Sampling Method/Media: **Low-Flow Sampling/Groundwater**	Title: **Standard Operating Procedure for Low-Flow Groundwater Sampling**
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1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instruction for the collection of groundwater samples using the low flow (minimal drawdown) sampling technique. This procedure is suitable for the collection of all sample parameters. Low flow sampling is a preferred method for sampling in both high and low-yield wells; however, if the yield is too low or the water level too low to support pumping, then another conventional sampling method may be required.

This SOP forms part of the British Columbia Field Sampling Manual (BCFSM). Additional information on low flow sampling is provided in Part E2 – Groundwater, which must be used in conjunction with the information provided in this SOP. Further guidance regarding groundwater is provided in the Water Sustainability Act (WSA) and the Groundwater Protection Regulation (GPR) which are available at:

https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/laws-rules/groundwater-protection-regulation.

The Environmental Management Act (EMA), the Contaminated Sites Regulation (CSR) and associated guidance documents provide information specific to groundwater monitoring wells installed to investigate and remediate contaminated sites; these documents are available at:

https://www2.gov.bc.ca/gov/content/environment/air-land-water/site-remediation/contaminated-sites.

Groundwater sampling and monitoring conducted for regulatory purposes within the provincial jurisdiction of BC must be carried out with consideration to the WSA, the GPR, the EMA, and the CSR, all as applicable, Part E2 of the BC Field Sampling Manual, and this document.

2. Document Control

This Standard Operating Procedure (SOP) is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

3. Principle of the Sampling Method

Low-flow sampling is designed to minimize the volume of purge water produced and the amount of disturbance to the water column. This method also maximizes the contribution of formation water from the screened interval.

4. Quality Control

- Ensure that all instruments are decontaminated, functioning and properly calibrated before starting and that all required information is recorded in the field.
- Choose the most appropriate pump based on well characteristics:
  - Peristaltic pump: maximum depth approximately 7 m (23’)
  - Submersible pump (bladder/double valve): maximum depth approximately 150 m (492’).

- Use only clean tubing and dedicated pump equipment.
- Use only clean fittings and connecting tubing.
- Peristaltic pumps are not considered suitable for sampling volatile chemicals, because they draw water under a vacuum which may result in sample degassing (i.e. negative bias), especially when there is significant head (>3 m) between the pump and water.
- Purged water may contain regulated contaminants. Collection, treatment and disposal requirements must be understood and addressed in the sampling/monitoring plan. If on-site disposal is deemed appropriate dispose purged liquid well away from the sampling location.
- Follow proper field and laboratory quality assurance (QA) (i.e., duplicate sample) procedures.

5. Recommended Equipment and Materials

Field equipment should include the following:

- Peristaltic or submersible pump,
- Flow through cell,
- Instrumentation to measure pH, conductivity, temperature, dissolved oxygen, redox potential, and turbidity,
- Water level probe,
- Borehole logs/well construction table,
- In-line filters where specified by the sample handling SOP (e.g. for dissolved metals),
- Laboratory-supplied sample collection bottles, labels and spare labels,
- Coolers,
- Cleaning solutions and spray bottles,
- Decontamination equipment,
- Indelible felt pen (volatile organic compounds [VOC] -free),
- Waste container(s) (drums or totes for on-site temporary storage, plastic buckets with lids to transport wastewater from the wells to drums or totes),
- Field book/field forms,
- General tools,
- Repair tools; and,
- Site map.

Pump Specific Requirements:

- Peristaltic Pump:
  - Flexible low or high density polyethylene (LDPE/HDPE) tubing, one per sample location
  - Two polyethylene fittings of compatible diameter for each end of the tube (or friction fit into ends of LDPE/HDPE tubing) for peristaltic pump
  - Required length of LDPE/DPE tubing for sample collection (suction)
  - LDPE/HDPE discharge tubing for each sample location
  - portable 12V deep cycle battery and charger
- Submersible Pump:
  - Flexible LDPE/HDPE tubing, one per sample location
  - Generator (with required power for given pump)
  - Control unit and applicable invertors
  - Spare battery/power source
  - Stop watch and volume gauge

6. Sampling Considerations

- Flexible PVC can cause phthalate ester contamination. Silicone rubber tubing can alleviate the problem,

but both types of tubing can cause sample bias due to sorption and desorption reactions; the use of short silicone tubing lengths can remedy the issue.

- Flow through cells can heat up significantly in the sun; if possible, use a waterproof parameter sonde and keep the cell submerged in your purge water bucket.

7. Purging Procedures

1) *Confirm the sampling location* on a site plan and record in the field notes. Misidentification of sampling locations is the primary source of error in groundwater sampling programs.
2) *Lay out* a sheet of polyethylene (such as a large garbage bag) beside the well for placement of monitoring and sampling equipment or set up a clean utility table.
3) *Measure organic vapours and depth to water and/or light non-aqueous phase liquid (LNAPL).* Do not measure the depth to bottom, as this will disturb any sediment that has accumulated in the well.

Purging using a Peristaltic Pump

1. *Cut tubing to the appropriate length*: refer to the borehole logs and water level depth to determine the length of 1/4" or 3/8" I.D. suction tubing required. If the well is installed to monitor hydrocarbon plumes and the water table is within the well screen, the tubing intake should be a maximum of 0.6 m below the water table. To minimize turbidity, the tubing intake should be 0.6 m above the base of the well. For other types of plumes or when the water level is above the screen, the depth of the tubing intake for sampling should be the mid-point of the saturated screen interval or at the zone of interest. The sample intake depth should remain consistent between each sampling event at each specific well. If the saturated thickness in the well is less than 0.6 m, ensure that the tubing is at least 0.3 m above well bottom to minimize turbidity in the sample.

   Determine the length of discharge tube required and cut a piece to the appropriate length. To ensure that the small diameter suction tubing hangs straight down into the well without coiling, the tubing should be "pulled straight" at ground surface. A polyethylene fitting on the suction end can be used to weight the suction tubing.
2. *Assemble the pump and tubing connections.* Connect the suction and discharge tubes to a 30 cm length of clear peristaltic pump tubing using the polyethylene fittings. Note that excess tubing can affect the temperature of the water sampled, which could affect sample chemistry. Load pump tubing into the adjustable jaws of the pump and close the jaws until snug. Turn the hand crank to ensure the mechanism is engaged. Attach the discharge tubing to the flow through cell and prepare the field monitoring instruments (pH, conductivity, temperature, dissolved oxygen, redox potential, and turbidity meters) according to the site's sampling plan and appropriate sampling procedures.
3. *Carefully place the end of the suction tube* (i.e., to minimize disturbance to the water column) down the monitoring well to the desired sampling depth. The end of the suction tube should be located within the screen. Turn the crank to start the flow of liquid up the tube. If flow does not rise in the tube, increase the tension on the pump jaws and check that the connections are tight at the fittings.
4. *Start the pump at a flow rate of 100 to 500 mL/min.* The water level should be monitored approximately every minute until stable. A steady state flow rate should be maintained with minimal drawdown. If required, decrease the flow rate to enable the drawdown to stabilize. Try to maintain a drawdown of < 0.1 m, if possible, and do not exceed more than 0.3 m of drawdown. If greater drawdown is recorded, purge and sample using a conventional method. Care should be taken to maintain pump suction and to avoid entrainment of air in the tubing.
5. *Monitor indicator parameters in the flow through cell during purging.* Monitor and record the water quality field indicator parameters every time the flow cell is completely cleared (i.e., the flow rate is 250 ml/min, the flow cell volume is 500 ml, the parameters can be recorded every two minutes). The well is considered stabilized and ready for sample collection when the water quality field indicator parameters have stabilized for three consecutive readings as follows:

Parameter	Stabilization Criterion
Temperature	+/- 0.2°C *
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	± 10%
Redox Potential (ORP or eH)	+/- 10 mV*

* these values represent the unit's accuracy; replace values with your unit's accuracy ratings.

6. When the parameter values have stabilized for three consecutive readings, disconnect the flow through cell from the discharge tubing. Sampling flow rates of approximately 500 ml/min are acceptable for non-volatile samples; reduced rates of <250 ml/min are required for volatiles. Note that sampling for volatile analysis at depths of greater than 3 m using a peristaltic pump is not considered suitable due to degassing. If the sample is to be analyzed for volatiles, collect the sample using a T-connector and valve before the tubing enters the peristaltic pump. If required, reduce flow rate and collect samples for volatiles first. Fill all required sample containers by allowing the pumps discharge to flow gently down the inside of the each sample container with minimal turbulence. Following volatile sampling, do not increase the flow rate because this may disturb the steady state flow conditions.
7. *If filtering is required for the desired analytical parameter (e.g., dissolved metals),* without stopping the pump, connect the inline filter to the discharge side of the pump. Condition the filter by purging at least 250 mL of sample water through the filter prior to sample collection. Collect filtered samples last.
8. *Field data specific to peristaltic pump purging and sampling that should be recorded includes*: suction tube inlet placement depth (i.e., relative to well screen position and static water level), initial static water level, initial pumping rate, drawdown measurements, stabilized pumping water level, final pumping rate, water quality indicator and turbidity measurements, times for all measurements, and sampling flow rate. Record measurements in field book or on a low flow sampling field form.

Purging using a Submersible Pump

1. *Determine pump intake depth*. If the well is installed to monitor hydrocarbon plumes and the water table is within the well screen, the pump intake should be a maximum of 0.6 m below the water table. To minimize turbidity, the tubing intake should be 0.6 m above the base of the well. For other types of plumes, the depth of the pump intake for sampling should be the mid-point of the saturated screen interval or at the zone of interest. The sample intake depth should remain consistent between each sampling event at each specific well. If the saturated thickness in the well is less than 0.6 m, ensure that the tubing is at least 0.3 m above well bottom to minimize turbidity in the sample. If there is insufficient water (<0.5 m), then using a bailer or a no purge sampler may be required.
2. *Clean the pump* using an appropriate cleaning solution.
3. *Attach sample tubing and check valve (if required) to submersible pump*. The check valve ensures no back flow of the groundwater when the pump is shut off.
4. *Slowly lower the pump and sample tubing to the required depth*. A water level probe lowered on top of the pump is useful to ensure the intake is set at the correct depth. Once at depth, secure the pump at the surface.
5. *Connect the pump to the controller and the controller to a power source or an air compressor (e.g., for bladder pumps and double valve pumps)*.
6. *Cut the sample tubing to a suitable length above the top of casing.* Ensure the length is sufficient for storage in and retrieval from the well.
7. *Connect the sample tubing to the flow-through cell and attach the field parameter meter* (e.g., temperature, conductivity, etc.) into the flow-through cell.
8. *Ensure that the controller is off and start the generator or air compressor.*
9. *Reduce the flow rate on the controller and set the input source into the correct AC/DC setting based on power*

source. Turn the control unit on in the forward setting (for pumps with both forward and backward settings).

10. *Start the pump at a flow rate of 100 to 500 mL/min.* The water level should be monitored approximately every minute until stable. A steady state flow rate should be maintained with minimal drawdown. Try to maintain a drawdown of < 0.1 m, if possible, and do not exceed more than 0.3 m of drawdown. If greater drawdown is recorded, purge and sample using a conventional sampling method. If required, decrease the flow rate to enable drawdown to stabilize. The flow rate can be increased (up to 1 L/min) if drawdown is minimal and the screened formation is very coarse. Care should be taken to maintain pump suction and to avoid entrainment of air in the tubing.

9. *Monitor indicator parameters in the flow through cell during purging.* Monitor and record the water quality field indicator parameters every time the flow cell is completely cleared (i.e., the flow rate is 250 ml/min, the flow cell volume is 500 ml, the parameters can be recorded every two minutes). The well is considered stabilized and ready for sample collection when the water quality field indicator parameters have stabilized for three consecutive readings as listed in the following table.

Parameter	Stabilization Criterion
Temperature	+/- 0.2°C *
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	± 10%
Redox Potential (ORP or eH)	+/- 10 mV*

10. Once the readings have stabilized for three consecutive readings, disconnect the flow through cell from the sample tubing.

11. Flow rates of approximately 500 ml/min are acceptable for non-volatile samples; reduced rates of <250 ml/min are required for volatiles. If required, reduce flow rate and collect samples for volatiles first. Fill all required sample containers by allowing the pump discharge to flow gently down the inside of the sample container with minimal turbulence. Following volatile sampling do not increase the flow rate or you may cause steady state flow to end.

12. *If filtering is required for the desired analytical parameter (e.g., dissolved metals),* without stopping the pump, connect the inline filter to the discharge side of the pump, between the pump tubing and the discharge tubing. Condition the filter by purging at least 500 mL of sample water through the filter prior to sample collection. Collect filtered samples last.

13. *Field data specific to submersible pump purging and sampling that should be recorded include*: Pump intake placement (i.e., relative to well screen position and static water level), initial static water level, initial pumping rate, drawdown measurements, stabilized pumping water level, final pumping rate, water quality indicators and turbidity (if required), times for all measurements, and sampling flow rate.

8. Sample Collection Procedures

1) Confirm sample handling techniques, minimum sample volume requirements, preservation requirements and maximum hold time specifications for each parameter with the laboratory. These may vary slightly between laboratories. The Ministry of Environment & Climate Change Strategy (ENV) maintains a table that lists required sample containers, storage temperatures, preservation requirements and hold times on their website at:

   https://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/monitoring/emre/summary-of-sample-preservation-and-hold-time-requirements.pdf.

2) Obtain the appropriate numbers and types of sample containers from the laboratory. Only use clean, new

containers that have been provided by the laboratory that will be performing the analyses. It is recommended that extra sample containers and supplies be available in the field to accommodate any change of scope or sampling error requiring the collection of additional samples.

3) Confirm sampling priority and order. A typical sampling order by parameter is:
   - Volatile organics,
   - Samples requiring field filtering (e.g. dissolved metals),
   - Semi-volatile organics,
   - Non-volatile organics,
   - Total metals,
   - Nutrients; and,
   - Other general chemistry parameters.

The following instructions provide current sampling techniques for the parameters listed above:

Volatile Organics:

1. This sampling procedure is appropriate for VOCs, including benzene, toluene, ethylbenzene, and xylenes (BTEX), chlorinated solvents and trihalomethanes (THMs), and petroleum hydrocarbons (PHC) F1.
2. Samples are typically collected in at least two 40 mL to 60 mL purge and trap vials. Some laboratories require three vials and/or additional sampling containers.
3. Depending on the laboratory, the vials may be charged with a preservative. Potential preservatives include copper sulphate or sodium bisulphate crystals or liquid, or hydrochloric acid to minimize biological degradation of organics. Sodium thiosulphate may be used to minimize the formation of chlorinated organic compounds by free chlorine, which may be a concern when sampling treated drinking water.
4. Due to the volatility of these compounds, the more the sample is agitated or exposed to the air during the transfer of sample from the source to the vial, the greater the volatilization will be resulting in a low biased concentration in the sample. Up to 80% of volatiles can be lost during sample collection.
5. Ensure that the vials are filled slowly to the rim of the container to eliminate all air and minimize loss of preservative. A dome or convex meniscus should be present when full. A slight loss of sample may occur when the cap is applied.
6. When capped, the Teflon® liner or septum should be in contact with the sample. Assess air trapped in the vial by turning the vial upside down to examine for air bubbles. If an air bubble covers the bottom of the vial (> approximately 2 mL of air volume), the sample may be compromised and another should be collected using a fresh container.
7. Inspect the sample for a non-aqueous layer; if a layer exists, it may not be suitable for analysis.

Extractable (Semi- and Non-Volatile) Organics:

1. This sampling procedure is appropriate for PHCs F2 to F4, extractable petroleum hydrocarbons (EPH), mineral oil and grease, polycyclic aromatic hydrocarbons (PAHs), and semi-volatile organics, such as Base Neutral Acid (BNA) Extractables, polychlorinated biphenyls (PCB), pesticides, and herbicides herein referred to Extractable Organics.
2. Samples are typically collected in amber glass containers.
3. For some extractable organics, a chemical preservative is not required; however, others may be preserved with sodium bisulphate, sulphuric acid, or hydrochloric acid to reduce the pH of the sample to less than 2.
4. If the sample is turbid, ensure that it is marked on the chain-of-custody and/or determine whether the sample should be submitted.
5. Extractable organics are relatively stable; therefore, containers do not need to be filled to the top. Fill to approximately 50 mL short of capacity to allow laboratories to complete sample extraction in the container.
6. Samples collected under reducing conditions may form red flocs of iron precipitate during sample

collection due to exposure with atmospheric oxygen; these do not create a sampling bias.

Dissolved Metals:

1. This sampling procedure is appropriate for dissolved metals, including mercury, hexavalent chromium, hydride-forming metals, and dissolved organic carbon (DOC).
2. Samples are typically collected in HDPE, Teflon®, or glass containers and multiple sample containers may be required. Field filtering is required for a full metals suite but should be confirmed for speciated metals as there are some exceptions.
3. Samples for dissolved metals must be field filtered using an in-line 0.45 micron filter immediately following collection and prior to adding preservative or filling pre-charged containers. Water samples are generally preserved with hydrochloric acid or bromine chloride for mercury, a buffer solution such as sodium hydroxide for hexavalent chromium and nitric acid for all other metals or a full metals suite. Check with the laboratory to ensure that the proper preservative is utilized.
4. Various methods are available for field filtering. Dedicated, individually wrapped disposable field filters should be used. If water is highly turbid, multiple filters may be required per well. Samplers should monitor for break-through conditions and replace filters as needed. The most common method to filter is to connect the inline filter to the discharge hosing of the peristaltic pump or submersible pump. Samplers should be aware that filters may contain trace concentrations of metals that can add to the metals in the sample; this is especially important for low-level analysis when sampling 'clean' water sources and for collecting long term trend data where low concentrations of metals are of interest. An equipment (filter) blank should be submitted with regular samples if this is a concern. Condition the filter by allowing a portion of the sample water to flow through the filter prior to obtaining samples.
5. Do not fill the sample container to the top; fill to the base of the container's neck leaving room to add preservative.
6. Preserve the sample immediately after filtration to reduce the sample pH to less than 2.
7. If reducing conditions are present, the oxidation of certain dissolved metals can be rapid causing the precipitation of metal oxides or hydroxides. As such, samples for dissolved metals must be field filtered and preserved as quickly as possible.
8. If a precipitate appears upon acidification, the laboratory may need to digest the sample and analyse for total metals. If precipitate is noted ensure it is included on the chain-of-custody and confirm whether it should be analysed for dissolved parameters or held for a latter determination.

Total Metals:

1. This sampling procedure is appropriate for total metals. Field filtering is generally not conducted however there are a few exceptions such as sampling for total mercury which may require field filtering and as such should be confirmed with the laboratory.
2. Samples are typically collected in HDPE, PTFE, Teflon®, or glass containers and multiple sample containers may be required.
3. Unless otherwise directed by the testing laboratory, samples for total metals are not field filtered. Water is transferred into the sample container and generally preserved with hydrochloric acid or bromine chloride for mercury, a buffer solution (sodium hydroxide) for hexavalent chromium, and nitric acid for all other metals and or a full metals suite. Check with the laboratory to confirm whether the containers have been pre-charged with a preservative or if preservative must be added following collection.
4. Do not fill the sample container to the top; fill to the base of the container's neck leaving room to add preservative.
5. If required preserve the sample immediately after collection to reduce the sample pH to less than 2.

Nutrients and General Chemistry Parameters:

1. This sampling procedure is appropriate for non-volatile and non-metallic water quality parameters, such as anions, alkalinity, chloride, hardness, nitrate and nitrite, sulphate, etc.
2. The number and type of sample containers, preservative requirements and hold times for each parameter should be confirmed with the laboratory prior to sample collection. A separate sample container may be required for each analytical parameter.

Sample Submission and Site Cleanup

1. Complete the sample submission and chain-of-custody form. Be sure to specify to the laboratory the analytical detection limit desired. For some parameters low level analyses at an extra cost may be required to achieve the detection limits required for comparison of results to provincial or federal water quality criteria or for continuing long term trend data. Place the forms in a sealable bag.
2. Transportation must be arranged to ensure the laboratory receives the samples within the shortest hold time of the samples submitted.
3. Place the samples in a cooler chilled with ice (double-bagged) for transport to the laboratory. It is important that cooling begins as soon as possible following sampling, particularly for organic analyses. Samples should be cooled and maintained at a temperature below 10°C throughout storage and delivery.
4. Secure the sample submission forms to the underside of the cooler's lid. Seal the cooler and attach the shipping label if being transported via courier.
5. Dispose of all wastes (liquids, used gloves, and materials) in an appropriate manner. Note that tubing can be retained/stored within a well for later sampling of the same well. **Leave site in a tidy condition.**

9. References

1. ASTM D6517-00e1, 2012. Standard Guide for Field Preservation of Groundwater Samples, ASTM International, West Conshohocken, PA.
2. *ASTM D6634 / D6634M-14, 2014. Standard Guide for the Selection of Purging and Sampling Devices for Groundwater Monitoring Wells, ASTM International, West Conshohocken, PA, 2014.*
3. ASTM D6771-02, Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations (Withdrawn 2011), ASTM International, West Conshohocken, PA, 2002.
4. Lane, S.L., Flanagan, Sarah, and Wilde, F.D., 2003, *Selection of equipment for water sampling (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations*, book 9, chap. A2, March, accessed July 2011 at http://pubs.water.usgs.gov/twri9A2/
5. Nielsen, D.M. (ed). 2006. Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring. 2nd Edition. CRC Press, Taylor & Francis Group, 1,318 pp.
6. U.S. Geological Survey, 2006, *Collection of water samples (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations*, book 9, chap. A4, September, accessed July 2011 at http://pubs.water.usgs.gov/twri9A4/
7. Puuls, R.W., and M.J. Barcelona, 1996. *Low-Flow (Minimal Drawdown) Groundwater Sampling Procedures*, EPA/5340/S-95/504, dated April 1996.

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Approval