you install a sensor into port 1 first; followed by DO installation, then port 2, and lastly C/T.

	Port 1 Options	Port 2 Options	DO Port Options	CT Port Options
Quatro Cable (pn: 605790)	pH	pH	Polarographic DO	5560 Conductivity/ Temperature sensor only
	ORP	ORP	Galvanic DO	
	pH or pH/ ORP*	pH or pH/ ORP*	none (port plug)	
	ammonium	ammonium		
	chloride	chloride		
	nitrate	nitrate		
		none (port plug)		

* If using a Quatro cable, a sensor must be installed in port 1 for correct operation of port 2. If you install a pH/ORP combo sensor into a Quatro cable, ORP will not be measured. It is not recommended to use a pH/ORP combo sensor on a Quatro cable.

ⓘ *Before installing either dissolved oxygen sensor, the instrument must be configured for the sensor being installed. See the Setup - Dissolved Oxygen section of this manual for instrument configuration instructions. Failure to do this may result in damage not covered under warranty.*

First, ensure both the sensor connector and sensor port on the cable are clean and dry. To connect the sensor, grasp the sensor with one hand and the sensor connection end of the cable (bulkhead) in the other. Push the sensor into the connector on the cable until it is properly seated and only one o-ring is visible. Failure to properly seat the probe may result in damage. Twist the sensor clockwise to engage threads and finger tighten (Figure 2). Do not use a tool. This connection is waterproof. Please refer to the sensor installation sheet that is included with each sensor for detailed instructions.

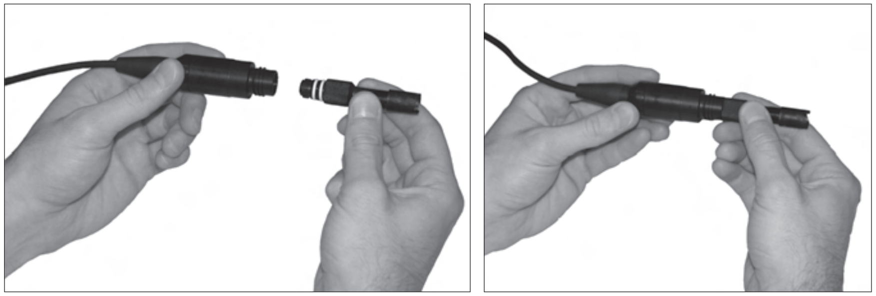


Figure 2. The image on the left shows a clean, dry sensor being aligned with the bulkhead. On the right, the sensor has been pushed into the bulkhead and is being screwed into place.

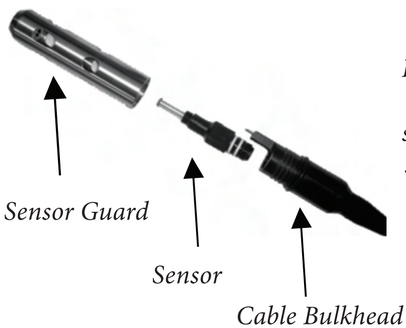


Figure 3. The sensor(s) will install directly in the cable bulkhead. Once installed, the sensor guard will protect the sensor during sampling (DO cap membrane not shown).

CONDUCTIVITY/TEMPERATURE SENSOR INSTALLATION IN A QUATRO CABLE

As mentioned, the installation of the Conductivity/Temperature sensor (model 5560) in a Quatro cable is different from all other Pro Series sensor installations. Follow these instructions when installing a conductivity/temperature sensor in a Quatro cable:

1. Locate the C/T port and, if replacing, remove the old sensor using the installation tool to loosen the stainless steel retaining nut. Once the stainless steel retaining nut has been completely unscrewed from the bulkhead, remove the old sensor from the bulkhead by pulling the sensor straight out of the bulkhead.
2. Apply a thin coat of o-ring lubricant (supplied with the sensor) to the o-rings on the connector side of the new sensor.

> ⓘ *Visually inspect the port for moisture. If moisture is found, it must be completely dried prior to sensor installation.*

3. Align the connectors of the new sensor and the port. With connectors aligned, push the sensor in towards the bulkhead until you feel the sensor seat in its port. You will experience some resistance as you push the sensor inward, this is normal
4. Once you feel the sensor seat into the port, gently rotate the stainless steel sensor nut clockwise with your fingers, Do not use the tool.
5. The nut must be screwed in by hand. If the nut is difficult to turn, STOP, as this may indicate cross threading. If you feel resistance or cross threading at any point, unscrew the nut and try again until you are able to screw the nut down completely without feeling any resistance. Damage to your cable/ sensor may occur if you force the parts together.
6. Once completely installed, the nut will seat flat against the bulkhead. At this point, use the tool that was included with the sensor to turn the nut an additional ¼ to ½ turn so it cannot come loose (figure 4). DO NOT over tighten.

> ⓘ *Do not cross thread the sensor nut. Seat nut on face of bulkhead. Do not over tighten.*

Please refer to the sensor installation sheet that is included with the conductivity/ temperature sensor for detailed instructions.

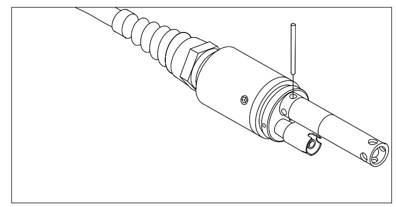


Figure 4. Installation tool used to tighten stainless steel retaining nut of 5560 conductivity/temperature sensor.

INSTALLING PORT PLUGS IN UNUSED PORTS

As necessary, install a port plug into any port that does not have an installed sensor. This will protect the bulkhead from water damage. Port plugs and a tube of o-ring lubricant are included with all Quatro cables. These items can be ordered separately if needed. To install a port plug, apply a thin coat of o-ring lubricant to the two o-rings on the port plug. After application, there should be a thin coat of o-ring lubricant on the o-rings. Remove any excess o-ring lubricant from the o-ring and/or port plug with a lens cleaning tissue. Next, insert the plug into an empty port on the bulkhead and press firmly until seated. Then, turn the plug clockwise to engage the threads and finger-tighten until the plug is installed completely. Do ***not*** use a tool to tighten the plug.

CONNECTING THE CABLE TO AN INSTRUMENT

To connect a cable, align the keys on the cable connector to the slots on the instrument connector. Push together firmly, then twist the outer ring until it locks into place (figure 5). This connection is water-proof.

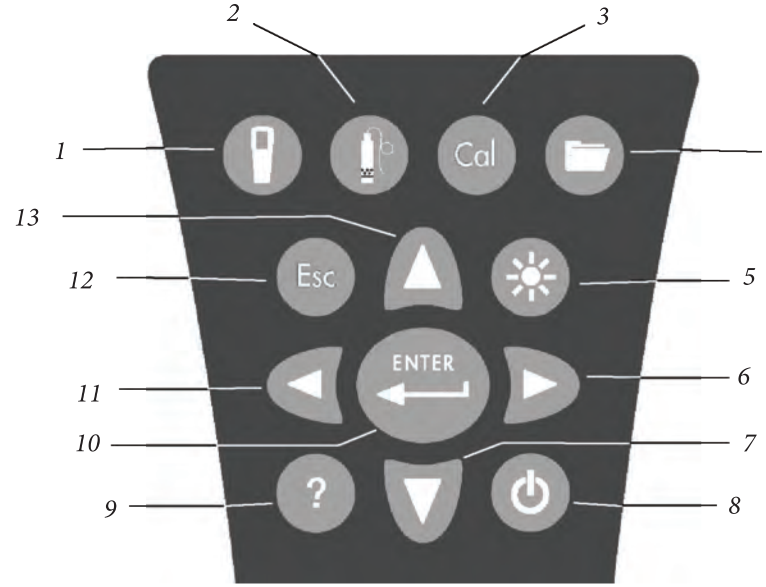
Figure 5. Note the keyed connector. The cable and instrument connectors can only be mated once the keys are properly aligned.

> ⓘ *When a sensor is not installed, the sensor and cable sensor connectors are NOT water-proof. Do not submerge the cable without a sensor or port plug installed in all available ports.*
>
> *When the cable is disconnected, the cable's instrument connector and the connector on the instrument maintain an IP-67 rating.*

SENSOR STORAGE

The cable assembly is supplied with a storage container, or sleeve, that installs on to the cable. The container is used for short-term storage (less than 30 days). Be sure to keep a small amount of moisture (tap water) in the container during storage. This is done to maintain a 100% saturated air environment which is ideal for short-term sensor storage (see Care, Maintenance, and Storage for more detailed information). Do not submerge the sensors in an aqueous solution. The intent is to create a humid air storage environment.

KEYPAD

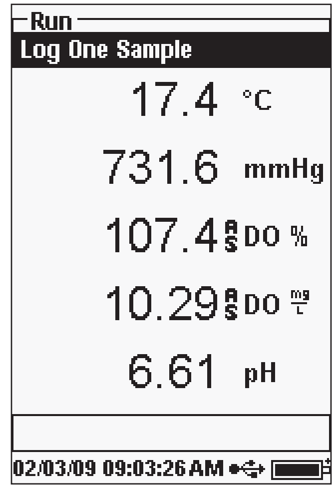


Number	*Key*	*Description*
1		**System** Opens System Menu from any screen. Use to adjust system settings.
2		**Sensor** Opens Sensor Menu from any screen. Use to enable sensors and display units.
3		**Calibrate** Opens Calibrate Menu from any screen. Use to calibrate all parameters except temperature.
4		**File** Opens File Menu from any screen. Use to view data and GLP files, set up site and folder lists, and delete data.
5		**Backlight** Press to turn the instrument backlight on and off and to adjust the display contrast when pressed with the left or right arrow key.

Number	Key	Description
6		**Right Arrow** Use to navigate right in alpha/numeric entry screens. Can be pressed simultaneously with Backlight key to increase display contrast.
7		**Down Arrow** Use to navigate through menus and to navigate down in alpha/numeric entry screens.
8		**Power** Press to turn the instrument on. Press and hold for 3 seconds to turn off.
9		**Help** Press to receive hints & tips during operation.
10		**Enter** Press to confirm selections, including alpha/numeric key selections.
11		**Left Arrow** Use to navigate left in alpha/numeric entry screens. Press to return to previous menu in all screens except alpha/numeric entry. Can be pressed simultaneously with Backlight key to decrease display contrast.
12		**Exit/Escape** Exits back to Run Screen. When in alpha/numeric entry screen, escapes to previous menu.
13		**Up Arrow** Use to navigate through menus and to navigate up in alpha/numeric entry screens.

MAIN DISPLAY

Press the Power key to turn the instrument on. The instrument will briefly display the splash screen with the YSI logo then go directly to the main run screen. The first time the instrument is powered up or if the instrument has had a battery change (with batteries removed for more than 2 minutes), you will need to set the date and time. Follow the instructions under **System Menu | Date/Time**.



The display at the left shows the run mode (main display) with temperature in °C, barometer in mmHg, DO in % and mg/L, and pH as the reported parameters. The date, time and battery level are indicated at the bottom of the screen. The logging preference of Log One Sample at a time is indicated at the top of the screen.

This screen also shows the message line towards the bottom of the display above the date and time. In this case, it doesn't show a message but messages will appear frequently to indicate calibration steps, set date and time, etc.

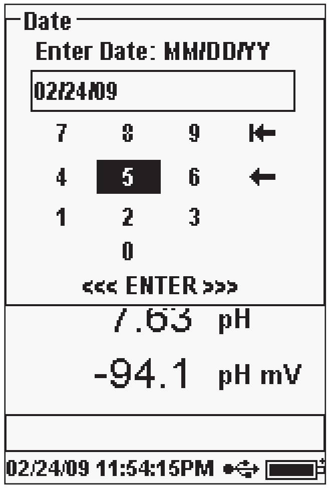
A USB symbol will show up on the bottom of the display when connected to a PC through USB with the communications saddle. The instrument will display full battery power when it is receiving power through the USB connection.

> ⓘ ***Contrast*** *– the contrast adjustment can be accomplished by pressing the backlight key and the left or right arrow key at the same time.*

MENU LAYOUT

Press Esc at anytime in the menus to escape back to the Run screen. The left arrow can be used to go back to the previous menu in all screens except alpha/numeric entry screens. You must use Esc to get out of the alpha/numeric screens if you want to exit before finishing or without saving changes. Functions that are enabled appear as a circle with a dot ⦿ or a box with a check mark ☑. Disabled functions appear as a circle only ○ or an empty ☐.

ALPHA/NUMERIC ENTRY



The numeric screens will display numbers only (shown on the left). Alpha/numeric screens will display numbers across the top and letters along the bottom rows (shown on the right). Letters appear as a common keyboard arrangement.

When an alpha or numeric character is required, the screen will show the alpha/numeric entry screen. To select a character, highlight it by using the arrow keys to move the highlight box over the desired selection. Then, press **Enter** on the keypad to confirm the selection. After confirming the selection, it will appear in the line at the top of the display.

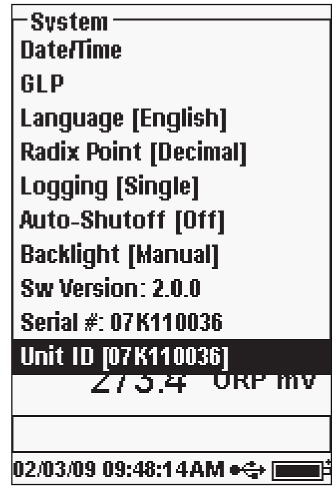
For capital letters or lower case entry, highlight "SHIFT" and press **Enter** on the keypad to change the characters from upper to lower case.

To delete the entire line of the current entry, highlight ⇤ and press **Enter** on the keypad. The ← symbol functions as a backspace key in the alpha/numeric entry screens by deleting one character at a time. Use the "SPACE" function to add a space between characters.

When you have finished entering the correct information (16 character max), highlight <<<ENTER>>> at the bottom of the screen and press **Enter** on the keypad to confirm.

The key cannot be used to escape to the previous menu from an alpha/numeric entry screen. Instead, use the Esc key to go back to the previous menu when in alpha/numeric entry screens.

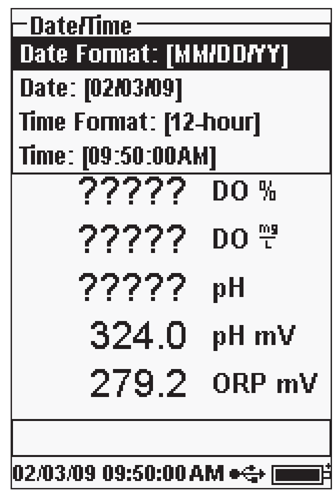
SYSTEM MENU



Press System to access any of the following menu items.

The System menu will allow you to access the setup options of the instrument including; **Date/Time**, **GLP**, **Language**, **Radix Point**, **Logging**, **Auto-Shutoff**, **Backlight**, **SW** (Software) **Version**, **Serial #**, and **Unit ID**. Any item with [brackets] shows the current setting inside the brackets. For instance, in the example at the left, Radix Point is currently set to [Decimal]. The brackets will also give a quick visual clue as to what items can be changed.

DATE/TIME



Highlight **Date/Time** from the **System** menu. Press enter to select.

Date Format – Highlight and press enter to open a sub menu for selecting the preferred date format: YY/MM/DD, MM/DD/YY, DD/MM/YY, or YY/DD/MM.

Date – Highlight and press enter to use the numeric entry screen to set the correct date.

Time Format – Highlight and press enter to open a submenu to select the preferred time format from 12-hour or 24-hour.

Time – Highlight and press enter to use the numeric entry screen to set the correct time.

The date and time will need to be reset if a battery change takes longer than 2 minutes. When this occurs, the Date/Time menu will automatically appear upon power up and require you to set the date and time.

GLP

The GLP or 'Good Laboratory Practice' file saves detailed information about calibrations. It also includes diagnostic information about the sensors. Calibrations are logged into a file, the GLP, for later review as needed. A single GLP file is utilized to store all calibration records and is capable of storing 500 records. Once the GLP file is full, the instrument will begin to overwrite the oldest record with each new calibration record.

> ⓘ *In order to keep all of your GLP records, periodically download the GLP to Data Manager and export it to another program. Otherwise, the unit will overwrite the oldest record once the memory is full. Also, since Data Manager saves GLP files under the Unit ID, you must periodically export and rename the GLP file on your PC or it will be overwritten each time you upload the GLP file from the instrument.*

Several calibration parameters are saved for each calibration record including optional ones that can be enabled by the user. Standard parameters include date/time stamp, calibration method, and sensor information. Optional, user selectable parameters include User ID, Probe ID, and User Fields 1 and 2.

The sensor specific information that is saved with each calibration point is different for each sensor. The sensor specific values saved are:

Conductivity
Method (Spec Cond, Cond, Salinity)
Cal Value (value of calibration solution)
Sensor Value (Cell Constant)
Temperature Reference (User selected in Sensor Setup menu)
Temperature Compensation Coefficient %/°C (User selected in Sensor Setup menu)
TDS Constant (User selected in Sensor Setup menu)
Temperature
Cal Cell Constant
Calibrate Status

DO
Method (%, mg/L)
Cal Value
Sensor Value (Sensor Current)
Sensor Type (Polarographic/Galvanic)
Membrane Type (Teflon Black, PE Yellow, PE Blue)
Salinity Mode (user entered value if in Manual Salinity Mode)
Temperature
Barometer
Calibrate Status

pH (up to 6 calibration points)
Buffer Value
Sensor Value (mV)
Temperature
Slope (mV/pH)
Slope (% of ideal)
Calibrate Status

ORP
Cal Solution Value
Sensor Value
Temperature
Calibrate Status

Ammonium
Buffer Value
Sensor Value (mV)
Temperature
Calibrate Status

Chloride
Buffer Value
Sensor Value (mV)
Temperature
Calibrate Status

Nitrate
Buffer Value
Sensor Value (mV)
Temperature
Calibrate Status

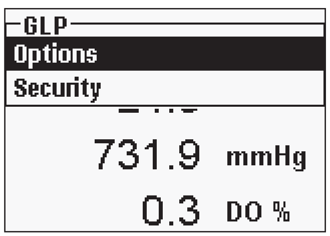
An example of a GLP record

(Operation performed is single point % DO Calibration)

*** Calibrate – DO% ***

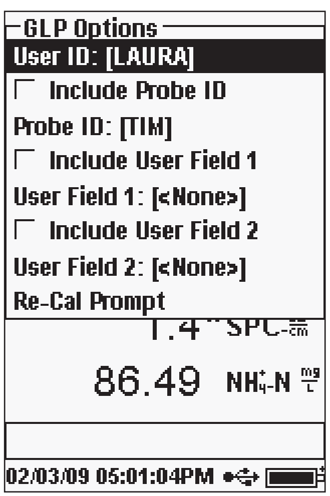
Date	02/03/09 MM/DD/YY
Time	12:14:57PM 12-hour
User ID:	Tech 1
Probe ID	08D
Method	DO Air Calibrate
Cal Value:	100.00%
Sensor Value:	5.175155uA
Sensor Type	Polarographic
Membrane Type	1.25 PE Yellow
Salinity Mode	5.175165 Auto
Temperature	23.9 °C
Barometer	731.4 mmHg
Calibrate Status	Calibrated

GLP SETTINGS



In the System menu, highlight **GLP** and press enter to view and modify the GLP settings.

Highlight Options and press enter to access **User ID**, **Probe ID**, **User Defined Fields**, and **Re-Cal Prompt**.

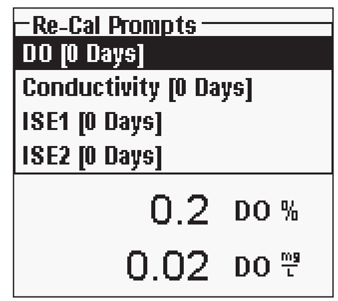


User ID may be used to identify the person calibrating the instrument. Highlight **User ID** and press enter to select, edit, or delete a User ID from a list of previously entered IDs. Or, highlight **Add New** and press enter to create a new User ID using the alpha/numeric entry screen. The User ID may also be changed in the **Calibration** menu during the calibration process. The selected User ID will be stored in the GLP file with each calibration record. A User ID could be a person's initials or badge number. The character limit is 16 characters.

Probe ID is stored with the calibration record and may be used to distinguish one cable/probe

assembly from another, typically by serial number. Highlight **Include Probe ID** and press enter to turn this function on (☑) and off (☐). Highlight **Probe ID** and press enter to add, view, edit, delete, or select a Probe ID. The Probe ID may also be changed in the **Calibration** menu during the calibration process. The character limit is 16 characters.

User Fields 1 and 2 are stored with the calibration record and may be used to enter other parameters pertinent to the user, such as weather conditions, elevation, etc. Highlight **Include User Field 1** or **Include User Field 2** and press enter to turn this function on and off. Highlight **User Field 1** or **User Field 2** and press enter to add, delete, view, edit, or select a User Field. The character limit is 16 characters. When enabled, a prompt for selecting a User Defined Field will appear during the calibration process.



Re-Cal Prompt may be used to remind the user to perform a calibration. To set a time interval, highlight the parameter you wish to be reminded about and press enter to access the numeric entry screen. Enter a value in days and press enter to confirm the reminder time. To turn off the Re-cal prompt, set the reminder to zero (0) days (this is the default).

The **Security** section of the GLP menu is a password protected area. This area includes options to set a new password and to lock access to the calibration menu. When first viewing the security menu, you will be required to enter a password. Use the "shift" on the alpha/numeric screen to switch to lower case if necessary and enter "**ysi123**". This is the default password.

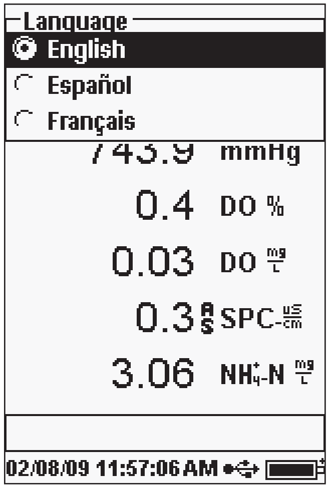
Protect Cal can be enabled (☑) or disabled (☐). When enabled, the user must know and enter the instrument's password to enter the calibration menu option. Highlight **Protect Cal** and press enter to enable or disable this feature.

Set Password allows a user to set the security password. Highlight **Set Password,** press enter, and use the alpha/numeric entry screen to set the new password. The password can have up to 16 characters.

Contact YSI Technical Support at environmental@ysi.com or +1 937 767-7241 if you forget or misplace your password.

> *Once a password is set, and the GLP security screen exited, a password must be entered to make changes under GLP security. Keep passwords in a safe place.*

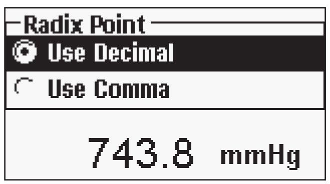
LANGUAGE



The Pro Plus can be configured to display all text in English, Spanish, French, German, Portuguese, Italian, Norwegian, Simplified Chinese, Traditional Chinese, or Japanese. From the factory, the instrument includes English, Spanish, and French language options. The other language options can be downloaded from www.ysi.com/support.

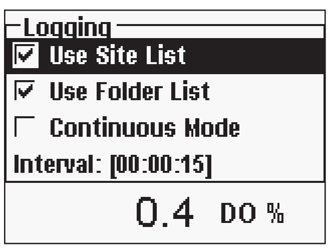
Once the appropriate language file is in the instrument, press System , highlight **Language,** and press enter. Highlight the desired language and press enter to confirm.

RADIX POINT



Radix Point allows the user the option to choose between a comma or a decimal in numeric displays. For example, 1.00 becomes 1,00 when **Use Comma** is selected. Highlight **Use Decimal** or **Use Comma** and press enter to make your selection.

LOGGING



From the System menu, highlight **Logging** and press enter to view or change the logging options. Logging options include **Use Site List**, **Use Folder List**, **Continuous Mode**, and **Interval**.

Use Site List and **Use Folder List** are optional ways of filing or 'tagging' your logged data points. If these settings are enabled, you will be prompted to select a Site and/or Folder to 'tag' to the logged data point. See the **File and Site Lists** section of this manual for information on creating Site and Folder Lists.

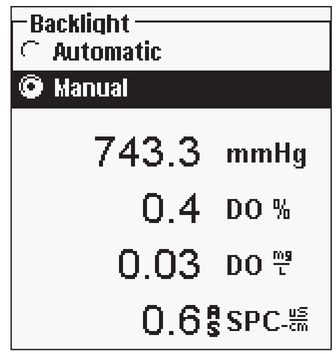
Check the box for **Continuous Mode** if you want to log samples continuously at a specific time interval. To set the length of time between logged samples, highlight **Interval** and press enter. Enter the interval as HH:MM:SS. This interval will display at the top of the screen when you select the **Start Logging** option in run mode.

To log one sample at a time, uncheck **Continuous Mode**. When Continuous Mode is unchecked, **Log One Sample** will appear at the top of the run screen.

AUTO SHUTOFF

Auto Shutoff powers the instrument off after a user specified time period. Highlight **Auto Shutoff** and press enter. Using the alpha/numeric entry screen, enter a value between 0 and 360 minutes. To disable auto shutoff, set the value to 0 (zero).

BACKLIGHT



Backlight can be set to **Automatic** or **Manual**. Automatic turns the backlight on when you turn the instrument on and when you press any key. Manual allows you to turn the backlight on or off with the backlight key . When in Automatic mode, the instrument will turn the backlight off 60 seconds after the last key press. The instrument will "reset" the 60 second time period every time a key is pressed. The lighted keypad will turn off after approximately 20 seconds.

SW VERSION (SOFTWARE VERSION)

SW Version shows the instrument's software version. The instrument's software can be updated via www.ysi.com/support. There you will find the new software files and instructions on how to update the instrument. There is no need to send the instrument back to the factory for upgrades.

SERIAL

Serial # shows the instrument's serial number and allows you to match it with the number engraved on the back of the instrument's case.

UNIT ID

Unit ID is used to identify instruments in the Data Manager software program that was included with your instrument. It is also used to identify GLP files, Site Lists, Configuration files, and Data files transferred from the instrument to the PC. The default Unit ID is the instrument's serial number. To modify the Unit ID, highlight **Unit ID**, press enter and then use the alpha/numeric entry screen. The character limit is 16 characters.

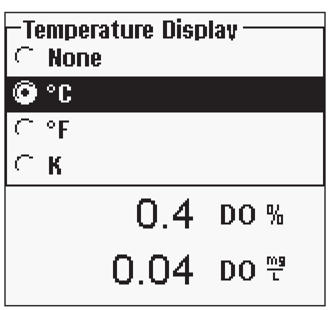
PARAMETERS: SETUP, DISPLAY, AUTO STABLE, AND CALIBRATION

The following section is separated by parameter and will discuss sensor setup, display options, auto stable features, and calibration procedures for each parameter. The sections are separated by parameter due to the versatility of the Pro Plus. You may focus solely on the parameters of your choice.

For the highest accuracy, calibrate or verify each sensor regularly. For your convenience, YSI offers 5580 Confidence Solution® which allows you to check the accuracy of pH, conductivity, and ORP readings to help determine if a sensor calibration is necessary.

If you receive an error message during a calibration that indicates questionable results, you have the option to either accept or decline the calibration. YSI recommends that you decline a questionable calibration since accepting it may result in erroneous data. After declining a questionable calibration, ensure the sensor is clean, the calibration solution is good, the calibration vessel is clean, and that you are entering the correct calibration value if entering manually. Then, try to recalibrate the sensor. If you continue to have problems, see the Troubleshooting section of this manual.

TEMPERATURE



All probe/cable assemblies, except the Quatro, have a built-in temperature sensor. The Quatro cable ships with a Conductivity/Temperature sensor that must be installed on the cable. Temperature calibration is not required nor is it available.

To set the units, press Sensor, highlight **Display** and press enter. Highlight **Temperature** and press enter. Highlight the desired

temperature units of **°F**, **°C**, or **K** and press enter to confirm the selection. Only one temperature unit may be displayed at a time. You may also choose not to display temperature. If you choose not to display temperature, other parameters that require a temperature reading will still be temperature compensated.

DISSOLVED OXYGEN (DO)

DO sensors can be used on 60520-X, 6051020-X, 6052030-X, and Quatro cables.

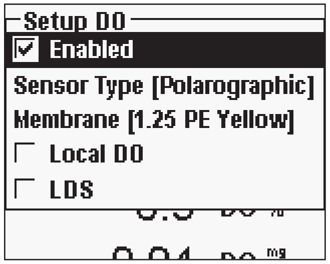
PREPARING THE DO SENSOR FOR THE FIRST TIME

The dissolved oxygen sensor is shipped with a dry, protective red cap that will need to be removed before using. It is very important to put a new membrane with electrolyte solution on the sensor after removing the red cap.

Prepare the membrane solution according to the instructions on the bottle. After mixing, allow the solution to sit for 1 hour. This will help prevent air bubbles from later developing under the membrane. Ensure you are using the correct electrolyte solution for the correct sensor. Galvanic sensors utilize electrolyte with a light blue label and Polarographic sensors utilize electrolyte with a white label. The dissolved oxygen sensor is supplied with cap membranes specific to the sensor type ordered (Polarographic or Galvanic). 5912, 5913, and 5914 membrane kits are for Galvanic sensors and the 5906, 5908, and 5909 membrane kits are for Polarographic sensors. See the **Setup - Dissolved Oxygen** section of this manual for more information on the different types of membranes available from YSI.

Remove the red cap by pulling it straight off the sensor tip. Discard or save for later use during long term storage. Thoroughly rinse the sensor tip with distilled or deionized water. Fill the cap membrane 3⁄4 full of electrolyte solution, then tap the cap with a finger to release any trapped air. Be careful not to touch the membrane portion of the cap. Thread the membrane cap onto the sensor, moderately tight. Do not use a tool. It's typical for some of the electrolyte solution to spill over. For detailed instructions on changing a membrane cap, see the **Care, Maintenance, and Storage** section of this manual.

Press Sensor, highlight **Setup** and press enter. Next, highlight **DO** and press enter.



Enabled allows you to enable or disable the Dissolved Oxygen function. Highlight **Enabled** and press enter to activate(☑) or deactivate(☐) dissolved oxygen. Disable dissolved oxygen if you do not have a dissolved oxygen sensor connected to the instrument.

> *If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable, false reading, ?????, or ----- next to the units.*

Sensor Type sets the type of oxygen sensor being used: either Polarographic (black) or Galvanic (grey). Highlight **Sensor Type** and press enter. Highlight the correct sensor type installed on the cable and press enter to confirm.

If using a ProBOD sensor/cable assembly, the sensor type should be set to polarographic.

The Pro Plus has two compatible sensors for use with a field cable:

Polarographic – This sensor has a black sensor body and is engraved with the model number 2003.

Galvanic – This sensor has a grey sensor body and is engraved with the model number 2002.

In terms of physical configuration, membrane material, and general performance, YSI Professional Series Galvanic dissolved oxygen sensors are exactly like the Professional Series Polarographic sensors. The advantage of using Galvanic sensors is convenience. Galvanic sensors provide for an instant-on sensor without the need for warm-up time but this affects the life of the sensor. Polarographic sensors last longer and have a longer warranty but require a 5-15 minute warm-up time before use or calibration.

> **IMPORTANT** – *The instrument default setting is Galvanic. Please change the **Sensor Type** to match the correct sensor. If you observe readings very close to 0 or extremely high readings (i.e. 600%), your **Sensor Type** setting (Polarographic or Galvanic) may be set incorrectly and you should immediately ensure it matches the sensor installed on your cable.*

Membrane sets the type of membrane used on the dissolved oxygen sensor. Highlight **Membrane** and press enter. Highlight the correct membrane type installed on the sensor and press enter to confirm. The DO sensor is supplied with membranes specific to the sensor type ordered and are color coded as described in the following tables.

Galvanic membrane kits:

Item	*Color*	*Material*	*Description*
5912	Black	1 mil Teflon®	Traditional membrane material
5913	Yellow	1.25 mil polyethylene	Improved response time and less flow dependence than Teflon® Ships standard with the sensor.
5914	Blue	2 mil polyethylene	Less flow dependence than 1.25 mil but somewhat slower response

Polarographic membrane kits:

Item	*Color*	*Material*	*Description*
5906	Black	1 mil Teflon®	Traditional membrane material
5908	Yellow	1.25 mil polyethylene	Improved response time and less flow dependence than Teflon® Ships standard with the sensor.
5909	Blue	2 mil polyethylene	Less flow dependence than 1.25 mil but somewhat slower response

Selecting a Dissolved Oxygen Membrane:

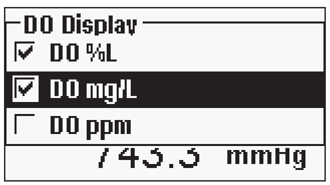
Membrane Type	*Flow Dependence After 4 Minutes*	*Typical Response Time - 95%*
5912, 5906 - Black	60%	18 seconds
5913, 5908 - Yellow	25%	8 seconds
5914, 5909 - Blue	18%	17 seconds

Local DO allows for localized DO% measurements. This sets the calibration value to 100% regardless of the altitude or barometric pressure. Highlight **Local DO** and press enter to enable (☑) or disable (☐) this function. Local DO is a method for the Pro Plus to factor in the barometric pressure on each DO measurement. In essence, if the barometric pressure changes you wouldn't notice the difference in the DO% readings in air-saturated water or water-saturated air. Local DO is ideal for EU compliance. When Local DO is enabled, an L will appear next to DO% on the run screen. DO mg/L readings are unaffected by the selection of DO Local.

LDS (Last Digit Suppression) rounds the DO value to the nearest tenth; i.e. 8.27 mg/L becomes 8.3 mg/L. Highlight **LDS** and press enter to enable (☑) or disable (☐) this function.

DISPLAY - DISSOLVED OXYGEN

Press Sensor, highlight **Display** and press enter. Highlight **DO** and press enter. All DO units can be displayed simultaneously. Highlight the unit(s) and press enter to activate (☑) or deactivate (☐) units from the run screen. Note - You will not be able to display dissolved oxygen unless it is **Enabled** in the Sensor Setup menu first, see previous section.



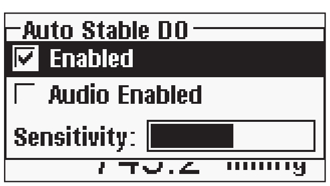
DO % will show DO readings in a percent scale from 0 to 500%.

DO mg/L will show DO readings in milligrams per liter (equivalent to ppm) on a scale from 0 to 50 mg/L.

DO ppm will show DO readings in parts per million (equivalent to mg/L) on a scale from 0 to 50 ppm.

AUTO STABLE - DISSOLVED OXYGEN

Auto Stable indicates when a reading is stable.When Auto Stable is enabled, **AS** will blink next to the parameter until it is stable. Once the parameter is stable, **AS** will stop blinking.



To enable Auto Stable, press Sensor, highlight **Auto Stable** and press enter. Highlight **DO** and press enter.

Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability

is achieved) and press enter to confirm. The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.05%
75	0.62525%
50	1.275%
25	1.8875%
0 - Least Sensitive, Sensitivity bar is set to the far left	2.5%

Example:

The instrument obtained the following data:

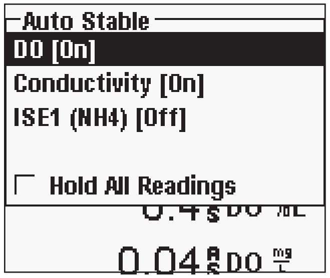
Reading #1 95.5 DO%
Reading #2 95.7 DO%
Reading #3 95.8 DO%
Reading #4 96.1 DO%
Reading #5 95.3 DO%

The instrument is programmed to determine the minimum and maximum data value over the previous 5 samples, and to compute the percent difference between those values. In this example, that gives a percent change of:

% Change = 100 * ((96.1 – 95.3) / 95.3)
% Change = 0.83%

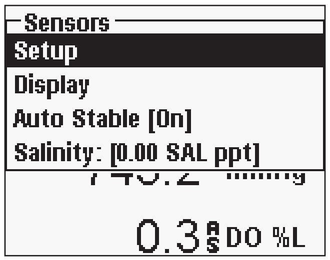
In this example, if the Sensitivity bar is set to the far right, the Auto Stable requirement would not be met and AS would continue to blink. However, if the sensitivity bar is set to the median threshold (1.275%), the Auto Stable requirement would be met and AS would display steadily on the display.

Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if DO and pH have



Auto Stable and Hold All Readings enabled, then the display will hold the readings once DO and pH have both reached their Auto Stable settings. You must press the **Esc** key to "release" the held display in order to take subsequent readings **Hold All Readings** must be reactivated after each use!

SALINITY CORRECTION



The last feature in the **Sensor** menu is the **Salinity** correction value which is used to calculate the dissolved oxygen mg/L and ammonia readings when a conductivity sensor is not in use. Press Sensor, highlight **Salinity**, and press enter. Then, use the numeric entry screen to enter the Salinity value of the water you will be testing from 0 to 70 ppt.

If using a cable with a conductivity sensor, the salinity measured by the conductivity sensor will be used in the DO and ammonia mg/L calculations and 'As Measured' will be displayed next to **Salinity** in the Sensor menu.

As the salinity of water increases, its ability to dissolve oxygen decreases. For example, fully oxygenated 20 °C water at sea level with zero salinity will hold 9.092 mg/L of dissolved oxygen. If that same sample had a salinity value of 9 ppt, then it would hold 8.621 mg/L of dissolved oxygen. Therefore, to obtain accurate mg/L readings, it is important to know the salinity of the water you will be testing and to input that value into the instrument. The salinity of fresh water is typically 0-0.5 ppt and seawater is typically 35 ppt. You will also have the opportunity to enter or modify the Salinity correction value during DO calibration.

CALIBRATION - DISSOLVED OXYGEN

The Pro Plus offers several options for calibrating dissolved oxygen: DO% in water saturated air, DO mg/L and DO ppm in a solution of known dissolved oxygen determined by a Winkler Titration, and a Zero point. If performing a zero point calibration, you must also perform a %, mg/L, or ppm calibration following the zero calibration. For both ease of use and accuracy, YSI recommends performing the following 1-point DO % water saturated air calibration:

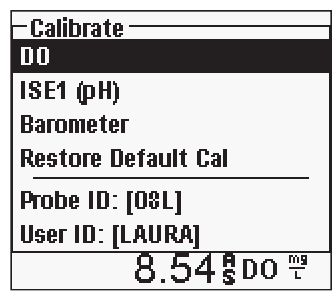
It is not necessary to calibrate in both % and mg/L or ppm. Calibrating in % will simultaneously calibrate mg/L and ppm and vice versa.

Calibrating DO % in Water Saturated Air: **1-Point Calibration**

The supplied sensor storage container (a grey sleeve for a single port cable or a screw on plastic cup for the dual-port and Quatro cables) can be used for DO calibration purposes.

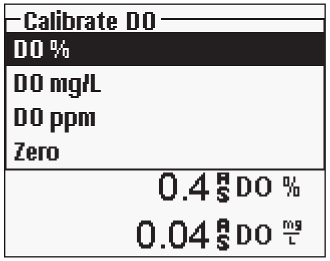
Moisten the sponge in the storage sleeve or plastic cup with a small amount of clean water. The sponge should be clean since bacterial growth may consume oxygen and interfere with the calibration. If using the cup and you no longer have the sponge, place a small amount of clean water (1/8 inch) in the plastic storage cup instead.

Make sure there are no water droplets on the DO membrane or temperature sensor. Then install the storage sleeve or cup over the sensors. The storage sleeve ensures venting to the atmosphere. If using the cup, screw it on the cable and then disengage one or two threads to ensure atmospheric venting. Make sure the DO and temperature sensors are not immersed in water. Turn the instrument on and wait approximately 5 to 15 minutes for the storage container to become completely saturated and to allow the sensors to stabilize.



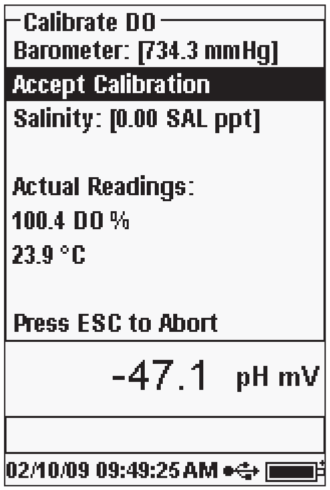
Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting your User ID and/or Probe ID if appropriate, highlight DO and press enter.



Highlight **DO %** and press enter to confirm.

The instrument will use the internal barometer during calibration and will display this value in brackets at the top of the display. Highlight **Barometer** and press enter to adjust it if needed. If the barometer reading is incorrect, it is recommended that you calibrate the barometer. Note - the barometer should be reading "true" barometric pressure (see Barometer section for more information on "true" barometric pressure). If the value is acceptable, there is no need to change it or perform a barometer calibration.



The Salinity value displayed near the top of the screen is either the salinity correction value entered in the Sensor menu or the Salinity value as measured by the conductivity sensor in use and enabled. If you are not using a conductivity sensor, the Salinity correction value should be the salinity of the water you will be testing. Highlight **Salinity** and press enter to modify this setting if necessary. See the **Salinity Correction** section of this manual for more information.

Wait for the temperature and DO% values under "Actual Readings" to stabilize, then highlight **Accept Calibration** and press enter to calibrate. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled in the GLP menu, you will be prompted to select these inputs and then press Cal to complete the calibration. The message line at the bottom of the screen will display "Calibrating Channel..." and then "Saving Configuration...".

Calibrating DO% in Water Saturated Air:
2-Point Calibration with Zero Solution

Place the sensor in a solution of zero DO.

A zero DO solution can be made by dissolving approximately 8 - 10 grams of sodium sulfite (Na_2SO_3) into 500 mL tap water or DI water. Mix the solution thoroughly. It may take the solution 60 minutes to be oxygen-free.

Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting the Probe ID and/or User ID if appropriate, highlight DO and press enter. Highlight **Zero** and press enter. Wait for the temperature and DO% values under "Actual Readings" to stabilize, then press enter to **Accept Calibration**. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then press Cal to complete the calibration. The screen will then prompt for a follow-up second point calibration.

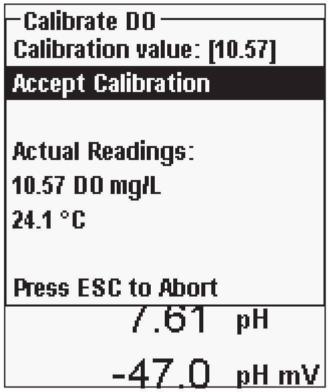
Highlight **DO%** and press enter to continue with the next calibration point. Rinse the sensor of any zero oxygen solution using clean water. Then follow the steps under Calibrating DO % in Water Saturated Air to complete the second point.

Calibrating in mg/L or ppm as a Titration:
1-Point Calibration

Place the sensor into an adequately stirred sample that has been titrated to determine the dissolved oxygen concentration. Allow the sensor to stabilize.

Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting the Probe ID and/or User ID if appropriate, highlight DO and press enter. Highlight **DO mg/L or ppm** and press enter.



Highlight **Calibration value** and press enter to manually input the sample's dissolved oxygen value. Highlight **Accept Calibration** and press enter once the temperature and Dissolved Oxygen readings stabilize. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled in the GLP menu, you will be prompted to select the fields after selecting **Accept Calibration**. After making your selection, press Cal to complete the calibration. After completing the calibration, the message line will display "Calibrating Channel..." and then "Saving Configuration...".

Calibrating in mg/L or ppm as a Titration:
2-Point Calibration with Zero Solution

Place the sensor in a solution of zero DO.

A zero DO solution can be made by dissolving approximately 8 - 10 grams of sodium sulfite (Na_2SO_3) into 500 mL tap water. Mix the solution thoroughly. It may take the solution 60 minutes to be oxygen-free.

Press Cal . Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting the Probe ID and/or User ID if appropriate, highlight DO and press enter. Highlight **Zero** and press enter. Wait for the temperature and DO% values under "Actual Readings" to stabilize, then press enter to **Accept Calibration**. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then Press Cal to complete the calibration. The screen will then prompt for a follow-up second point calibration.

Highlight the desired calibration units (mg/L or ppm) and press enter to continue with the next point. Rinse the sensor of any zero oxygen solution using clean water. To complete the second calibration point, follow the steps under Calibrating in mg/L or ppm as a Titration: **1-Point Calibration**.

BAROMETER

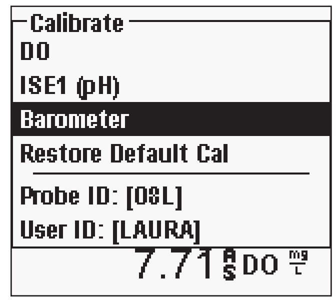
All Professional Plus instruments contain an internal barometer.

DISPLAY - BAROMETER

Press Sensor , highlight **Display** and press enter. Highlight **Barometer** and press enter. The measurement unit options are: mmHg, inHg, mBar, PSI, kPa, or Atm. Only one unit can be displayed at a time. Select **None** if you do not want to display a barometric pressure reading.

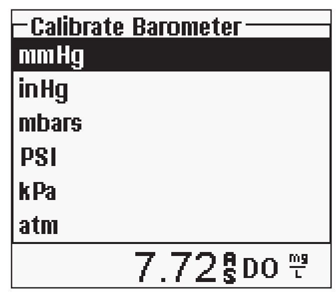
Whether or not you choose to display the barometer reading, the barometric pressure will still be used for calibrating DO% and for compensating for pressure changes if **Local DO** is enabled.

CALIBRATION - BAROMETER

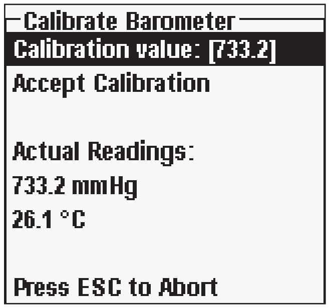


The barometer in the instrument is calibrated at the factory. If the barometer requires calibration, press **Cal** . Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting the Probe ID and/or User ID if appropriate, highlight **Barometer** and press enter.



Highlight the desired unit and press enter.



Highlight **Calibration Value** and press enter to manually enter the correct "true" barometric pressure. Next, highlight **Accept Calibration**, and press enter. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then press Cal to complete the calibration or press Esc to cancel the calibration.

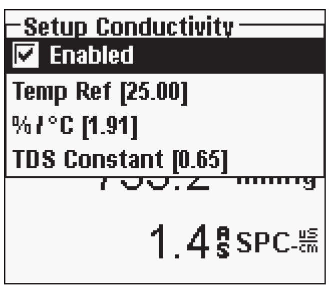
> *Laboratory barometer readings are usually "true" (uncorrected) values of air pressure and can be used "as is" for barometer calibration. Weather service readings are usually not "true", i.e., they are corrected to sea level, and therefore cannot be used until they are "uncorrected". An approximate formula for this "uncorrection" is below:*

True BP = [Corrected BP] – [2.5 * (Local Altitude in ft. above sea level/100)]

CONDUCTIVITY

Conductivity sensors are supplied with 60530-X, 6051030-X, 6052030-X , and Quatro cables. Conductivity sensors are built into the 60530-X, 6051030-X, and 6052030-X cables and are not replaceable. Conductivity/Temperature sensors are shipped with the Quatro cable, must be installed, and are replaceable.

SETUP - CONDUCTIVITY



Press Sensor, highlight **Setup,** and press enter. Highlight **Conductivity**, press enter.

Enabled allows you to enable or disable the conductivity measurement. Highlight **Enabled** and press enter to activate (☑) or deactivate (☐) conductivity. Disable conductivity if you do not have a conductivity sensor connected to the instrument.

> *If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable, false reading next to the units.*

Temp Ref (Temperature Reference) is the reference temperature used for calculating temperature compensated Specific Conductance. This will be the temperature all Specific Conductance values are compensated to. The default is 25 °C. To change the Reference Temperature, highlight **Temp Ref** and press enter. Use the numeric entry screen to enter a new value between 15.00 and 25.00 °C. Next, highlight <<<ENTER>>> at the bottom of the screen and press enter on the keypad to confirm.

%/°C (Percent per Degree Celsius) is the temperature coefficient used to calculate temperature compensated Specific Conductance. The default is 1.91% which is based on KCl standards. To change the temperature coefficient, highlight %/°C and press enter. Use the numeric entry screen to enter a new value between 0 and 4%. Next, highlight <<<ENTER>>> at the bottom of the screen and press **Enter** on the keypad to confirm.

TDS Constant is a multiplier used to calculate an estimated TDS (Total Dissolved Solids) value from conductivity. The multiplier is used to convert Specific Conductance in mS/cm to TDS in g/L. The default value is 0.65. This multiplier is highly dependent on the nature of the ionic species present in the water sample. To be assured of moderate accuracy for the conversion, you must determine a multiplier for the water at your sampling site. Use the following procedure to determine the multiplier for a specific sample:

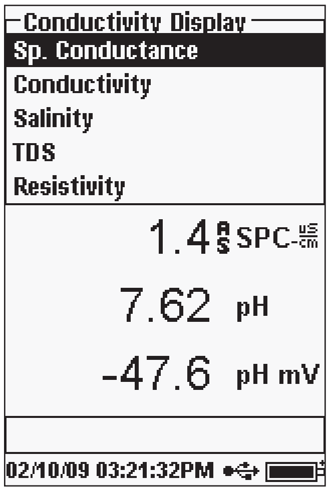
1. Determine the specific conductance of a water sample from the site;
2. Filter a portion of water from the site;
3. Completely evaporate the water from a carefully measured volume of the filtered sample to yield a dry solid;
4. Accurately weigh the remaining solid;
5. Divide the weight of the solid (in grams) by the volume of water used (in liters) to yield the TDS value in g/L for this site; Divide the TDS value in g/L by the specific conductance of the water in mS/cm to yield the conversion multiplier. Be certain to use the correct units.

> *If the nature of the ionic species at the site changes between sampling studies, the TDS values will be in error. TDS cannot be calculated accurately from specific conductance unless the make-up of the chemical species in the water remains constant.*

To change the multiplier, highlight **TDS Constant** and press enter. Use the numeric entry screen to enter a new value between 0 and 0.99. Highlight <<<ENTER>>> at the bottom of the screen and press **Enter** on the keypad to confirm.

DISPLAY - CONDUCTIVITY

Press Sensor, highlight **Display** and press enter. Highlight **Conductivity** and press enter. Highlight **Sp. Conductance** (Specific Conductance), **Conductivity**, **Salinity**, **TDS**, or **Resistivity**, and press enter to select the reporting units for each parameter. One reporting unit per parameter may be enabled. To disable a parameter, select **None**. You will not be able to display any of these parameters unless the Conductivity sensor is **Enabled** in the Sensor Setup menu first.



Sp. Conductance can be displayed in us/cm or ms/cm. Specific conductance is temperature compensated conductivity.

Conductivity can be displayed in uS/cm or mS/cm. Conductivity is the measure of a solution's ability to conduct an electrical current. Unlike specific conductance, conductivity is a direct reading without any temperature compensation.

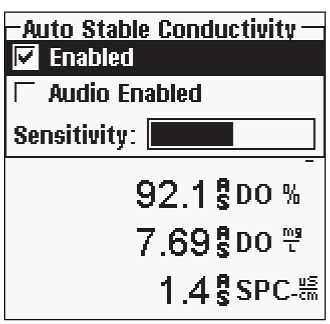
Salinity can be displayed in ppt (parts per thousand) or PSU (practical salinity units). The units are equivalent as both use the Practical Salinity Scale for calculation.

TDS can be displayed in mg/L (milligrams per liter), g/L (grams per liter), or kg/L (kilograms per liter).

Resistivity can be displayed in ohm-cm (ohms per centimeter), kohm-cm (kilo ohms per centimeter), or Mohm-cm (mega ohms per centimeter).

AUTO STABLE - CONDUCTIVITY

Press Sensor, highlight **Auto Stable** and press enter. Highlight **Conductivity** and press enter.

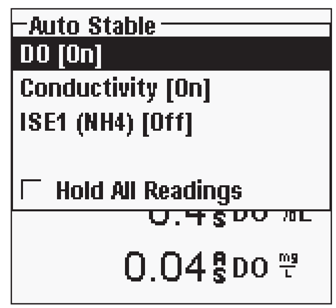


Auto Stable indicates when a reading is stable. Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability is achieved) and press enter enable (☑) or disable (☐). When Auto Stable is enabled, **AS** will blink next to the parameter until it is stable. Once the parameter is stable, **AS** will stop blinking.

The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

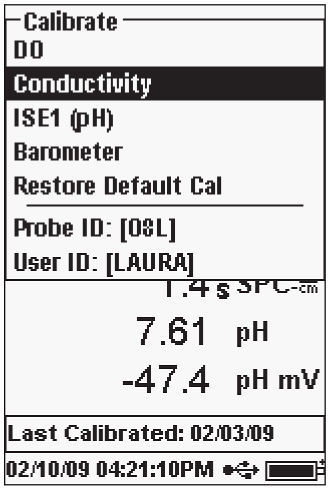
Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.025%
75	0.39375%
50	0.7625%
25	1.13125%
0 - Least Sensitive, Sensitivity bar is set to the far left	1.5%



Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if conductivity and DO have Auto Stable and Hold All Readings enabled, then the display will hold the readings once conductivity and DO have both reached their Auto Stable settings. You must press the **Esc** key to "release" the held display in order to take subsequent readings. **Hold All Readings** must be reactivated after each use!

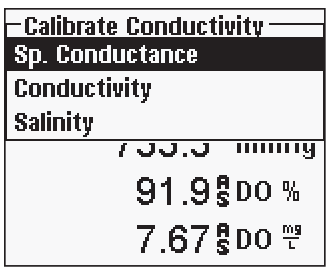
CALIBRATION - CONDUCTIVITY

> *The 6051030 ISE/conductivity cable has a specialized calibration container that resembles a large test tube. This calibration chamber can be used to calibrate the conductivity sensor with an ISE sensor installed. A ring-stand should be used to support this chamber.*



Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.

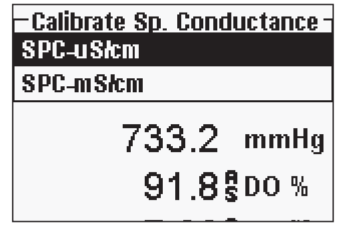
After selecting the User ID and/or Probe ID if appropriate, highlight **Conductivity** and press enter.



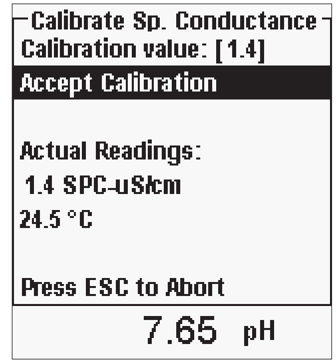
Highlight the desired calibration method; **Sp. Conductance**, **Conductivity**, or **Salinity** and press enter. YSI recommends calibrating in specific conductance for greatest ease.

Calibrating in Specific (Sp.) Conductance or Conductivity

Place the sensor into a fresh, traceable conductivity calibration solution. The solution must cover the holes of the conductivity sensor that are closest to the cable. Ensure the entire conductivity sensor is submerged in the solution or the instrument will read approximately of half the expected value!



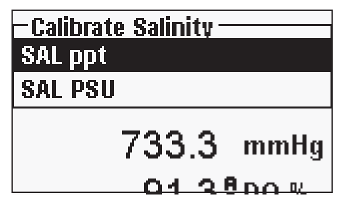
Choose the units in either **SPC-us/cm**, **C-us/cm** or **SPC-ms/cm**, **C-ms/cm** and press enter.



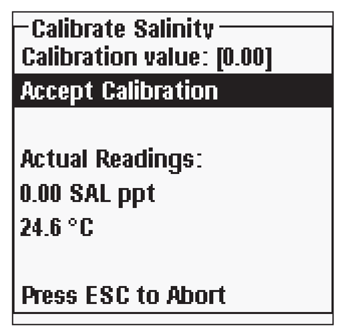
Highlight **Calibration value** and press enter to input the value of the calibration standard. Then, once the temperature and conductivity readings stabilize, highlight **Accept Calibration** and press enter. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled in the GLP menu, you will be prompted to select the fields and then press Cal to complete the calibration. After completing the calibration, the message line at the bottom of the screen will display "Calibrating Channel..." and then "Saving Configuration...".

Calibrating in Salinity

Place the sensor into a salinity calibration solution. The solution must cover the holes of the conductivity sensor that are closest to the cable. Ensure the entire conductivity sensor is submerged in the solution or the instrument will read approximately of half the expected value!



Select **SAL ppt** or **SAL PSU** and press enter.



Highlight **Calibration value** and press enter to input the value of the calibration standard. Then, once the temperature and conductivity readings stabilize, highlight **Accept Calibration** and press enter. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then press Cal to complete the calibration.

pH

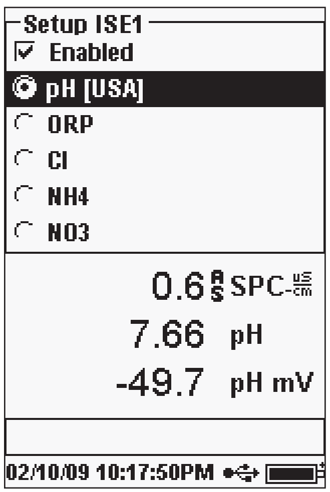
pH sensors can be used on 60510-X, 6051020-X, 6051030-X, 6051010-X, and Quatro cables.

If using a 605103 pH/ORP combination sensor on a 6051020 or 6051030 cable you can report both pH and ORP by configuring ISE1 as pH and ISE2 as ORP in the Sensor Setup menu.

The 605103 pH/ORP combination sensor is not recommended for use on a 6051010 or Quatro cable. If used on one of these cable, only pH will be reported and ORP will not be measured.

SETUP - pH

Press Sensor, highlight **Setup**, press enter. Highlight **ISE1** if using a 60510, 6051020, or 6051030 cable. If using a 6051010 or Quatro cable, highlight **ISE1** if the pH sensor is installed in port 1 or highlight **ISE2** if the pH sensor is installed in port 2(a sensor must be installed in port 1 for port 2 to operate). Press enter.



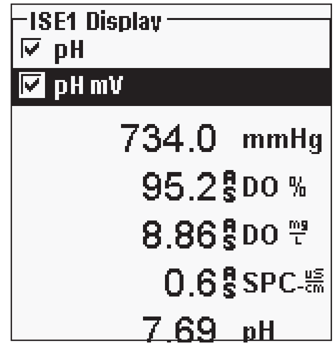
Enabled allows you to enable or disable the ISE function and select which ISE sensor is installed on the cable. Highlight **Enabled** and press enter to enable (☑) or disable (☐) the ISE you selected previously (either ISE1 or ISE2). Disable the ISE function(s) if you do not have a ISE sensor connected to the instrument.

After enabling the ISE function, ensure that it is set to pH as shown in the left screen shot. If necessary, highlight pH and press enter to set the ISE to pH.

Highlighting **pH[USA]** and pressing enter will also allow you to select the values for auto buffer recognition which are used during calibration. The buffer options are **USA** (4, 7, 10), **NIST** (4.01, 6.86, 9.18), and **User-Defined**. The selected option will be displayed in [brackets].

> *If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable false reading, ?????, or ----- next to the units.*

DISPLAY - pH



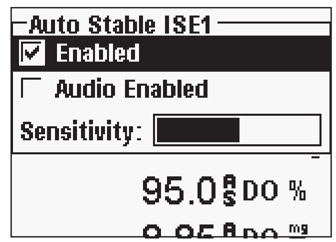
Press Sensor, highlight **Display** and press enter.

Highlight **ISE (pH)** and press enter. You will not be able to **Display** the sensor unless it is **Enabled** in the Sensor Setup menu.

Highlight **pH** and/or **pH mV**, press enter to enable (☑) or disable (☐). Both can be reported at the same time.

AUTO STABLE - pH

Press Sensor, highlight **Auto Stable** and press enter. Highlight **ISE (pH)** and press enter.

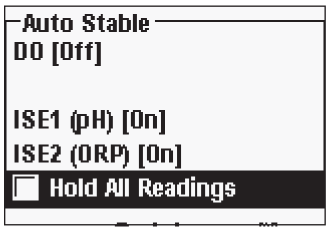


Auto Stable indicates when a reading is stable. Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability is achieved) and press enter enable (☑) or disable (☐). When Auto Stable is enabled, **AS** will blink next to the parameter until it is stable. Once the parameter is stable, **AS** will stop blinking.

The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

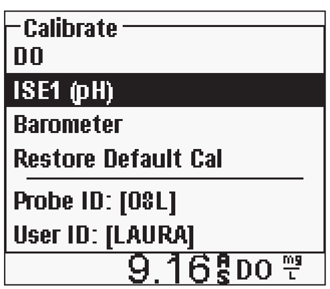
Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.025%
75	0.39375%
50	1.5%
25	1.13125%
0 - Least Sensitive, Sensitivity bar is set to the far left	0.15%



Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if ORP and pH have Auto Stable enabled and Hold All Readings is enabled, then the display will hold the readings once ORP and pH have both reached their Auto Stable settings. You must press the **Esc** key to "release" the held display in order to take subsequent readings. **Hold All Readings** must be reactivated after each use!

CALIBRATION - pH

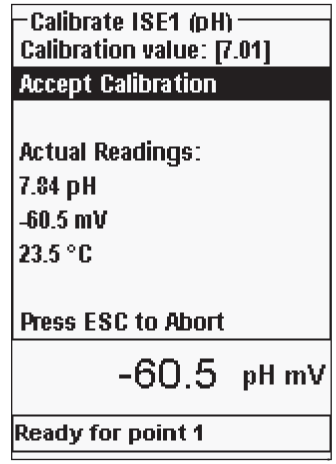
Calibration can be accomplished in any buffer order. pH 7 buffer should be used regardless of how many calibration points you use but it does not have to be used first.



Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting your User ID and/or Probe ID if appropriate, highlight **ISE (pH)** and press enter. The message line will show the instrument is "Ready for point 1". The pH calibration allows up to six calibration points.

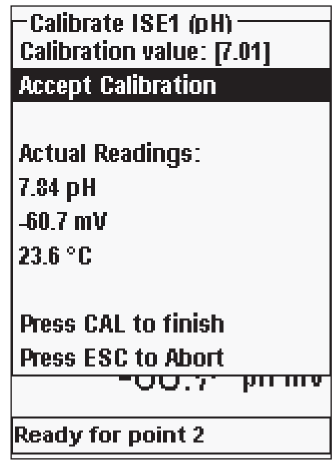
Place the sensor in a traceable pH buffer solution. The instrument should automatically recognize the buffer value and display it at the top of the calibration screen. If the calibration value is incorrect, the auto buffer recognition setting



in the Sensor Setup menu may be incorrect. If necessary, highlight the **Calibration Value** and press enter to input the correct buffer value.

Once the pH and temperature readings stabilize, highlight **Accept Calibration** and press enter to accept the first calibration point. The message line will then display "Ready for point 2".

If you do not wish to perform a second point, press Cal to finalize the calibration. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal to finalize the calibration.



To continue with the 2nd point, place the sensor in the second buffer solution. The instrument should automatically recognize the second buffer value and display it at the top of the screen. If necessary, highlight the **Calibration Value** and press enter to input the correct buffer value. Once the pH and temperature readings stabilize, highlight **Accept Calibration** and press enter to confirm the second calibration point. The message line will then display 'Ready for point 3" and you can continue with the 3rd calibration point if desired.

If you do not wish to perform a 3rd calibration point, press Cal to complete the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal to finalize the calibration.

Continue in this fashion until the desired number of calibration points is achieved (up to six).

Once you've achieved the desired number of cal points you must press Cal to finalize the calibration and to allow the instrument to update the pH offset and slope. The instrument will not take these cal values into account until Cal has been pressed.

The actual readings displayed during the calibration will NOT reflect the updated calibration information. These values will not change until Cal is pressed to finalize the calibration and to update the instrument.

ORP

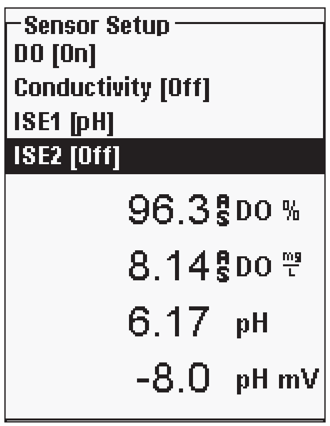
ORP sensors can be used on 60510-X, 6051020-X, 6051030-X, 6051010-X, and Quatro cables.

If using a 605103 pH/ORP combination sensor on a 6051020 or 6051030 cable you can report both pH and ORP by configuring ISE1 as pH and ISE2 as ORP in the Sensor Setup menu.

The 605103 pH/ORP combination sensor is not recommended for use on a 6051010 or Quatro cable. If used on one of these cable, only pH will be reported and ORP will not be measured.

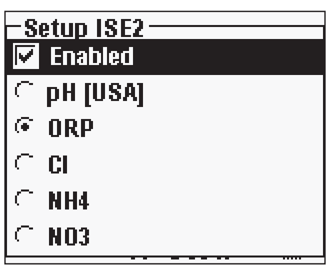
SETUP - ORP

Press Sensor, highlight **Setup**, press enter.



Highlight **ISE1** if using a 605102 (ORP sensor) on a 60510, 6051020, or 6051030 cable. Highlight **ISE2** is using a 605103 (pH/ORP sensor) on a 60510, 6051020, or 6051030 cable. If using a 6051010 or Quatro cable, highlight **ISE1** if the ORP sensor is installed in port 1 or highlight **ISE2** if the ORP sensor is installed in port 2 (a sensor must be installed in port 1 for port 2 to operate). Press enter.

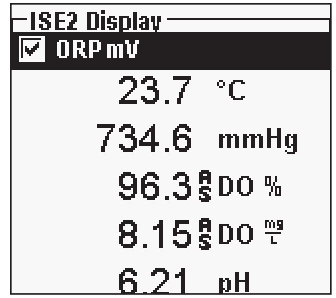
Enabled allows you to enable or disable the ISE function and select which ISE sensor is installed on the cable. Highlight **Enabled** and press enter to enable (☑) or disable (☐) the ISE you selected previously (either ISE1 or ISE2).



After enabling the ISE function, ensure ORP is selected as the ISE sensor as shown in screen shot to the left. If necessary, highlight ORP and press enter to set the selected ISE to ORP.

If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable false reading, ?????, or ----- next to the units.

DISPLAY - ORP

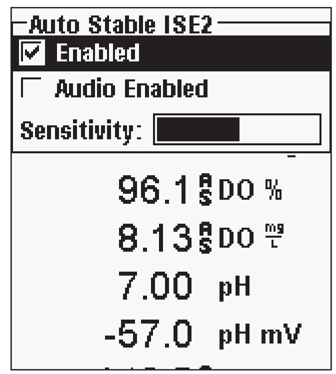


Press Sensor, highlight **Display** and press enter.

Highlight **ISE (ORP)** and press enter. You will not be able to **Display** the sensor unless it is **Enabled** in the Sensor Setup menu.

Press enter to enable (☑) or disable (☐) **ORP mV.**

AUTO STABLE - ORP



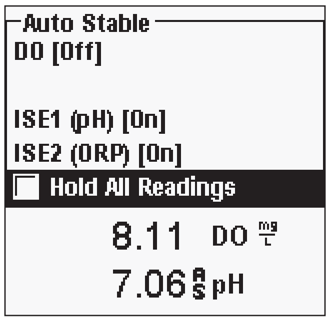
Press Sensor, highlight **Auto Stable** and press enter. Highlight **ISE (ORP)** and press enter.

Auto Stable indicates when a reading is stable. Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability is achieved) and press enter enable (☑) or disable (☐). When Auto Stable is enabled, **AS** will blink next to the parameter until it is stable. Once the parameter is stable, **AS** will stop blinking.

The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

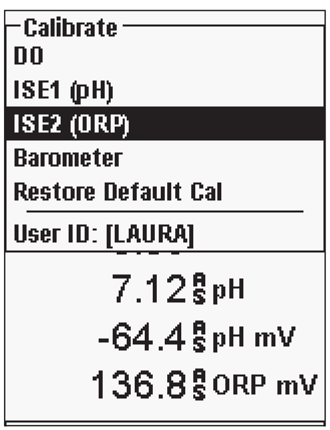
The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.05%
75	0.62525%
50	1.275%
25	1.8875%
0 - Least Sensitive, Sensitivity bar is set to the far left	2.5%



Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if ORP and pH have Auto Stable enabled and Hold All Readings is enabled, then the display will hold the readings once ORP and pH have both reached their Auto Stable settings. You must press the **Esc** key to "release" the held display in order to take subsequent readings. **Hold All Readings** must be reactivated after each use!

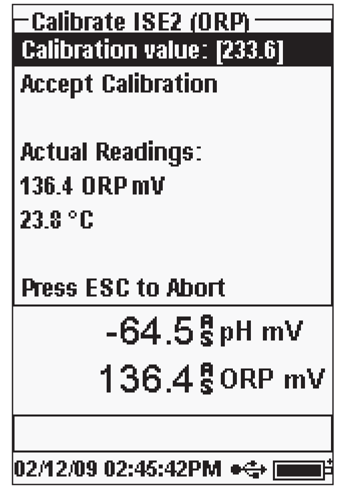
CALIBRATION - ORP



Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting your User ID and/or Probe ID if appropriate, highlight **ISE (ORP)** and press enter. The message line will show the instrument is "Ready for point".

Place the sensor in a solution of known ORP and wait for the readings to stabilize.



Highlight **Calibration value** and press enter to input the value of the ORP calibration standard. If using the YSI Zobell calibration solution, the Pro Plus will automatically determine the calibration value. However, the calibration value should be verified against the chart on the side of the Zobell bottle. Next, once the temperature and ORP readings stabilize, highlight **Accept Calibration** and press enter to calibrate. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then press Cal to complete the calibration.

AMMONIUM, NITRATE, CHLORIDE

Ammonium, Nitrate, and Chloride sensors can be used on 60510-X, 6051020-X, 6051030-X, 6051010-X, and Quatro cables. These cables also accommodate pH and ORP sensors so instrument setup is important.

> ⓘ **WARNING**: *Ammonium, Nitrate, and Chloride sensors should only be used at DEPTHS OF LESS THAN 55 FEET (17 METERS). Use of the sensors at greater depths is likely to permanently damage the sensor membrane.*

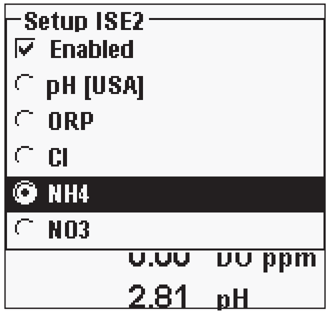
> ⓘ **WARNING**: *Ammonium, Nitrate, and Chloride sensors should only be used in FRESHWATER.*

SETUP - AMMONIUM, NITRATE, CHLORIDE

Install the Ammonium, Nitrate, or Chloride sensor in Port 2 if using in conjunction with pH or ORP sensor on a 6051010 or Quatro cable. See the **Getting Started Setup** section of this manual for a complete list of cable/sensor configurations.

Press Sensor, highlight **Setup**, press enter. Highlight **ISE1** if using an ammonium, nitrate, or chloride sensor on a 60510, 6051020, or 6051030 cable.

If using a 6051010 or Quatro cable highlight **ISE1** if the sensor is installed in Port 1 or highlight **ISE2** if the sensor is installed in Port 2. Press enter.



Enabled allows you to enable or disable the ISE function and select which ISE sensor is installed on the cable.

Highlight **Enabled** and press enter to enable (☑) or disable (☐) the ISE you selected previously (either ISE1 or ISE2).

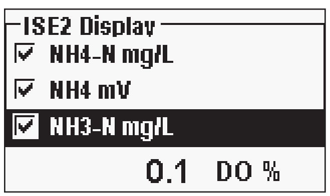
After enabling the ISE function, choose the parameter you want enabled for that ISE. In this example, NH4 is selected.

Cl - Chloride
NH4 - Ammonium
NO3 - Nitrate

> *If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable, false reading next to the units.*

DISPLAY - AMMONIUM, NITRATE, CHLORIDE

Press Sensor, highlight **Display**, press enter. Highlight **ISE2(NH4)**, press enter. You will not be able to **Display** the sensor unless it is **Enabled**.



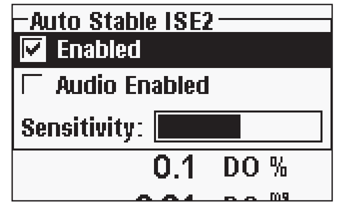
Highlight the value you wish to display and press enter to enable (☑) . Ammonium can be displayed as **NH4-N mg/L** (Ammonium)**, NH3-N** (Ammonia) and/or **NH4 mV** (sensor signal).

The same steps would be followed to display nitrate or chloride.

Ammonia is calculated from the pH, salinity, and temperature readings. If a pH sensor is not in use, the instrument will assume the sample is neutral (pH 7) for the calculation. If a conductivity sensor (Salinity) is not in use, the instrument will use the salinity correction value entered in the Sensor Menu for the calculation (see Salinity Correction within the Dissolved Oxygen Setup section of this manual for more information).

AUTO STABLE - AMMONIUM, NITRATE, CHLORIDE

Auto Stable indicates when a reading is stable. When Auto Stable is enabled, **AS** will blink next to the parameter until it is stable. Once the parameter is stable, **AS** will stop blinking.

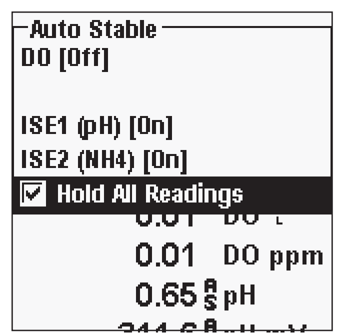


To enable Auto Stable, press Sensor, highlight **Auto Stable** and press enter. Highlight **ISE1** or **ISE2** and press enter.

Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability is achieved) and press enter to confirm. The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.05%
75	0.62525%
50	1.275%
25	1.8875%
0 - Least Sensitive, Sensitivity bar is set to the far left	2.5%



Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if pH and Ammonium have Auto Stable enabled and Hold All Readings is also enabled, then the display will hold the readings once pH and Ammonium have both reached their Auto Stable settings. You must press the **Esc** key to "release" the held display in order to take subsequent readings. **Hold All Readings** must be reactivated after each use!

CALIBRATION - AMMONIUM, NITRATE, CHLORIDE

The 6051030 ISE/conductivity cable has a specialized calibration container that resembles a large test tube. This calibration chamber can be used to calibrate the ISE sensors with the conductivity sensor. A ring-stand should be used to support this chamber.

> *The ISE sensors can be calibrated at 1, 2, or 3-points.*
> **A 2-point calibration without chilling a third calibration solution is extremely accurate and is the preferred method.**
> *Greatest accuracy is achieved if the actual samples to be measured are within 10 ˚C of the calibration solutions.*

CALIBRATION TIP: Exposure to the high ionic content of pH buffers can cause a significant, but temporary, drift in the ammonium, nitrate, and chloride ISE sensors. Therefore, when calibrating the pH sensor, YSI recommends that you use one of the following methods to minimize errors in the subsequent readings:

- When calibrating pH, remove ISE sensors from the cable bulkhead and plug the ports. After pH calibration is complete, replace the ISE sensors and proceed with their calibration with no stabilization delay.

- Calibrate pH first, immersing all of the sensors in the pH buffers. After calibrating pH, place the sensors in 100 mg/L nitrate or ammonium standard or 1000 mg/L chloride standard depending on the sensor in use and monitor the reading. Usually, the reading starts low and may take awhile to reach a stable value. When it does, proceed with the calibration. This may take several hours.

Preparing Chloride Standards

The following recipes are provided for preparation of 10 and 1000 mg/L chloride reagents. Nitrate and Ammonium standards can be purchased from YSI or other laboratory supply companies.

It is important to note that some of the chemicals required for these solutions could be hazardous under some conditions. It is the responsibility of the user to obtain and study the MSDS for each chemical and to follow the required instructions with regard to handling and disposal of these chemicals.

You will need: Solid sodium chloride or a certified 1000 mg/L chloride solution from a supplier, magnesium sulfate, high purity water, a good quality analytical

balance, 1000 mL volumetric flask, an accurate 10 mL measuring devices, and 1000 mL glass or plastic storage vessels.

1000 mg/L Standard: Accurately weigh 1.655 grams of anhydrous sodium chloride and transfer into a 1000 mL volumetric flask. Add 0.5 grams of anhydrous magnesium sulfate to the flask. Add 500 mL of water to the flask, swirl to dissolve all of the reagents , and then dilute to the volumetric mark with water. Mix well by repeated inversion and then transfer the 1000 mg/L standard to a storage bottle. Rinse the flask extensively with water prior to its use in the preparation of the 10 mg/L standard. Alternatively, simply add 0.5 grams of magnesium sulfate to a liter of a 1000 mg/L chloride standard from a certified supplier.

10 mg/L Standard: Accurately measure 10 mL of the above 1000 mg/L standard solution into a 1000 mL volumetric flask. Add 0.5 grams of anhydrous magnesium sulfate to the flask. Add 500 mL of water, swirl to dissolve the solid reagents, and then dilute to the volumetric mark with water. Mix well by repeated inversion and then transfer the 10 mg/L standard to a storage bottle.

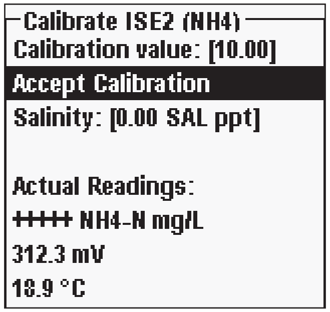
AMMONIUM (NH4+) , NITRATE (NO3-), AND CHLORIDE CL- 2-POINT

The calibration procedures for ammonium, nitrate, or chloride are similar to pH. The only differences are the calibration solutions. Recommended values for calibration solutions and the order of calibration are as follows:

Sensor	*1^{st} Point*	*2^{nd} Point*
Ammonium-nitrogen (NH4-N)	1 mg/L	100 mg/L
Nitrate-nitrogen (NO3-N)	1 mg/L	100 mg/L
Chloride (Cl-)	10 mg/L	1000 mg/L

Place the proper amount of 1 mg/L standard for Ammonium or Nitrate (10 mg/l for Chloride) into a clean, dry or pre-rinsed calibration cup. Carefully immerse the sensor into the solution. Allow at least 1 minute for temperature equilibration before proceeding.

Press Cal (Cal). Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.



After selecting your User ID and/or Probe ID if appropriate, highlight **Ammonium**, **Nitrate**, or **Chloride** to access the appropriate calibration, and press enter. The parameter you want to calibrate may appear under ISE1 or ISE2 depending on your cable type and setup. The message line will show the instrument is ready for the 1st calibration point.

The instrument will display the calibration value at the top of the screen. If necessary, highlight the **Calibration value** and press enter to input the correct value.

Once the readings stabilize, highlight **Accept Calibration** and press enter to accept the first calibration point. The message line will then display "Ready for point 2".

If you do not wish to perform a second point, press Cal to finalize the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal to finalize the calibration. Alternatively, you may press Esc to cancel the calibration.

To continue with the 2nd point, rinse the sensor with clean water, then dry it before placing it in the second calibration standard. Allow at least 1 minute for temperature equilibration before proceeding. The instrument will display the second calibration value at the top of the screen. If necessary, highlight the **Calibration value** and press enter to input the correct buffer value. Once the readings stabilize, highlight **Accept Calibration** and press enter to confirm the second calibration point. The message line will then display "Ready for point 3" and you can continue with the 3rd calibration point if desired.

If you do not wish to perform a 3rd calibration point, press Cal to complete the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal to finalize the calibration. Alternatively, you may press Esc to cancel the calibration.

AMMONIUM (NH4+) , NITRATE (NO3-), AND CHLORIDE CL- 3-POINT

A 2-point calibration without chilling a third calibration solution is extremely accurate and is the preferred method. If you must perform a 3-point calibration, the following procedure requires one portion of the high concentration calibration solution and two portions of the low concentration calibration solution. The

high concentration solution and one of the low concentration solutions should be at ambient temperature. The other low concentration solution should be chilled to less than 10 °C prior to calibration.

> ⚠ **WARNING**: *The chilled calibration solution MUST BE CHILLED TO AT LEAST 5 °C COOLER THAN THE 1ST CALIBRATION POINT, otherwise the 1st point will be OVERRIDDEN.*

Follow the procedure for a 2-point cal. After the second calibration point is complete, the message line with state 'Ready for point 3". Place the proper amount of chilled 1 mg/L standard (10 mg/L for the chloride) into a clean, dry or pre-rinsed calibration cup. Carefully immerse the sensor into the solution. Allow for temperature equilibration. If necessary, highlight **Calibration value** and press enter to manually enter the 3rd buffer value. Once the readings are stable, highlight **Accept Calibration** and press enter to confirm. Press Cal to complete the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal to finalize the calibration. Alternatively, press Esc to cancel the calibration.

TAKING MEASUREMENTS

To obtain the most accurate readings, be sure the instrument is calibrated before taking measurements.

DISSOLVED OXYGEN

Turn the instrument on and wait 5-15 minutes if using a polarographic sensor. If using a field cable/sensor, install the sensor guard to protect the sensor and membrane. Place the probe in the sample to be measured and give the probe a quick shake to release any air bubbles. Allow the temperature readings to stabilize. Next, stir the probe in the sample to overcome the stirring dependence of the dissolved oxygen sensor. You must provide at least 3 inches per second for 2.0 PE membranes, 6 inches per second for 1.25 PE membranes, and 12 inches per second for Teflon® membranes. Once the values plateau and stabilize, you may record the measurement and/or log the data set. The dissolved oxygen reading will drop over time if stirring is ceased.

If placing the DO sensor into a stream or fast flowing waters it is best to place it perpendicular to the flow and NOT facing into the flow.

If using the DO sensor in an aeration tank/basin, it is helpful to make sure bubbles do not burst on the membrane since this may cause unstable readings. You should be able to prevent this by pointing the sensor upwards so it's facing the sky and then twist tying, zip tying, or rubber banding the bulkhead to the cable. Making a simple curve to the cable without bending or breaking the cable will allow you to lower the sensor into the aeration tank while the sensor points skyward so the bubbles are no longer bursting on the membrane surface.

CONDUCTIVITY

The conductivity sensor will provide quick readings as long as the entire sensor is submerged and no air bubbles are trapped in the sensor area. Immerse the probe into the sample so the sensors are completely submerged and then shake the probe to release any air bubbles. Occasional cleaning of the sensor may be necessary to maintain accuracy and increase the responsiveness. To clean the sensor, use the conductivity cleaning brush with a mild detergent.

pH/ORP

pH and ORP readings are typically quick and accurate. However, it may take the sensors a little longer to stabilize if they become coated or fouled. To improve the response time of a sensor, follow the cleaning steps in the Maintenance section of this manual.

AMMONIUM, NITRATE, AND CHLORIDE

These sensors may take a little longer to stabilize if the tips are dirty or fouled. If installed with a pH sensor, always maintain a clean pH sensor for a more rapid sensor stabilization.

These sensors can only be used in freshwater.

LOGGING DATA

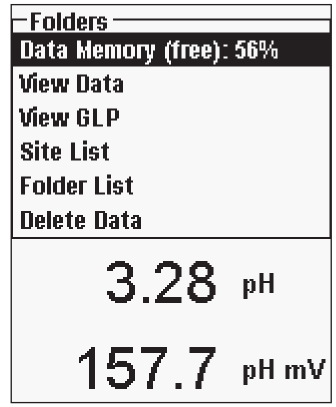
Log One Sample is already highlighted in Run mode. Press enter to open a submenu. If **Use Site List** and or **Use Folder List** are enabled in the Logging Setup menu, you will have to option to select these two items before the data point is logged. If necessary, use the keypad to create a new Site or Folder name. If Site List and Folder List are disabled in the **System** menu, you will not see these options when logging a sample. Once the Site and/or Folder name is selected, highlight **Log Now** and press Enter. The instrument will confirm that the data point was successfully logged.

If you would like to log at a specific interval vs. logging one sample at a time or vice versa, press **System**, then highlight **Logging** and press enter. Select **Continuous Mode** and adjust the time Interval if necessary. On the Run screen, the option to log will change from **Log One Sample** to **Start Logging** based on the time interval entered in the Logging Menu.

During a continuous log, the Start Logging dialog box on the Run screen will change to Stop Logging. Press Enter to stop continuous logging.

FILES AND SITE LISTS

FILE MEMORY

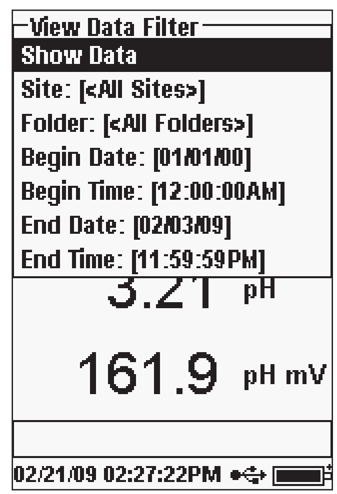


To view the file memory, press **File**.

The **Data Memory** shows a percentage indicating the amount of memory available. If the file memory is near 0%, files should be downloaded to a PC and/or deleted to free up memory.

VIEWING SAVED DATA

Press **File**, highlight **View Data** and press enter.

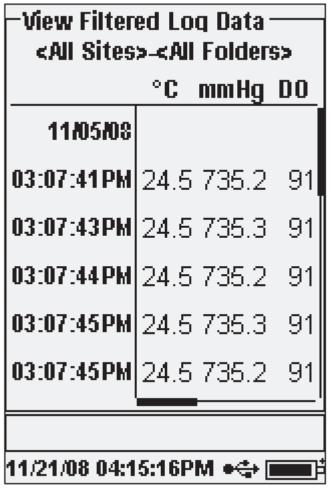


Configuring your data view:

Site: will allow you to view data from one particular site or all sites. Highlight **Site**, press enter, and select the site you wish to view data from or select **All Sites** to view data from all sites.

Folder: will allow you to view data from one particular folder or all folders. Highlight **Folder**, press enter, and select the file you wish to view data from or select **All Folders** to view data from all folders.

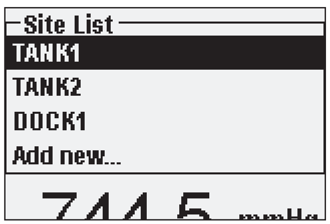
Begin Date, Begin Time, End Date, and **End Time:** will allow you to view data collected between a specific time period. Highlight the



time qualifier you would like to set, press enter, and use the numeric entry screen to select the date/time you wish to view.

After making your selections in the Data Filter, highlight **Show Data** and press enter. The data will have date and time stamps. You will likely have to scroll up and down and side to side using the arrow keys to completely view the data file. No more than 100 data records can be viewed at one time.

SITE LIST



To modify the **Site List**, press **File**, highlight **Site List**, and press enter. Enter new site names or edit existing sites with the alpha/numeric entry screen. Site lists can also be created and edited on your PC with Data Manager and then downloaded to the instrument.

FOLDER

To modify the **Folder List**, press **File**, highlight **Folder List**, and press enter. Enter new Folder names or edit existing folders with the alpha/numeric entry screen.

DELETE DATA

Press **File**, highlight **Delete Data**, and press enter. Enter the criteria for the data you wish to delete in the Delete Data Filter, then highlight **Delete Data** and press enter.

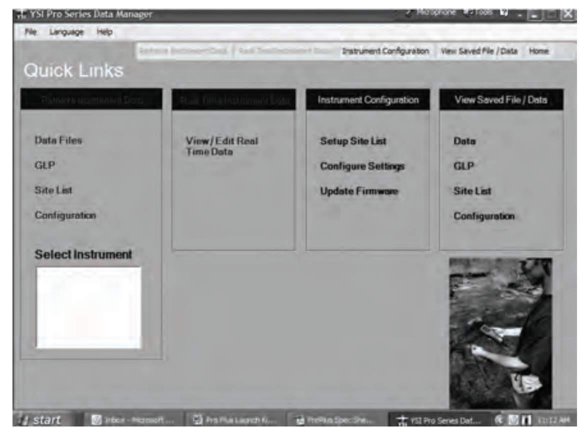
DATA MANAGER DESKTOP SOFTWARE

Data Manager is provided with the purchase of a Pro Plus Instrument. Data Manager is a powerful Windows® based software that will allow you to easily manage logged data, set up instruments, and conduct real time studies.

Minimum PC system requirements for Data Manager are Windows® 2000 with SP4 (minimum) or Windows® XP with SP2 (minimum) Operating System, 300 MHz or higher Pentium®-compatible CPU, 128 MB of RAM or higher, 80 MB or more of free hard-disk space, USB 2.0, and Microsoft® .NET.

Data Manager needs to be installed on a PC before use and before you try to connect a Pro Plus to your PC. First install Data Manger, then connect the communications saddle to the PC and, lastly, connect the saddle to your Pro Plus. Data Manager will identify the connected instruments by their Unit ID.Refer to the Data Manager Readme file for detailed installation instructions. Data Manager will then recognize the attached instruments.

From the 'home' screen of Data Manager, see below, you can select one of the following functions: Retrieve Instrument Data, Real Time Instrument Data, Instrument Configuration, or View Saved File/Data.



USING THE COMMUNICATIONS SADDLE

> ⚠ **WARNING**: *DO NOT connect the Communications Saddle to your PC before installing Data Manager. The Communication Saddle drivers MUST be installed prior to connecting it to your PC. The drivers will install automatically during the Data Manager installation. The first time the saddle is connected to the PC, you may have to walk through a couple of installation wizards. For detailed instruction, please refer to the Readme file located on the CD that was included with your instrument.*

A PC will recognize the Communications Saddle (saddle) as a YSI water quality instrument with or without the Pro Plus installed in the saddle.

To connect the saddle to a Pro Plus, simply align the saddle to the oval section on top of the instrument and push it down to snap it in place (Figure 6).

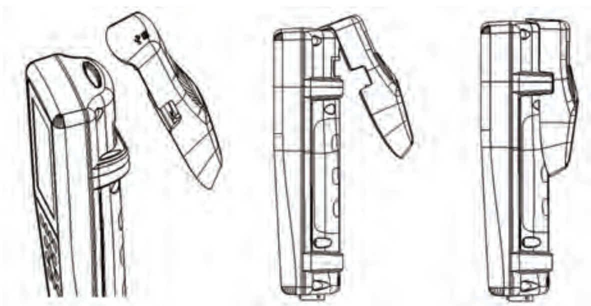


Figure 6. Locate the oval alignment groove at the top of the instrument and inside the saddle. Insert the saddle into this oval groove. Press the saddle towards the back of the instrument until it snaps into place.

Connect the USB cable to the top of the saddle and to a USB port on the PC. Once Data Manager is launched, the program will recognize all saddles with instruments connected to the PC.

The instrument will be powered through the saddle and USB connection when connected to the PC. However, the instrument must still have batteries installed in order to keep the date and time correct when powering the PC off at night. Make sure the instrument is turned off first, then turn off the PC to keep the instrument from running all night on the batteries. If you power it off and power off the PC the instrument will keep the correct date and time if it has batteries installed. If batteries are not installed, the instrument's date and time will not remain correct and will need to be reset each morning.

MANAGE LOGGED DATA

Data that has been logged to the Professional Plus can easily be uploaded to the PC via the provided USB saddle. You can upload sensor data, GLP files, site lists, and instrument configuration files individually or all at once. After connecting the instrument to the PC via the USB saddle and cable and launching Data Manager, click the **Retrieve Instrument Data** tab. Click on the Instrument's Unit ID you would like to retrieve data from, then select the files you would like to retrieve and click Start.

Once the sensor data is uploaded to the PC, you can graph and view tabular data by instrument Unit ID, date/time, site name, and/or folder name. This allows you to configure the report according to your needs. You can choose to view all data from all instruments, or select a certain date/time range for only a few specific instruments, there are multiple ways to view the data. Once the report has been defined, you will be able to print the graph and/or export the table.

Data Manager takes information management one step further and allows you to delete specific points instead of entire files. This allows you to clean up data that is no longer needed or that may have been collected erroneously, for example, when the sensor was out of the water. If you can not delete data due to regulation and compliance purposes, Data Manager has the solution. While viewing logged data or real time data, you have the ability to 'tag' individual data points with comments.

In addition to sensor data, you will be able to view GLP files, site lists, and configuration files that have been uploaded from the instrument. These can be printed and exported as well.

REAL TIME STUDIES

Data Manager allows you to view real time data on the PC.

After selecting your instrument, click the **Real Time Instrument Data** tab. Next, input your sample interval, site/folder name, select the parameters you wish to view and click **OK**. You must click **Start** on the next screen to begin your real time study. Choose to hide the table or graph by unchecking the box next to these options. Click **Stop**, then **Edit Setup** to change the Y-scale min/max of the graph, to select different colors, or to name your graph. Add a comment to a data point by clicking in the comment field of the table next to the data point. You may also **Print** the graph and **Export** the data for viewing in another program.

CONFIGURE INSTRUMENTS

Data Manager allows for easy and quick configuration of single or multiple instruments. Once you have uploaded a site list or configuration file, you can edit it as needed, save it, and download it to other instruments. You no longer need to configure each instrument individually. By using the same configuration file for all instruments, you can rest assured that all instruments will have identical settings.

New site lists and configuration files can be created in Data Manager as well. These lists and files can be downloaded to one or multiple instruments. Save time by creating these files on your PC and downloading them to the instrument as opposed to creating them on the instrument.

CARE, MAINTENANCE, AND STORAGE

This section describes the proper procedures for care, maintenance and storage of the sensors. The goal is to maximize their lifetime and minimize down-time associated with improper sensor usage.

UPDATING INSTRUMENT FIRMWARE

The instrument's firmware can be updated via www.ysi.com. There you will find the new firmware file and instructions on how to update the instrument. There is no need to send the instrument back to the factory for upgrades.

GENERAL MAINTENANCE

GENERAL MAINTENANCE - O-RINGS

The instrument utilizes o-rings as seals to prevent water from entering the battery compartment and sensor ports. Following the recommended procedures will help keep your instrument functioning properly.

If the o-rings and sealing surfaces are not maintained properly, it is possible that water can enter the battery compartment and/or sensor ports of the instrument. If water enters these areas, it can severely damage the battery terminals or sensor ports causing loss of battery power, false readings, and corrosion to the sensors or battery terminals. Therefore, when the battery compartment lid is removed, the o-ring that provides the seal should be carefully inspected for contamination (e.g. debris, grit, etc.) and cleaned if necessary.

The same inspection should be made of the o-rings associated with the sensor connectors when they are removed. If no dirt or damage to the o-rings is evident, then they should be lightly greased without removal from their groove. However, if there is any indication of damage, the o-ring should be replaced with an identical o-ring. At the time of o-ring replacement, the entire o-ring assembly should be cleaned.

To remove the o-rings:
Use a small, flat-bladed screwdriver or similar blunt-tipped tool to remove the o-ring from its groove. Check the o-ring and the groove for any excess grease or contamination. If contamination is evident, clean the o-ring and nearby plastic parts with lens cleaning tissue or equivalent lint-free cloth. Alcohol can be used to clean the plastic parts, but use only water and mild detergent on the o-ring itself. Also, inspect the o-rings for nicks and imperfections.

⚠ *Using alcohol on o-rings may cause a loss of elasticity and may promote cracking. Do not use a sharp object to remove the o-rings. Damage to the o-ring or the groove may result.*

Before re-installing the o-rings, make sure to use a clean workspace, clean hands, and avoid contact with anything that may leave fibers on the o-ring or grooves. Even a very small amount of contamination (hair, grit, etc.) may cause a leak.

To re-install the o-rings:
Place a small amount of o-ring grease between your thumb and index finger. (More grease is NOT BETTER!)

Draw the o-ring through the grease while pressing the fingers together to place a very light covering of grease to the o-ring. Place the o-ring into its groove making sure that it does not twist or roll.

Use your grease-coated finger to once again lightly go over the mating surface of the o-ring.

⚠ *Do not over-grease the o-rings. The excess grease may collect grit particles that can compromise the seal. Excess grease can also cause the waterproofing capabilities of the o-ring to diminish, potentially causing leaks. If excess grease is present, remove it using a lens cloth or lint-free cloth.*

GENERAL MAINTENANCE - SENSOR PORTS

It is important that the entire sensor connector end be dry when installing, removing or replacing. This will prevent water from entering the port. Once a sensor is removed, examine the connector inside the port. If any moisture is present, use compressed air to completely dry the connector or place directly in front of a steady flow of fresh air. If the connector is corroded, return the cable to your dealer or directly to an YSI Repair Center.

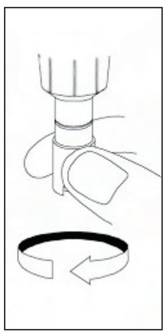
ⓘ *Remove sensors upside down (facing the ground) to help prevent water from entering the port upon removal.*

SENSOR MAINTENANCE

SENSOR MAINTENANCE - DISSOLVED OXYGEN

Membrane Cap Installation

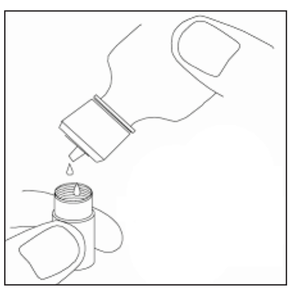
The DO sensor (Polarographic and Galvanic) is shipped with a dry, protective red cap that will need to be removed before using. Remove the protective cap or used membrane cap and replace it with a new membrane cap following these instructions:



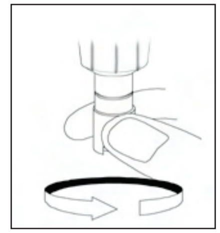
Remove the sensor guard to access the sensor tip.

Unscrew and remove any old membrane cap by holding the sensor when unscrewing the membrane cap and discard.

Thoroughly rinse the sensor tip with distilled or DI water.



Fill a new membrane cap with O2 sensor electrolyte solution that has been prepared according to the directions on the bottle. Be very careful not to touch the membrane surface. Lightly tap the side of the membrane cap to release bubbles that may be trapped.



Thread the membrane cap onto the sensor. It is normal for a small amount of electrolyte to overflow.

Polarographic Sensors - Model # 605203

The KCl (potassium chloride) solution and the membrane cap should be changed at least once every 30 days during regular use. In addition, the KCl solution and membrane should be changed if (a) bubbles are visible under the membrane; (b) significant deposits of dried electrolyte are visible on the membrane; and (c) if the sensor shows unstable readings or other sensor-related symptoms.

During membrane changes, examine the gold cathode at the tip of the sensor and the silver anode along the shaft of the sensor. If either the silver anode is black in color or the gold cathode is dull, the sensor may need resurfaced using the fine sanding disks included in the membrane kit. Do not sand the electrode every membrane change as this is not routine maintenance. In fact, visually, the anode may appear tarnished and operate just fine. YSI recommends using the 400 grit wet/dry sanding disks to resurface the electrodes if the sensor has difficulty stabilizing or calibrating after a membrane change.

To resurface the sensor using the fine sanding disk, follow the instructions below.

Gold Cathode:

For correct sensor operation, the gold cathode must be textured properly. It can become tarnished or plated with silver after extended use. Never use chemicals or abrasives not recommended or supplied by YSI.

First dry the sensor tip completely with lens cleaning tissue. Wet a sanding disk with a small amount of clean water and place it face up in the palm of your hand. Next, with your free hand, hold the sensor in a vertical position, tip down. Place the sensor tip directly down on the sanding disk and twist it in a circular motion to sand the gold cathode. The goal is to sand off any build-up and to lightly scratch the cathode to provide a larger surface area for the O2 solution under the membrane. Usually, 3 to 4 twists of the sanding disk are sufficient to remove deposits and for the gold to appear to have a matte finish. Rinse thoroughly and wipe the gold cathode with a wet paper towel before putting on a new membrane cap. If the cathode remains tarnished, contact YSI Technical Support or the Authorized dealer where you purchased the instrument.

<u>Silver Anode</u>

After extended use, a thick layer of Silver Chloride (AgCl) builds up on the silver anode reducing the sensitivity of the sensor. The anode must be cleaned to remove this layer and restore proper performance. The cleaning can be chemical or mechanical:

<u>Chemical cleaning</u>: Remove the membrane cap and rinse the electrodes with deionized or distilled water. Soak the sensing anode section of the sensor in a 14% ammonium hydroxide solution for 2 to 3 minutes or in a 3% ammonia solution overnight for 8-12 hours (most household ammonia cleaners are typically around 3%). Rinse <u>heavily</u> in cool tap water followed by a thorough rinsing with distilled or deionized water. The anode should then be thoroughly wiped with a wet paper towel to remove the residual layer from the anode. You can smell the tip of the sensor to help ensure all the ammonia has been rinsed off. Trapping residual ammonia under the new membrane cap can quickly tarnish the electrode and/or give false readings.

> *Chemical cleaning should be performed as infrequently as possible. First attempt a membrane change and recalibrate. If a new membrane does not resolve the problem, then proceed with cleaning.*

<u>Mechanical cleaning</u>: In order to sand the silver anode along the shaft of the sensor, simply hold the sensor in a vertical position. Wet the sanding disk with a small amount of clean water then gently wrap it around the sensor shaft and twist it a few times to lightly sand the anode (the goal is to simply sand off any build-up without scratching or removing layers of the anode itself). Usually, 3 to 4 twists of the sanding disk are sufficient to remove deposits. However, in extreme cases, more sanding may be required to regenerate the original silver surface.

After completing the sanding procedure, repeatedly rinse the electrode with clean water and wipe with lens cleaning tissue to remove any grit left by the sanding disk. Thoroughly rinse the entire tip of the sensor with distilled or deionized water and install a new membrane.

> **IMPORTANT**: *Be sure to: (1) Use only the fine sanding disks provided and (2) Sand as mentioned in the above procedures. Not adhering to either of these instructions can damage the electrodes. If this procedure is unsuccessful, as indicated by improper electrode performance, contact YSI Technical Support or the Authorized dealer where you purchased the instrument.*

Galvanic Sensors – Model # 605202

We recommend that the Sodium Chloride (NaCl) solution and the membrane cap be changed at least once every 60 days during regular use. In addition, the NaCl solution and membrane should be changed if (a) bubbles are visible under the membrane; (b) significant deposits of dried electrolyte are visible around the membrane; and (c) if the sensor shows unstable readings or other sensor-related symptoms.

The Galvanic dissolved oxygen sensor is continuously reducing oxygen even when the display of the instrument is not active. This factor allows the sensor to be used with no warm-up period as soon as the instrument is powered on (instant on DO). However, because the sensor is "on" all the time, some solid from the oxidation of the zinc anode will form in the electrolyte within 1-2 weeks of activation. Small amounts of the solid will generally cause no performance problems, but excessive amounts may result in jumpy dissolved oxygen readings. The rate of solid formation is dependent on the type of membrane installed. The formation of solids based on membrane type typically form more rapidly with the 5912 (1 mil Teflon), less rapid with 5913 (1.25 mil PE), and least rapid with 5914 (2 mil PE).

> *The Galvanic DO sensor solution will appear milky white after use but will NOT affect the accuracy of the sensor unless there is excessive build up. The color change is acceptable and normal as long as DO readings remain stable.*

At the time the membrane cap is changed, YSI recommends that you rinse the anode (silver shaft of the sensor) with purified water and wipe with a clean paper towel. If white deposits are evident on the anode after cleaning, YSI recommends that you remove this material by sanding the anode with the sandpaper disk enclosed in your membrane kit. Follow the "Mechanical Cleaning" instructions under the Polarographic Silver Anode section.

> **IMPORTANT**: *Be sure to: (1) Use only the fine sanding disks provided and (2) Sand as mentioned in the above procedures. Not adhering to either of these instructions can damage the electrodes.*
> **WARNING**: *DO NOT PERFORM THE POLAROGRAPHIC CHEMICAL CLEANING ON A GALVANIC SENSOR. If this procedure is unsuccessful, as indicated by improper electrode performance, contact YSI Technical Support or the Authorized dealer where you purchased the instrument.*

SENSOR MAINTENANCE - CONDUCTIVITY

The openings that allow sample access to the conductivity electrodes should be cleaned regularly. The small cleaning brush included in the Maintenance Kit is ideal for this purpose. Dip the brush in clean water and insert it into each hole 10 to 12 times. In the event that deposits have formed on the electrodes, it may be necessary to use a mild detergent (laboratory grade soap or bathroom foaming tile cleaner) with the brush. Rinse thoroughly with clean water, then check the response and accuracy of the conductivity cell with a calibration standard.

> ⓘ *If this procedure is unsuccessful, as indicated by improper electrode performance, contact YSI Technical Support or the Authorized dealer where you purchased the instrument.*

SENSOR MAINTENANCE - TEMPERATURE

You must keep the temperature portion of the sensor free of build up. Other than that, the sensor requires no maintenance. The conductivity cleaning brush can be used to scrub the temperature sensor if needed. Alternatively, you can use a toothbrush to clean the sensor.

SENSOR MAINTENANCE - pH, ORP AND COMBINATION pH/ORP

> ⓘ *Typical working life for pH and ORP sensors is approximately 12-24 months depending on usage, storage, and maintenance. Proper storage and maintenance generally extends the sensor's working life.*

Cleaning is required whenever deposits or contaminants appear on the glass and/or platinum surfaces or when the sensor's response slows. The cleaning can be chemical and/or mechanical.

Removing the sensor from the cable may make cleaning easier. Initially, use clean water and a soft clean cloth, lens cleaning tissue, or cotton swab to remove all foreign material from the glass bulb and/or platinum button. Then use a moistened cotton swab to carefully remove any material that may be blocking the reference electrode junction of the sensor.

> ⚠ **CAUTION**: *When using a cotton swab, be careful NOT to wedge the swab between the guard and the glass sensor. If necessary, remove cotton from the swab tip, so that the cotton can reach all parts of the sensor tip without stress. You can also use a pipe cleaner for this operation if more convenient.*

If good pH and/or ORP response is not restored, perform the following additional procedure:

1. Soak the sensor for 10-15 minutes in clean water containing a few drops of commercial dishwashing liquid.
2. GENTLY clean the glass bulb and platinum button by rubbing with a cotton swab soaked in the cleaning solution.
3. Rinse the sensor in clean water, wipe with a cotton swab saturated with clean water, and then rerinse with clean water.

If good pH and/or ORP response is still not restored, perform the following additional procedure:

1. Soak the sensor for 30-60 minutes in one molar (1 M) hydrochloric acid (HCl). This reagent can be purchased from most lab supply distributors. Be sure to follow the safety instructions included with the acid.
2. Rinse the sensor in clean water, wipe with a cotton swab saturated with clean water (not DI water), and then rerinse with clean water. To be certain that all traces of the acid are removed from the sensor crevices, soak the sensor in clean water for about an hour with occasional stirring.

If biological contamination of the reference junction is suspected or if good response is not restored by the above procedures, perform the following additional cleaning step:

1. Soak the sensor for approximately 1 hour in a 1:1 dilution of commercially-available chlorine bleach.
2. Rinse the sensor with clean water and then soak for at least 1 hour in clean water with occasional stirring to remove residual bleach from the junction. (If possible, soak the sensor for a period of time longer than 1 hour in order to be certain that all traces of chlorine bleach are removed.) Then rerinse the sensor with clean water and retest.

> ⓘ *Dry the port and sensor connector with compressed air and apply a very thin coat of o-ring lubricant to all o-rings before reinstallation.*

SENSOR MAINTENANCE - CHLORIDE

> ⓘ *Typical working life for chloride sensors is approximately 3-6 months depending on usage, storage, and maintenance. Proper storage and maintenance generally extends the sensor's working life.*

The chloride sensor is considered a pellet membrane ISE. As always, when handling sensors, care should be taken to avoid damaging the membrane. This sensor can be regenerated by washing with alcohol and/or gently polishing with fine emery paper in a circular motion to remove any deposits or discoloration, then thoroughly washing with deionized water to remove any debris. The sensor may require soaking in the high standard chloride calibration solution to recover its performance.

SENSOR MAINTENANCE - AMMONIUM AND NITRATE

> ⓘ *Typical working life for ammonium and nitrate sensors is approximately 3-6 months depending on usage, storage and maintenance. Proper storage and maintenance generally extends the sensor's working life.*

The ammonium and nitrate sensors are PVC membranes. As always, when handling a sensor, care should be taken to avoid damaging the membrane. After extensive use the membranes may become coated with a deposit or scoured with fine scratches which may cause a slow or reduced response (low slope) or unstable readings. Deposits may be removed with a fine jet of deionized water or rinsing in alcohol followed by soaking in the high standard calibration solution. Gently dab dry with a lint-free tissue before taking measurements.

SENSOR STORAGE

SHORT-TERM STORAGE

The cable assembly is supplied with a sensor storage container, or sleeve, that attaches to the cable. The container is used for short-term storage (less than 30 days). Be sure to keep a small amount of moisture (tap water) in the container during storage. This is done to maintain a 100% saturated air environment which is ideal for short-term sensor storage. The sensors should not be submersed in water. The intent is to create a humid air storage environment.

LONG-TERM STORAGE

Long-term Storage - Temperature

No special storage is required. The temperature sensor can be stored dry or wet as long as solutions in contact with the thermistor are not corrosive (for example, chlorine bleach).

Long-term Storage Temperature: -5 to 70°C (23 to 158°F)

Long-term Storage - Conductivity

No special storage is required. Sensors can be stored dry or wet as long as solutions in contact with conductivity electrodes are not corrosive (for example, chlorine bleach). However, it is recommended that the sensor be cleaned with the provided brush prior to and after long term storage.

Long-term Storage Temperature: -5 to 70°C (23 to 158°F)

Long-term Storage - Dissolved Oxygen

Dissolved oxygen sensors (Polarographic and Galvanic) should be stored in a dry state for long term storage First, remove the membrane cap and thoroughly rinse the sensor with clean water. Next, either blow it dry with compressed air or allow to air dry completely. Install a clean, dry new membrane cap over the sensor to keep it dry and to protect the electrodes.

After storing the sensor for a long period of time, it is necessary to "condition" the sensor by putting a new membrane with electrolyte solution on the sensor and then turning the instrument on to allow the sensor sufficient time to stabilize.

Long-term Storage Temperature: -5 to 70°C (23 to 158°F)

Long-term Storage - pH

The key to pH sensor storage, short or long-term, is to make certain that the sensor does not dry out. Sensors which have been allowed to dry out due to improper storage procedures may be irreparably damaged by the dehydration and will require replacement. You can try to rehydrate the sensor by soaking it (preferably overnight) in a potassium chloride solution or a pH 4 buffer before attempting to calibrate.

To store the sensor, remove it from the cable and seal the vacant port with a port plug. Fill the original shipping/storage vessel (plastic boot or bottle) with buffer 4 solution and then submerge the sensor into the solution. The sensor should remain submerged in the solution during the storage period; therefore, make certain that the vessel is sealed to prevent evaporation and periodically check the vessel to ensure the sensor does not dry out.

Long-term Storage Temperature: 0 to 30°C (32 to 86°F)

> ⓘ *It is important not to store the pH sensor in distilled or deionized water as the glass sensor may be damaged by exposure to this medium.*

Long-term Storage - ORP

To store, remove the sensor from the cable and seal the vacant port with the provided plug. Fill the original shipping/storage vessel (plastic boot or bottle) with buffer 4 solution and then submerge the sensor into the solution. The sensor should remain submerged in the solution during the storage period; therefore, make certain that the vessel is sealed to prevent evaporation and periodically check the vessel to ensure the sensor does not dry out.

Long-term Storage Temperature: 0 to 30°C (32 to 86°F)

Long-term Storage - Ammonium, Nitrate, and Chloride

The key to ISE sensor storage, short or long-term, is to make certain that the sensor does not dry out. Sensor junctions that have been allowed to dry out due to improper storage procedures may be irreparably damaged by the dehydration and will require replacement. You can attempt to rehydrate the sensor by soaking it (preferably overnight) in the sensor's high calibration solution before attempting to calibrate.

The recommended storage of these sensors is in moist air. Remove the sensor from the cable and seal the vacant port with the provided plug. Place the sensor in its original shipping storage vessel (plastic boot or bottle) with a small amount of tap water or its high calibration standard. The vessel should remain a saturated air environment. The sensor only needs to be kept in moist air, not submerged. Make certain that the vessel is sealed to prevent evaporation.

Long-term Storage Temperature: 0 to 30°C (32 to 86°F)

TROUBLESHOOTING

Illegal Value may appear during alpha/numeric entry on the message line. This only appears if the values entered do not match the formatting. This will also appear in GLP security area if the password is incorrect.

If you forget the GLP Security Password please contact YSI Tech Support at environmental@ysi.com, 800-897-4151, or +1 937 767-7241.

HELP

During use of the Professional Plus instrument, press **Question** ? from any screen to view help messages directly on the display.

ERROR MESSAGES

If readings for a certain parameter are over range you will see a series of +++++ and if the readings are under range you will see a series of ----- plus the error message along the bottom of the screen. If you see a series of ????? that will indicate that a certain parameter can not be calculated. The following are potential error messages:

Probe Temp over range
Probe Temp under range
Case Temp over range
Case Temp under range
pH over range
pH under range
ORP over range
ORP under range
Cl over range
Cl under range
NH4 over range
NH4 under range
NO3 over range
NO3 under range
DO over range
DO under range
Conductivity over range
Conductivity under range
Barometer over range
Barometer under range

Error messages for the sensors typically indicate a need to properly clean the sensor. First verify the sensor is properly setup in the Sensor menu, then conduct the recommended cleaning and attempt to calibrate the sensor. If this does not work, it may indicate the useful life of the sensor has been reached and may need to be replaced. You may also contact Technical Support to help determine the next step.

DISSOLVED OXYGEN

The dissolved oxygen sensors will use Probe Current (DO uA) and Probe Slope (%/uA) as part of their GLP file records. The following information indicates the acceptable values for each of these readings:

Polarographic DO at 25 °C, 100% saturated air environment at 760 mmHg

- Probe Current
  - 1.25 mil PE membrane
    - Average 6.15 uA (min. 4.31 uA, max. 8.00 uA)
  - 2.0 mil PE membrane
    - Average 3.38 uA (min. 2.37 uA, max. 4.40 uA)
  - 1 mil Teflon® membrane
    - Average 16.29 uA (min. 11.40 uA, max. 21.18 uA)
- Probe Slope
  - 1.25 mil PE membrane
    - Average 16.26 % sat/uA (min. 12.51 uA, max. 23.23 uA)
  - 2.0 mil PE membrane
    - Average 29.56 % sat/uA (min. 22.74 uA, max. 42.23 uA)
  - 1 mil Teflon® membrane
    - Average 6.14 % sat/uA (min. 4.72 uA, max. 8.77 uA)

RESTORE DEFAULT CALIBRATION VALUES

Occasionally, the instrument may need to have the factory calibration default values restored. In order to accomplish this press Calibrate Cal, highlight **Restore Default Cal** and press enter. Highlight the parameter you wish to restore to default and press enter. Next you will be asked to confirm the operation. Highlight **Yes** and press enter to confirm.

ACCESSORIES / PART NUMBERS

*Cable Part Number**	*Description*
6050000	Professional Plus Instrument
60510-1, -4, -10, -20, or -30	1, 4, 10, 20, or 30-meter cable for ISE/temp
60520-1, -4, -10, -20, or -30**	1, 4, 10, 20, or 30-meter cable for DO/temp
60530-1, 4, -10, -20, or -30	1, 4, 10, 20 or 30-meter cable for Cond/temp
6051010-1, 4, -10, -20, or -30	1, 4, 10, 20, or 30-meter cable for ISE/ISE/temp
6051020-1, -4, -10, -20, or -30	1, 4, 10, 20, or 30-meter cable for ISE/DO/temp
6051030-1, 4, -10, -20, or -30	1, 4, 10, 20, or 30-meter cable for ISE/Cond/temp
6052030-1, -4, -10, -20, or -30	1, 4, 10, 20 or 30-meter cable for DO/Cond/temp
605790-1, -4, -10, -20, or -30	1, 4, 10, 20 or 30-meter Quatro cable for DO/Cond/temp/ISE/ISE
605107	1-meter pH/temp single junction lab-grade combo electrode
605177	4-meter pH/temp single junction lab-grade combo electrode
605108	1-meter ORP/temp single junction lab-grade combo electrode
605178	4-meter ORP/temp single junction lab-grade combo electrode
605109	1-meter pH/ORP/temp single junction lab-grade combo electrode
605179	4-meter pH/ORP/temp single junction lab-grade combo electrode

Sensor Part Number	*Description*
605202	Galvanic DO sensor
605203	Polarographic DO sensor
605101	pH (ISE)
605102	ORP (ISE)
605103***	pH/ORP Combination (ISE)
605104****	Ammonium (ISE)

Sensor Part Number	*Description*
605105****	Chloride (ISE)
605106****	Nitrate (ISE)
605780	Self-Stirring BOD sensor
005560	Conductivity/Temperature sensor for Quatro cable

* All cables include temperature.
Cables with conductivity include sensor
(no need to order separate conductivity sensor).
** Special order cables up to 100-meters are available with 60520 cables.
*** Not compatible with 6051010-X or Quatro cables.
**** Freshwater only

Accessory Part Number	*Description*
603059	Flow cell, standard, 203 mL (for two-port sensors) 
603077	Flow cell kit, 1 or 2 port sensor (includes 603059 flow cell for two-port sensors with the 603078 adapter for one-port sensors) 
603078	Flow cell adapter, single port (use with 603059 flow cell to accommodate one-port sensors)

Accessory Part Number	*Description*
605990	Flow cell kit for Quatro cable assemblies.
603056	Flow cell mounting spike 
605604	Communications saddle kit 
605515	Data Manager desktop software
603075	Carrying case, soft-sided 
603074	Carrying case, hard-sided 
605745	Maintenance kit
038213	Brush, tube cleaner
601205	Grease, o-ring

Accessory Part Number	*Description*
603069	Belt clip 
063517	Ultra clamp 
063507	Tripod clamp 
603062	Cable management kit 
605978	Weight, sensor/cable, 4.9 oz. 
063019	Weight, sensor/cable, 24 oz., 3”
063020	Weight, sensor/cable, 51 oz., 6”
603070	Shoulder strap

Solutions Part Number	*Description*
3161	1,000 us/cm conductivity solution (quart)
3163	10,000 us/cm conductivity solution (quart)
3169	50,000 us/cm conductivity solution (8 pints)
3682	Zobell ORP solution (125 mL)
3824	pH 4, 7, 10 buffers (2 pints of each)
3841	1 mg/L ammonium solution (500 mL)
3842	10 mg/L ammonium solution (500 mL)
3843	100 mg/L ammonium solution (500 mL)
3885	1 mg/L nitrate solution (500 mL)
3886	10 mg/L nitrate solution (500 mL)
3887	100 mg/L nitrate solution (500 mL)
5580	Confidence Solution (verifies pH, ORP, conductivity sensor performance)

DECLARATION OF CONFORMITY

The undersigned hereby declares on behalf of the named manufacturer under our sole responsibility that the listed product conforms to the requirements for the listed European Council Directive(s) and carries the CE mark accordingly.

Manufacturer:	YSI Incorporated 1725 Brannum Lane Yellow Springs, OH 45387 USA
Product Name:	Professional Plus Water Quality Instrument
Model Numbers	
Instrument/Accessory:	Professional Plus (6050000) / ProComm (605604)
Probe/Cable Assemblies:	605107, 605177, 605108, 605178, 605109, 605179, 605780, 60510, 60520, 60530, 6051010, 6051020, 6051030, 6052030, 605790
Sensors:	605202, 605203, 605780, 605101, 605102, 605103, 605104, 605105, 605106, 005560
Conforms to the following:	
Directives:	EMC 2004/108/EC RoHS 2002/95/EC WEEE 2002/96/EC

Harmonized Standards:	• EN61326-1:2006, Electrical equipment for measurement, control, and laboratory use – EMC requirements – Part 1: General Requirements • EN61326-2-3:2006, Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 2-3: Particular Requirements – Test configuration, operational conditions, and performance criteria for transducers with integrated or remote signal conditioning. • EN61000-3-2:2006, Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current < 16A per phase). • EN61000-3-3:1995 +A1:2001 +A2:2005, Electromagnetic compatibility (EMC) – Part 3: Limits – Section 3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current < 16A.
Supplementary Information:	All performance met the continuous unmonitored operation criteria as follows: 1. ESD, EN61000-4-2, Performance Criterion B 2. Radiated Immunity, EN61000-4-3, Performance Criterion A 3. EFT, EN61000-4-4, (EFT) Performance Criterion B 4. Surge, EN61000-4-5, Performance Criterion B 5. Conducted Immunity, EN61000-4-6, Performance Criterion A 6. Voltage Interrupts, EN61000-4-11, Performance Criterion B 7. RF Emissions, EN55011:1998, A1:1999 Class B equipment
Authorized EU Representative	YSI Hydrodata Ltd Unit 8, Business Centre West, Avenue 1 Letchworth, Hertfordshire, SG6 2HB UK

Signed: Lisa M. Abel Date: 22 February 2008
Title: Director of Quality

The undersigned hereby declares on behalf of the named manufacturer under our sole responsibility that the listed product conforms to the requirements for electrical equipment under US FCC Part 15 and ICES-003 for unintentional radiators.

Manufacturer:	YSI Incorporated 1725 Brannum Lane Yellow Springs, OH 45387 USA
Product Name:	
Model Numbers	
Instrument/Accessory:	Professional Plus (6050000) / ProComm (605604)
Probe/Cable Assemblies:	605107, 605177, 605108, 605178, 605109, 605179, 605780, 60510, 60520, 60530, 6051010, 6051020, 6051030, 6052030, 605790
Sensors:	605202, 605203, 605780, 605101, 605102, 605103, 605104, 605105, 605106, 005560
Conforms to the following:	
Standards:	• FCC 47 CFR Part 15-2008, Subpart B, Class B, Radio Frequency Devices • ICES-003:2004, Digital Apparatus
Supplementary Information:	Tested using ANSI C63.4-2003 (excluding sections 4.1, 5.2, 5.7, 9, and 14)

Signed: Lisa M. Abel Date: 22 February 2008
Title: Director of Quality

The undersigned hereby declares on behalf of the named manufacturer under our sole responsibility that the listed product conforms with the Australian and New Zealand Electromagnetic Compatibility (EMC) requirements for generic products to be used in residential, commercial, and light industrial environments.

Manufacturer:	YSI Incorporated 1725 Brannum Lane Yellow Springs, OH 45387 USA
Product Name:	Professional Plus Water Quality Instrument
Model Numbers	
Instrument/Accessory:	Professional Plus (6050000) / ProComm (605604)
Probe/Cable Assemblies:	605107, 605177, 605108, 605178, 605109, 605179, 605780, 60510, 60520, 60530, 6051010, 6051020, 6051030, 6052030, 605790
Sensors:	605202, 605203, 605780, 605101, 605102, 605103, 605104, 605105, 605106, 005560
Conforms to the following:	
Standards:	• AS/NZS 4251.1:1999, Electromagnetic Compatibility (EMC) – Generic emission standard – Part 1: Residential, commercial, and light industry.

Signed: Lisa M. Abel Date: 22 February 2008
Title: Director of Quality

RECYCLING

YSI is committed to reducing the environmental footprint in the course of doing business. Even though materials reduction is the ultimate goal, we know there must be a concerted effort to responsibly deal with materials after they've served a long, productive life-cycle. YSI's recycling program ensures that old equipment is processed in an environmentally friendly way, reducing the amount of materials going to landfills.

- Printed Circuit Boards are sent to facilities that process and reclaim as much material for recycling as possible.
- Plastics enter a material recycling process and are not incinerated or sent to landfills.

- Batteries are removed and sent to battery recyclers for dedicated metals.

When the time comes for you to recycle, follow the easy steps outlined at www.ysi.com.

CONTACT INFORMATION

ORDERING AND TECHNICAL SUPPORT

Telephone:	800 897 4151 (US) +1 937 767 7241 (Globally) Monday through Friday, 8:00 AM to 5:00 ET
Fax:	+1 937 767 9353 (orders) +1 937 767 1058 (technical support)
Email:	environmental@ysi.com or proseries@ysi.com
Mail:	YSI Incorporated 1725 Brannum Lane Yellow Springs, OH 45387 USA
Internet:	www.ysi.com

When placing an order please have the following available:
1.) YSI account number (if available)
2.) Name and phone number
3.) Purchase Order or Credit Card
4.) Model Number or brief description
5.) Billing and shipping addresses
6.) Quantity Telephone: 800 897 4151 (US)

SERVICE INFORMATION

YSI has authorized service centers throughout the United States and Internationally. For the nearest service center information, please visit www.ysi.com and click 'Support' or contact YSI Technical Support directly at 800-897-4151.

When returning a product for service, include the Product Return form with cleaning certification. The form must be completely filled out for a YSI Service Center to accept the instrument for service. The form may be downloaded from www.ysi.com by clicking on the 'Support" tab, then the Product Return Form button.

Item # 605596
Rev D
Drawing # A605596
March 2009

Appendix A4-3

Downhole Camera

www.heroninstruments.com

dipper-See EXAMINER

Vertical Downhole Inspection Camera

Operating and Maintenance Instructions

HERON ALSO MANUFACTURES:

- Water Level Meters
- Data Loggers
- Interface Meters
- Conductivity Meters
- Temperature Meters
- Well Casing Indicators
- Well Depth Indicators
- Tag Lines

HERON INSTRUMENTS INC.
447 Moxley Road, Dundas, ON L9H 5E3 CANADA
1-800-331-2032 or 905-628-4999
info@heroninstruments.com

Please visit our **www.heroninstruments.com** for more information on the complete **Heron** product line.

Made in Canada

(Figure #1 DVR Operating Instructions)

IR remote control

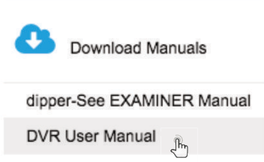
Buttons	Functions
▲	Up/volume up(during playback)
▼	Down/volume down(during playback)
◄	Left/fast backward(during playback)
►	Right/fast forward(during playback)
OK	Set/record(during playback)
MENU	Menu
P/P	Play/pause/delete files
STOP	Stop
ESC	Return to last menu/playback

Use Remote Control to Operate DVR
- Use the ▲/▼ buttons to select options to be adjusted.
- To set up recording, select "MENU" button - set up all parameters.
- Press "OK" to set selection.
- Press "ESC" to return to last menu or exit preview mode.
- NOTE: DVR MUST BE IN NTSC MODE.
- After last item is set-up, all data will be saved and screen will return to preview mode.
- "OK" will start/stop recording.
- Select "PLAY" on remote to enter playback mode.
- "OK" will start and/or stop playback.

DVR and Other Accessories

- Make sure unit is off.
- Insert SD card into DVR.
- Make sure wires are connected properly into DVR.
  WARNING: Wrong wire placement will damage the unit.
- Remove cap from connector on back of frame. DO NOT lose the cap, this protects the connector from moisture intrusion.
- Connect DVR to dipper-See EXAMINER:
  - Line up white dot on DVR male connector to the top of the connector on monitor housing.
  - Line up pins and tighten the connectors to provide a water tight seal.
  - Fasten DVR to nose bridge on the back of the monitor housing with the supplied Velcro.
- Push POWER button on.
- Push MODE button to activate DVR. The red LED light will be on if DVR is activated. If the viewing screen is blue, check all connections.
  - Record status will flash while recording, bottom left corner.
  - Record time is located top right corner of screen.
  - Date & time is located bottom right hand of screen, adjust information with remote control.

For full DVR instructions, refer to manufacturer's manual found at: www.heroninstruments.com/products/vertical-downhole-inspection-cameras/dipper-see-examiner



Operating and Maintenance Instructions Inside

General Care of the dipper-See EXAMINER

The dipper-See EXAMINER is a robust and cost effective vertical downhole inspection camera. The dipper-See EXAMINER will provide years of reliable service when these recommendations are followed:

- Avoid sharp edged casing, use the tape guide on the unit to prevent damage to the tape.
- Take care to avoid tape becoming entangled with other equipment.
- Neatly rewind and clean the tape after each use.
  Refer to: Cleaning the dipper-See EXAMINER

DO NOT open monitor housing; warranty will be void.

DO NOT allow the tape to "freefall" down the well, it may become caught in other equipment or damage the lens.

DO NOT clean the lens with any alcohol based product.

Warranty is conditional upon adherence to these guidelines.

Equipment Check

The dipper-See EXAMINER operates in two functions: Function one is for real-time downhole viewing. Function two, with the **MODE** button pressed (LED light on), records video and audio on the external **DVR.**

Before taking the unit into the field, carry out these simple tests:

- Make sure both batteries are fully charged.
- Connect battery to dipper-See EXAMINER.
- Check the condition of the camera probe:
  - Lens is clean
  - Connections are tight
  - No cracks in lens
  - No water in lens
- Test the dipper-See EXAMINER by turning the unit on.
- Ensure image is displaying properly (image will take up to 5 seconds to appear).
- If DVR is not being used, make sure MODE button is not pressed.

Use in the Field

Familiarize yourself with all of the functions of the dipper-See EXAMINER before taking the unit out in the field.

- To use centralizer - large clip should be attached to the camera probe and the small clip to the tape. Adjust the width by repositioning the clip on the tape (**DO NOT** slide the clip up and down on the tape).

- To avoid damaging the tape on the side of the casing, hang the dipper-See EXAMINER on the casing (1) and run the tape over the guide on the frame leg (2). If you cannot hang the unit, drape a soft cloth over the edge of the casing, guide the tape down the center of the well away from the side.

- If using DVR, connect to unit (Use Operating Instructions provided with DVR) and push MODE button.
- Turn on the monitor by pressing the Power button.
- For video voice over, insert microphone to monitor house (bottom)
- Adjust the adjustable positioning arm to view the HD display screen at different angles or lighting conditions, or use the provided Monitor Visor.
- Lower the camera probe.
- When camera probe hits water, shake camera to remove bubbles.
- Take depth measurement from the tape markings every meter or foot. Indicate findings through the audio attachment (microphone) or manually note the information.
- When rewinding the tape, use a clean dry cloth to remove as much water and debris from the tape and camera probe as possible.

Cleaning the dipper-See EXAMINER

Always clean the dipper-See EXAMINER after use in the field to maintain optimal performance and extend the life of the unit.

Keep monitor and camera probe clean with cloth provided.
The dipper-See EXAMINER may be cleaned with mild household dishwashing detergent (or Alconox) and rinsed with water.
IMPORTANT: Remove battery before cleaning, MAKE SURE DVR cap is closed.

DO NOT USE: Alcohol or Chlorine or other harsh cleaners that may damage the lens and tape.
Please note that the monitor is rated IP65 and should be covered during wet or inclement weather and protected against direct exposure to water projection (spraying).

DO NOT remove camera probe for cleaning.

Troubleshooting the dipper-See EXAMINER

Q. Why won't the monitor turn on when POWER button is pushed?
A. Make sure the battery is fully charged and connected.

Q. Why does the monitor have a blue screen?
A. Make sure probe is attached - check all connections.
A. Make sure the **MODE** function is not on. If on, press **MODE** button to turn off.

Q. How do I start the DVR?
A. Refer to DVR Operating Instructions (Figure #1).

Please go to www.heroninstruments.com for more FAQ.

Contact Heron Instruments or your Heron Distributor if you cannot isolate the problem.

Warranty (2 Year)

Heron Instruments Inc. warrants to repair or replace any defective equipment or part upon inspection by a **Heron** service technician. Warranty will be determined to our satisfaction to have a defect in workmanship or original material. The customer is responsible for all shipping fees to return the item to **Heron.**

This warranty shall not apply to damage of equipment caused by improper installation, usage, storage, alteration or inadequate care.

In no event shall **Heron** be held liable for any direct, indirect or consequential damages, abuse, acts of third parties (rental equipment), environmental conditions or expenses which may arise in connection with such defective equipment.

To prevent Electro Static Discharge from damaging the unit, please discharge your body by touching a grounded surface before touc handling the camera probe or DVR. When handling the camera use the black connector as the point of contact.

Heron Instruments Warranty coverage does not extend to the following:

- Tape
- Battery or charger used with the product
- Accessories provided with product
- Products used as rental equipment
- Products contaminated by material which are known to be hazardous and have rendered the unit unserviceable
- Parts failure due to neglect in cleaning or servicing
- Failure of parts caused by misuse

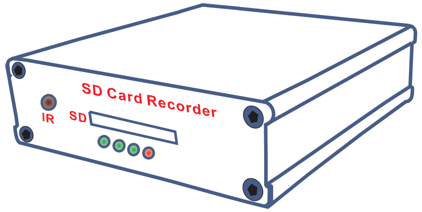
For service information:

Visit www.heroninstruments.com
Email service@heroninstruments.com
Call **1-800-331-2032 or 905-628-4999**

Warranty is conditional upon adherence to these guidelines.

Manual

Mobile DVR
OK
MENU
STOP
ESC
PLAY
DEL.
Remote Control



SD Card Recorder
IR
SD

Contents

Manual

Attention!

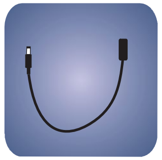
1. Don't take SD card out when DVR is working
2. Use original power cable and AV cables
3. Format SD card by DVR system on your first use
4. Install the unit in dry and ventilatory environment
5. Use genuine SD card
6. Warranty and free maintenance will be invalidated if you disassemble the unit

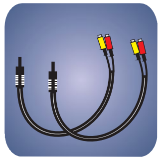
Description

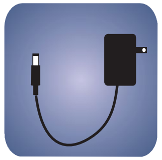
Welcome to use our product!
This DVR unit is designed for in-vehicle security surveillance, with IR remote to control the unit; SD CARD for data storage is shockproof on vehicles and enables easy playback.

Accessories

Remote control


Power cable

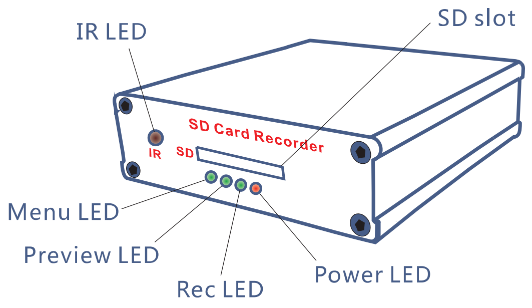

AV cable


Power adapter

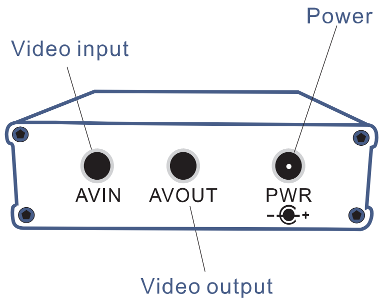
Manual

1.Introduction

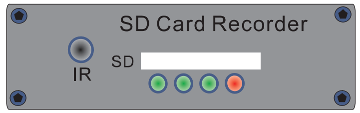
1.1 DVR



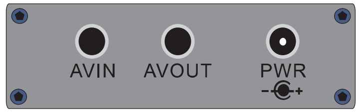
1.2 DVR slot



1.3 Panel



IR	IR led for remote control
SD	SD card slot, 32GB max.
1st Green Led(from left)	menu led, constant on when in menu mode; blinks when in playback mode
2nd Green Led	review led, constant on when in review mode; blinks when reading SD card
3rd Green Led	record led, blinks when recording
4th Green Led	power led, blinks when working

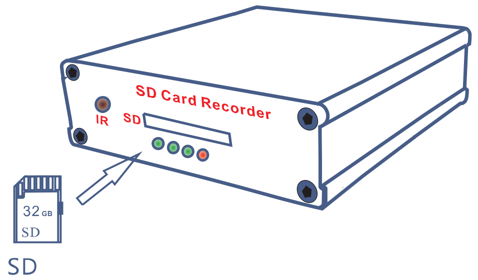


AVIN	video input
AVOUT	video output
PWR	power plug-in(5-30V)

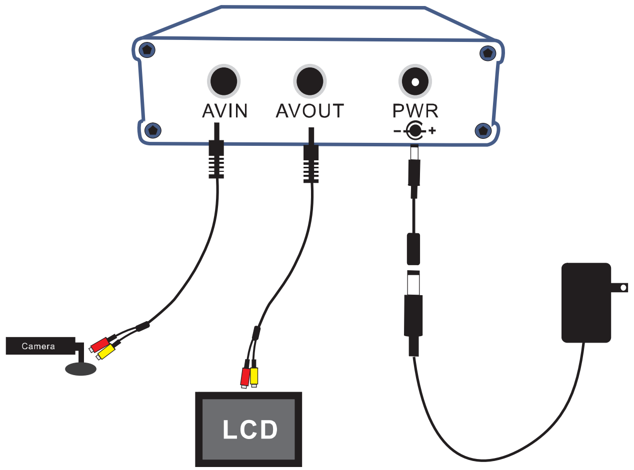
2. IR remote control

Buttons	Functions
	Up/volume up(during playback)
	Down/volume down(during playback)
	Left/fast backward(during playback)
	Right/fast forward(during playback)
OK	Set/record(during playback)
MENU	Menu
P/P	Play/pause/delete files
STOP	Stop
ESC	Return to last menu/playback

3.Insert the SD card



4.AV cables, power cable connection



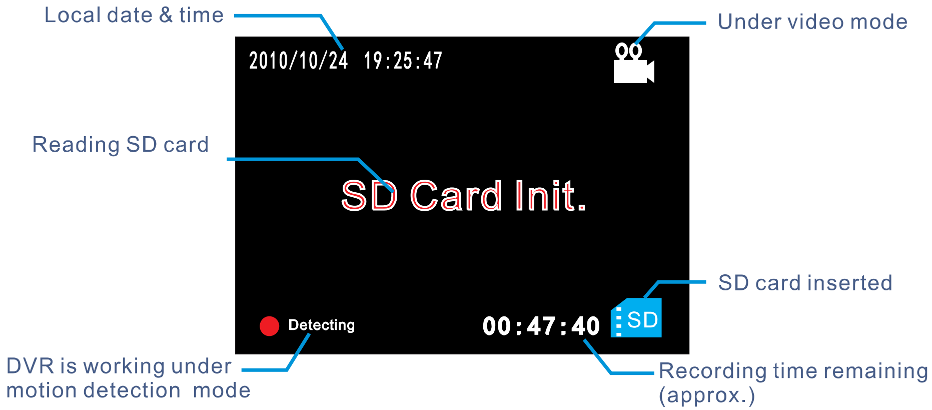
Note: please connect all cables correctly, in case of system failure.

Manual

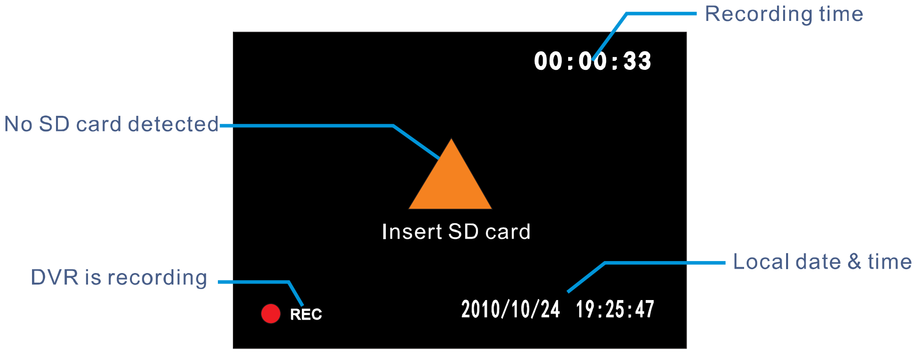
5. Screen icons instruction

5.1 Standby mode

*The following pictures are for references only



5.2 Recording mode



6.Set up

* You need to connect the DVR with TV or monitor before set-up

6.1 Operating DVR with IR remote control

Buttons	Functions
	Up/volume up(during playback)
	Down/volume down(during playback)
	Left/fast backward(during playback)
	Right/fast forward(during playback)
OK	Set/record(during playback)
MENU	Menu
P/P	Play/pause/delete files
STOP	Stop
ESC	Return to last menu/playback

Main operations:

Enter into system menu: press “MENU” on remote

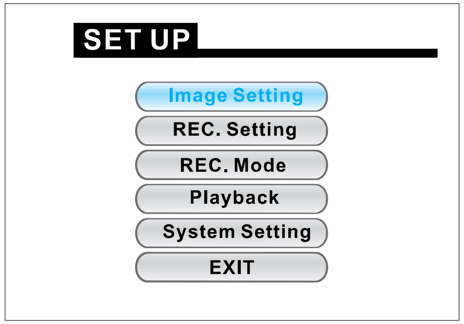
Choose items to set up: press direction keys

Confirm your choice: press “OK”

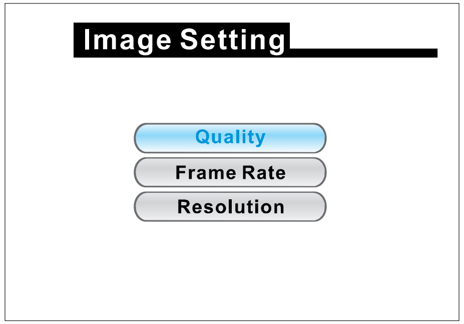
Return to last menu: press “ESC”

6.2 Image setting

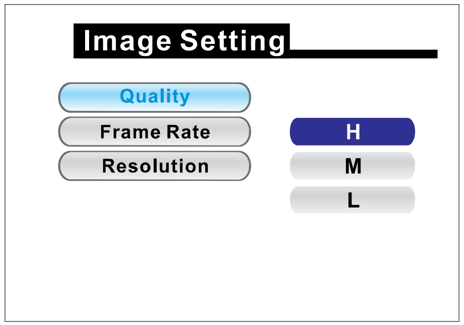
6.2.1 Image quality



A. press “MENU” key to enter into system SET-UP.



B. press “OK” to set



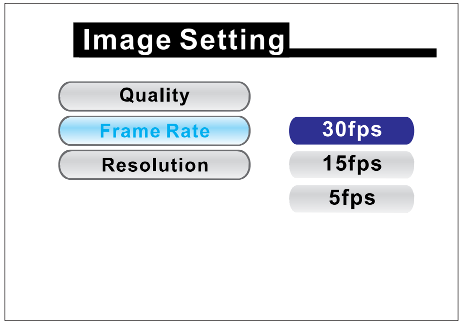
H: best image quality

M: normal image quality

L: low image quality

* the lower the image quality, the longer the recording time

6.2.2 Video frame rate



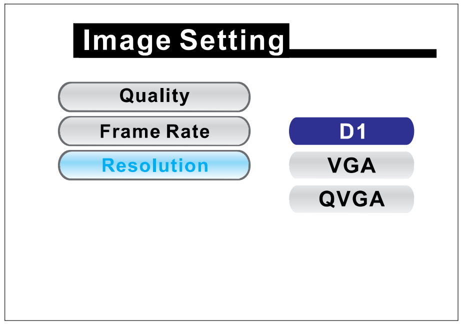
30fps: smooth image

15fps: not so smooth image

5fps: jerky image

*the lower the frame rate, the longer the recording time

6.2.3 Image resolution



D1: 704X576

VGA: 640X576

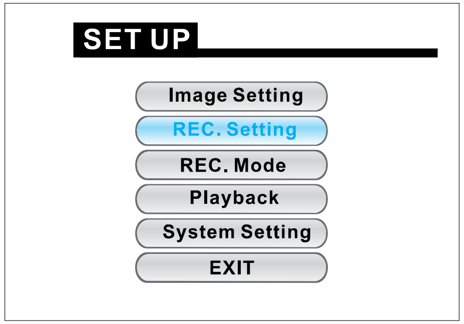
QVGA: 320X288

*the lower the resolution, the longer the recording time

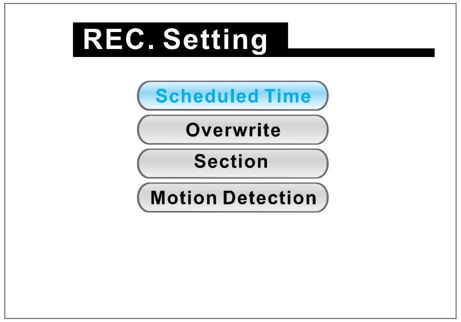
Manual

6.3 Recording setting

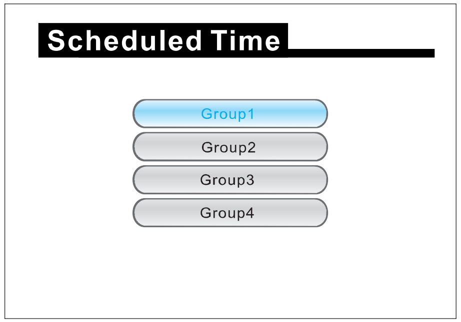
6.3.1 Scheduled time



A. press “MENU” key to enter into system SET-UP.



B. system starts and stops recording automatically according to the scheduled time period



C. press “OK” for 4 groups

press UP/DOWN to choose

press “OK” to enter into each group

*Weekly

Weekly　　Once　　Off

Start Time : 07 : 00

End Time : 13 : 00

SUN MON TUE WED THU FRI SAT

A. press LEFT/RIGHT to choose modes:

Weekly: auto record weekly
Once: auto record once
Off: switch off this group

B. e.g. to choose "Weekly" mode, press UP/DOWN, "Weekly" mode is confirmed when it's in blue;
press "OK" to the next step, select Start Time & End Time

Weekly　　Once　　Off

Start Time : 07 : 00

End Time : 13 : 00

SUN MON TUE WED THU FRI SAT

C. press UP/DOWN to change time; and RIGHT to move on and select days that is needed

Weekly　　Once　　Off

Start Time : 07 : 00

End Time : 13 : 00

SUN MON TUE WED THU FRI SAT

D. e.g. to choose MON, press UP/DOWN to select/dis-select it;

refer to the picture on the left, MON-FRI are all selected

Note: purple font means selected, black font means dis-selected

E. press "OK" to finish weekly set-up, the 2 yellow triangle will go back onto "Weekly"(in blue)

F. press "ESC" to save and return to group list for other groups set-up

*Once(Daily)

Weekly　　Once　　Off

Start Time : 2011/01/01 07 : 00

End Time : 2011/01/01 13 : 00

A. choose "Once", press UP/DOWN, "Once" mode is confirmed when it's in blue

B. press "OK" to move on, please refer to "Weekly" set-up

*Off

Weekly　　Once　　Off

A. choose "off", press UP/DOWN, the group is switched off when it's in blue

B. press "ESC" to switch off this group

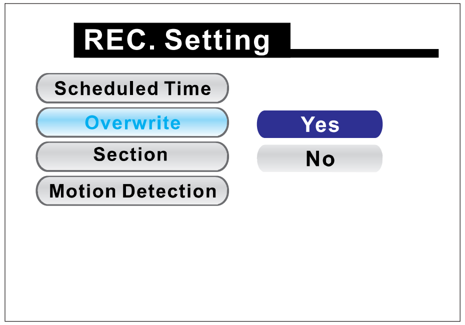
Note:

A. in each group, only one mode can be selected among "Weekly", "Once" and "Off";

B. if scheduled period in "Weekly" overlaps with those in "Once", system will auto choose to record under the longer period; the same method applies to overlaps in between different groups;

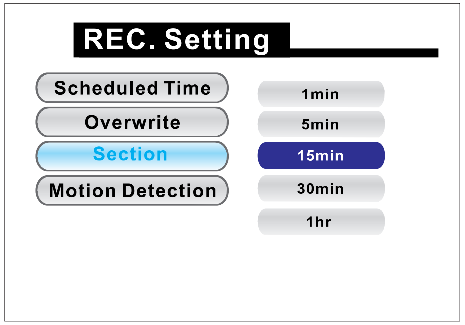
C. press UP/DOWN to select each mode in a group, blue font means mode selected;

6.3.2 Overwrite



A. system will delete the first 300MB files once the SD card is full to save new files

6.3.3 Section recording time set up

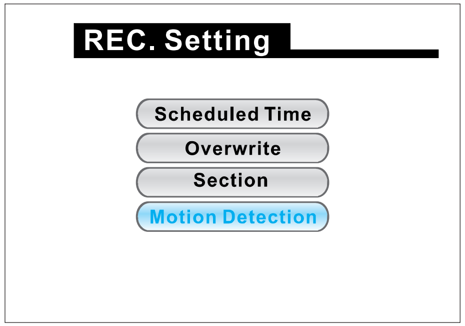


B. set up section recording time

* only available under "Manual", "Scheduled" and "Power Up Rec." modes

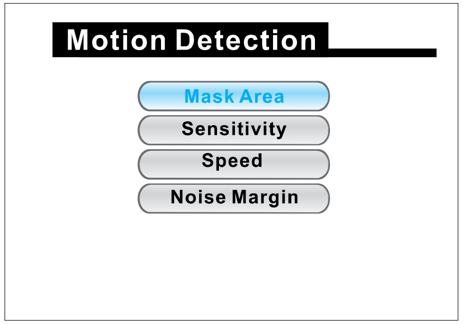
*2.5 min section recording time is fixed under "Motion Detection" mode

6.3.4 Motion detection

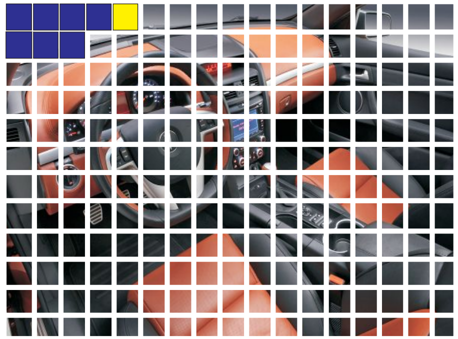


C. set motion detection details

6.3.4.1 Mask Area



A. enter into "Mask Area", the screen will be shown in grids as below:

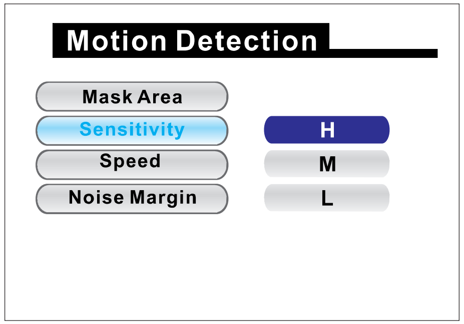


B. press direction keys to move the cursor to choose the area needn't be detected

C. press "OK" to confirm blue grids area won't be motion-detected

D. all grids area that the camera covers are recorded in image

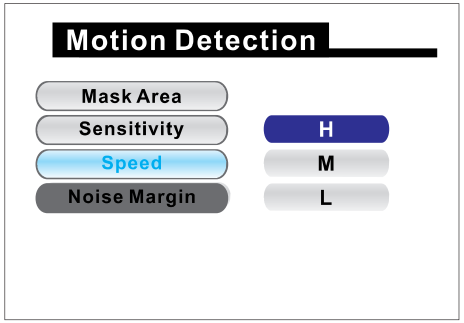
6.3.4.2 Sensitivity



H: high level
M: middle level
L : low level

* system will be triggered very easily if sensitivity is set under high level.

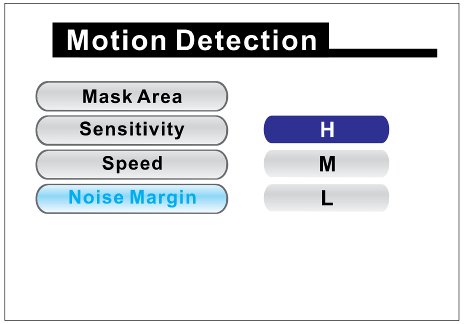
6.3.4.3 Speed



A. different speed levels to trigger system

*system will be triggered very easily
if speed is set in low level.

6.3.4.4 Noise Margin

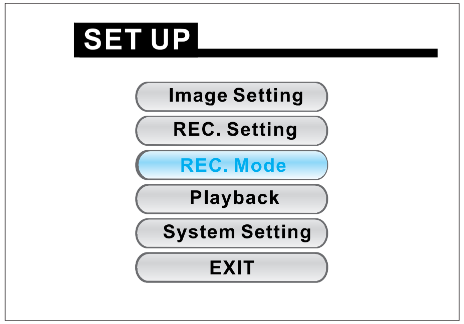


B. different noise levels to trigger system

*system will be triggered very easily
if noise is set in low level

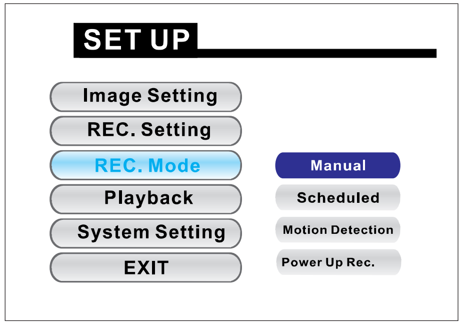
Manual

6.4 Recording mode set up



set the recording mode for system

6.4.1 Recording modes



choose a mode first:

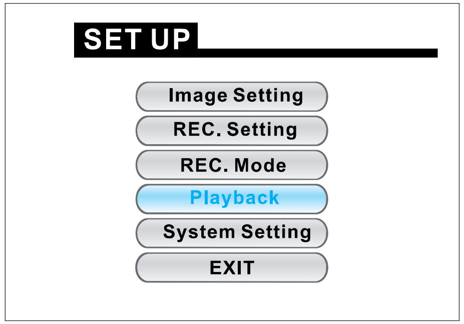
Manual:
under this mode, press "OK" to start recording, and "STOP" to stop recording

Scheduled:
system starts and stops recording according to the scheduled period preset

Motion Detection:
system starts recording automatically by detecting motions in the area preset;
*2.5min section recording time is fixed

Power Up Rec.:
system starts to record as soon as the power is on

6.5 Playback and delete video files



A. press “OK” to enter into file list

6.5.1 Under file list mode

File Name	Date	Start Time
00000001	2010/10/24	06:57:54
00000002	2010/10/24	08:11:31
00000003	2010/10/24	13:53:24
00000004	2010/10/25	07:27:05
00000005	2010/10/25	07:28:35
00000006	2010/10/25	08:11:04
00000007	2010/10/26	22:55:14
00000008	2010/10/26	22:56:54

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Delete:
A. press UP/DOWN to choose the file(s) you want to delete

B. press “P/P” or “DEL.” to delete

Play:
A. press UP/DOWN to choose and “OK” to open the file

B. press “P/P” to play

Fast forward/backward:
Press RIGHT/LEFT to fast forward/backward, one press increases play speed rate (can choose 2,4,8,16 rates).

Volume up and down
Press UP/DOWN to turn volume up/down. Highest volume level is 8.

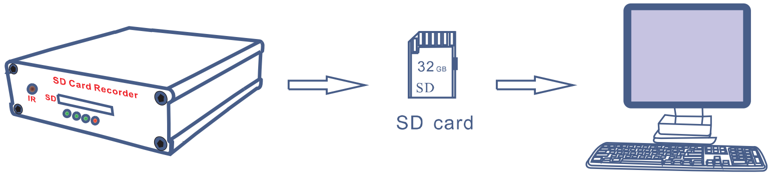
Pause:
Press “P/P” to pause, press it again to start.

Stop:
Press “STOP” to stop playing.

Exit playing mode:
Press “ESC” to return to file list.

6.5.2 Playback video files on computer

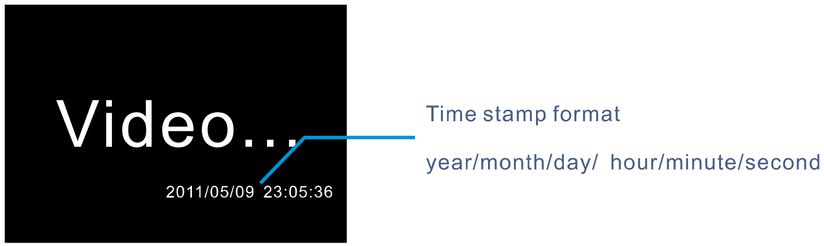
*playback via Media Player



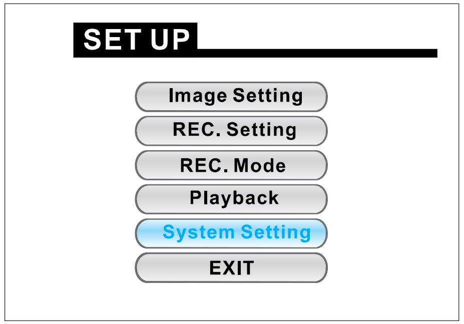
6.5.3 Icons instructions under playback mode

A. Playback on TV set or monitor

B.Playback on computer

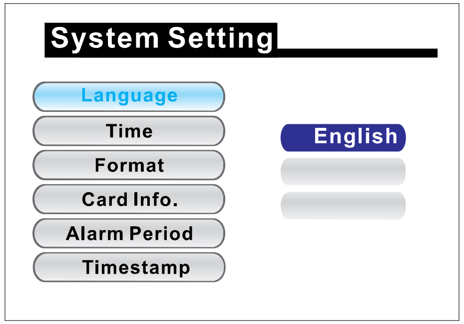


6.6 System Setting



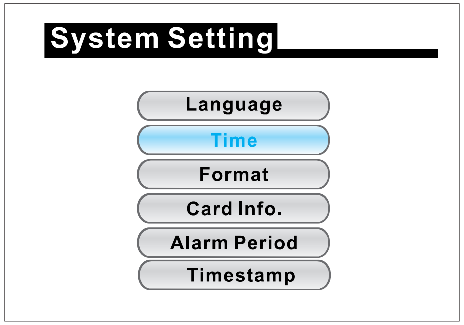
*system set-up

6.6.1 Language



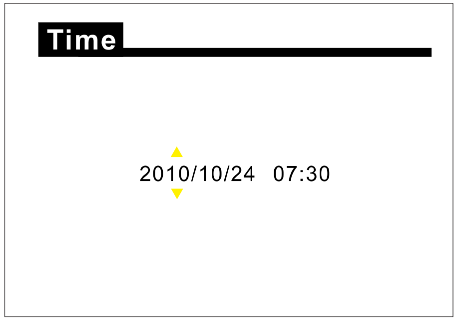
*choose your language

6.6.2 Date and time



*set local date & time

6.6.2.1 Date and time

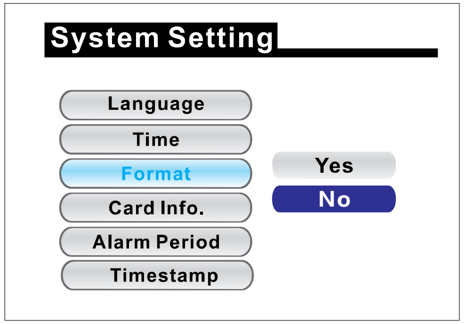


*press LEFT/RIGHT to move the cursor

*press UP/DOWN to adjust the values

*press "OK" to save the setting

6.6.3 Format

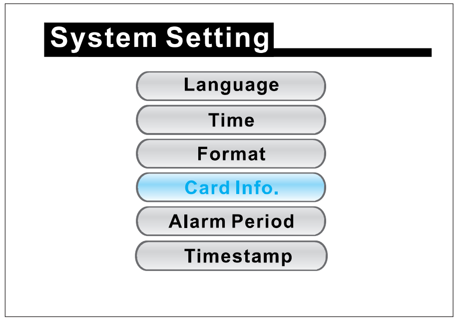


*choose "Yes" to format SD card

Attention!

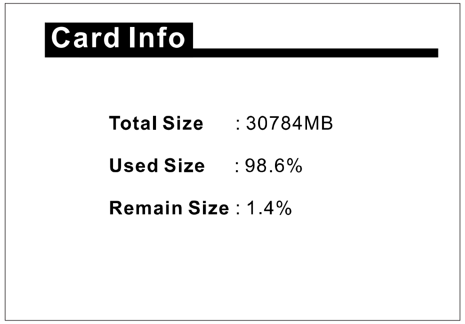
all files can not be restored after being formatted from SD card

6.6.4 Memory card information



*check SD memory capacity

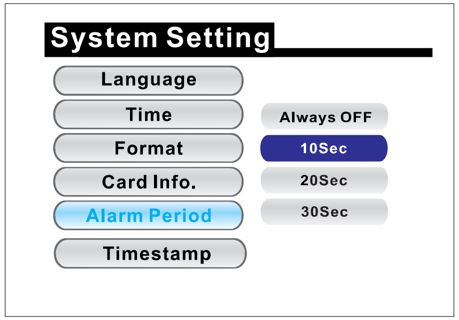
6.6.4 Memory card information



*check card memory

*press "ESC" to exit

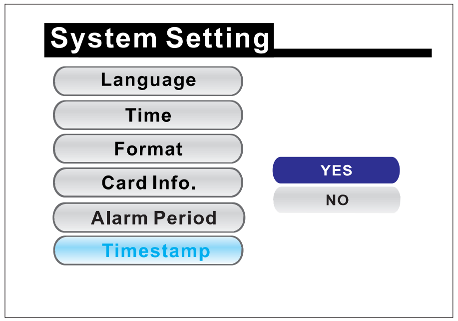
6.6.5 Alarm Period



* choose alarm ON/OFF, and length

* system outputs a 12V voltage for external alarm devices when motion detection is triggered

6.6.6 Time Stamp



* choose Timestamp ON/OFF

7. F.A.Q.

Q: DVR can not read SD card.
A: Please use 1GB to 32GB genuine SD card.

Q: No images on TV after turn on the DVR.
A: Please check the cable is correctly connected. Yellow connector should connect with video input port on TV.

Q: No sounds when playing video.
A: Please check the cable is correctly connected. Red connector should connect with audio input port on TV.
B: The camera connected with DVR should be with audio feature.

Q: No recorded files in SD card after system records.
A: 1. Please check if the SD card works with DVR normally;
2. Please use 1GB to 32GB genuine SD card.

Q: DVR system crashes when it is on.
A: 1. You can not take out or insert SD card when it is on;
2. Please make sure it is a genuine SD card.

Q: DVR doesn't record video when motion detected.
A: 1. Please set "Recording mode" to "Motion Detection"
2. Set "Sensitivity","Speed" and "Noise Margin" according to the suggestions on page 13-14.

Q: Remote control is not working.
A: 1. Check whether remote battery is flat: connect DVR with camera and monitor, press any buttons on remote, with remote LED facing the camera to see whether there is a spark in the monitor; if not, please replace a new battery;
2. Remote control only works in open space.

Appendix A5

Downhole Camera SOP

A5.1 DOWNHOLE CAMERA SOP

This SOP provides instructions to be used when inspecting a well using a downhole camera and the findings should be documented.

A5.1.1 General

Downhole camera inspections should be completed at least every 5 years or when there are problems suspected with regards to the well casing and / or screen. A downhole camera inspection should identify the following:

1. The condition of the well casing:
   a. Is the casing corroding?
   b. Are the walls covered with biofouling?
   c. Are there cracks, holes, or other obvious signs of damage to the casing?
   d. Are there any blockages in the well (e.g., dropped equipment)?
2. The condition of the well screen (if present):
   a. What length of the well screen remains clearly exposed and in good condition?
   b. Is there a significant amount of sediment at the bottom of the well? How much of the well is infilled (compare visible screen length / end-of-hole depth to well record)?
   c. Is there biofouling / encrustation covering the screen?

A5.1.2 Equipment

Task-specific equipment (refer to the **Equipment Checklist** in **Appendix A1** for a complete list of recommended equipment for site visits):

- Clipboard with **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]) (or device with electronic field sheet);
- Field notebook;
- Downhole camera (charged) and associated equipment, see **Figure A5-1.1**;
- Industrial (shop) paper towels;
- Water;
- Camera; and
- Water level tape.

Figure A5-1.1 Downhole camera equipment.

Photo source: Heron Instruments 2022.

A5.1.3 Procedure

Before leaving for the field, ensure camera is operating, SD card is installed into the DVR, and batteries are charged.

Below is general guidance for completing a downhole camera inspection which should be used in conjunction with the manufacturer's instructions (**Appendix A4**):

- A manual water level measurement and recording live datalogger pressure / level readings should be the **first task** that is completed at the beginning of any site visit prior to any work at the well that could potentially alter the cable length of the pressure transducer or water levels in the well. Refer to the **Groundwater Level Data Downloading SOP** and record these notes on the **Site Visit Data Download & Calibration Field Sheet** (both documents can be found in **Appendix A2** [**Section A2.1.5.1**]).
- If the well is >7.6 cm (3 in) in diameter:
  - Use the provided centralizer. For standard 15 cm (6 in) wells, keep the centralizer width to about 10 cm (4 in) as the well screen casing is typically a smaller diameter.
  - It is generally recommended to (carefully) remove the submerged pressure transducer from the well to avoid the tape / cables becoming tangled later when the camera is removed. Take care not to bend / kink the pressure transducer cable.
- If the well is <76 mm (3 in) in diameter:
  - Do not use the centralizer.

- There is no need to remove the submerged pressure transducer as the centralizer is typically the primary reason the tape / cables become tangled.

- Plug in the DVR and battery into the back of the camera display, as shown in **Figure A5-1.2**.
- Plug microphone into camera display, if not already installed.
- Turn the camera on and ensure the displayed date and time are correct. Adjust as needed.
  - Tip: the remote has to be pointed directly at the DVR box (small silver coloured box as shown in **Figure A5-1.2**) to work.
  - To format the time: go to *'Menu'* → *'System Settings'* → *'Format'* and click '*Yes*'. Then hit *'Menu'* twice and to return to the display screen with the recording now started.

Figure A5-1.2 Downhole camera battery pack.

Photo source: BC ENV.

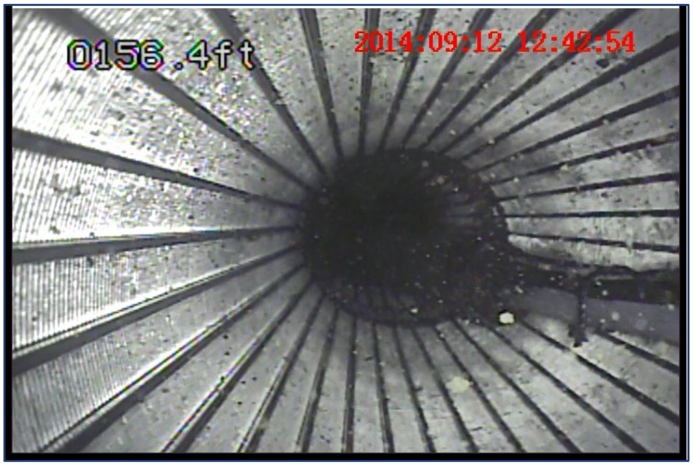
- Deploy the downhole camera down the well, taking care not to allow the line (fiberglass tape measure) to rub against the metal rim of the top-of-pipe as this could cut / damage the line. Set-up should look similar to **Figure A5-1.3** below.

Figure A5-1.3 Downhole camera set-up.

Photo source: Heron Instruments 2022.

- As the camera travels slowly down the well, record the depth below top-of-pipe of the following features and note other observations of importance to the functioning of the well:
    - Depth of any blockages or cracks in the well casing;
    - Depth to the visible well screen (top and bottom depths);
    - Note any evidence of extreme biofouling, corrosion and infilling of the well;
    - Note if your observations were hampered by the turbidity of the water;
    - End-of-hole depth; and
    - Depth of any other unusual aspects of the well.
    - While the camera will record audio, it is critical to write down all relevant notes in a field notebook to ensure there is a written record, especially in the event that the audio does not record clearly.
    - **Figure A5-1.4** has examples of stainless steel and PVC well screens in good condition.

Figure A5-1.4 Examples of well screens.



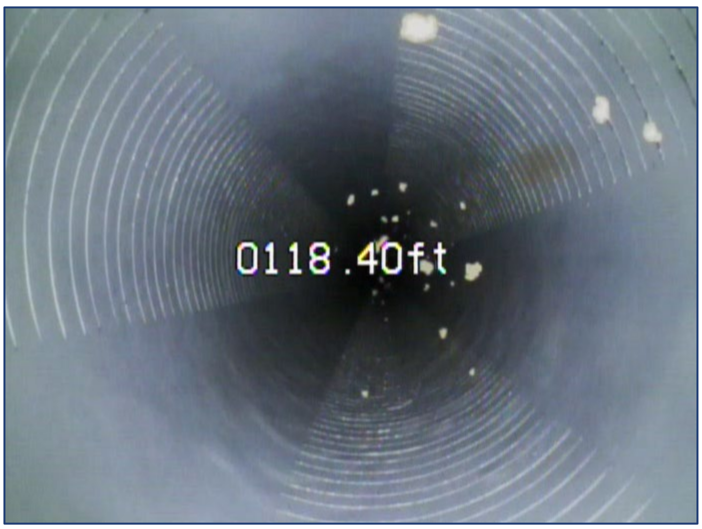


Photo source: BC ENV.

- When removing the camera from the well, use a wet shop towel to clean the tape as it is reeled up. Once the camera is at the surface, rinse it with water and wipe it down.
- If the pressure transducer was removed from the well, redeploy the transducer.
- Collect another manual water level measurement. Then record the live static water level reading from the pressure transducer and, for telemetry stations, calculate the necessary offset to apply to the datalogger. Download the logger data at this time as well (**Groundwater Level Data Downloading SOP** and **Site Visit Data Download & Calibration Field Sheet** in **Appendix A2** [**Section A2.4** and **A2.1.5.1**]).
- Upon return to the office:

- **Do not** store the camera batteries at full power for prolonged periods of time as they can bloat and pose a safety concern. If the batteries are full, leave the camera running to partially drain them.

- Ship the downhole camera to the next region requesting use of the camera (check the **Downhole Camera Tracker Spreadsheet** on the **PGOWN MS Teams Channel**).

A5.1.4 Miscellaneous

A5.1.4.1 Best Practice Tips

- Begin downhole camera recording by stating the Provincial Observation Well number and location. It is also a good idea to first point the camera at the well sticker, displaying the observation well number in case the microphone fails to pick up the audio clearly.

- Conduct a downhole camera inspection before sampling or conducting other work in the well that could increase turbidity in the well water.

- If the well water is mostly clear, there is no need to rush the downhole camera inspection. However, if there is significant biofouling / turbidity in the well, then as the camera is lowered, it will disturb more and more material. In that case, continuously lower the camera to stay ahead of the falling cloud of turbidity. Quickly record depths of features of interest (e.g., well screen length).

- Measuring to the nearest centimetre is sufficient when noting the depths of features of interest. Be sure to label the units as ‘m btoc’ if not correcting for stick-up height.

A5.1.5 Troubleshooting

Observation	Potential Consequences	Potential Causes	Possible Next Steps
Camera cannot make it into the well screen area	▪ Unable to complete inspection of well screen.	▪ Well screen is a smaller diameter than the width of the centralizer. ▪ Pump or other equipment is blocking the camera / centralizer.	▪ Remove camera from well and adjust centralizer. Redeploy. ▪ If water is too turbid after lowering / raising camera, return another day to conduct the inspection.
Water is too turbid to see casing or screen	▪ Unable to conduct proper inspection and document depths of features of interest.	▪ Extreme biofouling of well. ▪ Suspended clay / silt particles. ▪ Moving camera up and down length of well, disturbing biofouling or sediment in the well. ▪ Conducting inspection after sampling the well or other downhole work.	▪ Return another day to conduct the inspection. ▪ Try to complete the inspection in one attempt (i.e., without raising / lowering camera, or long pauses). ▪ Consider redevelopment the well and / or chemical treatment. Discuss with Groundwater Monitoring Specialist.
Blockage or dropped item observed	▪ May prevent completion of downhole camera inspection or other future downhole maintenance / field activities (e.g., sampling).	▪ Previous fieldwork where items were accidentally dropped into the well. ▪ Collapsed well casing or open hole bedrock well due to ageing / poor construction.	▪ Use the attachable hook included with the downhole camera set-up to retrieve the item, if possible. Alternatively hire a contractor (well driller). ▪ If the blockage is due to a collapsed casing or bedrock open hole, discuss decommissioning and replacing the well with the Regional Hydrogeologist and Groundwater Monitoring Specialist.
Problems with DVR, camera display, etc.	▪ Unable to complete inspection of well casing and screen. ▪ Unable to record downhole video and / or audio.	▪ Loose connections. ▪ Low battery. ▪ Damaged wiring.	▪ Check all connections. ▪ Check that the battery is charged. Replace with available spare battery if needed. ▪ If frayed wiring is found (on tape measure of downhole camera), contact Groundwater Monitoring Program Supervisor to send camera in for repairs. ▪ Consult manufacturer's instructions for additional troubleshooting (**Appendix A4**).

A5.1.6 Record Keeping

After completion of every downhole camera inspection, there are various records that need to be saved / updated and potential follow-up actions taken, depending on the findings of the inspection:

- Save video files to the respective project folders. Save with the format: **YYYYMMDD_OW###**.
- Delete videos from the SD card only after confirming they have been properly saved.
- Compare observed well screen length and depth to well record. Update the written field notes to include details on the degree of well infilling / screen encrustation. The field notes should be scanned and saved to the project folder.
- If the well record in GWELLS is missing details on the well construction (e.g., screen depth or length, depth of surface casing for open hole bedrock wells, etc.), update the well record with information obtained from the downhole camera inspection (be sure to adjust depth values to metres below ground surface).
- Track the date of the downhole camera inspection in the **PGOWN Equipment & Station Information Spreadsheet** on the **PGOWN MS Teams Channel**, as well as the findings (e.g., well casing / screen are in good condition with minimal infilling or biofouling, screen no longer visible and well may require rehabilitation, blockage observed at this depth, etc.).
- Notify the Groundwater Monitoring Program Supervisor and Groundwater Monitoring Specialist of any major repairs or well decommissioning that may be required.

A5.1.6.1 Field Sheet

There is not a specific field sheet for downhole camera inspections.

Appendix A6

Groundwater Data Grading, Review & Approval

Appendix A6-1

Groundwater Level Data Grading Spreadsheet

Groundwater Level Data Grading Spreadsheet

Sensor Make / Model	Sensor Range (m)	Sensor Full Scale Range (FSR) Accuracy (%)	Resulting Water Measurement Accuracy (cm)	Manual Water Level Tape Measurement Error (centimeters, +/-)	Total Low Range Error in cm (-0.5 cm from manual tape)	Total High Range Error in cm (+0.5 cm from manual tape)	Grade 51 / Excellent (within 1 cm of Total High Range Error, in cm)	Grade 41 / Very Good (Grade A[2], in cm)	Grade 31 / Good (Grade A[3], in cm)	Grade 11 / Poor (Grade A[4], in cm)	Grade 2 / Substandard	Grade 1 / Unverified	Grade 0 / Undefined	Grade -1 / Unspecified
INW PT12-BV Barometric and Vacuum Sensor											Must be used when the drift correction required exceeds the upper limit of the 'Poor' data grade.	Must be used when it is not possible to use a reliable manual groundwater level measurement to correct the data. E.g., site visit occurred during a period when the datalogger was shutdown (power failure); therefore, the manual water level measurement during the site visit could not be used to confidently determine sensor drift. Should also be used for imported historical data for which the manual water level measurements are not available or otherwise not reliable.	Auto-assigned by Aquarius to the ingested telemetry data, prior to grading.	Auto-assigned by Aquarius to the appended logger data prior to grading.
0-5	5	0.05%	0.25	0.5	n/a	n/a	0 - 2.00	2.01 - 4.00	4.01 - 8.00	8.01 - 16.00				
0-8	8	0.05%	0.4	0.5	n/a	n/a	0 - 2.00	2.01 - 4.00	4.01 - 8.00	8.01 - 16.00				
0-10	10	0.05%	0.5	0.5	0	1	0 - 2.00	2.01 - 4.00	4.01 - 8.00	8.01 - 16.00				
0-15	15	0.05%	0.75	0.5	0.25	1.25	0 - 2.25	2.26 - 5.06	5.07 - 11.39	11.40 - 25.63				
0-18	18	0.05%	0.9	0.5	0.4	1.4	0 - 2.40	2.41 - 5.76	5.77 - 13.82	13.83 - 33.18				
0-20	20	0.05%	1	0.5	0.5	1.5	0 - 2.50	2.51 - 6.25	6.26 - 15.63	15.64 - 39.06				
0-21	21	0.05%	1.05	0.5	0.55	1.55	0 - 2.55	2.56 - 6.50	6.51 - 16.58	16.59 - 42.28				
0-25	25	0.05%	1.25	0.5	0.75	1.75	0 - 2.75	2.76 - 7.56	7.57 - 20.80	20.81 - 57.19				
0-30	30	0.05%	1.5	0.5	1	2	0 - 3.00	3.01 - 9.00	9.01 - 27.00	27.01 - 81.00				
Leveloggers														
3001 Mini LT Levelogger F30/M10	10	0.05%	1.01	0.5	0.51	1.51	0 - 2.51	2.52 - 6.30	6.31 - 15.81	15.82 - 39.68				
3001 LT Levelogger Gold M20/F65	20	0.05%	1.51	0.5	1.01	2.01	0 - 3.01	3.02 - 9.06	9.07 - 27.27	27.28 - 82.07				
3001 Mini LT Levelogger F100/M30	30	0.05%	2.01	0.5	1.51	2.51	0 - 3.51	3.52 - 12.32	12.32 - 43.24	43.25 - 151.76				
Keller Acculevel														
0-10	10.0	0.10%	1.00	0.5	0.50	1.50	0 - 2.50	2.51 - 6.25	6.26 - 15.63	15.64 - 39.06				
0-20	20.0	0.10%	2.00	0.5	1.50	2.50	0 - 3.50	3.51 - 12.25	12.26 - 42.88	42.89 - 150.06				
0-30	30.0	0.10%	3.00	0.5	2.50	3.50	0 - 4.50	4.51 - 20.25	20.26 - 91.13	91.14 - 410.06				
Campbell Scientific FTS SDI-PT														
0-10	10	0.10%	1	0.5	0.5	1.5	0 - 2.50	2.51 - 6.25	6.26 - 15.63	15.64 - 39.06				
0-20	20	0.10%	2	0.5	1.5	2.5	0 - 3.50	3.51 - 12.25	12.26 - 42.88	42.89 - 150.06				
0-50	50	0.10%	5	0.5	4.5	5.5	0 - 6.50	6.51 - 42.25	42.26 - 274.63	274.64 - 1785.06				
Diver														
Mini Diver DI501	10	0.05%	0.51	0.5	0.01	1.01	0 - 2.01	2.02 - 4.02	4.03 - 8.06	8.07 - 16.16				
TD-Diver DI801	10	0.05%	0.51	0.5	0.01	1.01	0 - 2.01	2.02 - 4.02	4.03 - 8.06	8.07 - 16.16				
TD-Diver DI802	20	0.05%	1.01	0.5	0.51	1.51	0 - 2.51	2.52 - 6.28	6.29 - 15.72	15.73 - 39.38				
Micro Diver DI601	10	0.10%	1.01	0.5	0.51	1.51	0 - 2.51	2.52 - 6.28	6.29 - 15.72	15.73 - 39.38				
Micro Diver DI602	20	0.10%	2.01	0.5	1.51	2.51	0 - 3.51	3.52 - 12.29	12.30 - 43.06	43.07 - 150.92				
CTD Diver DI261	10	0.10%	1.01	0.5	0.51	1.51	0 - 2.51	2.52 - 6.28	6.29 - 15.72	15.73 - 39.38				

Appendix A6-2

Groundwater Level Data Review and Approval SOP

A6.2 Groundwater Level Data Review and Approval SOP

This SOP provides instructions for reviewing and approving field visits and appended logger data in Aquarius.

The depth of this endless manual is matched only by the deepest depth of our PGOWN wells! Let the Groundwater Monitoring Specialist know if you are reading this ridiculous paragraph, so they know that people actually read this document.

A6.2.1 General

Field Technicians are responsible for downloading logger data and collecting accurate manual groundwater level measurements from each site at least once every 6 months (excluding sites that are seasonally inaccessible). The technicians will then append this data in Aquarius, apply the necessary corrections, grade the data (**Section 4.2**).

Following this work by the technicians, the Groundwater Monitoring Specialists will review and approve the data, or else request revisions to the data processing.

Please note it is expected that Groundwater Monitoring Specialists will have already completed adequate training with Aquarius, including procedures around creating the various types of datasets, entering field visits, appending data, and applying data corrections. In addition, specialists should be familiar with **Section 4.2**. For further information, please discuss with the Groundwater Monitoring Program Supervisor.

A6.2.2 Equipment

No specialized equipment is required for this SOP.

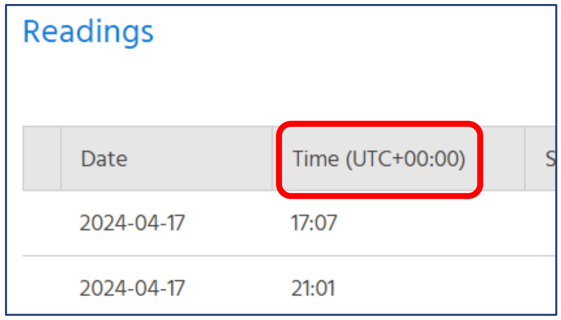
A6.2.3 Procedure

Groundwater Monitoring Specialists should follow the steps listed below when reviewing and approving groundwater level data in Aquarius.

Confirm the following:

1. The most recent Aquarius Field Visit has been entered properly.

    a. Compare the measurement time and depth below ground surface value from the field notes to the values entered into Aquarius. Ensure that the measurement time has been adjusted to align with the time zone indicated in the Aquarius Field Visit column. In the example below, the time of the Field Visit should be adjusted as being in the UTC time zone (i.e., PST + 8 hours or PDT + 7 hours).



b. The measurement method listed under “Readings” should be “Water Level Tape”.

c. The field notes should be scanned / uploaded to the Field Visit.

d. After the above are confirmed, change the status of the Field Visit to “Approved”.

2. Data downloaded from the Provincial Observation Well has been properly appended to the ‘**Logger**’ dataset(s) up to the point of the most recent field visit.

   a. Check that ‘**Logger**’ dataset(s) is not offset in time from the ‘**Working**’ dataset which can happen if the incorrect time zone was assigned to the appended logger data when uploaded to Aquarius.

   b. Appending the logger data should have automatically filled any data gaps if the datasets have been set-up such that the ‘**Logger**’ dataset(s) will feed the ‘**Working**’ dataset. If this is not the case, then ensure that data gaps have been filled with ‘**Logger**’ data by manually copying the data over.

3. Outliers or unrepresentative data have been deleted (e.g., sampling events).

4. Data aligns with the entered Aquarius Field Visits (i.e., drift and / or offset has been applied appropriately).

5. Data grade applied is based on actual sensor drift (i.e., manual water level measurement compared to live pressure transducer reading collected during the site visit).

6. Review the hydrograph for any obvious deviations from past behaviour that could indicate a malfunctioning pressure transducer(s) or other potential sources of error (such as a shifted cable length).

7. If the above steps are complete, approve the groundwater level data in Aquarius. If revisions are required, ask the Field Technician to make any necessary changes or clarify any issues.

   a. Please note that the corresponding ‘**GW Elevation**’ dataset must also still be approved (although no corrections need to be applied to the elevation data as the corrections are propagated forward from the ‘**Working**’ dataset).

A6.2.4 Miscellaneous

A6.2.4.1 Best Practice Tips

- Field notes or data sheets should have been scanned or uploaded to the respective project folder by the Field Technician and attached to the Aquarius Field Visit.
- Data grading should be based solely on the sensor drift (manual measurement compared to live pressure transducer reading), and the make / model / pressure range of the transducer. Other correctable sources of error, typically human error, should not count toward lower data grades. For example:
    - Initially processing the data using an incorrect stick-up height and then correcting for that in Aquarius.
    - An incorrectly applied datalogger offset programmed during a site visit which is then corrected for in Aquarius.
- If there is uncertainty regarding field notes, manual measurements or data corrections, contact the respective Field Technician as opposed to making assumptions.

A6.2.5 Record Keeping

There is no additional record keeping required as all data changes and approvals are logged within Aquarius.

Appendix A7

Well Installation & Development

Appendix A7-1	Borehole Log Field Sheet and Well Construction Diagram Templates
Appendix A7-2	Well Development SOP
Appendix A7-3	Slug and Bail Testing SOP

Appendix A7-1

Borehole Log Field Sheet and Well Construction Diagram Templates

Borehole Log Field Sheet

Obs Well Number:	______________________	**Date:**	______________________
Location:	______________________	**Time (PDT / PST):**	______________________
Weather:	______________________	**Crew:**	______________________

DRILLING EQUIPMENT DETAILS

Drilling Contractor:	______________________	Surface Casing Diameter:	__________	(mm / inches)
Drilling Method:	______________________	Well Borehole Diameter:	__________	(mm / inches)

Depth			Lithology Description and Observations	Sample Log
From	**To**	**At**	e.g., lithology type, texture modifiers, consistency/density, colour, moisture, particle size range/angularity or plasticity, other (i.e. odour, coal, oxidation, rootlets, geologic origin, weathered, etc.).	**Depth / ID**

See Reverse Side

Reminder: archive all field sheets into appropriate project folder after site visit.

Borehole Log Field Sheet

Depth			Lithology Description and Observations	Sample Log
From	To	At	e.g., lithology type, texture modifiers, consistency/density, colour, moisture, particle size range/angularity or plasticity, other (i.e. odour, coal, oxidation, rootlets, geologic origin, weathered, etc.).	Depth / ID

Logged By: ______________________________ **Signature:** ______________________________

See Reverse Side

Reminder: archive all field sheets into appropriate project folder after site visit.

Borehole Log Field Sheet

BOREHOLE SUMMARY NOTES

Drilling Start Date:	______________		Drilling Start Time:	______________	
Drilling Completion Date:	______________		Drilling Completion Time:	______________	
Total Borehole Depth:	______________	(m bgs / ft bgs)	Depth to Groundwater (and timestamp):	______________	(m bgs / ft bgs)
Northing:	______________		Easting:	______________	
UTM Zone:	______________		Elevation:	______________	(m asl)

WELL CONSTRUCTION DETAILS

Well Casing Diameter:	______________	(mm / inches)	Seal Material (Grout, Bentonite, etc.):	______________	
Surface Casing Diameter:	______________	(mm / inches)	Surface Seal Depth:	______________	(m bgs / ft bgs)
Surface Casing Depth:	______________	(m bgs / ft bgs)	Filter Pack Material (20/40 Sand, etc.):	______________	
Well Screen Diameter:	______________	(mm / inches)	Top of Filter Pack:	______________	(m bgs / ft bgs)
Top - Bottom of Screen:	______________	(m bgs / ft bgs)	End of Hole Backfill Material:	______________	(if applicable)
Slot Size:	______________		Completed Well Depth:	______________	(m bgs / ft bgs)
Casing Material (PVC / Steel):	______________		Stickup Height:	______________	(m / ft)

NOTES (e.g., well development, issues encountered during drilling / installation, changes to original drilling plan, etc.)

Reminder: archive all field sheets into appropriate project folder after site visit.

Well Construction Diagram

Obs Well Number: ____________________ **Drilling Company:** ____________________

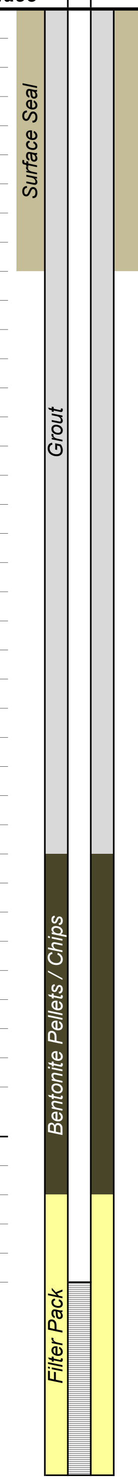
Location: ____________________ **Field Crew:** ____________________

Start Date: ____________________ **Drilling Method:** ____________________

End Date: ____________________

LITHOLOGY & CONSTRUCTION DETAILS

From (m)	To (m)	Lithology	Ground Surface	Additional Comments



	Surface Casing	Well Casing	Screen	Backfill	Filter Pack	Surface Seal
Material / Type:						
Depth / Range (m):						
Diameter (mm):				N/A	N/A	N/A
Thickness (mm):						
Slot Size:	N/A	N/A		N/A	N/A	N/A

Borehole Depth (m): ____________

Well Depth (m): ____________

Stick-Up (m): ____________

Water Level (m btoc): ____________ at HH:MM *(before development)*

Water Level (m btoc): ____________ at HH:MM *(after development)*

Appendix A7-2

Well Development SOP

A7.2 WELL DEVELOPMENT SOP

This SOP provides a general description of the procedures and standards to be followed to develop Provincial Observation Wells. For more specific guidance, please consult with your Regional Hydrogeologist or Groundwater Monitoring Specialist.

A7.2.1 General

Development is required to remove sediment and drilling fluids from the well, typically shortly after the well is installed. A properly designed and developed Provincial Observation Well should produce water representative of the geological formation with minimal artificially induced turbidity.

- Development should preferably occur at least 24 hours after installation to allow grout or bentonite seals to solidify or hydrate in place. Development is usually done using a dedicated or disposable pumping system (e.g., PVC bailer or Waterra tubing), or with specialized downhole tooling.
- Rehabilitation of existing Provincial Observation Wells may occasionally be necessary if the functioning of the well to produce representative groundwater data becomes a concern or other issues are identified (e.g., well becomes infilled with sediment). This SOP covers development activities that could be undertaken as part of rehabilitation but does not include all rehabilitation activities and steps (e.g., cleaning and disinfection of the well, etc.). For further information on well rehabilitation methods, consult your Groundwater Monitoring Specialist.
- Gather Provincial Observation Well information and details, such as the drilling method employed, diameter and depth of the well, construction details (borehole logs or construction diagrams), depth to groundwater measurements, and existing hydrograph information where available.
- Determine what method of development is practical for the situation.
    - For shallow Provincial Observation Wells with a 76 mm (3 in) or smaller diameter, development may be accomplished by hand with Waterra tubing and surge blocks for coarse-grained formations, and with bailers for low-yield formations. This manual work would be completed by field staff, as opposed to a drilling contractor but has a practical limit of roughly 10 m (30 ft) due to the physical work involved (increasing weight with well depth). Alternatively, a Waterra Hydrolift Pump could be used to remove the need for manual labour; these pumps can operate up to approximately 45 m (150 ft).
    - The drill rig used to drill and install the Provincial Observation Well can jet, air lift, or surge the well to clean the screened interval. Discuss well development options in advance with the drilling contractor.
    - These methods are discussed in greater detail in the sections to follow.
- Determine if purge water is to be captured or discharged at surface. This is determined on a site-specific basis, considering potential contamination or specific release requirements (e.g., property owner preference, potential for property damage, or permit requirements).

A7.2.2 Equipment

Task-specific equipment (refer to **Equipment Checklist** in **Appendix A1** for a complete list of recommended equipment for site visits):

- Borehole logs / construction diagrams;
- **Well Development Field Sheet** (**Section A7.2.5.1**);
- Water level tape;
- Camera; and
- Method-specific development equipment such as:
  - Waterra tubing, foot valves, surge blocks, inertial pump, and power source;
  - Bailers and rope; or
  - Drill or service rig.

A7.2.3 Procedure

In wells already instrumented with pressure transducers / dataloggers, collect an initial manual groundwater level measurement and follow the **Groundwater Level Data Downloading SOP** instructions, prior to removing equipment from the well or deploying development equipment. Record the manual measurement and live datalogger readings in the **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]).

Development can be completed using many different techniques and types of equipment. However, the same generalized field procedures (below) are employed for each technique and type of equipment.

The generalized well development field procedures are as follows:

- Assemble development equipment around the Provincial Observation Well.
- Measure the depth to groundwater and total depth of the Provincial Observation Well. Calculate and record the volume of the water column height on the **Well Development Field Sheet** (**Section A7.2.5.1**). The formula for calculating the volume of groundwater in a well is as follows:

  $$\boldsymbol{V} = (\pi \times r^2 \times h) \times 1000$$

  Where: “V” is the volume in litres, “r” is the radius in metres, and “h” is the height of the water column in metres.

- Begin well development and record the physical characteristics (colour, clarity [turbidity measurement preferred or else visually determined] and odour) of the groundwater on the **Well Development Field Sheet**.
- Continue to develop the well and periodically note the approximate volume removed and the physical characteristics observed. Development continues until:

    - Water has a turbidity of less than 50 nephelometric turbidity units (NTUs), or appears visually clearer; and
    - Sand, fine-grained cuttings or drilling additives are no longer present in the development (purge) water.
- The end point for development may be a combination of the guidelines listed above and professional judgement. It may require additional time to develop Provincial Observation Wells with very high turbidity; if stabilization **does not** occur within **five well volumes** purged, consult with the Regional Hydrogeologist or Groundwater Monitoring Specialist. At the end of development, record the following information on the field data sheet:
    - Final groundwater physical characteristics (i.e., colour, clarity and odour);
    - Duration of development;
    - Volume of groundwater removed; and
    - The static groundwater level (as measured at the end of development just before leaving the site).

A7.2.3.1 Manual Development Methods

Developing a well by hand can be completed at shallow wells of up to 76 mm (3 in) in diameter. The exact depth limit will depend on the depth to water, well screen depth, and other factors. Consult with your Regional Hydrogeologist or Groundwater Monitoring Specialist to determine which, if any, manual well development methods would be most appropriate.

It should be noted that developing a well by hand can be quite labour intensive and new Provincial Observation Wells are typically developed by the drilling contractor at the time of installation.

Hand Bailing

Development via bailer is typically the simplest method. Bailers which are nearly as wide as the Provincial Observation Well and have additional weight added work best. Bailers are suggested to be used in shallow wells that are known to have slow recovery or high fine sediment content. The general procedure to be followed by Field Technicians is outlined below:

- Follow the generalized development instructions outlined above in **Section A7.2.1**.
- Measure the depth to the bottom of the Provincial Observation Well, and ensure there is enough retrieval line (e.g., string, rope, or cable) attached to the bailer to reach the bottom of well.
- Allow the bailer to sink to the bottom of the well and then pull up quickly on the retrieval line.
- Bail the well to lower the groundwater level down to the screen interval. This allows the bailer (which fills from the bottom) to effectively collect sediment accumulated in the bottom of the well. If the groundwater level cannot be bailed down into the screen interval (e.g., because of a high K formation), consider using a different development method.

    - Be sure to double check the knot or method of attachment of the retrieval line and top of the bailer. Many types of rope and string are prone to coming undone when wet.
- Measure the depth to the bottom of the well post-development and record this value.

Hand Surging – Waterra Tubing & Surge Block

Development via Waterra tubing, a foot-valve and surge block is quite common for shallow, narrow-diameter wells screened in coarse sediment. The general procedure to be followed by field staff is outlined below:

- Follow the generalized development instructions outlined above in **Section A7.2.1**.
- Field staff should start by measuring the depth to the bottom of the Provincial Observation Well.
- Order tubing, foot-valve, and surge blocks of suitable dimensions for the well diameter and depth. The surge block should ideally be as close in diameter as possible to the well screen while still fitting inside the well.
- Assemble these three pieces and run the end of the tubing with the surge block and foot-valve to the bottom of the well. Cut the top end of the tubing after allowing for additional length (roughly 2 m).
- Lift the tubing up and down, repeatedly, in relatively quick succession. The well water should reach the top of the tubing after a moment (tubing will get progressively heavier) and ideally be ejected into a bucket to allow for measuring of the purged volume and assessment of the physical characteristics (colour, clarity, etc.).
- Work the full length of the well screen with the surge block. Depending on the length of the screen, this may require developing the screen in intervals.
    - E.g., start by running the foot-valve up and down the top 60 cm of the screen, develop for a period, and then move down the well screen by another 60 cm and continue the process until the entire screen has been developed and the purge water runs clear.
- Consider renting a Waterra Hydrolift Pump to reduce the physical labour required for well development. This becomes increasingly necessary for deeper wells as the weight of the water column (plus any sediment) in the tubing can become quite heavy.
- Measure the depth to the bottom of the well post-development and record this value.

A7.2.3.2 Drill or service Rig Development Methods

Most Provincial Observation Wells are developed by a drill or service rig. The well development method will be project-specific and determined during the planning stage. Typically, field staff can defer to the expertise of the drilling contractor as to which development method would be most appropriate given the well construction and depth to water.

There are numerous equipment configurations which may be utilized to develop wells, and the basics are included here. Specific procedures will vary, and it is vital to communicate the preferred method and objective with the drilling contractor. Regardless, always maintain a purged water total volume for the borehole during development, both by asking the drilling contractor to keep track and by verifying their volumes with observations. Some of the more common methods are outlined below.

It should be noted that air and mud rotary drill rigs may introduce additional fluid to the formation during the drilling process. Mud rotary drilling can result in a “mud cake” where the drilling mud infiltrates into the aquifer. Record how much fluid has been introduced into the Provincial Observation Well during drilling by asking the drilling contractor to keep a balance, and development should remove this volume as an absolute minimum. If specific additives were used during a mud drilling program, it may be pertinent to collect a sample from the Provincial Observation Well before and after development to determine the effectiveness of the development process in removing the additives.

Surge Block and Wireline Bailing

This type of surge block and bailer is usually constructed of steel and should **only be used** in Provincial Observation Wells constructed with **steel casing.** When used, the surge block and bailer are attached to the wireline or sandline on a service rig which is used to lower the tools in and out of well by the driller. The general procedure is outlined below:

- Field staff should start by measuring the depth to the bottom of the Provincial Observation Well, and provide the measurement to the drilling contractor (unless the drilling contractor does this themself). They will need to ensure the wireline / sandline is long enough to reach the bottom of the well.
- The drilling contractor will attach a weighted surge block onto the wireline or sandline and lower it to the bottom of the Provincial Observation Well. The surge block is worked up and down across the screen interval following a similar method as described in **Section A7.2.3.1**.
- Occasional, or when sediment has accumulated in the bottom of the Provincial Observation Well, the drilling contractor will remove the surge block, attach a bailer onto the wireline/sandline. The steel bailer will be lowered to the bottom of the well and is quickly lifted and lowered to fill with sediment and groundwater. Ideally, the groundwater level inside the well will be lowered down to the screen interval during this process. This allows the bailer (which fills from the bottom) to effectively collect sediment accumulated in the bottom of the well.
- The driller will lift the bailer to the surface and empty the contents of the bailer onto the ground. A sample of the development water of the bailer should be attempted to be collected using a bucket if safely possible.
    - If a sample can be safely collected, the physical parameters (including turbidity) should be assessed (**Section A7.2.1**)
- Measure the depth to the bottom of the well post-development and record this value.

These steps are repeated until the development criteria are achieved (i.e., development water runs clear).

Air Lifting & Backwashing

Air lifting (or air jetting) and surging is a process where compressed air is injected into the screened interval to mobilize sediments and then turned off once water reaches surface. This process is repeated several times (compressed air is turned on and off) causing a surging response. The general procedure is outlined below:

- Field staff should start by measuring the depth to the bottom of the Provincial Observation Well.
- Drill rod or tremie pipe (development string) is lowered into the Provincial Observation Well by the driller to a depth approximately 1 m above the top of the screened interval.
- The driller then slowly injects air into the well to create air bubbles within the water column to lift the water to the surface.
- As water discharges at the surface, field staff should monitor the physical characteristics of the purged water (i.e., colour, clarity, and odour). The drilling contractor will surge the well by repeatedly turning the air off, waiting for a couple of seconds and turning it on again, until sediment is no longer visible (i.e., development water is no longer turbid).
    - If feasible, use a bucket to estimate the yield of the well (and the total volume purged) by determining the length of time it takes to fill the bucket.
- Measure the depth to the bottom of the well post-development and record this value.

A7.2.3.3 Technical Considerations

If the total measured depth to the bottom of the Provincial Observation Well is less after development than before development (i.e., suggesting that the bottom of the Provincial Observation Well screen may be partially filled with sediment), another development method may be necessary, and the well will need to be cleaned out again.

A7.2.4 Miscellaneous

Not applicable.

A7.2.5 Record Keeping

It is important to document the details regarding well development on applicable field sheets (i.e., **Well Development Field Sheet** in **Section A7.2.5.1** and **Site Visit Data Download & Calibration Field Sheet** in **Appendix A2** [**Section A2.1.5.1**] and to include these details in the well construction record in GWELLS.

Photos of the well development process should also be taken and all field notes, or field data sheets, and photos should be scanned / saved to the project folder upon returning to the office.

A7.2.5.1 Field Sheets

The applicable field sheet is included on the following page and on the **PGOWN MS Teams Channel**.

Well Development Field Sheet

Obs Well Number: ______________________ **Date:** ______________________

Location: ______________________ **Time (PDT / PST):** ______________________

Weather: ______________________ **Crew:** ______________________

PROVINCIAL OBSERVATION WELL INFORMATION

Diameter: _________ (mm / inches)

Pre-Development			**Post-Development**		
Static Water Level (SWL):	______________	(m btoc)	Static Water Level (SWL):	______________	(m btoc)
Stick-up:	– ______________	(m ags)	Stick-up:	– ______________	(m ags)
Calculated SWL:	= ______________	(m bgs)	Calculated SWL:	= ______________	(m bgs)
Measurement Time:	______________	(PST / PDT)	Measurement Time:	______________	(PST / PDT)
Depth to Well Bottom:	______________	(m btoc)	Depth to Well Bottom:	______________	(m btoc)

DEVELOPMENT

Method: ❑ Waterra ❑ Bailer ❑ Submersible ❑ Over pumping (rig) ❑ Jetting (rig) ❑ Other: ______________

Calculated Well Volume*: ______________ (L) Water Intake Depth: ______________ (m btoc)

Est. Total Purge Volume: ______________ (L) Flow Rate: ______________ (L/min)

****Refer to well volume calculation factors and formula on third page.***

Time	SWL (m btoc)	Est. Purge Volume (L)	Colour	Clarity (clear / slight / mod. / very)	Odour (sulphuric / hydrocarbon / etc.)	Comments
Start		0	-	-	-	Start of development.

See Reverse Side

Reminder: archive all field sheets into appropriate project folder after site visit.

Well Development Field Sheet

Time (min)	SWL (m btoc)	Est. Purge Volume (L)	Colour	Clarity (clear / slight / mod. / very)	Odour (sulphuric / hydrocarbon / etc.)	Comments

WATER DESCRIPTION (AT END OF DEVELOPMENT)

Odour: Y / N Description:	Clarity: Relative scale, indicate start and end value
Sheen: Y / N Description:	1 2 3 4 5 6 7 8
Turbidity (Clear / Slightly / Moderately / Very):	
Colour: Y / N Description:	Start: End:
Well Yield (Good / Moderate / Poor):	Other:

Logged By: ______________________ **Signature:** ______________________

See Next Page

Reminder: archive all field sheets into appropriate project folder after site visit.

Well Development Field Sheet

NOTES

Well Volume Calculation Factors

1" Well	0.5 L/m
1.5" Well	1.1 L/m
2" Well	2.0 L/m
3" Well	4.6 L/m
4" Well	8.1 L/m
4.5" Well	10.3 L/m
6" Well	18.2 L/m
8" Well	32.4 L/m

Formula for One Well Casing Volume (L)

$$Volume = Well\ Volume\ Calculation\ Factor \left(\frac{L}{metre}\right)\ x\ (Total\ Well\ Depth\ [m\ btoc] - Static\ Water\ Level\ [m\ btoc])$$

Reminder: archive all field sheets into appropriate project folder after site visit.

Appendix A7-3

Slug & Bail Testing SOP

A7.3 SLUG & BAIL TESTING SOP

This SOP provides a description of the procedures and standards to be followed to conduct slug and bail tests (also known as single well response tests, rising or falling head tests, or hydraulic conductivity tests) on Provincial Observation Wells.

A7.3.1 General

- Gather borehole logs / well construction diagrams and review existing hydraulic conductivity information where available. Determine whether the wells to be tested have been previously developed. Well development should happen prior to hydraulic conductivity (K) testing. Ensure that K-tests do not displace more water than development to avoid mobilizing fines into and out of the well (i.e., dynamic skin effect).
- Determine if either slug or bail down tests will be conducted. In general, slug testing should be conducted for higher hydraulic conductivity formations (e.g., gravel, sand, or highly fractured formations with K >10-5 m/s) and bail down tests should be conducted for lower K formations (e.g., clay, silty clay, tight bedrock formations with K <10-5 m/s).
    - For low hydraulic conductivity formations, if the water level is above the screened interval of the well, it is preferable to maintain this state (i.e., avoid bailing the water level down to the screen and draining the well filter pack).
- Determine the number of tests to be conducted at each location.
    - When a slug is used, typically at a minimum a falling head test (lowering slug into well) and a rising head test (removing slug from well) are conducted (i.e., two tests total). For formations with recovery times in the order of a couple of minutes or faster, it may be useful to repeat the rising and falling head tests multiple times to ensure reproducibility of results.
    - For very low hydraulic conductivity formations with response times of several hours to over a day, generally only a single test is practical. In these cases, it may be appropriate to conduct smaller displacement slug tests.
- The use of a pressure transducer will be required for accurate continuous data collection.
- Manual water level measurements are used as an independent check on the pressure transducer data.
- If conducting a slug test:
    - Purchase an engineered slug with known displacement volume. This would consist of a solid PVC tube with a hole / hook for attaching Kevlar string or rope and, ideally, with tapered ends to reduce the impact of the slug hitting the water surface;
    - The diameter of the slug should be small enough to easily fit into the well and not disrupt the suspended transducer while conducting the test;

- The slug should be long enough to create a sufficiently large displacement of the water column to result in accurate measurements. To do this, calculate the theoretical initial water level displacement based on the volume of the slug and the dimensions of the well casing. While the water level should never be below the top of the well screen in a Provincial Observation Well, if that is the case, then include the sand pack and representative porosity if the water level is below the top of the screen. Generally, an induced water level change (i.e., displacement) of 0.30 to 1.0 m is sufficient; and
- This guidance document from the U.S. Geological Survey may be useful in determining the appropriate dimensions of a slug, and also provides other useful slug test information: GWPD 17—Conducting an Instantaneous Change in Head (Slug) Test with a Mechanical Slug and Submersible Pressure Transducer.

A7.3.2 Equipment

Task-specific equipment (refer to **Equipment Checklist** in **Appendix A2** for a complete list of recommended equipment for site visits):

- Borehole logs / construction diagrams;
- A **Hydraulic Conductivity Testing Field Sheet** (**Section A7.3.6.1**);
- For slug testing:
    - A solid PVC slug or pneumatic slug test set-up;
    - Rope; and
    - Leather gloves (to avoid rope burn).
- For bail down tests:
    - A purging method (e.g., bailer, Waterra tubing, submersible pump, etc.);
    - Bucket or drum for capturing purge water; and
    - If using a pump, a check valve is required to prevent backflow into the well.
        - Please note that Grundfos submersible pumps do not have check valves.
- Pressure transducer with associated equipment:
    - A field laptop;
    - Optical reader;
    - Kevlar string or direct-read cable to suspend the transducer; and
    - Barometric transducer for long duration (i.e., >3 hours) tests (if using non-vented transducers).
- Timer (stopwatch);

- Camera; and
- Water level tape.

A7.3.3 Procedure

Water displacement can be accomplished by:

- Adding and removing a solid cylinder (a slug test, also known as a falling and rising head test);
- Physically removing water from the well (a bail down test, also known as a rising head test); or
- Using compressed air with a pneumatic slug test set-up (a variation on a rising head test).

Slug and bail down tests are typically conducted in smaller diameter (i.e., 101.6 mm (4 in) or less) monitoring wells. Pumping tests are required for larger diameter wells (discuss with Groundwater Monitoring Specialist or Regional Hydrogeologist).

In wells already instrumented with pressure transducers / dataloggers, collect an initial manual groundwater level measurement and download the data. Follow the **Groundwater Level Data Downloading SOP** instructions (**Appendix A2** [**Section A2.4**]), prior to removing equipment from the well or deploying development equipment. Record the manual measurement and live datalogger readings in the **Site Visit Data Download & Calibration Field Sheet** (**Appendix A2** [**Section A2.1.5.1**]).

A7.3.4 Slug Testing

The basic slug test procedure involves inserting a slug into the well to displace groundwater and monitoring the response until the groundwater level returns to static (falling head test). The slug is then removed and the water level is again monitored until it rises back to the static level (rising head test).

- Record the slug dimensions and any equipment identification numbers in the **Hydraulic Conductivity Testing Field Sheet** (**Section A7.3.6.1**). Use the slug dimensions to determine the approximate volume of groundwater that should be displace.
  - Note: manufactured slugs will come with the dimensions and displacement volume listed.
- Measure the static water level and total depth of the Provincial Observation Well and measure the casing stick-up (if not previously established).
- Remove any unnecessary equipment in the well that will interfere with the test, and temporarily store it in clean plastic bags or on sheeting. It is important to avoid lines tangling.
- Measure the length of cable or Kevlar string for the pressure transducer. The pressure transducer should be deployed **a minimum of 1.5 m below the static water level** to avoid interference with the slug; however, minimize the depth of deployment for **high K** formations (e.g., sand / gravel). Attach the cable to a secure point so the pressure transducer will maintain at a constant depth throughout the tests.

- Program the pressure transducer at an appropriate recording frequency and deploy the transducer down the well. The transducer should be hung in the well for **at least 5 minutes** prior to conducting testing to equilibrate to the well conditions.
    - Pressure transducers within wells that penetrate highly permeable material should be set to have a high recording frequency, such as **2 seconds or less**.
- Collect a manual groundwater level reading and then raise the water level tape just enough so it will not be submerged in water when the slug is lowered. Leave the water level tape in this position so during the test it will be easier to collect measurements.
- Slowly lower the slug down the well until it is just above the static water level. If using a direct-read cable, the live readings can be watched as the slug is lowered to determine if the slug has inadvertently touched the water. The falling head portion of the slug test occurs when slug is then quickly (but smoothly) lowered into the water so it is fully submerged by about 1 m and record the time. After the water level has risen as a result of the insertion of the slug (referred to as the initial displacement), the water level will begin to drop back to its static level.
    - If using a direct-read cable, watch the live pressure readings and wait until the water level has returned to static (at least 95% of initial displacement level) before collecting another manual water level tape measurement (record the time of the measurement and water level recovery).
    - If not using a direct-read cable, collect manual measurements approximately every 5 minutes until the water level has returned to static. If it is believed that the well will take over 30 minutes to return to static, collect manual measurements every 10 minutes.
    - Take any additional notes on whether ropes / cables became entangled, or the pressure transducer was inadvertently moved. If this is the case, repeat the test.
    - Slug tests may be concluded within seconds for high K formations or can take hours (or days) for low K formations. During longer tests, consider having an anchor point available to tether the slug rope / cable.
- Once the water level has recovered to the initial static level, record the time and level. The well is now ready for the rising head test. Using the same procedure as outlined in the step above, quickly remove the slug and begin the test. Then wait for 95% recovery, collect a manual measurement, and record the time.
- Repeat the slug test at least one other time to confirm results (this may not be feasible for extremely slow recovering wells).
- After completing the slug tests, the pressure transducer can be removed from the well.
- Download and review the data in the field to ensure the tests occurred as planned. Check to see if the initial displacement was as expected based on the slug volume, and if the response was similar between the falling and rising legs of the test. If anomalous and / or unexpected results are evident, the test should be repeated.

- Figure A7-3.1 illustrates a typical data time series for a falling (slug in) and rising (slug out) head test, while Figure A7-3.2 shows an oscillatory response for a very high hydraulic conductivity well.

- Return any equipment that was temporarily removed from the well and reprogram the datalogger / pressure transducer as needed (**Groundwater Level Data Downloading SOP** in **Appendix A2** [**Section A2.4**]).

- Close and secure the Provincial Observation Well.

Figure A7-3.1 Typical slug test response.

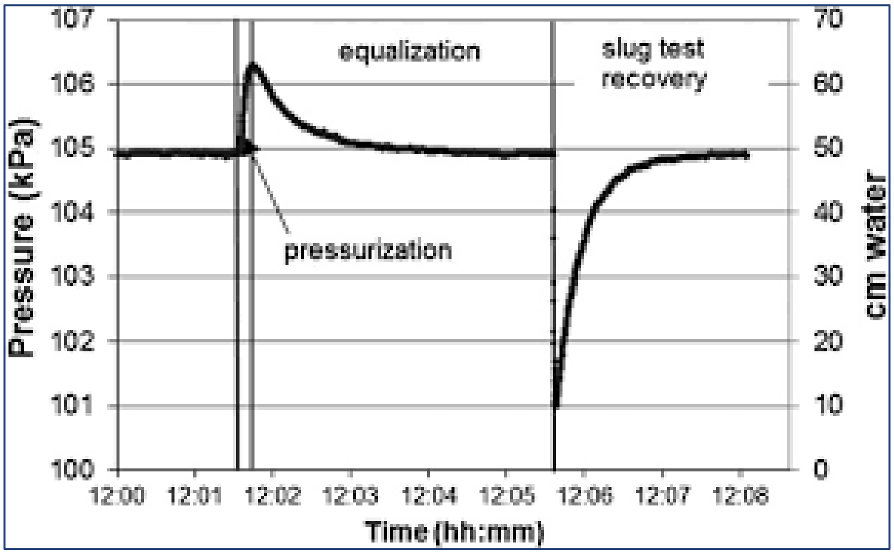


Photo source: Fritz, Mackley, and Arntzen, 2016

Figure A7-3.2 Potential oscillatory slug test response if aquifer hydraulic conductivity is very high.

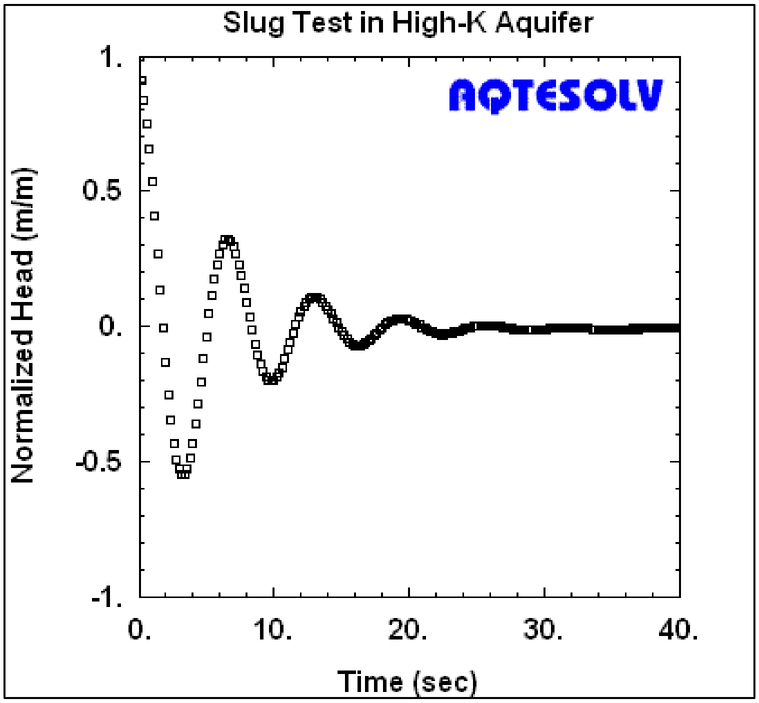


Photo source: HydroSOLVE 2019.

A7.3.4.1 Bail Down Testing

In this approach, the water level is lowered by purging the well, and the recovery response (rising head) is measured.

- Measure the static water level and total depth of the Provincial Observation Well and measure the casing stick-up (if not previously established). Record the method of purging in the field data sheet.
- Remove any unnecessary equipment in the well that will interfere with the test, and temporarily store it in clean plastic bags or on sheeting. It is important to avoid lines tangling.
- Measure the length of cable or Kevlar string for the pressure transducer. The pressure transducer should be positioned around **0.3 m above the bottom of the well**.
  - The pressure transducer needs to be placed deep enough in the well that it will be out of the way of any purging equipment (i.e., Waterra tubing or bailer).
- Program the pressure transducer at an appropriate recording frequency (**2 seconds or greater**, depending on the estimated duration of the test) and deploy the pressure transducer inside the well. The pressure transducer should be hung in the well for **at least 5 minutes prior** to conducting testing to equilibrate to the local conditions.
  - If the test will run for longer than 3 hours, deploy a barometric pressure transducer to collect atmospheric pressure (if using non-vented pressure transducers) at identical time intervals

as the submerged pressure transducer (i.e., both measurements should be synchronized to facilitate data processing).

- Collect a manual water level reading and then reel up the tape just enough such that it will not be submerged when the well recovers after purging / will not interfere with the equipment. Leave the water level tape in position so that it is easier to collect measurements later on.
- Purge the well with an available method such as a bailer, Waterra tubing or a submersible pump, until sufficient drawdown is achieved (about 1 m). Purging should be conducted as rapidly as possible.
    - A submersible pump is the best method for avoiding potential tangling between the pressure transducer line, water level tape, etc. It also reduces the potential for "noisy" pressure transducer data. However, the submersible pump should be equipped with a check valve (placed immediately above the pump) to prevent water inside the tubing from dropping back into the Provincial Observation Well.
    - It is best practice to avoid lowering the water level into the screen (which results in drainage of the well filter pack).
    - After purging is stopped, immediately collect a manual water level measurement and record the time.
- Collect manual water level measurements every 10 minutes until the well has recovered to static.
    - Water levels are to be monitored until they return to 95% of the initial static water level.
    - When using a pressure transducer, water levels do not necessarily need to be manually measured for the extent of the test, particularly when there are restraints on time. Always record the first hour of the test and the final water level and time prior to terminating the test. The exact length of the test should be determined with the Groundwater Monitoring Specialist or Regional Hydrogeologist.
    - Take any additional notes on whether lines became entangled, or the transducer was inadvertently moved. If this is the case, repeat the test.
- Download data and review the data in the field to ensure the test occurred as planned. If anomalous and / or unexpected results are evident, the test should ideally be repeated depending on whether this is logistically feasible given test duration and time constraints.

A7.3.5 Miscellaneous

A7.3.5.1 Quality Assurance and Quality Control

- When possible, collect both automated and manual water level measurements to:
    - Confirm transducer data with manual measurements in the field;
    - Correct the water level to elevation; and

    - Provide back-up in case of pressure transducer malfunction or accidental data loss.

- All measurements are to be recorded on the **Hydraulic Conductivity Testing Field Sheet** (**Section A7.3.6.1**). Field notebooks are acceptable if the data are legible and clearly organized.
- Review data in the field when possible and follow proper naming convention of data files.
- A limitation to consider is that slug and bail down tests are heavily dependent on the quality of the well screen. If the screen is compromised (clogged or damaged), or if the well was never properly developed, then the groundwater intake will be affected, and the results of the slug and bail down test may not be representative of the materials in the vicinity of the well. Conducting rising and falling head tests with multiple slug volumes can provide insight into the well condition.
    - These tests can shed light on the condition of the well screen and, therefore, the hydraulic connection between the well and the aquifer formation which may indicate the need to re-develop the well or conduct other necessary maintenance. Discuss with your Groundwater Monitoring Specialist or Regional Hydrogeologist.

A7.3.5.2 Tips

- If conducting a bail down test, use the “air mode” function (if available) on the water level tape and deploy 1 m below the initial static water level. The water level tape will then sound when the water level has dropped to the desired depth during purging.
- If a direct-read cable is used with the pressure transducer, real-time pressure data can be viewed and used to determined when the water level has reached equilibrium. This reduces the potential for background noise in the pressure transducer dataset caused by the manual water level tape.
- Slug Tests:
    - The following file naming convention is recommended for slug test data: **OW###_RAW_SlugTest_yyyymmdd.csv / .xls**
- Bail Down Tests:
    - The following file naming convention is recommended for bail down test data: **OW###_RAW_BailDown_yyyymmdd.csv / .xls**

A7.3.6 Record Keeping

It is important to document the details regarding hydraulic conductivity testing on applicable field sheets (i.e., **Hydraulic Conductivity Testing Field Sheet** in **Section A7.3.6.1** and **Site Visit Data Download & Calibration Field Sheet** in **Appendix A2** [**Section A2.1.5.1**]). Details should be updated in the **Regional PGOWN Tracking Spreadsheet**.

Photos of the slug and bail test should also be taken and all field notes, or field data sheets, and photos should be scanned / saved to the project folder upon returning to the office.

A7.3.6.1 Field Sheets

The applicable field sheet is included on the following page and on the **PGOWN MS Teams Channel**.

Hydraulic Conductivity Testing Field Sheet

Obs Well Number:		**Date:**	
Location:		**Time (PDT / PST):**	
Weather:		**Crew:**	

PRE-TEST INFORMATION

Static Water Level (SWL): ____________ (m btoc)

Sub. Transducer Make / Model: ____________

– Stick-up: ____________ (m btoc)

Sub. Transducer S/N: ____________

= Calculated SWL: ____________ (m)

Logging Frequency: ____________

Measurement Time: ____________ (PST / PDT)

Groundwater Displacement Method: ____________
(e.g., Solid slug, Bailer, Waterra tubing, etc.)

Slug Details: ____________
(e.g., diameter, length, material)

Groundwater Volume Displaced: ____________ (L)

GROUNDWATER LEVEL MEASUREMENTS

Time	Elapsed Time (min)	SWL (m btoc)	Change in Head (m)	Comments
	0		-	Immediately prior to slug entering water column.

See Reverse Side

Reminder: archive all field sheets into appropriate project folder after site visit.

Hydraulic Conductivity Testing Field Sheet

Time	Elapsed Time (min)	Water Level (m btoc)	Change in Head (m)	Comments

Logged By: ______________________________ **Signature:** ______________________________

Reminder: archive all field sheets into appropriate project folder after site visit.

Appendix A8

Network Expansion & Contraction

Appendix A8-1

Adding a Well to PGOWN Systems SOP

A8.1 ADDING A WELL TO PGOWN SYSTEMS SOP

This SOP describes the necessary procedures to follow when incorporating a new Provincial Observation Well into the PGOWN. Several applications, databases and staff are involved with the operation of the provincial network. The procedures herein are intended to be followed by PGOWN staff to update the various PGOWN-related systems.

A8.1.1 General

A description of each database as it relates to the PGOWN is provided below:

- **Environmental Monitoring System (EMS) Database:** this database houses the PGOWN analytical water chemistry data.
- **GWELLS**: this database contains the PGOWN well construction records.
- **Aquarius Time-series Management Database**: this database stores the groundwater level data produced by Provincial Observation Wells.
- **Groundwater Level Data Interactive Map**: this interface posts PGOWN groundwater level data publicly for viewing and downloading.

A8.1.2 Required Information

Provincial Observation Well details required to proceed with this SOP:

- Provincial Observation Well number;
- Latitude and longitude coordinates;
- Construction details;
- Aquifer number; and
- Telemetry information (if applicable).

A8.1.3 Procedure

Start by obtaining a Provincial Observation Well number from the Groundwater Monitoring Program Supervisor, if you do not already have one (e.g., “OW123”), then update the various PGOWN systems as described below and in this order:

A8.1.3.1 EMS Database

- Set-up the new well in EMS and record the EMS ID.
  - Ensure that the Provincial Observation Well number and location (city, park, regional district, etc.) are listed in the comments section when creating the new EMS ID.
  - This EMS ID is required in order to link the water chemistry data from a station to GWELLS, the Aquarius database and the Groundwater Level Data Interactive Map. The EMS ID also

allows the analytical lab to upload the water chemistry analytical results directly to this database.

- Email EMSHELP@gov.bc.ca if you have questions about EMS.

A8.1.3.2 GWELLS Database

- Enter or update the well record in GWELLS.
  - Email GWELLS@gov.bc.ca to receive training and approval to enter / edit well records in GWELLS, ask questions, or report any GWELLS system issues.
  - When entering a new well record, double check that all information is correct and complete. Include the following at a minimum:
    - Location details (address, cross-streets, city, survey information, etc.);
    - Well ID plate number;
    - EMS ID;
    - Lithology;
    - Well casing and screen details (depth, diameter, material, screen type and size);
    - Drilling depth;
    - Well completion depth;
    - Surface seal details;
    - Well development details; and
    - Attach the scanned well driller record to the "Documents" section (if available).
    - All Provincial Observation Wells part of the network should have the following attributes listed on their well records in GWELLS (**Table A8-1.1**):

Table A8-1.1 GWELLs well record attribute details.

Class of Well	Monitoring
Well Subclass	Permanent
Intended Water Use	N/A (this field will be inaccessible once the well subclass is selected)

  - After creating the well record, write down the Well Tag Number and go into "Edit" mode to complete the following fields:
    - The Provincial Observation Well number; and
    - The aquifer number.

A8.1.3.3 Aquarius Database & Interactive Map

- New stations will need to be set up in Aquarius and the Interactive Map by the Water Data Specialist (Aquarius Administrator) before groundwater level data can be ingested into the database and published. To update these systems, please follow the steps below.
  - The information required for the set-up of new stations in Aquarius is shown in **Table A8-1.1** and **Table A8-1.2**. Copy these tables into an email to the Groundwater Monitoring Program Supervisor and enter the necessary information. Enter "n/a" as applicable.
  - Information in **Table A8-1.2** is required to ensure the transmitted parameters from telemetry stations are properly ingested by Aquarius. Confirm the parameter measurement interval values are correct by reviewing the saved Field Visit (FTS datalogger configuration file). The default values listed in **Table A8-1.2** are the standard intervals used at most stations.
    - If satellite telemetry is not used at this station, there is no need to complete **Table A8-1.2**.
  - The "About this Well" descriptor displayed on the Interactive Map must be completed as per the following template. Please copy this descriptor into the aforementioned email and edit the blue text fields:

*Observation Well **XXX** was included in the network in **YYYY**. It is located in **a / an confined / unconfined / sand and gravel / bedrock / unmapped aquifer** identified as Aquifer **#123 (Aquifer Name?) on / at / in / near Location**.*

  - Send the email containing the completed tables, along with photographs of the well and the "About this Well" descriptor, to the Groundwater Monitoring Program Supervisor who will then ensure the information is complete and accurate before having the station entered into Aquarius and the Interactive Map.

Table A8-1.1 Station identification and location details.

Obs Well #	*Enter OW ###*
Location Description	*City or Local Name (or Regional District or Park if unincorporated and no local name available)*
Latitude / Longitude	*To 6 decimal places*
Natural Resource Region	*E.g., West Coast, Skeena, etc.*
Data Source	*Telemetry or Non-Telemetry*
GOES ID	*Telemetry address (e.g., BC12A345)*
Transmission Period	*Typically every 24 hours*
Status	*Active or Inactive*
Well Tag Number	*Identification # generated by GWELLS*
EMS ID	*Identification # generated by EMS*

Table A8-1.2 Naming conventions of parameters transmitted by FTS dataloggers.

Transmitted Satellite Telemetry Parameters	FTS Naming Convention	Parameter Measurement Interval (min)* *how often a measurement is collected
Water Level	SGWL	60 = hourly
Water Temperature	TW	360 = every 6 hours
Battery Voltage	Bvolt	120 = every 2 hours
Battery Voltage @ transmission	YB	1440 = once every 24 hours

A8.1.4 Miscellaneous

Not applicable.

A8.1.5 Record Keeping

During the process of adding a Provincial Observation Well to the PGOWN, it is important to document all the details of the project (e.g., research, contracts, photos, etc.) and maintain those records. This information should be saved to the respective project folders. The **Regional PGOWN Tracking Spreadsheet** should also be updated with the new well information.

A8.1.6 Field Sheets

There are no specific field sheets for the addition of new wells into the network.

Appendix A8-2

Removing a Well from PGOWN Systems SOP

A8.2 REMOVING A WELL FROM PGOWN SYSTEMS SOP

This SOP describes the necessary procedures to follow when an existing Provincial Observation Well is removed from the PGOWN. Several applications, databases and staff are involved with the operation of the provincial network. The procedures herein are intended to be followed by PGOWN staff to update the various PGOWN-related systems.

A8.2.1 General

A description of each database as it relates to the PGOWN is provided below:

- **Environmental Monitoring System (EMS) Database:** this database houses the PGOWN analytical water chemistry data.
- **GWELLS**: this database contains the PGOWN well construction (and decommissioning) records.
- **Aquarius Time-series Management Database**: this database stores the groundwater level data produced by Provincial Observation Wells.
- **Groundwater Level Data Interactive Map**: this interface posts PGOWN groundwater level data publicly for viewing and downloading.

A8.2.2 Required Information

Provincial Observation Well details required to proceed with this SOP:

- The Well Tag Number; and
- EMS ID.

A8.2.3 Procedure

The following systems must be updated as described below.

A8.2.3.1 GWELLS Database

Update the GWELLS database when an observation well is removed from the network by first logging into GWELLS, searching for the well record in question, hitting 'Edit' and then following these steps:

- Double check the 'Well Owner' name is accurate (note: this refers to mistakes with the 'Well Owner' name and is different than actually transferring well ownership). Update 'Well Owner' name if needed. If instead a well ownership transfer is occurring, first complete an **Acknowledgement, Release and Indemnity** agreement (contact the Groundwater Monitoring Program Supervisor). If there is a well ownership change, indicate in the 'Comments' section that: "This well operated as a Provincial Observation Well from **YEAR** to **YEAR**";
- Update the 'Observation Well Status' to 'Inactive';
- In the publicly available 'Comments' section add: "Removed from Provincial Groundwater Observation Well Network in **MONTH/YEAR** due to **SHORT DESCRIPTION WHY**". Hit 'Save'.

    - Include additional comments, if necessary, in 'Internal Office Comments';

- If the well has been decommissioned, also change the 'Well Status' by selecting 'Closure', and then complete the 'Well Decommission Information' section of the well record. Under the 'Attachments' section, attach a scanned copy of the well decommissioning report by selecting 'Document Type' > 'Well Decommissioning Report'. Hit 'Save'; and

    - Email the well decommissioning report to the Groundwater Monitoring Program Supervisor if the well has been decommissioned.

Email GWELLS@gov.bc.ca to receive training and approval to enter / edit well records in GWELLS, ask questions, or report any GWELLS system issues.

A8.2.3.2 EMS Database

In EMS, a 'Closed Date' needs to be entered in the 'Monitoring Location' record to indicate that it is permanently closed, no further sampling will be completed, and all analytical results have been uploaded into EMS.

To enter a 'Closed Date' in EMS, from the main page under 'Enter / Edit / View', click on 'Monitoring Locations'. Enter the EMS ID in the field provided and click on the 'More' button on the bottom right-hand corner of the screen to get to the form that contains the 'Closed Date'.

Email EMSHELP@gov.bc.ca if you have questions about EMS.

A8.2.3.3 Aquarius Database & Interactive Map

In Aquarius, the status of the well will need to be updated to ensure it is no longer listed as an active station. Under 'Location Details', change the station status to 'Inactive'. In addition, update the "About this Well" descriptor (displayed on the Groundwater Level Data Interactive Map but stored in Aquarius) by completing the following template. Please copy this descriptor into the 'Description' field of 'Location Details' after editing the blue text fields:

> *RESP:PGOWN Observation Well **XXX** was active between **YYYY** and **YYYY**. It was located in **a / an confined / unconfined / sand and gravel / bedrock / unmapped aquifer** identified as Aquifer #**123 (Aquifer Name?) on / at / in / near Location**.*

Contact the ENV Water Data Specialist (Aquarius Administrator), if you have questions about Aquarius.

A8.2.4 Miscellaneous

Not applicable.

A8.2.5 Record Keeping

During the process of removing a Provincial Observation Well from the PGOWN, it is important to document the decision-making process as to why and how the well was removed (e.g., well decommissioning), and maintain those records. This information should be saved to the respective project folder.

A8.2.6 Field Sheets

There are no specific field sheets for the addition of new wells into the network.