Low Hydraulic Stress Groundwater Sampling in Alberta's Oil Sands Region

Standard Operating Procedure

Classification: Public

Low Hydraulic Stress Groundwater Sampling in Alberta’s Oil Sands Region | Alberta Environment and Protected Areas

Government of Alberta

Alberta Environment and Protected Areas

Oil Sands Monitoring Branch

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Symbols & Acronyms

Symbol/Acronym	Meaning
AEPA	Alberta Environment and Protected Areas
cm	centimetre
CoC	Chain of Custody
°C	degrees Celsius
DO	Dissolved Oxygen
DTW	Depth to Water
EC	Electrical Conductivity
EDD	Electronic Data Delivery
EPA	United States Environmental Protection Agency
ESP	Electrical Submersible Pump
GNSS	Global Navigation Satellite System
GoA	Government of Alberta
GOWN	Groundwater Observation Well Network
IHR	Induced Hydraulic Response
kPaG	kilopascal gauge
KiWQM	Kisters Water Quality Module
L	litre
LHS	Low Hydraulic Stress
µ	micro
MAD	Maximum Allowable Drawdown
mg	milligram
µS	microsiemens
µS/cm	microsiemens per centimetre
min	minute
mL	millilitre
mm	millimetre
MP	Measuring Point
mV	millivolts
NPSH	Net Positive Suction Head
NPSHA	Net Positive Suction Head Available
NPSHR	Net Positive Suction Head Required
NTU	Nephelometric Turbidity Unit
ODO	Optical Dissolved Oxygen
OHS	Occupational Health and Safety
ORP	Oxidation-Reduction Potential
OSM	Oil Sands Monitoring
PI	Principal Investigator
PPE	Personal Protective Equipment
psig	pounds per square inch gauge
PTFE	Polytetrafluoroethylene
PWL	Pumping Water Level
QA/QC	Quality Assurance and Quality Control

Symbol/Acronym	Meaning
SC	Specific Conductance
SOP	Standard Operating Procedure
SOS	Save Our Souls
SPT	Submersible Pressure Transducer
SS	Stainless Steel
SSHA	Site-Specific Hazard Assessment
SWL	Static Water Level
TDS	Total Dissolved Solids
ToP	Top of Pump
ToS	Top of Screen
USGS	U.S. Geological Survey
VFD	Variable Frequency Drive
VOCs	Volatile Organic Compounds
VSD	Variable Speed Drive
WISKI	Water Information Systems KISTERS

Revision History

Date	Revision #	Summary of Changes	Approver	Section
08/27/2026	01	Initial Release	Seth Xeflide	All Sections

1 Background

Alberta Environment and Protected Areas (AEPA) has tasked the Oil Sands Monitoring (OSM) Branch with implementing a long-term ambient groundwater monitoring program in Alberta's oil sands region. As part of this task, groundwater samples are collected from the Provincial Groundwater Observation Well Network (GOWN).

In support of the monitoring mandate, the OSM Program has developed this Standard Operating Procedure (SOP) to ensure the application of groundwater sampling techniques that adhere to best practices for long-term, high-quality monitoring. In this context, best practices include consistent and standardized sampling methods, collection of representative groundwater samples that reflect in situ conditions, and implementation of appropriate QA/QC procedures.

The existing monitoring well infrastructure has been developed over many years and includes a variety of wellbore sizes, casing materials, sampling intervals, and well completion types. Over time, the GOWN has been affected by physical, geochemical, and biological processes that may influence well performance, sample representativeness, and data comparability. As a result, appropriate sampling methods and maintenance practices are required to ensure the network remains suitable for OSM long-term monitoring objectives.

Given the current condition of the GOWN and the program's monitoring needs, low hydraulic stress (LHS) groundwater sampling using dedicated stainless steel (SS) electrical submersible pumps (ESPs) has been selected as the preferred approach because it supports consistent sampling, minimizes hydraulic disturbance, and is well suited for long-term groundwater monitoring.

2 Application & Scope

This SOP is designed for OSM groundwater technologists and contractors working on behalf of the OSM Program. It provides procedures for collecting representative groundwater samples from the GOWN that are intended to characterize in situ groundwater quality, including mobile dissolved and colloidal fractions of organic and inorganic constituents.

The presence of fouling solids in the GOWN underscores the importance of minimizing hydraulic stresses—such as those in the aquifer, filter pack, screen interface, and sampling interval—during purging and sampling. Maintaining minimal water-level drawdowns and screen velocities significantly reduces colloidal transport and sample degassing.

Another important advantage of the LHS sampling approach is that mixing between groundwater in the well screen and stagnant water in the overlying casing is minimized during pump operation. Consequently, pump discharge from the screened interval is more likely to represent water entering from the adjacent formation.

The use of a predetermined purge volume does not always provide a technically defensible basis for determining when representative formation water has reached the sampling point. The method does not account for variations in site-specific hydrogeology, well response, or pumping rate, nor does it provide independent confirmation that representative formation water has reached the sampling point (Barcelona et al., 1994; Nielsen and Nielsen, 2006; Thornton and Wilson, 2008). Instead, the appropriate time to begin sample collection is determined by the stabilization of field indicator parameters (e.g., pH, specific conductance, dissolved oxygen, oxidation-reduction potential, and temperature) during the purging process.

Groundwater samples collected using Low Hydraulic Stress (LHS) methods in conjunction with stabilization of field indicator parameters are intended to be representative of the formation water entering the well through the monitored interval. These samples are suitable for the analysis of a wide range of analytes, including volatile organic compounds (VOCs), dissolved gases, metals, other inorganic constituents, and naturally occurring compounds.

Dedicated pumps provide three principal advantages for long-term groundwater monitoring. First, they reduce field setup time, simplify field logistics, and improve operational efficiency, allowing more wells to be sampled with available field resources while reducing overall monitoring costs. Second, they minimize mixing between stagnant casing water and formation water, reduce purge volumes, and reduce the potential for contamination associated with repeatedly installing portable tubing and pumps. Third, because dedicated pumps remain installed within the well, they provide a standardized sampling configuration that improves consistency and reproducibility among sampling events.

3 Health & Safety

To ensure public and worker safety, appropriate precautions must be observed during groundwater sampling activities in accordance with applicable Alberta Occupational Health and Safety (OHS) requirements. Additional information is available at: https://www.alberta.ca/occupational-health-safety

Upon arriving at each well site, OSM field personnel must complete a Site-Specific Hazard Assessment (SSHA) form. This process involves evaluating the surroundings for potential risks, unusual hazards, or conditions, with all findings documented on the form. The SSHA is an essential tool for identifying site-specific hazards, increasing risk awareness, and implementing control measures to mitigate and manage risks associated with field activities at the well site.

During work activities, field personnel must remain vigilant, continuously monitoring their environment for any changes that could affect safety.

Note: *Site conditions may change during fieldwork. The SSHA must be updated to reflect any changes in site conditions.*

4 Training

Before participating in fieldwork, all groundwater technologists must complete the prerequisite training courses outlined in the OSM Safety Matrix.

Additionally, they must receive training from the groundwater Team Lead on the proper use of sampling instruments, equipment, pertinent software (see Section 4.1), and the field Electronic Data Delivery (EDD) form (Appendix A).

Groundwater technologists must be familiar with and trained in the applicable GoA field emergency procedures.

4.1 Software

Groundwater technologists must be proficient in all software products used to operate monitoring instrumentation. They must also ensure that the latest operating software and firmware required for the operation of submersible pressure transducers (SPTs) and multiparameter sondes are installed. This includes:

- **Kor** software for YSI EXO1 multiparameter water quality sondes
- **Win-Situ 5** software or **VuSitu** mobile app for Level TROLL 500 SPTs

5 Responsibilities

Groundwater sampling shall be conducted by a minimum of two trained personnel to ensure safe and effective field operations.

5.1 Technologist

Conducts LHS groundwater sampling, including purging, monitoring field indicator parameters, collecting samples, recording field data, and properly storing and shipping samples.

5.2 Team Lead

Ensures that sampling is carried out in compliance with this SOP, oversees the process, and addresses any issues related to equipment, methods, or site conditions.

5.3 Principal Investigator (Hydrogeologist)

Oversees compliance with this SOP; prepares, maintains, and updates the SOP as necessary; reviews field data for accuracy and consistency; and ensures all procedures align with program requirements.

6 Project Planning

The success of any groundwater sampling campaign relies on careful planning and preparation. In alignment with the OSM Quality Assurance Framework, the Principal Investigator (PI), in collaboration with the Field Operations Team Lead, is responsible for developing a detailed sampling plan that addresses the project objectives, data-quality requirements, QA/QC procedures, sample handling requirements, and field methods.

7 Important Considerations

7.1 Well Recovery Rate – Hydraulic Response

A well should not be sampled using an ESP unless the water level has recovered to at least 90% of the pumping-induced drawdown within 24 hours after pumping stops. In other words, residual drawdown should not exceed 10% of the maximum drawdown (USGS, 2006). Failure to meet this criterion may indicate poor well recovery, which could affect sample representativeness. In such cases, alternative sampling methods, such as passive or no-purge techniques, should be considered in consultation with the PI.

Note: *Passive or no-purge sampling techniques are not discussed in this SOP, as the OSM Program currently samples only wells that can sustain a minimum pumping rate of 0.10 L/min under low hydraulic stress conditions. The applicability of passive or no-purge sampling techniques will be reviewed annually, and the SOP will be updated as necessary.*

7.2 Pump Installation

The intake of a dedicated pump or drop-tube assembly should be positioned at the midpoint of the saturated monitoring interval, where site conditions permit, to optimize the collection of representative formation-water samples.

7.3 Drawdown Limit

It is recommended to adjust the pumping rate to maintain minimal drawdown, ideally not exceeding 10 cm. This small pumping-induced head difference promotes inflow of formation water while minimizing turbulence and hydraulic disturbance.

By utilizing the minimal drawdown method, groundwater pressure at the sampling point (e.g., screen midpoint) is more likely to remain above the bubble point pressure, thereby minimizing groundwater degassing.

In certain situations, a drawdown greater than 10 cm may be required to induce flow into the well, referred to as an Induced Hydraulic Response (IHR). In such cases, two important considerations must be addressed regarding the drawdown limit (DDL):

1. **Net Positive Suction Head (NPSH):** NPSH Available ($NPSH_A$) must be greater than NPSH Required ($NPSH_R$). If $NPSH_A$ is less than $NPSH_R$, cavitation may occur, potentially resulting in the release of dissolved gases and compromising sample integrity.

   Note: *In wells with a limited saturated interval or in low-yield aquifers, pumping may substantially reduce the water column above the pump intake. Under these conditions, $NPSH_A$ may become less than $NPSH_R$, increasing the potential for groundwater degassing. Based on OSM operational experience, the valve on the discharge line may be partially closed, where appropriate, to apply controlled backpressure, thereby maintaining positive pressure within the sampling system and minimizing groundwater degassing. The valve should be adjusted only enough to achieve this objective and should not be used as the primary means of controlling the pumping rate.*

2. **Maximum Allowable Drawdown (MAD):** The distance between the top of the screen (ToS) and the top of the pump (ToP), or drop tube intake, determines the MAD during IHR sampling. To ensure that stagnant casing water does not enter the pump during sampling, the drawdown must not exceed MAD (Figure 1).

   Special Limiting Case (Figure 1)
   Figure 1 illustrates a special limiting case in which the drawdown limit equals the maximum allowable drawdown defined by the well geometry. In this boundary condition:

   - PWL − SWL = DDL = MAD

     and

   - MAD = ToP − ToS

This equality represents the maximum permissible drawdown during IHR sampling, where the full geometric allowance between ToS and ToP is utilized. It does not represent the standard minimal-drawdown operating condition.

Under typical IHR sampling, DDL < MAD.

Note: *When IHR is required, allow the well to recover at least 90% of the pumping-induced drawdown (i.e., the residual drawdown does not exceed 10%) before proceeding with sample collection.*

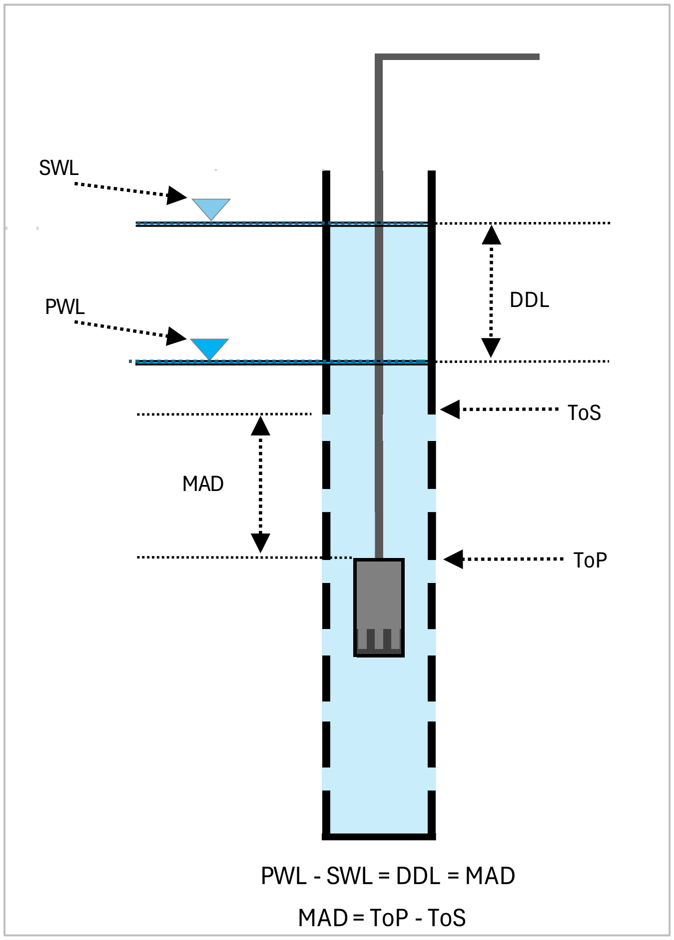

Figure 1. Conceptual diagram illustrating the special limiting case in which the drawdown limit (DDL) equals the maximum allowable drawdown (MAD). DDL is the pumping-induced difference between the static water level (SWL) and pumping water level (PWL), whereas MAD is the vertical distance between the top of the screen (ToS) and the top of the sampling pump (ToP). In this limiting configuration, DDL = MAD = ToP − ToS. All water levels are expressed as depths below the designated measuring point.

7.4 Purging Rate

The pumping rate should be maintained between **0.1 L/min** and **1.0 L/min**, depending on the well's hydraulic response and minimal drawdown requirements.

7.5 Pump Operation

- Start the pump at a low controller setting and gradually increase the pump speed until a stable discharge is established.
- Establish a continuous flow by using the variable frequency drive (VFD) or variable speed drive (VSD) depending on the pump type.
- Avoid using the discharge valve as the primary means of reducing the pumping rate. Excessive restriction of the discharge line may create pressure gradients and turbulence that promote groundwater degassing and the loss of VOCs and other dissolved gases. Pumping rate should normally be controlled using the pump controller. Where groundwater degassing is observed or anticipated, the discharge valve may be adjusted only as necessary to maintain positive pressure within the sampling system and minimize groundwater degassing.

7.6 Dynamic Well Response

The yield of a well can change over time due to variations in site-specific hydrogeological conditions (e.g., recharge), pumping activities, and biofouling, the latter often leading to a decline in well yield (Figure 2).

As part of long-term monitoring programs, it is crucial to track the well's hydraulic response and document its performance over time. This ensures that appropriate monitoring and maintenance practices are effectively implemented.

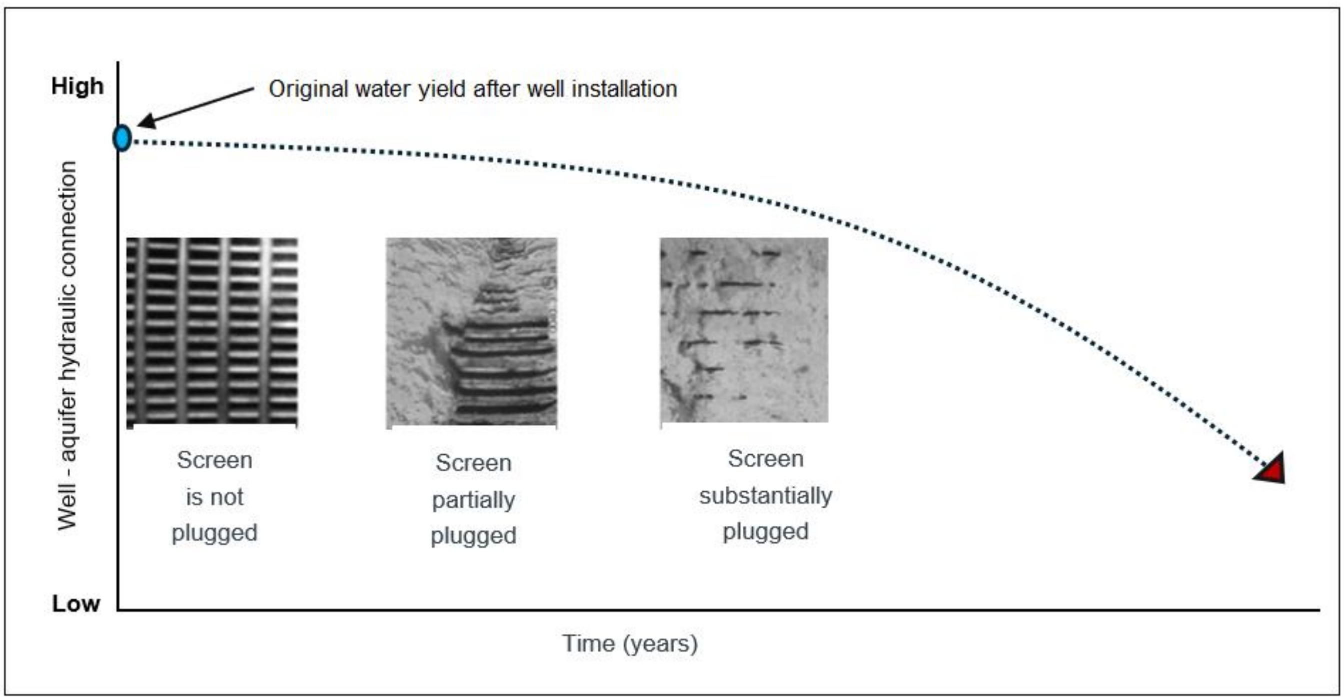

Figure 2. An illustration of decreasing hydraulic connection between the well and aquifer as a result of fouling at the screen – aquifer interface.

7.7 Purging Duration

Purging duration can vary significantly depending on the stabilization of indicator field parameters. Typically, monitoring wells with low hydraulic response or screen diameters greater than 10 cm (4 inches) require longer purging times.

Under circumstances where indicator field parameters have not stabilized after three hours of purging, one of the following actions may be taken:

1. Continue pumping until stabilization is achieved.
2. Abort groundwater sampling.
3. Do not prolong purging if continued pumping is unlikely to achieve stabilization. Collect the groundwater samples, clearly document that stabilization criteria were not achieved, record the rationale for sample collection, notify the PI as soon as practicable, and qualify the resulting data accordingly.

7.8 Turbidity

Turbidity should be monitored and documented because elevated suspended and colloidal material may influence measured metals concentrations, particularly total metals (Puls and Barcelona, 1996; USGS, 2006). For turbidity measurement, collect the water sample upstream of the flow-through cell using a cuvette-based portable turbidimeter.

The target turbidity for low hydraulic stress sampling is $\leq 10\ \mathrm{NTU}$. If turbidity remains above 50 NTU prior to sampling despite maintaining minimal drawdown and flow rates:

- Proceed with sample collection per the analytical schedule.
- Clearly document the final turbidity value and note in the field EDD that sampling occurred under elevated turbidity conditions (> 50 NTU).
- Notify the PI so analytical data (especially total metals) can be qualified accordingly during data review.

7.9 Bubble Interference

Bubbles often form in the sampling line and flow-through cell due to groundwater degassing caused by pressure changes during the pumping process. As these bubbles travel toward the discharge point, some adhere to the surfaces of the tubing and instrumentation. The quantity and composition of dissolved gases vary among aquifer units and may influence the formation and persistence of gas bubbles within the sampling system. When bubbles adhere to the sonde sensors, they can interfere with the accurate measurement of key field indicator parameters, particularly dissolved oxygen. To minimize air bubble interference, technologists should routinely inspect the sampling system for air bubble accumulation. If bubbles are observed adhering to the sonde sensors, gently agitate the sonde to dislodge them and restore stable field parameter measurements.

7.10 Heterogeneous Transmissivity

The sampling interval may exhibit geologic layers with higher transmissivity, which are preferentially sampled (Puls and Barcelona, 1996), especially in the case of longer screens. In monitoring wells where preferential flow paths exist, the contributions from individual flow paths to the pump discharge depend not only on the transmissivity of the layer but also on the distribution of hydraulic head across the layers intersecting the well borehole. Therefore, the contribution of geologic layers to the pump discharge is proportional to their transmissivity, regardless of the pump intake's location. This results in a flux-averaged concentration in the sample stream.

Where a screened interval intersects geologic layers with varying transmissivities and hydraulic heads, groundwater contributions to the pumped sample vary among the intersected layers. Higher-transmissivity zones commonly contribute a greater proportion of the total flow; however, contributions are also influenced by vertical hydraulic gradients, screen hydraulics, wellbore flow, pumping rate, and pump-intake position. Consequently, the resulting sample stream represents a flow-weighted, flux-averaged mixture of groundwater entering the monitored interval.

7.11 Indicator Parameters Equilibration Time

The following factors may influence the time required for field indicator parameters to stabilize and should be considered when determining equilibration time during LHS sampling.

7.11.1 Thermal Currents

Vertical thermal currents in monitoring wells can cause mixing of screen and casing water. When the ambient air temperature is lower than groundwater temperature, the top of the water column cools in the casing, causing denser cold water to sink and warmer screen water to rise, creating a convection cell. During LHS groundwater sampling, this mixing can result in a blend of water from the well casing and aquifer (Vroblesky, 2007). This mixing can delay stabilization of indicator parameters and extend equilibration time.

7.11.2 Long Sampling Intervals

It may take longer for indicator parameters to reach equilibrium in monitoring wells with long sampling intervals. This is mainly due to heterogeneous transmissivity and preferential flow paths along the sampling interval, which require more time to achieve hydraulic equilibrium with respect to the pump intake. As a result, additional purging time may be required to achieve stabilization.

7.11.3 Screens with Large Diameters

Screens with large diameters, greater than 10 cm (4-inches), contain a larger volume of water. In monitoring wells completed in aquifers or water-bearing formations with low hydraulic connectivity, water contained within the screened interval may not be fully representative of formation groundwater, and larger purge volumes are needed to achieve stabilization of indicator parameters. Consequently, longer equilibration periods may be necessary before stabilization criteria are met.

7.12 Ambient Temperature

Groundwater sampling should preferably be conducted when the ambient temperature is above 0°C because freezing within the sampling line can restrict flow and compromise sample integrity.

If sampling must occur at or below 0°C, appropriate precautions should be implemented, such as insulating or heating tubing, enclosing equipment within a portable shelter, and minimizing the exposure of equipment and samples to cold conditions.

7.13 Degassing of Groundwater

The IHR method for groundwater sample collection reduces hydrostatic pressure within the water column and may cause groundwater pressure to fall below the pressure at which dissolved gases remain in solution, resulting in the exsolution of dissolved gases (degassing). Degassing, particularly the exsolution of carbon dioxide (CO_2), may increase groundwater pH by reducing dissolved carbonic acid. The resulting increase in pH and, where applicable, changes in oxidation conditions may promote the precipitation of carbonate and metal hydroxide minerals, potentially affecting dissolved concentrations of calcium (Ca^{2+}), iron (Fe^{2+}), manganese (Mn^{2+}), and associated trace metals.

7.14 Sources and Types of Error

Groundwater sampling may introduce systematic and random errors that compromise the representativeness of groundwater samples and the accuracy and reproducibility of analytical results.

The following are some common sources of sampling errors (Thornton and Wilson, 2008):

- Expired, contaminated, improperly prepared, incorrectly labelled, or inappropriate calibration and reference solutions.
- Inaccurate calibration or programming of instruments.
- Unsuitable well design.
- Malfunctioning sampling equipment.
- Poor preservation methods and handling of samples.
- Inability to identify or account for errors in measurements.
- Delay in recording values of temperature-sensitive parameters.

8 Materials & Equipment

8.1 Sampling Equipment

- 12-volt battery and charger
- Aluminum foil for covering sampling table
- Calibration check solutions
- Canopy or sun shelter
- Cleaning supplies (e.g., Liquinox® solution)
- Cooler
- Dissolved gas needle kit
- Electronic data recorder with monitor (i.e., field computer, tablet, cell phone)
- Field notebook (waterproof or water-resistant)
- Filter: High-capacity disposable filters with 0.45 µm and 0.2 µm pore sizes, as required by the analytical program
- Graduated cylinder and bucket: for measuring the flow rate
- Ice or ice packs
- Laminated analytical schedule sheet

- Power inverter (for Geosub2 pump)
- Sample bottle tray
- Sampling table
- SS ESP with pump controller
- Stopwatch
- Tarp or clean ground cover
- Tubing: Polytetrafluoroethylene (PTFE) lined tubing
- Well keys

8.2 Water Quality Meters

- Flow-through cell
- Multiparameter water quality sonde with following sensors:
  - pH
  - Electrical conductivity (EC)
  - Oxidation-reduction potential (ORP)
  - Optical Dissolved Oxygen (ODO)
  - Temperature
- Turbidity meter (EPA Method 180.1)

8.3 Water Quantity Meters

- Temporary SPT and cable
- Water-level tape

8.4 Sampling Containers

- Gas-tight glass vials with sealed caps for dissolved gas analysis (requires syringe and needle).
- Clean sample bottles (lab provided)
- Laboratory-prescribed preservative

8.5 Field Form and Electronic Data Delivery Form

- To record well location, sample details, field data, flow rates, and water quality parameters

8.6 Personal Protective Equipment (PPE)

- Based on the Safety Matrix and site’s hazard assessment
- Survival kit as described in Safety Matrix

8.7 Other Supplies & Equipment

- 4-gas monitor
- 1.2 m (4 ft) ladder
- After bite and sunscreen
- Aircraft cable clamps or sleeves (requires crimper)
- Barbed wire repair tools and supplies
- Bear spray kit
- Borehole inspection camera
- Caliper and measuring tape
- Canopy
- Carrying case for equipment
- Casing roller
- Chainsaw
- Cord/cable storage reel
- Deionized water — 4 L
- Digital camera
- Disinfecting wipes
- Duct tape
- Electrical splice kit
- Extension cord
- First aid kit and eye wash solution
- Flagging tape
- Flashlight
- Folding stool
- Fuel
- General hand tools set (include knife and file) and toolbox
- Generator/portable power station
- Handheld GNSS unit
- Laboratory grade detergent (Liquinox®)
- Nikal anti-seize thread lubricant
- Paint, paint pens and markers
- Personal multitool pocket kit
- Pipe wrench (up to 36-inch)
- Power tools for drilling, cutting and grinding
- Pressure gauge (rated for 2,000 psig or higher, with high-resolution 0–20 psig capability)
- Pry bar/crowbar
- RAD7 radon detector (where required)
- Rope and tie-down strap
- Satellite SOS messaging system
- Shovel, axe, pruning saw
- Silicone lubricant
- Sledgehammer/mallet hammer
- Small torch
- Spare pump motor module
- Spare well caps – various sizes
- Spill kit

- SS carabiner clip and quick chain link – various sizes
- Tagline and weight
- Traffic cones
- Tripod
- Two-way communication radio
- Waste bags for disposal of used sampling materials
- Zip ties – various sizes

9 Procedures

Sampling procedures must be followed precisely to ensure compliance with the relevant OSM protocols and alignment with the objectives of the sampling data. Any non-standard methods or deviations must be thoroughly detailed and documented.

A typical groundwater sampling campaign can be divided into the following steps:

9.1 Pre-Trip Preparation

To ensure data integrity, team safety, and operational efficiency, the following logistical, equipment, and safety checks must be executed and verified before departure:

- Develop a field-trip itinerary in consultation with the Team Lead.
- Prepare a trip plan for the duration of the field campaign, including confirmation of site access arrangements, verification that all required site access permits and approvals have been obtained, coordination with landowners or site operators (where applicable), and a review of weather forecasts and wildfire conditions.
- Calibrate the multiparameter water quality sonde and the turbidity meter, and maintain all calibration records.
- Ensure all equipment maintenance has been completed and that all field equipment is in proper working order.
- Gather all required supplies, equipment, and documentation as outlined in Section 8.
- Verify that all required sample containers, preservatives, chain-of-custody forms, laboratory requisition forms, and shipping materials are available before departure.
- Obtain previous sampling records, well drilling reports, and other relevant site information, where available.
- Include spare supplies and consumables (e.g., batteries, tubing, fittings, and field repair materials).
- Gather and organize all required PPE.
- Identify the location and operating hours of the nearest courier service, where applicable.
- Assemble digital and/or hard-copy maps, aerial imagery, and site access information.
- Perform vehicle inspections to confirm that vehicles are in good working condition and suitable for the planned field activities.
- Secure all supplies and equipment in vehicles or helicopters to prevent damage during transport.
- Obtain and confirm all required site-access permits.
- For remote well sites requiring helicopter transit, the Team Lead must oversee, or the deploying Field Technologist must ensure, that weight manifests, secured cargo, and declared dangerous goods comply with Transport Canada regulations and the chartered helicopter company's safety policies.

  Note: *Equipment calibration should be carried out in accordance with the manufacturer’s instructions.*

9.2 During Transport

- Vehicle operators must take rest breaks and manage driving hours in strict accordance with the approved journey-management plan and applicable Government of Alberta requirements.
- Ensure that there is enough ice to keep groundwater samples at approximately 4°C.

9.3 At the Wellsite

- Acquire access permits where required.
- Conduct initial site inspections and confirm the site matches the intended sampling location.
- Identify site hazards and implement appropriate controls before beginning work.
- Inspect the monitoring well condition and record any deficiencies.
- Complete an SSHA form.

9.4 Pre-Sampling Preparation

- Confirm that the correct monitoring well is being sampled.
- Initiate a field electronic data deliverable (EDD).
- Confirm whether the well is sealed or potentially pressurized. For all sealed or pressurized wells, field staff must complete the Appendix B pressure-safety procedure prior to loosening or opening any cap, plug, or wellhead component.

  Note: *Sealed groundwater monitoring wells require pressure testing before opening any wellhead valve(s) (Appendix B).*

- After the well has been safely opened, inspect the well condition and verify that the 4-gas monitor indicates safe atmospheric conditions before commencing field activities.
- Measure the depth to water (DTW) from the measuring point (MP).
- Download data from the dedicated submersible pressure transducer (SPT) and temperature sensor, if present.
- Prepare a clean work area adjacent to the monitoring well.
- Set up the canopy, if required, to protect equipment and samples from direct sunlight or precipitation.
- Set up the sampling table.
- Perform a calibration check, if required, and program the YSI EXO1 multiparameter water quality sonde.
- Ensure all sample bottles and vials are correctly labelled.
- Install and program the temporary SPT to monitor water levels during sampling.
- Set up the sampling equipment as shown in Figure 3.
- Connect the pump discharge line to the flow-through cell.
- Connect the pump electrical cable to the controller, inverter (if required), and power supply.

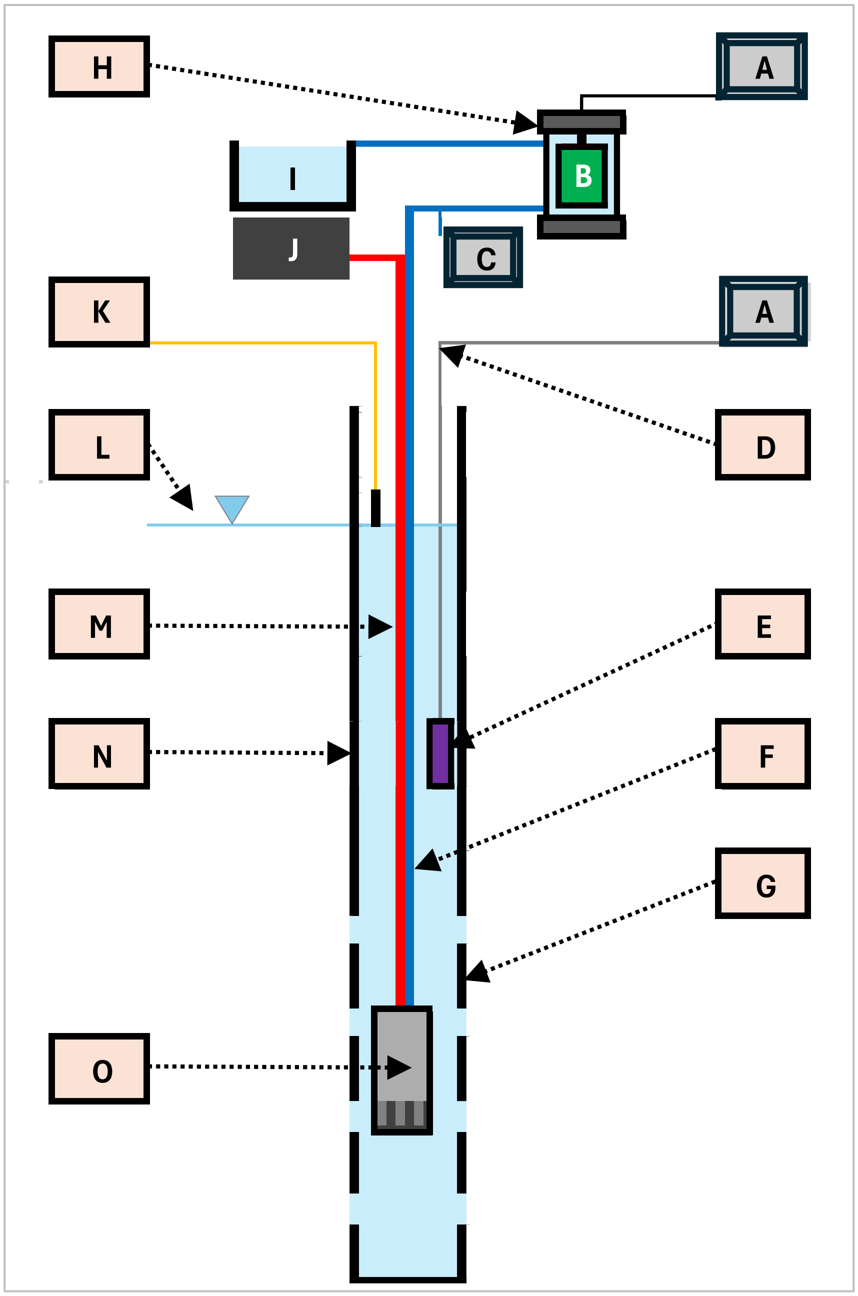

Figure 3. Schematics of sampling setup: A) Electronic data recorder with monitor (i.e., field computer, tablet, cell phone), B) multiparameter sonde, C) Cuvette-based portable turbidimeter, D) direct read communication cable, E) temporary SPT, F) PTFE (Teflon®) or PTFE-lined polyethylene tubing, G) well screen or open hole, H) flow-through cell assembly, I) graduated container for purge water, J) pump controller, K) water level tape, L) static water level, M) pump electrical wire, N) well casing, O) ESP.

9.4.1 Equipment Troubleshooting

Dedicated electrical submersible pumps (ESPs) and multiparameter sondes can occasionally experience malfunctions. Common issues include:

Electric Motor Failure in ESPs

- Water ingress is the predominant cause of electric motor failure in ESPs.

- In such cases, the ESP must be retrieved, and the motor module replaced.

Sensor Failure in Multiparameter Sondes

- Sensor failure is the most common issue encountered with multiparameter sondes.
- Troubleshooting these failures can be challenging because of the complexity of the sensors.
- A backup sonde should be available to minimize field downtime during equipment failures.

For additional guidance on the operation, maintenance, and troubleshooting of field equipment, refer to the manufacturer's documentation and training resources below.

Geotech Geosub2 Pump and Controller User Manual
https://www.geotechenv.com/Manuals/Legacy_Manuals/Geotech_Geosub2_and_Controller_1_9_23.pdf

Proactive Environmental Products – Sample Champ XL Pump and Controller
https://www.proactivedirect.biz/ss-sample-champ-xl-pump

Proactive Environmental Products – Sample Champ XL Controller
https://www.proactivedirect.biz/sample-champ-xl-controller

YSI EXO User Manual (EXO1 Multiparameter Water Quality Sonde)
https://www.ysi.com/File%20Library/Documents/Manuals/EXO-User-Manual-Web.pdf

YSI EXO University – Training Resources
https://video.ysi.com/ysi-university-exo

9.5 Sample Collection

- Start the pump at low frequency to minimize hydraulic disturbance. Adjust speed to achieve minimal, stabilized drawdown. Determine optimal flow rate and drawdown as soon as practical.
- Measure and verify flow rate using a graduated cylinder and stopwatch.
- Continue well purging while monitoring field parameters and water levels until indicator field parameters reach stabilization per Table 1.

  Note: *Field parameter stabilization is not typically assessed immediately after low hydraulic stress pumping begins because field parameters may fluctuate during the initial purging period. Stabilization is generally achieved when field parameter readings remain within the thresholds specified in Table 1 for at least three consecutive readings collected at 5-minute intervals.*

- Record water levels, calculated flow rate, and stabilized field parameters in the field EDD.
- Prior to sample collection, verify turbidity meter calibration and measure turbidity from a discrete sample collected upstream of the flow-through cell. Record reading in field EDD. If turbidity exceeds 50 NTU, note condition in EDD comments and proceed with sampling.
- Record observable physical characteristics of the groundwater in the field EDD (e.g., odour, colour, visual clarity/appearance).
- **Trip Blanks (Pre-Sampling Check):** Verify at least one sealed trip blank is included per sampling trip in every cooler used to store and transport samples intended for volatile organic compound (VOC) analysis.
- **Equipment Blanks**: Not required during routine monitoring of established dedicated systems. Collect an equipment blank only prior to initial deployment or replacement of dedicated sampling equipment.

- **Field Blanks:** Prepare field blanks at a cumulative frequency of 10% (1 field blank for every 10 primary samples collected across field trips). Prepare the blank at the designated wellhead prior to or during primary sample collection by pouring laboratory-provided deionized water directly into sample containers.
- **Primary Samples:** Organize bottles and collect primary groundwater samples per the analytical schedule.
- **Field Duplicates:** Collect field duplicates at a cumulative frequency of 10% (1 field duplicate for every 10 primary samples collected across field trips). Collect each duplicate from the same well and sampling interval immediately following primary sample collection.
- **Storage & Preservation:** Store and preserve all primary and QC samples in an iced cooler immediately following collection.

  Note: *Reduce flow rate during VOC sample collection to minimize groundwater aeration.*

Table 1. Stabilization criteria for field indicator parameters.

Parameter	Tolerance
pH	± 0.1 standard units
SC	± 10.0 µS/cm (for values ≤ 1000 µS/cm) ± 20.0 µS/cm (for values > 1000 µS/cm)
DO	± 0.05 mg/L (for values ≤ 1 mg/L) ± 0.2 mg/L (for values > 1 mg/L)
ORP	± 10 mV
Temperature	± 0.1 °C

9.5.1 Collecting Dissolved Gases

- Hold the sampling tube upright and gently shake it to dislodge any adhered air bubbles.
- Securely attach the needle assembly to the end of the sampling tube, ensuring an airtight connection.
- Adjust the flow rate, as needed, to maintain sufficient backpressure.
- Insert the needle through the rubber septum stopper, ensuring that approximately 3–5 mm of the needle tip protrudes beyond the bottom of the stopper. This step shall be performed while water is continuously discharging from the needle.
- Fill and seal the vial in accordance with the laboratory-provided method, including any specified headspace, preservative, overflow volume, and septum-handling requirements.
- Quickly withdraw the needle and immediately apply pressure to the punctured area of the septum to maintain the seal.
- Dispose of the needle immediately in an approved sharps container.

9.6 Post-Sampling

- Clean and pack the equipment properly after use.
- Document all field observations accurately.
- Collect and dispose of generated waste, ensuring the well site is returned to its original condition.
- Add fresh ice into the coolers as needed to maintain samples at approximately 4°C, where required by the analytical method.

9.7 Post-Fieldwork

- Finalize data entries, complete chain-of-custody forms (CoC) and prepare the samples for shipment to the laboratory.
- Submit the completed field EDDs.
- Decontaminate and clean the field equipment.

Note: *Ensure that all analytical holding times are met*.

9.8 Data Report

Ensure that all field observations and relevant sampling data are accurately documented and securely stored in the designated GoA network folder (Obs. Well Directory) and the applicable OSM databases, including WISKI (Water Information System KISTERS) and KiWQM (Kisters Water Quality Module).

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Appendix A

Table 2. Field Electronic Data Delivery (EDD) data elements.

Data Element		
Agency Code	Ambient Temperature	Calculated Flow Rate
Collection Code	Colour of Water	DO
GOWN #	Lab Code	Odour of Water
ORP	pH	Program Name
Project #	Pump #	Pumping Water Level
Radon	Remarks	Salinity
Sample #	Sample Matrix	Sample Type
Sampler ID	Sampling #	Sampling Date
Sampling Depth	Sampling Time	SC
Site Name	Static Water Level	Station Name
TDS	Turbidity	Water Temperature

Appendix B

Procedure for Opening a Sealed Water Well

This procedure applies only to groundwater monitoring wells equipped with a sealed wellhead that may be pressurized.

1. Prior to Opening the Wellhead Valves

Eliminate Ignition Sources

- Ensure all sources of ignition within 25 meters of the monitoring well are turned off or removed.

Activate Gas Monitor

- Turn on and verify the functionality of 4-gas monitors to detect potential hazards.

Position Personnel and Equipment Safely

- Confirm all field workers and equipment are positioned upwind or cross-wind, ensuring they remain at a safe distance from the venting area.

2. Wellhead Pressure Safety Check

Verify Isolation of Wellhead

- Verify the wellhead configuration upon arrival. If an isolation valve is found open, confirm with the client (or site representative) and the Team Lead that this is the intended wellhead configuration before proceeding. Do not change the valve configuration until confirmation has been obtained.
- Ensure all isolation valves are closed, except for the master valve or any valve where instrument cables are run through.
- Install a portable pressure gauge assembly (rated for 2,000 psig or higher, with adequate accuracy and resolution in the 0–20 psig range). If the well is equipped with a functional, permanently installed pressure gauge, verify that it is working before proceeding.
- Open the isolation valve required to measure the wellhead pressure.
- Observe the pressure gauge for a reading and allow it to stabilize:
    - If pressure is 140 kPaG (20 psig) or less: Record the reading, close the isolation valve, remove the pressure gauge, and proceed with the controlled venting procedure in the Opening the Wellhead section.
    - If pressure exceeds 140 kPaG (20 psig): Close the isolation valve immediately. Move to a safe upwind location and contact the Team Lead immediately.

IMPORTANT: The well MUST NOT be opened if the pressure gauge displays a value greater than 140 kPaG (20 psig).

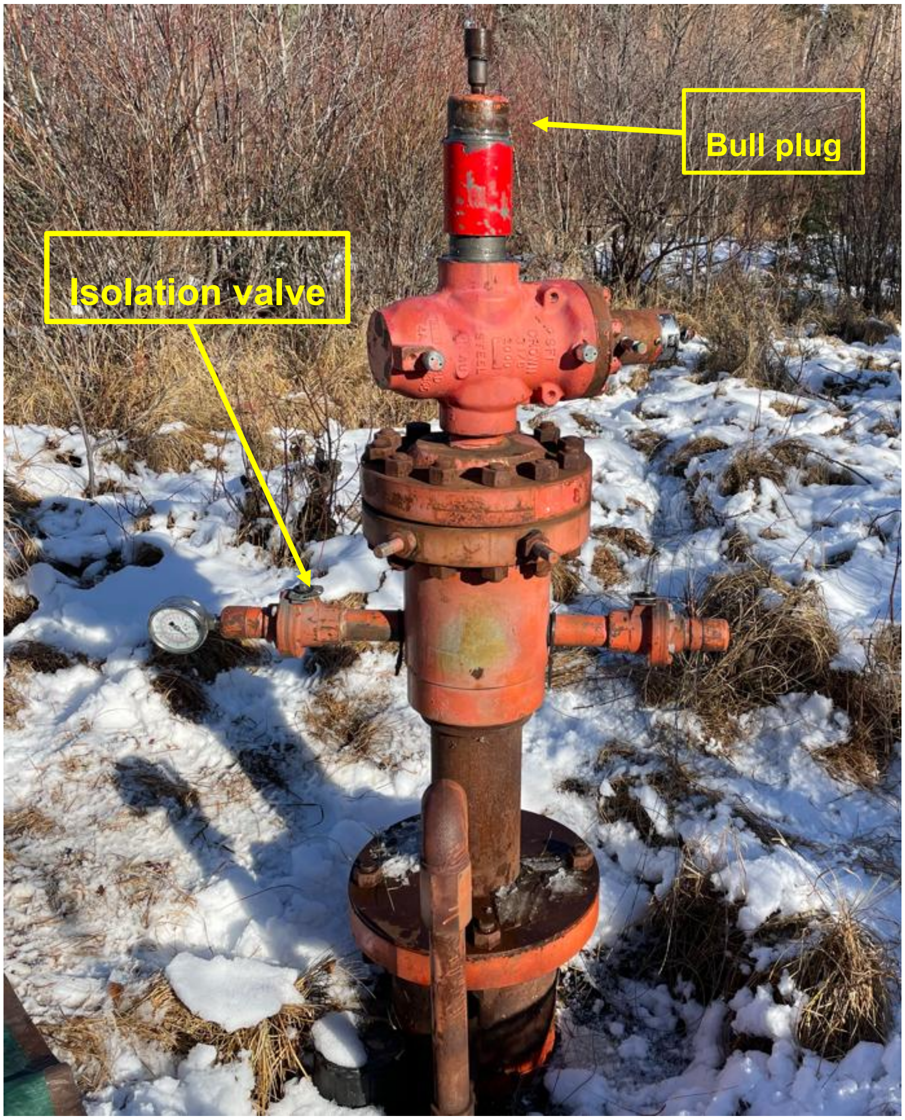

Image 1. A sealed wellhead showing the isolation valve and bull plug.

3. Opening the Wellhead

- Close the isolation valve (if not already closed).
- Safely remove the pressure gauge.
- Prepare for venting by installing a 1-inch diameter, 2-meter-long pipe. If needed, add a 90-degree connection to make sure the direction of venting is downwind.
- Gradually open the isolation valve to allow the well to equilibrate to atmospheric pressure.

> **IMPORTANT: Technologists must avoid working downwind of the direction of the venting line. The isolation valve should be opened in a safe and controlled manner to confirm valve operation and allow only a small amount of gas to be released.**

- **If the 4-gas monitor alarms during venting, immediately close the isolation valve (if safe to do so), move personnel to a safe location upwind or cross-wind, and notify the Team Lead before proceeding.**
- Once venting has occurred and no hazardous conditions are indicated by the 4-gas monitor, continue opening the isolation valve until fully open.
- Remove the bull plug after the well has equilibrated to atmospheric pressure. Use an appropriately sized pipe wrench (up to 36-inch) to remove the bull plug, applying counter-torque on the adjacent fitting or valve body directly below the plug to protect wellhead integrity. Do not use handle extensions or snipes. If the fitting remains seized after applying normal manual force, do not force the tool; contact the Team Lead to arrange for scheduled wellhead maintenance.

4. Closing the Wellhead

- Clean the threads of all removed fittings and apply Nikal anti-seize thread lubricant in accordance with the manufacturer's instructions prior to reinstallation.
- Reinstall all removed fittings (including the bull plug).
- Use an appropriately sized pipe wrench (up to 36-inch) to tighten all fittings with sufficient torque. Do not use handle extensions or snipes.
- Return all isolation valves to their required original operating position and verify that the wellhead has been restored to its original configuration. If the required valve configuration is uncertain, consult the Team Lead before leaving the site.

Definitions

Term	Description
Aquifer	A saturated geologic unit that stores and transmits usable quantities of groundwater.
Borehole	A borehole is an open or uncased subsurface hole, circular in plan view, into which casing, screens, or other components may be installed to construct a well. It is typically drilled, augered, or bored into the earth. The term 'borehole' may also refer to the inside diameter of the wellbore wall or the rock face that bounds the drilled hole.
Bubble Point	The bubble point is the pressure at which the first gas bubble forms in a liquid as pressure is reduced at a constant temperature. In groundwater, it defines the pressure at which dissolved gases (e.g., methane and carbon dioxide) begin to exsolve from solution, which may affect sample collection and groundwater chemistry. **Factors Influencing the Bubble Point:** • **Temperature**: Higher temperatures generally reduce the pressure required to reach the bubble point. • **Composition**: The type and concentration of dissolved gases and dissolved solutes influence the bubble point.
Casing Pipe	An impervious durable cylindrical device, flush-coupled or flush-joint, that is installed to maintain the physical integrity of the well opening and to provide a seal to prevent drainage or undesirable water, gas, or other fluids entering the well. Casing strings are manufactured to withstand a variety of forces such as borehole collapse. Most steel and plastic casing joints are fabricated with male threads on each end, and casing couplings with female threads are used to join the individual joints of casing together, or joints of casing may be fabricated with male threads on one end and female threads on the other end. There are several types of casing pipe: surface casing, well casing, and intermediate casing. Casing pipes are often targeted to be

	installed down to the first encountered competent geologic formation layer.
DTW	Distance from the established reference point, MP (generally top of well casing), to the top of the groundwater surface within the well.
Duplicate Sample	A field duplicate is a quality control sample collected in the field during environmental monitoring or sampling. It is essentially a second sample taken from the same location, at the same time, and under the same conditions as the primary sample. The purpose of collecting a field duplicate is to evaluate the precision and reproducibility of the sampling process, including the collection, handling, and analysis methods. Field duplicates are particularly useful for identifying variability in: Sampling techniques: Differences in how the samples are collected. Environmental conditions: Natural variations at the sampling site. Laboratory analysis: Variations in how the samples are analyzed. The results of field duplicates are compared to the primary sample results, and any significant differences might indicate inconsistencies or areas for improvement in the sampling or analytical processes.
EC	Electrical conductivity is a measure of a solution's ability to conduct electricity. It is influenced by the concentration of dissolved ions (such as salts, minerals, or other charged particles) in the solution.
Formation	A general term for the rock or sediment around the borehole. In the context of formation evaluation during well inspection, the term refers to the volume of rock that influences the measurements made in the borehole, as in a log or a well test.
Groundwater	Water occurring beneath the ground surface within the saturated zone.
Groundwater Monitoring Well	A well constructed or designated primarily for monitoring groundwater levels, groundwater quality, or both.

IHR	The intentional use of pumping-induced drawdown to create a hydraulic head difference that induces groundwater flow from the aquifer into the well.
Incrustation	The accumulation of mineral, chemical, biological, or physical deposits on the well screen, casing, or other well components that reduces hydraulic performance and well yield.
MP	A permanent, clearly identified reference point on the well casing or wellhead from which water levels and other depth measurements are made. For slanted well casings, the measuring point should be established at the highest point of the casing.
NPSH	The pressure condition at the pump inlet required to prevent the pumped liquid from vaporizing. Adequate Net Positive Suction Head Available (**$NPSH_A$**) must exceed Net Positive Suction Head Required (**$NPSH_R$**) to prevent cavitation.
Openhole	An uncased and unscreened interval of a borehole that is open directly to the surrounding formation.
Open Interval	The portion of a well or borehole that is hydraulically open to the surrounding formation, either through a well screen or as an uncased (openhole) interval.
pH	A logarithmic measure of hydrogen-ion activity that indicates the acidity or alkalinity of an aqueous solution.
PWL	Pumping water level is the distance measured from the established reference point, MP, to the water-level in the well, while the pump is operating at a specified discharge rate.
Representative Sample	A sample that adequately reflects the physical and chemical characteristics of groundwater entering the well from the monitored interval at the time of sampling.

Reproducibility	The closeness of agreement among results obtained under changed measurement conditions, such as different analysts, laboratories, instruments, or times.
Residual Drawdown	The difference between the recovering water level and the pre-pumping static water level after pumping has stopped.
Salinity	Salinity refers to the concentration of dissolved salts in a body of water.
SC	Specific conductance measures the electrical conductance of a solution at a standard temperature (25°C) to account for the temperature-dependent nature of conductivity.
Screen	A type of open interval with a cylindrical filtering device made of steel or plastic that allows water to enter a well from the surrounding geologic formations. The screen prevents or reduces the likelihood of sediment entering the well. Design and selection of well screens is based on geologic and hydraulic criteria.
SWL	Static water level is the distance measured from the established measuring point to the water surface in a well neither being pumped nor under the influence of pumping nor flowing under artesian pressure.
TDS	Total Dissolved Solids refers to the combined amount of organic and inorganic substances dissolved in water. These substances include minerals, salts, metals, cations, and anions.
Telescoping	The installation method in which a smaller casing or well screen is lowered through and installed inside a larger-diameter casing.
Trip Blank	A laboratory-prepared, analyte-free sample that accompanies sampling containers during transport and storage and remains unopened. It is used primarily to assess potential contamination of samples intended for volatile-organic analysis.

Water Well	A constructed well that comprises a wellhead and wellbore and is designed to access groundwater within an aquifer or other water-bearing formation.
Well Cap or Cover (End Cap)	A removable apparatus or device (often made of metal or PVC) to cover a wellhead or well casing which fastens tightly and may be lockable. The well cap is used to deter tampering and contamination of the well.
Well Casing	Pipe installed within a borehole to maintain borehole stability, isolate selected subsurface intervals, and provide access to the groundwater monitoring interval.
Wellhead	The above-ground assembly at the top of a well, including the well casing, valves, fittings, and other components used to access, monitor, or control the well.
Well Site	The physical location where one or more monitoring wells are installed and completed.
Well Plaque	A durable identification plaque permanently affixed to the outside of the visible well casing or to a permanent structure associated with the wellhead for well identification. The GOWN well plaque shall remain clearly visible and shall not be obscured by the well cap or any other well components or equipment.