


Groundwater Sampling Guidance

**Montana Department of
Environmental Quality**

Contaminated Site Cleanup Bureau

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GROUNDWATER SAMPLING GUIDANCE				

Purpose:	The purpose of this document is to provide consistent guidance to individuals or entities that complete groundwater monitoring as part of corrective action overseen by the Contaminated Site Cleanup Bureau.
Scope:	This guidance applies to all groundwater actions taken for Contaminated Site Cleanup Bureau regulated projects.

Revision Date	Revision Description

Executive Summary

The Montana Department of Environmental Quality prepared this guidance to assist responsible parties, environmental professionals, and DEQ technical staff in performing appropriate groundwater sampling activities, including low flow sampling. DEQ uses analytical data in its decision-making processes. The purpose of this document is to ensure consistent collection of groundwater samples that accurately represent site conditions.

Low-flow sampling is the Contaminated Site Cleanup Bureau's preferred sampling methodology for groundwater. However, situations exist where low-flow sampling is either not possible or impractical. This guidance identifies those situations. As with any cleanup decision, DEQ recommends that the responsible party or its representative communicate regularly and openly with the DEQ-assigned project manager.

This guidance document is organized into the following sections:

Section 1.0 Preparing for Sampling Events: This section gives an overview of how to prepare for a sampling event, including required background information, equipment lists, and Sampling and Analysis Plan/Health and Safety Plan preparation.

Section 2.0 Standard Sampling Procedures: This section describes standard sampling procedures that apply to all sampling events, regardless of pump type/purge method.

Section 3.0 Low-Flow Sampling: This section describes additional sampling procedures specific to low-flow methods. This is DEQ's preferred sampling method.

Section 4.0 Multiple Volume Purge Sampling: This section briefly describes the method and its advantages and disadvantages.

Section 5.0 No-Purge Sampling: This section briefly describes the method and its advantages and disadvantages.

Section 6.0 Passive Sampling: This section briefly describes the method and its advantages and disadvantages.

Section 7.0 Special Considerations: This section discusses specific sampling situations that may affect sample collection, including sampling groundwater when free product (LNAPL or DNAPL) is present in a well.

Section 8.0 References: This section contains references cited in this document.

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Acronyms

CSCB	Contaminated Site Cleanup Bureau
DEQ	Department of Environmental Quality
DNAPL	Dense non-aqueous phase liquid
DO	Dissolved Oxygen
DPT	Direct Push Technology
USEPA	U.S. Environmental Protection Agency
FAQ	Frequently asked questions
FID	Flame ionization detector
HASP	Health and Safety Plan
LNAPL	Light non-aqueous phase liquid
NTU	Nephelometric turbidity units
ORP	Oxidation-reduction potential (redox potential)
PCB	Polychlorinated biphenyl
PID	Photoionization detector
PVC	Polyvinyl chloride
SAP	Sampling and Analysis Plan
SI	Site investigation
SVOC	Semi-volatile organic compounds
VOC	Volatile organic compounds

Guidance Overview and Purpose

The Montana Department of Environmental Quality (DEQ) Contaminated Site Cleanup Bureau (CSCB) prepared this guidance to assist responsible parties, environmental professionals, and DEQ staff with the collection of defensible and reliable groundwater samples through the use of low-flow and other accepted groundwater monitoring techniques at DEQ CSCB regulated facilities. Data acquired from groundwater monitoring provides key information used in decision making processes. Therefore, sampling should be designed and implemented to maximize the representativeness of site conditions by using proven, accurate, and reproducible methods (Puls and Barcelona, 1996).

Low-flow sampling is the preferred DEQ sampling method unless site-specific and contaminant-specific conditions require alternate protocols. If alternate protocols are necessary, a written technical justification for deviation from this guidance should be submitted to the appropriate DEQ technical contact for approval prior to the sampling event. If this guidance is not clear or does not answer a specific question, please consult the appropriate DEQ technical contact or visit DEQ CSCB's frequently asked questions (FAQ).

DEQ encourages the use of this guidance in the preparation of sampling plans submitted to DEQ. DEQ has developed this guidance using its scientific and technical expertise, and relevant Montana-specific information, as well as technical documents. DEQ encourages parties to contact DEQ with any questions about this document, or if the party believes that DEQ has incorrectly characterized a particular process or recommendation.

Environmental professionals can collect groundwater samples using several techniques. The four most commonly seen by DEQ for contaminated site cleanup are the following:

- Low-Flow Sampling;
- Multiple Volume Purge Sampling;
- No Purge Sampling; and
- Passive Sampling.

Each method has inherent advantages and disadvantages. Based on the advantages described in this document, low-flow sampling is DEQ's preferred method. Other methods may be approved based on site conditions.

1.0 PREPARING FOR SAMPLING EVENTS

Prior to any sampling event, research should be conducted to fully understand site characteristics, monitoring well construction, and equipment needed. The analytical requirements and sampling schedule should be clearly understood and communicated to all personnel involved including the analytical laboratory, project managers, consultants and property owners. This information should be generated in the preparation of a Sampling and Analysis Plan (refer to Section 1.2 for the information that should be included). A copy of the plan should be available while in the field.

1.1 SITE BACKGROUND

A thorough site background should be compiled prior to the sampling event. Implementing any sampling method requires knowledge of the well construction and lithology surrounding the well and that the well is in good condition. Review well installation information including well depth, length of screen, and depth to top of well screen. If needed, collect well depth data the day before sampling begins (see Section 2.4 for further detail on measuring total depth). Review which wells are to be sampled and check well conditions in the field. The monitoring well screen should be located properly to intercept existing contaminant plumes and this information should be studied prior to sampling in the field to ensure proper pump placement for sampling. If installation information is unavailable, or screen silting/biofouling or other well construction issues have been observed, sampling the well might not be acceptable. Work directly with your DEQ technical contact for direction.

Sampling should not be conducted immediately following well development; the time needed for an aquifer to equilibrate after well development will depend on site conditions and methods of installation, but generally exceeds one week.

Formation lithology, permeability, transmissivity and location of expected contamination within the aquifer should all be known prior to initiating sampling (this helps determine the placement of the pump in the well screen as discussed in Section 2.4).

1.2 SAMPLING AND ANALYSIS PLAN

A Sampling and Analysis Plan (SAP) needs to be prepared prior to the initiation of the sampling event. The SAP is intended to document the procedural and analytical requirements for sampling events performed to collect groundwater samples. A basic SAP should include the following elements:

- **Introduction/Background:** This section should include the site history and current status, location, hydrology and hydrogeology, previous environmental investigations, environmental and/or human impact, reporting, and schedule.
- **Project Data Quality Objectives:** This section should include the data uses, expected data quality, data quality indicators, accuracy, precision, completeness, representativeness, comparability, lab data QA/QC, and reporting limits (which should be lower than the applicable screening levels).

- **Sampling Design:** The sampling design should include the number and location of wells sampled, the order the wells will be sampled, sampling methodology, standard operating procedures (SOPs) for all meters and equipment used, including details on the calibration method and frequency, laboratory analysis, groundwater sampling equipment checklist, chain of custody control, decontamination procedures, sample documentation and shipping, field quality assurance/quality control (QA/QC) samples, and data validation procedures.

1.3 HEALTH AND SAFETY PLAN

A site-specific health and safety plan (HASP), should be prepared prior to field activities. Field safety procedures, including safety equipment and clothing, hazard identification, and the location and route to the nearest hospital, will be included in the HASP. The HASP should be kept on site and available at all times to the personnel performing the sampling activities. Please follow the HASP with regard to activities and equipment required to mitigate personnel contact with physical, chemical, or biological hazards.

1.4 EQUIPMENT AND SUPPLIES

Before every sampling event, a maintenance check of all instruments should be performed to ensure equipment is working properly before being used in the field. The following sections provide a list of equipment and supplies necessary for a low-flow sampling event.

1.4.1 Informational Materials

These include health and safety plans (HASP), sampling and analysis plans/quality assurance project plans (SAP/QAPP), monitoring well construction data, location maps, field data from previous events, user manuals for relevant equipment. For detailed descriptions of these items, please refer to Sections 1.1 – 1.3 above.

1.4.2 Pumping Device

Low-flow sampling is the preferred DEQ sampling method unless site-specific and/or contaminant-specific conditions require alternate protocols. An adjustable rate pump capable of achieving flow rates of 0.1 – 0.5 liters per minute (L/min) is typically necessary to conduct low-flow sampling; however, this is dependent on site specific hydrogeology (Puls and Barcelona, 1996; ASTM 2005, NJDEP, 2003). Some extremely coarse-textured formations have been successfully sampled at flow rates up to 1 L/min. Examples of appropriate pumps include bladder, submersible, gas driven, and in rare instances peristaltic (Puls and Barcelona, 1996). DEQ acceptance of the pump type should be obtained prior to the sampling event.

The following sections provide a review of the most commonly used sampling pumps, and list the advantages and disadvantages associated with these pumps, which should be considered when selecting a sampling device. Bailers are also included to demonstrate why they are not suitable for low-flow sampling. The information below is based on Section 7.4 of the USEPA Region 8 Standard Operating Procedures for Groundwater Sampling (USEPA, 2017b).

A. Bladder Pumps

Bladder pumps are DEQ's preferred method for low-flow sampling.

Advantages	Disadvantages
<ul style="list-style-type: none"> • Maintains sample integrity • Can sample from discrete locations within the well • Can sample down to depths greater than 200 feet below ground surface 	<ul style="list-style-type: none"> • Requires decontamination as non-disposable equipment is placed in the well • Requires air compressor or pressurized gas source and control box

B. Other Submersible Pumps

If a bladder pump cannot be used, other types of pumps such as gear-drive, helical-rotor, or submersible centrifugal may be used with DEQ approval or when specified in an approved SAP. Other submersible pumps have advantages and disadvantages similar to bladder pumps.

C. Peristaltic Suction Pumps

Suction pumps, such as peristaltic pumps, are typically inappropriate for collecting VOCs, semi-volatile organic compounds (SVOCs), volatile petroleum compounds and some (pH-dependent) metals because of the potential for degassing and associated potential pH changes (Parker, 1994). However, peristaltic pumps may be acceptable for VOC sampling if the sampling is being conducted in conditions where high levels of contamination are present, and where the results are not being used as closure samples.

Peristaltic pumps may be appropriate for the collection of inorganic compound samples. However, peristaltic pumps may affect the stabilization of some water quality indicator parameters including dissolved oxygen (DO), pH, and oxidation-reduction potential (ORP). Due to its effect on water quality parameters, a peristaltic pump should not be used when data will be used to evaluate monitored natural attenuation of groundwater (NJDEP, 2003).

There may be situations where a peristaltic pump is the best alternative for sampling, such as very shallow wells where the water column is not long enough to sustain a submersible pump. If peristaltic pumps are used during the collection of VOCs, DEQ approval should be obtained and caution should be taken: ensure tubing is not pinched resulting in pressure changes that can cause volatilization; ensure tubing is completely filled with water prior to sampling; avoid sunlight on the exposed tube which could result in temperature changes leading to volatilization (USEPA, 2017a). These additional measures required to ensure appropriate data quality is attained may be difficult to demonstrate, making peristaltic pumps a less agreeable option.

Advantages	Disadvantages
<ul style="list-style-type: none"> • Portable • Inexpensive • Readily available 	<ul style="list-style-type: none"> • Limited to depths of approximately 20 to 25 feet below ground surface • Vacuum can cause loss of dissolved gasses and volatile organics

	<ul style="list-style-type: none"> • Tubing has the potential to absorb contaminants (see Section 1.4.3 for more detail)
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D. Bailers

Bailers should never be used for low-flow sampling because they generate turbulence in the well (ASTM, 2005; Puls & Barcelona, 1996). It may be necessary to use a bailer if groundwater levels in the well are not conducive (minimal volume) to placing a low-flow pump. Bailing cords should be composed of either nylon or coated stainless steel. Use of bailers should be approved by DEQ prior to use in the field.

Advantages	Disadvantages
<ul style="list-style-type: none"> • No power source needed • Portable • Inexpensive and readily available • Rapid, simple method for removing small volumes of purge water • Decontamination not required if the bailers are disposable 	<ul style="list-style-type: none"> • Not applicable to all sampling methods (e.g., not appropriate for low-flow sampling) • Improper use can cause aeration of sample and cause suspension of sediments • Time and labor intensive to purge deep wells or large water volumes • Transfer of samples to containers may cause aeration • Requires decontamination if bailers are not disposable

E. Dedicated vs. Portable Pumps

Dedicated pumps are preferable to portable pumps. Portable pumps may create disturbance in the water column during installation, and also require decontamination between wells. If a portable pump is used, new or dedicated tubing should be used at each sampling location, and the pump should be lowered gently into the well to minimize disturbance to the water column.

While not required, dedicated equipment is ideal for monitoring wells undergoing frequent, routine sampling over extended periods of time. Dedicated equipment saves the sampler time by reducing the need for decontamination, reducing disturbances in the well casing interfering with parameter stabilization and sample collection, and reduces variability in sampling results.

1.4.3 Tubing and Bladders

Pump tubing and bladders should be appropriate for the sampled analytes. Certain types of plastic tubing and bladders can either sorb contaminants from sample water or contribute contaminants to sample water as it flows through the tubing or bladders (Parker and Ranney, 1997; Parker and Ranney, 1998). Factors to consider when selecting tubing and bladders may

include data quality objectives, the well diameter, the type of pump to be used, the depth to groundwater, and the potential residence time the sample may have within the tubing. DEQ-acceptance of the tubing type should be obtained prior to the sampling event.

- Teflon, Teflon-lined and steel tubing or bladders appear to have the least potential to bias samples collected for organic compounds including VOCs, SVOCs, petroleum, pesticides and polychlorinated biphenyls (PCBs). If other tubing or bladders are used for these analytes, DEQ recommends that an equipment blank be used to check that contaminants are not being added to the water, and DEQ may require that a ‘spiked’ solution be run through the tubing to check for adsorption; contact the DEQ project manager for specific directions.
- In addition to Teflon and Teflon-lined tubing and bladders, PVC, polypropylene or polyethylene tubing and bladders are also appropriate for metals sampling. Stainless steel tubing is not appropriate for collecting metals samples, although equipment blanks may demonstrate whether or not there is an effect.
- Note that Teflon sampling equipment can interfere with the results when collecting samples for PFOA/PFOS compounds. If sampling for these compounds, please contact the DEQ project manager for specific directions.
- The smaller the diameter of tubing used, the easier it will be to maintain low flows without getting air bubbles in the tubing. It is recommended to use 1/4” or 3/8” (inside diameter) tubing to ensure that the tubing remains filled with groundwater when operating at very low pumping rates (USEPA, 2017a).
- In order to minimize diffusion between the water in the tubing and the atmosphere, maximize tubing wall thickness and minimize tubing length.
- Avoid sunlight on any exposed tubing, which could result in temperature changes leading to volatilization (USEPA, 2017a).
- If a peristaltic pump is used for low-flow sampling, pharmaceutical grade (“pharmed”) tubing should be used around the rotor head of the pump to avoid diffusion to/from the atmosphere.

1.4.4 Power Source

A power source for operating the pump will be necessary. If a petroleum powered generator is used, the power source should be located at least 30 feet downwind of the well and sampling apparatus so as not to interfere with sampling results (USEPA, 2017a).

1.4.5 Flow Measurement Supplies

A graduated cylinder (or measuring cup), stopwatch, and bucket are appropriate for measuring flow. An in-line flow meter may also be used; however, if using a multi-meter for turbidity and flow rate, turbidity should be collected before the flow meter due to the potential for sediment buildup and interference with turbidity results (Yeskis and Zavala, 2002).

1.4.6 Water Level Measuring Device

An electronic water-level indicator or an electronic interface probe (when LNAPL is present or suspected) capable of measuring to the nearest one hundredth of a foot (0.01 ft) should be used for measuring water table depth ensuring as little disturbance to the water surface as possible. A pressure transducer placed above the pump may be used for tracking water levels during pumping; however, it needs to be calibrated at the start and end of sampling by comparing measurements to those from an interface probe. Procedures for collecting water level measurements are described in Section 2.3.

1.4.7 Multi-Parameter Water Quality Meter

A multi-parameter water quality meter is preferred for monitoring stabilization parameters during sampling. If the multi-parameter water quality meter does not measure for turbidity, a “T” connector will be necessary for obtaining turbidity readings prior to water entering the flow-through cell. Within the approved SAP (Section 1.2), the type of multi-meter used (if known prior to sampling), along with a list of parameters to be measured, should be specified with details on the calibration method and frequency.

If a multi-parameter water quality meter is not available, individual water quality meters may be used for measuring the different stabilization parameters. The SAP should contain standard operating procedures (SOPs) for all meters used, including details on the calibration method and frequency.

Field notes should contain records of all field calibrations performed during the sampling event. In general, meter calibrations should be performed at the beginning of each day and/or after field conditions change (change in barometric pressure or temperature).

1.4.8 Flow-Through Cell

DEQ recommends using a flow-through cell during low-flow sampling activities. When collecting stabilization parameters, using multiple meters simultaneously to make repeated measurements can be a time-consuming and difficult task. Using a multi-parameter water quality meter with a water-tight seal inserted into a flow-through cell allows for multiple parameters to be recorded simultaneously. Post stabilization, field staff can disconnect the inflow tube to the flow-through cell to collect samples from the tube.

1.4.9 Decontamination Supplies

Decontamination supplies including approved cleaning solutions, paper towels, brushes, etc. as outlined in the approved SAP should be on site during sampling.

1.4.10 Record Keeping Supplies

Logbooks, chain of custody forms, equipment calibration forms, well monitoring forms, sample receipts, etc. will be necessary during sampling.

1.4.11 Sample Bottles/Labels/Preservatives

Sampling vials/bottles, labels, coolers filled with ice, zip-lock bags, and the appropriate preservatives (as outlined in the approved SAP and dictated by the chemical being sampled for and the analytical method) will be necessary during sampling.

1.4.12 Gloves

Appropriate gloves should be worn during sample collection; gloves should be changed between samples and prior to decontamination of equipment.

1.4.13 Miscellaneous Equipment

Supplies to aid in shading during hot weather and inhibit freezing of equipment in winter, drinking water supplies, first aid kit, tools for accessing wells (including keys for locks), well location maps, GPS, camera, cellphone, sunscreen, well construction information, calibration manuals, etc. as dictated by conditions and the nature of the work should be on hand during sampling.

2.0 STANDARD SAMPLING PROCEDURES

The following sections describe sampling procedures that apply to all sampling events, regardless of pump type/purge method. For details on additional procedures for specific pump types, including low-flow pumps, please refer to Sections 3.0 – 6.0.

2.1 SAMPLING ORDER

When previous water quality data is available, begin with the least contaminated wells, and proceed to increasingly contaminated wells. When contaminant distribution is unknown, begin with wells upgradient of likely contaminant source(s), continue with downgradient wells, and finish with wells in or closest to suspected contaminant source(s). Collect any necessary quality control samples as outlined in the SAP, including any equipment blanks.

2.2 INSTRUMENT CALIBRATION

Instruments should be calibrated at the beginning of each day. A calibration check is performed at the end of the day to ensure the instruments remained in calibration. All calibration procedures should be documented.

2.3 WATER LEVEL MEASUREMENTS

The measurement of water levels in monitoring wells provides critical data that can be used to determine groundwater flow direction and gradients, aquifer conditions relative to the well screen, and the effect that purging has on groundwater. Water level measurements should be taken in such a way as to minimize disturbance of the water surface and limit the potential to disturb sediments that may have collected within the well. Because water levels have the potential to be influenced by external factors such as barometric pressure, it is recommended that water level measurements be taken from all facility wells within a relatively short period of time to ensure the measurements are comparable.

Depth to groundwater in the monitoring well should be measured prior to installing the pump and/or tubing (if the monitoring well does not have a dedicated pump). If the well is equipped with a dedicated pump then record the static water level prior to initiating purging. If measuring in an active domestic or irrigation well, ensure the water level is static by measuring at least twice. Record the initial water level to the nearest 0.01 ft in the field logbook or field sampling form. Ensure that the water level probe is decontaminated and wiped clean before measuring another well.

Prior to beginning pumping, measure depth to groundwater again and record in the field logbook or field sampling form. If a pressure transducer is being used to document drawdown during sampling, install before pumping begins. Water level measurements should be collected to the nearest 0.01-foot as measured from a surveyed reference point. Once purging begins, water level measurements and pumping rate should be recorded every three to five minutes (along with stabilization parameters), and pump speeds should be adjusted to minimize drawdown.

Water level measurements should be taken continuously throughout the sampling event. Water level drawdown (Figure 1) provides the best indication of stress placed on the hydrologic system by a given flow-rate during sampling.

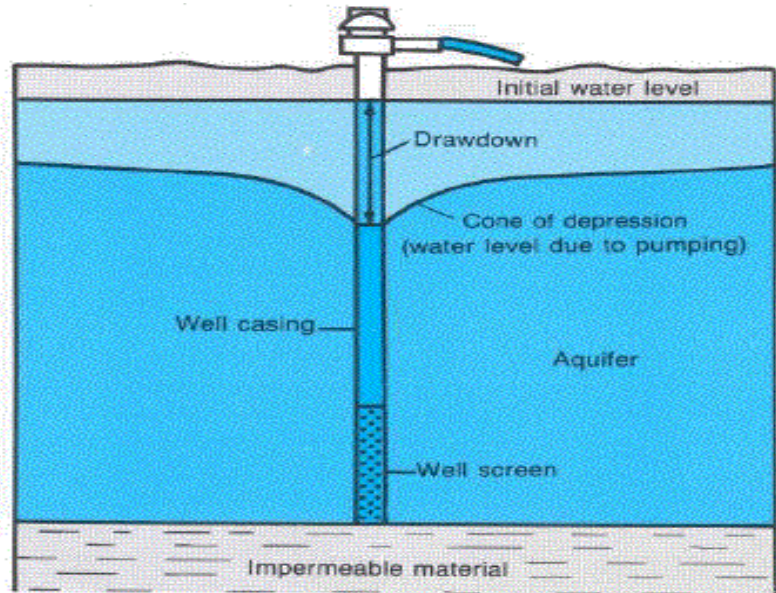


Figure 1: Water level draw down in well (USGS 2016)

2.4 PUMP PLACEMENT IN THE WELL SCREEN

Sampling devices should be lowered slowly and carefully into the well to avoid mixing of stagnant water in the casing above the screen. Sediment and particulates settled at the bottom of the casing can cause interference during sampling activities. Suspending this material will slow down the purge and sampling time and could cause false positives in water quality data. The goal is to minimize the disturbance of water and solids within the well (Figure 2).

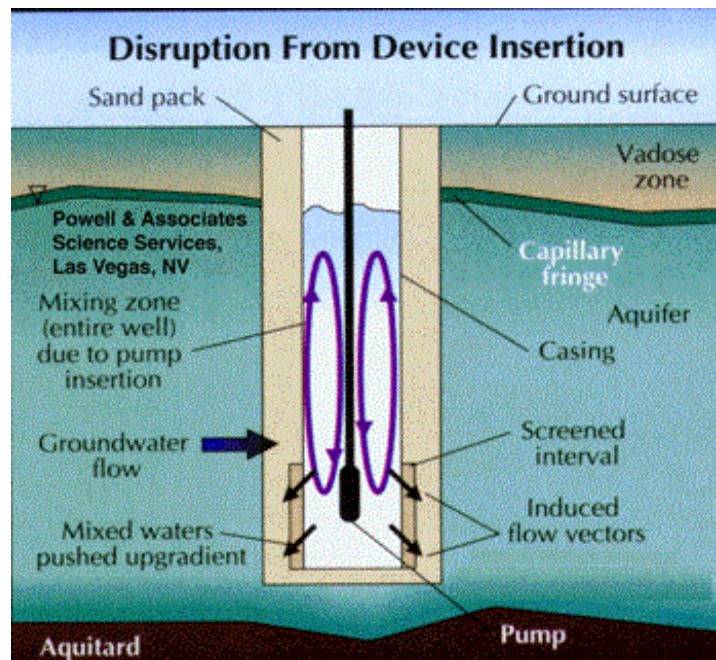


Figure 2: Disruption from device insertion (Powell & Assoc., 2016)

The measurement of the total depth of the well is used to help determine pump placement by assessing the well volume and potential interferences with the screen interval. Total depth is typically included on the well log; however, if changes are suspected due to sediment build-up, the total depth should be confirmed by measuring in the field. If well depth is to be measured, it may be measured the day before sampling or after the sampling event is complete to prevent sediments at the bottom of the well casing from becoming suspended in the water column and interfering with data quality and sample collection time. Placement of the pump within the well screen may be site or contaminant dependent. If a field specific change is required, ensure that the DEQ technical contact is notified verbally during field activities. Please consider the following field specific needs for pump placement:

- For most sites, and at wells with screens 10 feet long or shorter, the pump intake/inlet should be located at approximately the midsection of the saturated screened interval.
- For wells with screens longer than 10 feet, the primary flow zones and contaminant concentration intervals should be identified and the pump intake location should be determined in consultation with the DEQ technical contact.
- For sites with intervals of different contaminant concentrations within the well screen, the pump intake should be located in the most contaminated interval.
- For monitoring wells with LNAPLs, please see section 7.5.1. Care should be taken to ensure data quality is not affected either by small LNAPL globules in the sample or the inability to properly decontaminate the equipment between sampling locations. If low-flow sampling is proposed for a monitoring well where LNAPL is present, please consult the DEQ technical contact to ensure data quality objectives are being met.

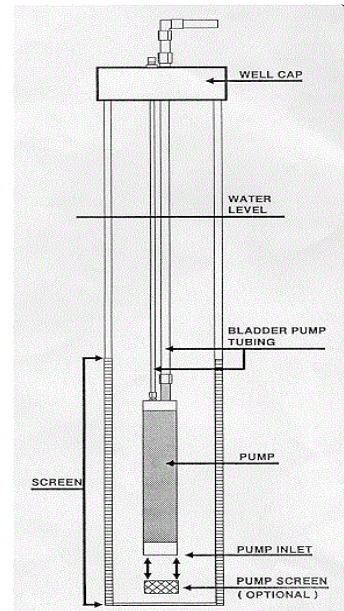


Figure 3: Pump located midsection of well screen (GWSP, 2016)

- For monitoring wells with dense non-aqueous phase liquids (DNAPLs), it may be appropriate to locate the pump intake in the lower portion of the well; however, the pump should not be placed in the lower two feet of the well if possible, so as to avoid disturbing sediment.
- For fractured bedrock sites and other sites with preferential contaminant flow pathways, the pump intake should be placed to sample the most hydraulically conductive interval, unless the sampling objective is to sample a different flow path.

2.5 STABILIZATION PARAMETERS

Water quality indicator parameters should be monitored during purging. Common water quality indicator parameters used to determine stabilization include pH, oxidation/reduction potential (ORP), conductivity, dissolved oxygen (DO), and turbidity. Temperature data can also be collected, but is not necessarily a required indicator of stabilization (Puls and Barcelona, 1996). Measurements should be taken every three to five minutes, and stabilization is considered achieved when three consecutive readings are within the following ranges for the stabilization parameters (NJDEP, 2003; USEPA, 2017a; Puls and Barcelona, 1996):

Water Quality Indicator Parameter	Stabilization Range
pH	± 0.1 units
Specific Conductance	± 3%
Dissolved Oxygen (DO)	± 10%
Turbidity	± 10%
Oxidation/Reduction Potential (ORP)	± 10 millivolts

Turbidity and DO will typically require the longest time for stabilization. It should also be noted that natural turbidity levels in groundwater may exceed 10 nephelometric turbidity units (NTU); therefore, turbidity can be considered stable when three consecutive readings are within 10% for values greater than 5 NTU and if three turbidity values are less than 5 NTU (USEPA, 2017a). For DO, if three consecutive values are less than 0.5 mg/L, consider the values as stabilized (USEPA, 2017a).

Where a flow-through cell is used, complete exchange of water through the flow-through cell is necessary between measurements. If the cell volume cannot be replaced in a five-minute interval, then the time between measurements should be increased accordingly. Stabilization of the indicator parameters allows the sampler to know when formation water has been accessed and sample collection may begin.

If the multi-parameter meter used during the sampling event does not have the capability of testing turbidity, turbidity samples should be collected before water enters the flow-through cell. Transparent flow-through cells can help field personnel monitor for particulate build-up, which can affect indicator field parameter values measured within the cell. If excessive turbidity is encountered during pump start-up, purging may need to continue until particulates settle to avoid build-up during parameter monitoring and sampling.

Depending on facility conditions, parameters may not stabilize during pumping. If parameters do not stabilize, please proceed with one of the following:

- Purge the well for a minimum of four hours prior to sampling if the static water level was stable prior to pumping, or
- Purge three well volumes from the well prior to sampling, or
- Discontinue purging and do not collect a sample.

If a sample is collected, lack of stabilization of parameter values should be documented in the field logbook. Whether to allow sampling when parameter stabilization is unattainable is a site-specific and contaminant-specific decision to be discussed with the DEQ technical contact.

2.6 SAMPLE COLLECTION

Samples should be collected once indicator parameters have stabilized as described in Section 2.5 above. When more than one sample contaminant type is to be collected from the well, samples should be collected in order from most volatile to least volatile analytes. The pump should not be turned off between purging and sampling although the pump rate may be decreased for sample collection in order to fill sample containers (often necessary to fill VOC sampling vials).

However, the rate may not be increased. Prior to collecting samples, disconnect tubing from the monitoring well from any inline-flow devices. Samples should be collected directly from the tube discharging from the monitoring well (unless an inline filter is required for the particular sample analysis). Immediately after a sample bottle has been filled it should be preserved according to the SAP, unless of course the sample container is pre-preserved by the laboratory.

2.7 DECONTAMINATION

Specific decontamination procedures depend on the equipment being used and the contaminants being sampled. Procedures for decontamination should be included in the SAP and purge water should be handled in a manner consistent with DEQ requirements. In general, sampling devices should be decontaminated prior to sampling the first well and then following the sampling of each well. The use of dedicated pumps, bladders, and tubing will reduce the amount of time spent on decontamination. Disposable bladders and tubing should be used only once unless dedicated to the well. Water level probes should be decontaminated between each sampling point by wiping or scrubbing off soil or other foreign material, washing with a laboratory grade detergent (Liquinox or equivalent)/clean-water solution, and rinsing with tap water followed by a final rinse with distilled or deionized water. If the probe comes in contact with free product or highly contaminated groundwater, wash equipment using a desorbing agent (e.g. dilute solution of water and isopropanol or methanol) followed by a detergent wash, a thorough tap water rinse, and a final distilled or deionized water rinse. The interior and exterior of the pump, tubing, support cables, electrical wires, and any other equipment which was in contact with the well should be decontaminated in a similar manner as well.

2.8 POST SAMPLING ACTIVITIES

After sampling, record the depth to groundwater again prior to ending the pumping event. If using dedicated pump tubing, hang it inside of the monitoring well or place within a dedicated container for storage until the next sampling event to avoid cross-contamination. Ensure the tubing is dry prior to long-term storage to avoid issues with mold. Secure the monitoring well. At the end of the sampling event, or end of day event, a calibration check of instruments should be performed and recorded.

3.0 LOW-FLOW SAMPLING

Low-flow sampling is when groundwater samples are collected with a pump set at a low flow rate. The measurement of water levels and stabilization parameters is used to determine when groundwater representative of the aquifer is being collected. This method minimizes disturbance of the well and formation water, and allows for groundwater sampling without purging multiple well volumes of water.

The procedure and considerations for low-flow sampling are described in *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures* (Puls and Barcelona, 1996).

Low-flow, also called “minimum drawdown” and “low stress” purging and sampling refers to the velocity with which water enters the pump intake; it does not necessarily refer to the flow rate of water discharged at the surface (Puls and Barcelona, 1996). Groundwater generally flows horizontally through a monitoring well screen with sufficient velocity to maintain an exchange with formation water surrounding the screen. When water is removed from a well at a rate minimizing vertical flow and the associated induced stress to the groundwater system, as measured by drawdown in the well, then the pumped water is more representative of the aquifer adjacent to the well screen (CalEPA, 2008).

Conventional groundwater purging and sampling methods (e.g. bailers and high-speed pumps) not only cause hydrologic stress on the groundwater system, but also cause other adverse impacts including the collection of samples with high levels of turbidity (Puls and Barcelona, 1996). Suspended sediment at the bottom of the well casing can bias contaminant concentrations high and filtering samples can remove naturally mobile particles biasing contaminant concentrations low (Puls and Barcelona, 1996). Note, however, that analysis of dissolved metals in groundwater does require appropriate filtering.

Field staff can ensure that low-flow conditions have been achieved and samples can be drawn from the well by following the procedures described in this document. Indicator field parameters (pH, redox potential (ORP), conductivity, dissolved oxygen (DO), temperature, and turbidity) and water level drawdown are measured during purging to determine when formation water has been accessed. It is important to establish stabilization prior to sample collection and consistently implement the same methods for each well sampled (stabilization criteria are discussed in Section 2.5). Consistently reproducing this methodology will improve data quality and help eliminate field errors that may cause DEQ to request sampling events to be repeated.

Any deviations made in the field need to be documented in writing where the supporting and resulting data are discussed, for example in the site investigation (SI) report or monitoring report, and in the field log book or groundwater sampling log. The following materials provide a generalized how-to approach to low-flow sampling.

Some of the advantages and disadvantages of the low-flow sampling process follow (ASTM, 2005; Puls and Barcelona, 1996):

Advantages	Disadvantages
<ul style="list-style-type: none"> • Generates less purge water than traditional purge methods, which decreases disposal costs • Less operator variability • Better sample consistency • Reduces adverse effects at the groundwater-well interface during sample collection by minimizing formation disturbance (e.g. mixing of stagnant casing water and settled sediment) adjacent to the screened interval • Minimal groundwater column drawdown and minimal disturbance of fines in the bottom of the well • Provides for sampling from discrete intervals in the well • Yields results representative of site contaminant conditions 	<ul style="list-style-type: none"> • Potentially greater set-up and/or sampling time in the field • Difficult to sample low-yield wells

3.1 LOW-FLOW SAMPLING PROCEDURE

Please refer to Sections 2.1 – 2.8 for standard sampling procedures (instrument calibration, sample collection, decontamination, etc.). Details regarding procedures specific to low-flow sampling are described in the following sections.

3.1.1 Installation of Low-Flow Pump

After attaching all necessary tubing and safety cables to the low-flow pump, lower the pump slowly into the monitoring well to the pre-determined depth. Pump tubing lengths outside of the monitoring well casing connected to flow-through cells and monitoring instruments should be kept as short as possible to minimize heating of the groundwater in the tubing by sunlight and ambient air temperatures. Heating of the groundwater in the tubing should be avoided as it may cause groundwater to degas, which can adversely affect data quality of samples for VOCs and dissolved gases.

3.1.2 Continued Water Level Measurement

Depth to groundwater measurements should be taken during the entire low-flow pumping and sampling procedure to ensure that stress is not being placed on the hydrologic system by a high pumping rate. The objective is to pump in a manner that minimizes water level drawdown in the system (Figure 1). At the beginning, drawdown may exceed the goal of <0.1 meters (m) [0.3 feet {ft.}] during purging and then “recover” as pump rates are adjusted. Aquifers with particularly high conductivity may be able to sustain higher flow rates with laminar flow into the well and without excessive drawdown. The flow rate used to achieve a stable pumping level should be recorded and remain constant while monitoring the indicator

parameters. Recording of water quality indicator parameters begins once the depth to groundwater level has stabilized and enough water has been purged to fill the flow-through-cell and submerge all water quality meter sensors (USEPA, 2017a).

3.1.3 Purging the Monitoring Well

Use previous sampling event data to assist in determining pump rate and pump settings. Flow rates of 0.1 – 0.5 L/min are necessary to conduct low-flow sampling; however, this is dependent on site specific hydrogeology (Puls and Barcelona, 1996; ASTM 2005, NJDEP, 2003). Some extremely coarse-textured formations have been successfully sampled at flow rates to 1 L/min.

Start the pumping at a low rate (0.1 L/min is suggested). Once low-flow pumping begins, all purged water is collected in a graduated container to determine the total volume of purge water, which is recorded in the field logbook or field sampling form. Slowly increase flow rate until water level begins to drop. Reduce flow rate slightly until water level stabilizes. Water levels should not drop below 0.3 ft of the initial water level. Record pump settings at this time and calculate flow rate. Continue to collect water level measurements every three to five minutes until water level stabilizes. If groundwater is highly turbid, continue to purge groundwater until the water visually clears. Do not allow the water level to drop below the pump intake.

3.1.4 Monitoring Stabilization Parameters

After the depth to groundwater has stabilized, ensure that the sample tubing and/or flow-through cell are free of gas bubbles. Begin collecting water quality field parameters (pH, ORP, conductivity, DO, and turbidity). Temperature data can also be collected, but is not a required indicator of stabilization (Puls and Barcelona, 1996). Collect water quality field parameters every three to five minutes until parameter stabilization is achieved. Note that a complete exchange of water through the flow-through cell is necessary between measurements; the flow cell volume should be recorded in the field book and flow should be monitored to confirm that complete exchange has occurred between parameter readings. If this is not achievable in five minutes, extend the sample time accordingly. See Section 2.5 of this Groundwater Sampling Guidance for more details on stabilization criteria.

4.0 MULTIPLE VOLUME PURGE SAMPLING

Multiple volume purge sampling is when groundwater samples are collected after a predetermined volume (generally three to five well volumes) of water has been removed from the well and field parameters have stabilized. Well volume is calculated by using the following equation:

$$V = \pi r^2 h(7.48)$$

where:

V = volume in gallons

r = radius of monitoring well in feet

h = height of the water column in feet (this may be determined by subtracting the depth to water from the total depth of the well as measured from the same reference point)

7.48 = conversion factor in gallons per cubic foot

Wells are typically purged by bailer or a pump in an effort to remove stagnant well water prior to sample collection. In low yield wells, the well is generally purged dry and sampled after sufficient recovery has occurred. Some of the advantages and disadvantages of multiple volume purge sampling follow:

Advantages	Disadvantages
<ul style="list-style-type: none"> • Easy to implement • Well yield does not limit the applicability of the sampling method except in low-yield wells that may be pumped dry. 	<ul style="list-style-type: none"> • High volumes of purge water that require treatment or disposal • Less sample consistency • Inadequate purging may cause stagnant well water to mix with formation water • High purge volumes can underestimate concentrations due to dilution. High purge rates can under- or over-estimate concentrations by pulling water from other vertical zones. • High purge rates can increase sample turbidity and may result in higher contaminant concentrations • In the case a low-yield well is pumped dry, sampling recovered water will likely result in underestimated VOCs due to cascading/aeration.

5.0 NO PURGE SAMPLING

No purge samples are generally collected by bailer or pump without purging the well. These samples are most commonly collected from temporary sampling points. The difficulties of sampling from temporary sampling points are discussed in Section 7.2. Although no purge samples can be useful as a screening tool, they are not typically used for groundwater monitoring. Bailers, pumps, or other sample collection devices may be used for no purge sampling. Some of the advantages and disadvantages of the no purge sampling process follow:

Advantages	Disadvantages
<ul style="list-style-type: none">• Easy to implement• Potentially no purge water generated• Minimal set-up and sample times	<ul style="list-style-type: none">• Less sample consistency• Potential for sample to contain sediment and/or stagnant well water• Uncertainties about representativeness• Depending upon the sampling method, low sample volumes may limit lab analyses

6.0 PASSIVE SAMPLING

Passive samplers collect groundwater samples from within the screened interval of a well without purging. Because purging is not required, there is minimal disturbance of the sampling point. Passive samplers may include more rapid samplers such as the Hydrasleeve™ and Snap Sampler®, or samplers that rely on sorption (Gore™ Module), or diffusion (passive diffusion bags). A thorough discussion of the use and considerations for passive samplers is provided in *Protocol for Use of Five Passive Samplers to Sample for a Variety of Contaminants in Groundwater* (ITRC, Feb. 2007). Some of the advantages and disadvantages of the passive sampling process follow:

Advantages	Disadvantages
<ul style="list-style-type: none">• Easy to implement• Generates no purge water• Provides for sampling from discrete intervals in the well• Less set-up and sample times	<ul style="list-style-type: none">• Method may require calibration with other sampling techniques to assess applicability• Requires equilibration with groundwater• Sorption or diffusion based sampling requires multiple mobilizations per sampling event• Sorption or diffusion based samplers are only applicable for certain constituents• Limited sample volume

7.0 SPECIAL CONSIDERATIONS

Different types of wells and borings may be available for DEQ and consultants to collect representative groundwater samples. The following are specific situations with examples to assist in quality groundwater sample collection. This may include instances where data collection from conventional monitoring wells is not possible, it is desirable to supplement groundwater data from conventional monitoring wells, or it may be important to determine the presence and concentration of contaminants in drinking water sources.

7.1 DIRECT PUSH TECHNOLOGY (DPT) WELLS

If direct push technology (DPT) wells are installed with filter packs, they may allow for well development and lower sample turbidity. The speed and mobility of DPT sampling may allow for the installation of more sample points, which may provide a more complete assessment of groundwater quality than would be available with conventional wells. Commercially available screen lengths as short as one foot allow DPT wells to be installed in a vertically precise manner (i.e., avoiding excessive or inadequate screen lengths). Drill cuttings and purge water volumes are minimal due to the smaller well diameters. Several studies have been completed comparing DPT installed wells with conventionally installed wells (USEPA, 1998; Kram, Mark et. al., 2001). The studies found no significant difference in the quality of samples taken from properly installed and developed DPT wells as compared to conventionally installed wells.

The limitations of DPT installed wells are a consequence of the small diameter of such wells. Specific limitations could include limited volumes of groundwater to obtain sufficient sample qualities. Also, USEPA specifically does not recommend DPT where telescoping wells are required to limit migration below confining layers (Ohio EPA, 2005). The inside diameter probe rods or temporary drive casings used for DPT wells range from 1 ½ to 3 ½ inches. The smaller diameters limit the choices of purging and sampling equipment. Several types of appropriate equipment are currently available, including small-diameter bladder pumps and small-diameter electric submersible pumps. If the DPT well is less than 2 inches, it may be necessary to use a peristaltic pump, although this is not the preferred method. In addition, due to the smaller well diameter, a smaller radius of the formation is impacted during well development, potentially resulting in a less developed well than a larger diameter well. As with all DPT applications, installation of wells with DPT is limited to unconsolidated sediments, and may be limited by depth or the presence of gravels or cobbles. These limitations should be considered in site sampling and analysis plans (Ohio EPA, 2005).

7.2 DPT ONE-TIME SAMPLE COLLECTION

DPT one-time samplers do not allow for long-term groundwater monitoring; however, they can be very useful as screening tools. With respect to site screening investigations in which groundwater samples are not being collected for compliance purposes, DPT (closed screen, open screen, and groundwater profilers) may delineate contaminated groundwater plumes more quickly and efficiently than monitoring wells. Because they are easy to use and do not require well construction materials, DPT one-time samplers typically have a significant advantage over traditional monitoring wells as site screening tools. In addition, they often facilitate hydrogeological evaluation and plume mapping, and can be very helpful in optimizing the

location and construction of permanent monitoring wells. Conversely, with respect to obtaining representative groundwater samples that generate accurate and verifiable data, the use of DPT one-time samplers does present a few challenges. Correct placement of the screened interval is particularly important given the short screen and discrete sampling interval, so that contaminant layers are not missed. The short time frame of many DPT investigations is often insufficient for adequate well development and equilibration with the surrounding formation water. Because there is no filter pack installed around a DPT sampling tool fines may clog the well screen when sampling in fine-grained formations preventing groundwater from reaching the sampler. Also, the lack of a bentonite seal may allow volatile organic compounds (VOCs) to off-gas into the atmosphere from the groundwater zone if the vadose zone/surficial materials are relatively cohesive and the annular space has not collapsed. Clogging of the screen could cause samples to be biased lower than actual contaminant concentrations. Problems with turbidity may arise due to the inability to adequately develop the sampler. Finally, when sampling objectives include trend analysis and monitoring of remediation efforts, the one-time sampling inherent in samples taken with DPT tools is often not appropriate for these monitoring requirements (Ohio EPA, 2005).

7.3 IRRIGATION WELLS

Construction and/or completion details about irrigation wells may be unknown or unreliable; therefore, before proposing use of irrigation wells for groundwater monitoring, DEQ advises considering several factors such as: whether the pumps are running continuously or intermittently and whether any storage/pressure tanks are located between the sampling point and the pump. The following considerations and procedures should be followed when purging wells with in-place plumbing. If the pump runs more or less continuously, no purge (other than opening a valve and allowing it to flush for a few minutes) is necessary. If a storage tank is present, a spigot, valve or other sampling point should be located between the pump and the storage tank. If not, locate the valve closest to the tank. Measurements of pH, specific conductance, DO, ORP, and turbidity are recorded at the time of sampling and compared to previous measurements to confirm that purging is complete. See Section 2.5 for parameter stabilization criteria.

If the pump runs intermittently or infrequently, the sampling team's best judgment, along with advice from DEQ, should be utilized to remove enough water from the plumbing to flush standing water from the piping and any storage tanks that might be present. Generally, under these conditions, 15 to 30 minutes will be adequate. Measurements of pH, specific conductance, DO, ORP, and turbidity should be made and recorded at intervals during the purge to determine when purging is complete, and the final field parameters measured at the time of sampling (USEPA, 2017a). Sampling through hoses or tubing should be avoided. Collecting groundwater samples from irrigation wells has limitations. Irrigation wells are commonly screened over a broad range of geological materials. Preferential flow paths in more hydraulically conductive units could influence or dilute evidence of chemicals of concern (Gosselin et al. 1994).

7.4 DOMESTIC OR RESIDENTIAL WELLS

In some instances, samples will be acquired from residential wells. Several factors should be considered when collecting samples from a residential well. Obtain a copy of the well log from Montana's Groundwater Information Center (GWIC) to determine the well depth, diameter, and estimated static water level so that the amount of water per well volume can be calculated for

purging. It should be determined if the residence is equipped with a water softener or other filtration system. Samples should be collected before any type of treatment system, if possible. Samples should also be collected from as close to the well influent as possible. Sampling through hoses or tubing should be avoided. The sample should be collected directly from spigots or faucets. In residences, the size of the holding tank should be determined. If it is not possible to collect a sample before the holding tank, then the volume of the holding tank should be purged before sample acquisition, if feasible. Water quality parameters should be collected during the purge to determine when purging is complete, and the final field parameters measured at the time of sampling. Sample analysis requirements are case specific.

DEQ personnel or contractors *should not* open the wellhead. If depth-to-water is a critical parameter, it can be measured with a sonic depth-to-water meter. Using a tape or probe to measure depth-to-water in a drinking water well is not advisable because they can easily get entangled with the discharge piping or electrical wiring for the submersible pumps.

If samples are being collected for bacteria, sterilize the spigot with bleach or 95% ethanol, then rinse with DI water prior to sample collection.

Collecting groundwater samples from domestic wells has limitations. Domestic wells are commonly screened over a broad range of geological materials. Preferential flow paths in more hydraulically conductive units could influence or dilute evidence of chemicals of concern (Gosselin et al., 1994). However, the importance of sampling domestic or residential wells is usually to monitor a direct exposure route.

7.5 SAMPLING WELLS WITH FREE PRODUCT

Sampling groundwater at wells with free product, light non-aqueous phase liquid (LNAPL) or dense non-aqueous phase liquid (DNAPL), is not a common occurrence and is not typically required. However, collecting groundwater samples beneath LNAPL may be necessary for determining the co-solvency effect upon dissolved-phase contaminant concentrations for product mixtures, evaluating coalescing contaminant plumes from multiple sources, designing groundwater treatment systems, and collecting natural attenuation parameters. If the collection of groundwater from a monitoring well where free product is observed is required at a facility, the following methods and procedures provide guidance for those activities. Alternative approaches will be considered if those methods can be shown to provide better or equivalent data quality.

7.5.1 Sampling Groundwater Below LNAPL

LNAPL can be a persistent source of groundwater contamination, frequently contributing to chemical groundwater exceedances above screening or cleanup levels. Standard groundwater sampling methods are inappropriate for sample collection beneath LNAPLs because sampling implements become coated as they pass through LNAPL, thereby potentially cross-contaminating groundwater samples. Entrained product increases contaminant loading of groundwater samples, and may damage field instrumentation. Typically, groundwater in monitoring wells containing LNAPL is not sampled due to complexity and the special handling needed to collect representative samples. However, if a circumstance exists to warrant collection of groundwater samples from beneath LNAPLs, DEQ recommends using

one of the following procedures. Please consult with the DEQ technical contact for approval of alternative methods that can achieve reliable results.

7.5.1.1 Sealed Casing Method

Water levels and LNAPL thickness is measured. A 1-inch diameter polyvinyl chloride (PVC) casing sealed at the bottom with plastic sheeting (i.e., cling film, saran wrap) is lowered through the LNAPL layer and placed approximately one to two feet below the bottom of the LNAPL. The plastic sheeting is attached using a band clamp. A ½ -inch diameter pipe is lowered inside the 1-inch diameter casing and pushed through the plastic sheeting at the bottom. The ½ -inch diameter pipe is placed approximately one to two feet below the bottom of the outer casing. Disposable plastic tubing is connected to a peristaltic pump configured to discharge air through the tubing instead of drawing air into the tubing. The tubing is lowered inside the ½ -inch piping until the intake end of the tubing reaches below the ½ -inch diameter piping and into the underlying groundwater column. The peristaltic pump is turned off, and the intake end of the tubing is lowered to the desired sample acquisition depth (e.g. typically near the bottom of the well screen in the lower portion of the water column, but not in the lower two feet of the well, if possible). Prior to sampling the well, the peristaltic pump configuration is reversed to draw water into the tubing, and a small quantity of groundwater (e.g., 100 ml) is discharged from the tubing (Revised Supplemental Work Plan for Investigation of Chlorinated Volatile Organic Compounds and Petroleum Hydrocarbons (3rd Revision), Burlington Northern Facility Havre dated May 2006 by Kennedy/Jenks Consultants, Inc. for BNSF Railway Company).

7.5.1.2 Ice-Coating Methods

In this procedure, ice is used as a barrier to inhibit sampling equipment from becoming coated with product during sample collection. Ice should be made from laboratory distilled or deionized water. A detailed description of this procedure is available online (<http://www.bioremediationgroup.org/BioReferences/Tier2Papers/collection.htm>), but is also directly cited below.

Ice is used as a temporary barrier to protect sampling implements from becoming product coated as they pass through LNAPLs within monitoring wells. Sampling implements are coated with approximately 0.1 to 0.3-inch-thick layer of ice (laboratory-grade distilled water) using simple molds fabricated from PVC pipe and end caps. Bench-scale testing of two different ice-coating procedures demonstrates that product initially coats the ice, but sloughs off within seconds as the ice begins to melt. The ice coating melts completely within a few minutes and the product-free implement is used to sample groundwater. Melting ice is expected to have a negligible effect on groundwater quality due to the minimal volume of ice relative to the storage capacity of most monitoring wells. If the impact of melting ice on groundwater quality is a concern, the standing water column could be purged or the well could be allowed to equilibrate prior to sampling. Note that this method does not prevent coating on the way back out of the well, so special care should still be taken to properly decontaminate the equipment. An example ice-coating

procedure is described below for sampling beneath LNAPLs.

Ice-Coating Method: Conduit Procedure

This procedure involves placing a silicon stopper in one end of a Schedule 40 PVC pipe and coating the end of the PVC pipe containing the stopper with ice. The ice-coated pipe is lowered through the LNAPL until the stoppered end of the PVC pipe extends at least three feet into groundwater. Following melting of the ice coating, a messenger rod is used to push the stopper from the end of the PVC pipe, creating a portal in the LNAPL through which sampling may be performed. A monofilament line attached to the stopper allows retrieval of the stopper from the well bore at the time the conduit is retrieved (Collection of Groundwater Samples from Beneath an LNAPL: An Ice-Coating Method, I. Richard Schafferner, JR., P.G., James M. Wieck, GZA GeoEnvironmental, Inc.).

7.5.2 Sampling Wells With DNAPL

DNAPLs are denser than water and have limited and varying solubilities in water (ITRC, 2015). The most common DNAPLs are chlorinated solvents such as trichloroethylene (TCE), tetrachloroethylene (PCE), and carbon tetrachloride.

Prior to sampling a groundwater well where DNAPL may be present, it is important to use an interface probe to monitor the total depth of the well and determine whether a DNAPL has accumulated at the bottom of the monitoring well. If the interface probe comes in contact with a DNAPL, immediate sampling should be delayed due to cross contamination on the interface probe moving through the water column as it is removed.

When sampling groundwater at a site with DNAPL present, it may be appropriate to locate the pump intake in the lower portion of the well or screen; however, if possible, the pump should not be placed in proximity (less than 2 feet) to the DNAPL to avoid disturbance of the DNAPL. The use of an appropriate low-flow sampling technique to ensure that the DNAPL is not disturbed during the sampling is important to ensure the data quality of the sample.

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