APPENDIX D

Sampling Analysis Plan

Sampling and Analysis Plan
Boeing Auburn Facility
Auburn, Washington

February 9, 2017

Prepared for

The Boeing Company
Seattle, Washington

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FIGURE

Figure D-1. Vicinity Map

APPENDICES

Appendix A. CMT Manuals
Appendix B. Field Sampling Forms
Appendix C. Soil Gas Sampling

LIST OF ABBREVIATIONS AND ACRONYMS

Boeing	The Boeing Company
bgs	below ground surface
CMT	continuous multichannel tubing
COC	chain of custody
COLIWASA	composite liquid waste sampler
°C	degrees Celsius
DI	de-ionized
DO	dissolved oxygen
DP	direct-push
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
facility	Auburn Fabrication Division facility
gpm	gallons per minute
ft	feet
HASP	health and safety plan
HSA	hollow-stem auger
ID	identification
IDW	investigation derived waste
in.Hg.	inches of mercury
L	liter
LAI	Landau Associates, Inc.
LLI	Eurofins Lancaster Laboratories, Inc.
mL/ft	milliliters per foot
NTU	nephelometric turbidity unit
OM	Osceola Mudflow
ORP	oxygen reduced potential
PCB	polychlorinated biphenyl
PDB	passive diffusion bag
PID	photoionization detector
PPE	personal protective equipment
PRT	post-run tubing
QA/QC	quality assurance/quality control
RI	remedial investigation
SAP	Sampling and Analysis Plan
SWMU	solid waste management unit
TWA	time weighted average
VOA	volatile organic analysis
VOC	volatile organic compound

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1.0 INTRODUCTION

The Boeing Company (Boeing) is currently undergoing corrective action at their Auburn Fabrication Division facility (facility) located at 700 15th Street Southwest in Auburn, Washington (Figure 1). Corrective action requirements are documented in Agreed Order No. DE 01HWTRNR-3345 dated August 14, 2002 and the First Amended Agreed Order dated February 21, 2006, both with Washington State Department of Ecology (Ecology). This Sampling and Analysis Plan (SAP) presents detailed descriptions of field procedures for corrective actions taking place at the facility and at downgradient properties (Site). Additionally, this SAP is intended to be used for other potential environmental investigations related to new or newly discovered releases at the site. This SAP should be used in conjunction with the Boeing Auburn Quality Assurance Project Plan (LAI 2016).

Various topics are discussed in this SAP, the topics include:

- Drilling methods
- Monitoring well installation
- Well development
- Groundwater sampling
- Surface water Sampling
- Soil sampling
- Soil vapor and air sampling
- Field documentation
- Sample handling and documentation
- Utility locating procedures
- Surveying
- Off-site field operations
- Waste handling.

2.0 DRILLING PROGRAM

This section describes the techniques used to advance soil borings for the installation of monitoring wells or collection of groundwater and/or soil samples for chemical analysis. The soil borings will be advanced using hollow-stem auger (HSA), rotosonic, or direct-push (DP) drilling techniques, depending on the expected conditions and boring depth. The completion depths of soil borings will be as described in pertinent work plans, as influenced by drilling conditions encountered and the depths of the water-bearing units. In general, shallow wells will be installed up to 30 feet (ft) below ground surface (bgs), intermediate wells will be installed from 40 to 60 ft bgs, and deep wells will be installed from 80 to 100 ft bgs. Water table wells are a subset of shallow wells and are installed with the screen across or near the water table. Depths of wells may vary depending on the data objectives for the well, depth of the geologic units, or varying geologic conditions within a unit. In particular, the final depth of deep zone wells will depend on the depth of the Osceola Mudflow (OM) deposit.

Near the Site, geologic conditions consist of alluvial sands and gravels that vary in thickness between 80 and 100 ft. The alluvial deposits are underlain by the OM, a lahar deposit originating at Mount Rainier approximately 5,700 years ago. The OM acts as an aquitard due to its silt and clay content and low permeability. It is important to protect the integrity of the OM to avoid potentially introducing a pathway for contaminated groundwater to travel beneath the aquitard. During the installation of deep wells, the boring will be advanced until the OM is identified, or to a depth of 110 ft bgs whichever is shallower. Once the top of the OM is identified, drilling will stop and the well screen will be installed 1 ft above the contact or if a silt layer is present, the well screen will be installed 1 ft above the silt layer.

Previous studies describe the OM as a heterogeneous deposit; typically gray and massive; containing gravel, sand, silt, and clay with occasional boulders; and possibly including wood and organic debris, angular volcanic clasts, or having mottled yellow patches and a sulfurous odor (Pacific Groundwater Group 1999; Dragovich et al. 1994). Borings completed as part of the project remedial investigation (RI) have described the OM as well-graded, gray, silty sand with clay and round to angular gravels, occasionally including trace organics or wood fragments, medium dense or stiff to dense or very stiff. Distinctive features of OM soil samples observed during RI drilling are a sticky texture and angular volcanic gravels. A layer of gray silt 1- to 5-ft thick overlying the OM has been described in a number of RI borings.

2.1 Drilling Methods

This section describes drilling methods to be used for investigation. Drilling methods used include HSA, rotosonic, and DP.

2.1.1 Hollow-Stem Auger

HSA drilling is accomplished with a truck-mounted or track-mounted drill rig. The HSA drilling method consists of rotating and applying pressure to a simple digging bit attached to helical auger flights. The bit loosens and pushes soil to the side of the borehole, where it is captured by the helical auger flights and lifted to the ground surface. A drill rod suspended in the hollow portion of the auger is used to simultaneously drive a center bit or plug that prevents drill cuttings from entering the hollow auger flights.

The HSA method allows for split-spoon sampling of soil borings utilizing the space within the hollow stem of the auger. Environmental or geotechnical split-spoon samples are retrieved by replacing the center bit with the split-spoon sampler and driving the sampler with an auto-hammer or down-hole hammer. The sampler and drill rod are then removed from the boring using the derrick cables. A standard penetration test split-spoon sampler, Dames and Moore U-Type, or equivalent split-barreled sampler may be used to collect soil samples for laboratory analysis.

2.1.2 Rotosonic

Rotosonic drilling is accomplished with a truck-mounted or limited-access, track-mounted drill rig. Rotosonic drilling uses high frequency mechanical oscillations, developed in a special drill head, to transmit resonant vibrations and rotary power through the drill tooling to the drill bit. Frequencies between 150 to 180 hertz are generated. These frequencies match the natural frequency of the drill tooling, causing no dampening of the vibratory wavelength to the bit and can be adjusted to optimize drilling in different formations.

One of the main advantages of the rotosonic drill is its ability to produce continuous core samples of both unconsolidated and consolidated formations. The core samples can be analyzed to provide a precise and detailed stratigraphic profile of any overburden condition including dry or wet saturated sands and gravels, cobbles and boulders, clays, silts, and hard glacial tills. Sample recovery near 100 percent is commonly achieved.

Another unique feature of the rotosonic drilling method is the ability to settle the filter pack and bentonite chip or pellet seal during well installation. This settling is achieved by the resonant vibration applied to the outer casing as it is extracted from the borehole leaving the well screen and riser, pack, seal, and grout or slurry installed in the borehole. The vibratory effect minimizes “bridging” and the potential problem of sand locking the well into the outer drilling casing and pulling it out as the casing is extracted.

2.1.3 Direct-Push

DP drilling is accomplished using a truck-mounted, track-mounted, or hand-portable DP rig. Depending on the manufacturer, make, and model, DP drill tooling is advanced by static push, pneumatic impact, or vibratory methods, or a combination thereof. Unlike rotosonic drilling, there is no rotation of the tooling. In its standard configuration, DP drilling collects a continuous soil core in a 2.25-inch diameter core barrel with a removable polyethylene liner. Once the desired depth is reached, the core is extracted from the ground and the liner and soil core are removed from the core barrel.

The main advantage to DP drilling is it is a fast way to collect high quality soil and groundwater grab samples in unconsolidated sediments where drilling depths are relatively shallow. DP drilling is most often used to collect one-time groundwater grab samples as described in Section 2.3. Permanent monitoring wells and piezometers can also be installed using DP drilling by using prepacked screens. In addition, DP drilling can be used to collect soil vapor samples as described in Section 5.

Due to the relatively low amount of energy imparted to the subsurface as compared to other drilling methods, DP drilling has significant depth limitations in over consolidated soils, soils with a high gravel content, and bedrock. In addition, as there is no way to properly construct a step-down seal with DP drilling, it is not an appropriate method for drilling that crosses more than one aquifer.

2.2 Equipment Decontamination

Prior to drilling at each location and prior to demobilization off site, all drilling equipment exposed to soil and groundwater with a high-pressure steam cleaner. Water used for cleaning will be obtained from a potable source and transported to the drilling site or from an approved facility source. Contaminating substances will not be introduced into the borings or wells during any part of the drilling, well installation, or well development process. Containers used to transport drilling water may not have been used for any other purpose. Containers of decontamination water will be labeled and stored separately from other containers.

2.3 Borehole Groundwater Sampling

During drilling, borehole groundwater samples are often collected from discrete intervals different from the final well screen (monitoring wells) or where no permanent well will be installed (soil borings). Borehole samples can be collected either from a temporary well installed during drilling and then removed before continuing with well installation, or from the permanent well screen immediately after installation and before development. When a borehole sample is to be collected, water may not be used during drilling to control heave. Once the sample has been collected, added water may be used as necessary to complete installation of the well.

2.3.1 Temporary Well Installation

Temporary wells will be installed during drilling for sampling depths other than the final screened interval. Temporary wells should consist of equivalent a 5-ft long PVC screen and PVC casing. The driller will advance the exploration to the desired depth, install the temporary well, place a sand pack (if needed) to a height of 2 ft above the screen and then pull the auger or casing (depending on drilling method) 5 ft up to expose the screen to the surrounding formation.

A new well screen will be used for each temporary well and will not be reused for construction of the permanent well. Riser pipe from a temporary well may be reused for deeper temporary wells in the same boring and for the permanent well installed at the same location. Reused riser pipe will be located at the same depth as in the temporary well.

2.3.2 Borehole Sampling Procedures

Temporary wells will be purged for 30 minutes or until field parameter readings including turbidity, pH, conductivity, and temperature stabilize, whichever is sooner. Borehole samples generally have very high turbidity, which does not substantially improve with additional purging. Therefore, the laboratory chain-of-custody (COC) will request that turbid samples either be allowed to settle or be centrifuged to allow collection of an aliquot from the clear portion of the liquid.

2.4 Well Installation

This section specifies the designs, procedures, and materials that will be used to construct monitoring and injection wells. The installation procedures are designed to avoid contamination of the water-bearing zone by drilling equipment, cross-contamination of wells during the drilling process, and vertical seepage of surface water to groundwater. Monitoring wells will be installed to obtain representative groundwater samples and evaluate hydrogeologic conditions. Injection wells are installed for the purpose of bioremediation.

The drilling subcontractor will install wells as overseen by a field geologist. The drilling subcontractor will be responsible for obtaining and submitting all well drilling permits, logs, and well identification (ID) tags as required by the State of Washington.

All wells will be constructed in accordance with the Ecology Minimum Standards for Construction and Maintenance of Wells (Washington Administrative Code 173-360) or in accordance with a variance obtained from Ecology. The most current version of this document at the time of installation will take precedence over all other well drilling and construction practices discussed elsewhere in this SAP.

2.4.1 Conventional Monitoring and Injection Well Construction

A single well screen and riser pipe will be placed at the selected depth interval after completing the boring and before retracting the casing or auger. A sand filter pack is installed in the annular space around the screen. A well seal, typically of bentonite chips, is installed above the filter pack. A locking well monument set in a concrete-surface seal will occupy the top 2 ft. Dispersing agents such as phosphates or acids will not be used in well installation or development. Each segment of the constructed well is discussed in detail in the following paragraphs.

2.4.1.1 Well Screen and Filter Pack

New, clean, 2-inch diameter, Schedule-40, flush-threaded PVC riser pipe and factory-slotted well screens will be used for all conventional well installations. The screen length will be described in a pertinent work plan and be determined based on the target groundwater zone, lithologic conditions, and estimated wet season groundwater depth. Typical screen lengths will be 10 ft. A threaded bottom cap will be attached to each screen prior to installation.

The purpose of the well screen is to allow groundwater to easily enter the well while preventing entry of filter pack sand. Screens with slot size of 0.010-inch or 0.020-inch will be used. A 0.020-inch slotted screen will be matched to a filter pack of size 10/20 silica sand (or equivalent). A 0.010-inch slotted screened can be matched to a filter pack of size 10/20 or 20/40 silica sand (or equivalent).

Sand pack is intended to minimize transport of fine-grained sediment into the well without restricting the flow of groundwater. Filter pack sand will be placed to approximately 2 ft above the screen as the drill casing is retracted. This 2 ft of filter pack sand above the top of the well screen will prevent migration of the overlying bentonite seal material into the screened intake zone.

Filter pack material will be poured slowly during placement to prevent bridging across the annulus. For wells constructed with HSA drilling where there is no vibratory energy during removal of the drill casing, the well screen will be surged frequently during placement to settle the sand pack. To monitor this settling, the top of the filter pack will be continuously sounded with a weighted measuring line (sounding tape) during placement of the filter pack. This process will be continued until the filter pack has filled the well annulus to the appropriate depth. The volume of sand emplaced will be recorded on the well construction log.

2.4.1.2 Well Riser

A flush-threaded, 2-inch-diameter, PVC well riser will be installed from the top of the screen to the ground surface. The riser will be cut flat at the top. A small, v-shaped notch or other permanent mark will be made in the lip as a mark from which all future water level readings will be made. By convention, the notch will be located on the north side of the well riser pipe.

2.4.1.3 Well Seal

A combination of bentonite chips or pellets, and bentonite grout will be used to construct the well seal. If using bentonite grout as an annular seal, a well seal of hydrated bentonite pellets or chips, at least 3-ft thick, will be installed above the filter pack to prevent the intrusion of overlying annular seal material (grout) into the filter pack. Grout will be placed using a tremie tube.

Cement bentonite grout will be used as the well seal for injection wells. Increased pressures and need for a crack/shrinkage resistant well seal require specific well design parameters. These specific requirements may also be recommended at monitoring wells in the immediate vicinity of the injection area, as these wells can be subject to similar forces.

For most monitoring wells, bentonite pellets or chips will be used as the seal material up to 2 ft bgs. Bentonite chips or pellets will be poured into the annulus at a rate no greater than 3 minutes per standard sack.

2.4.1.4 Surface Completion

A concrete surface seal and a well monument will constitute the surface completion. The concrete surface seal will be placed in the upper 2 ft of the boring. The monument will consist of an aboveground protective steel casing or a flush-mount monument.

For aboveground completions, a 6-inch-diameter steel protective casing, with a locking lid will be installed around the PVC well casing. It will extend no more than 6.5 inches above the top of the well casing and at least 2 ft bgs. A concrete pad will be poured around the steel monument. The protective aboveground casing will be set over the well such that the portion embedded in cement is greater than or equal to one-half the protective casing length, if possible. Sand will then be added inside the monument to 6 inches below the top of the well PVC. The pad around the well will be 6 inches thick, approximately 2 ft by 2 ft, sloped away from the well, and extend at least 3 inches bgs. Three metal posts (i.e., bollards), at least 3 inches in diameter, and painted with high-visibility paint (usually bright yellow) will be placed around each well or group of wells. The posts will be set in individual holes filled with concrete. If the posts are hollow, they will be filled with concrete after placement in the ground. The posts will not be placed in the concrete pad surrounding the protective casing. Keyed-alike locks for the wells will be obtained from the Boeing representative.

In areas where activity or traffic precludes the use of aboveground protective casings, flush-mount casings (minimum of 6 inches in diameter) will be used. The top of the flush monument will be at least 1 inch, but not more than 2 inches above the surrounding surface grade to allow for drainage away from the well location. A concrete pad is not required if the monument is installed in asphalt or concrete; however, a concrete pad will be installed around monuments set in soft surfaces such as gravel, dirt, or grass. No metal posts will be required for protection.

For injection wells, surface completions will be as follows:

- Wells will be completed in 8-inch diameter flush-mounted monuments with gasketed lids and bolts.
- Within the monument, injection wells will be completed with a 2-inch, PVC, male pipe thread adapter connected to a 2-inch, galvanized steel, threaded coupler. A lockable, expanding plug will be used to close the well casing. A 2-inch galvanized steel nipple with an aluminum female cam lock (by female threads) will be threaded into the coupler for injection. Well casings must be centered within the monuments. The pipe thread adaptor and attached coupler will be glued to the well casing to create a pressure-tight connection for injection; both surfaces should be primed but glue applied to outside of casing only (not inside of fitting) to avoid dripping of excess glue down the well casing.

2.4.2 Multi-level Monitoring Well Construction

Solinst® continuous multichannel tubing (CMT) multi-level wells may be used to monitor multiple groundwater zones from a single well. CMT wells are constructed from a single polyethylene tube with six channels running internally along its length and one cylindrical channel running down the center of the tubing. Each channel is completely separate from all other channels and screens are placed at specified depths in each channel to facilitate sampling from multiple groundwater zones.

Multilevel wells are assembled aboveground then inserted in the boring before the casing is retracted. Construction consists of creating intake ports in the various channels at the desired depths, installing watertight expansion plugs below each intake port, adding mesh screens, pre-grouting each channel segment below the screen, and sealing the bottom of the tubing with an additional expansion plug. The wells can be constructed on site if space is available or constructed off site and transported to the borehole location for installation. CMT wells are constructed in accordance with the Solinst CMT Multilevel System Assembly Manual (Appendix A; Solinst website 2016). Prior to installation, the outer CMT channels are grouted from below the sampling port to the bottom of the well. The purpose of pre-installing grout is to facilitate later decommissioning of the well by grouting instead of over drilling. Grouting is completed in accordance with the procedures described in the Solinst CMT Decommissioning Manual and Purge/Grout Adaptor Operating Instructions (Appendix A).

2.4.2.1 Well Layout

Before constructing the CMT well, sketch the well design; a template generated by Landau Associates, Inc. (LAI) is available for this purpose (Appendix B). This sketch may be a useful reference during construction and installation. Once the well is designed, mark the locations of the sampling ports on the CMT tubing by following these steps:

1. Lay out an appropriate length of plastic sheeting on the ground and uncoil the CMT tubing.
2. Cut the appropriate length of well tubing, while leaving additional length as “working” tubing to assist in handling of the well during installation.
3. Identify the anticipated location of the top of the well and mark it on the tubing.
4. From this point, measure the depth bgs where the Channel 1 sampling port will be assembled. A low profile repetitive marking “<< CMT >>” runs along the length of one of the channels, which designates Channel 1. By convention, Channel 1 is installed in the shallowest monitoring zone and the channels increase in number and depth clockwise around the tubing with the final and deepest port installed in the center channel, Channel 7.
5. Mark the anticipated center of the screen for sampling Port 1.
6. Draw a line parallel along the channel at least 6 inches above and below the depth mark to help guide the port cutting tool.
7. Make similar markings on Channels 2, 3, 4, 5, and 6 at the desired depths. The screen for Channel 7 is part of the well cap anchor and attaches to the bottom of the tubing.

2.4.2.2 Well Material and Tools

CMT wells are constructed with 1.7-inch-diameter polyethylene Solinst CMT, wire mesh screens, Oetiker clamps, expansion plugs, an end cap that also contains the central well screen, and a well cap. Tools needed for construction are a measuring tape, a PVC cutter, a marking pen, and a CMT installation toolkit (available from Solinst, which includes a port cutting tool, a hex wrench, snips, Oetiker clamp pliers, a 10-inch-pound torque driver, and a small Allen wrench). Supplies needed for pre-grouting are Nittetsu superfine cement with "Mighty 150" superplasticizer (available at Surecrete in Seattle, Washington), a grout adapter, grout plugs, hex plugs, and an internal O-ring (available from Solinst).

2.4.2.3 Sample Port Construction

The openings for the sampling ports are cut into each channel and wrapped with a wire screen. Construct the sample ports by following these steps:

1. Slide the port cutting tool over the tubing to Port 1 in line with Channel 1.
2. Align and center the cutting tool with the channel tracing. Hand-tighten the locking bolts on the back of the cutting tool to secure its placement.
3. Use the hex wrench to tighten the cutting bolts until they "bottom out."
4. Use the snips to cut away the exterior wall of the channel between the top two holes (the bottom hole is a vent for the pre-grouting). The distance between the cutting tool-generated holes is only 3 inches, so if the well design is for 6-inch screens, move the port cutting tool down the tubing another 3 inches and cut an additional hole for the pre-grouting vent. It is very important to snip with care, as any perforation of the channel walls will allow groundwater cross-connection between channels.
5. Once the channel wall between the cutting tool holes is removed, insert an expansion plug into the channel at the bottom of the area to be screened to seal the sampling port from the lower, pre-grouted section of tubing. Tighten the plug with the torque driver.
6. Center the wire mesh over the port opening and wrap it tightly around the tubing, and secure it at both ends with an Oetiker clamp. Construction of Port 1 is now complete.
7. Continue down the tubing and construct sampling Ports 2 through 6 in the same manner.

2.4.2.4 Pre-grouting

As an additional security measure, and to make future well decommissioning easier, grout each channel of the CMT below the sampling port prior to installation. Grouting the unused void below the port prior to installation ensures that, when the well is decommissioned through grouting in-place, the full length of the CMT well will be filled with grout. Pre-grout the channels by following these steps:

1. Insert the expanding hex plug into the center channel (Channel 7) to prevent Channel 7 from being grouted.
2. The pre-installation grout mixture comprises superfine cement and superplasticizer. Superplasticizer reduces the rate at which the concrete absorbs water, increasing the amount

of time available to work with the grout before it sets (typically 15-30 minutes depending on the amount of superplasticizer used). To estimate the volume of grout needed, keep in mind that the volume of each of the outer six channels is 40 milliliters per foot (mL/ft) and the volume of the center channel is 30 mL/ft.

3. Prepare an initial mixture of 2:1 grout to water, add 1 ounce of superplasticizer per gallon of grout (or approximately 4 percent by weight of cement). The grout should be thin enough to pump through the 1/4-inch tubing but not so thin that it pools in the bottom of the channels. Using a Marsh funnel and mud balance to measure the viscosity and weight of the grout mixtures to create a record of successful grout properties for grouting future wells is advised. Through experience, it has been discovered that a 100 ft well uses 12, 32-ounce measuring cups of cement; 6, 32-ounce measuring cups of water; and 15 ounces of superplasticizer. The grout is the correct viscosity when a full Marsh funnel empties in 2 to 2 1/2 minutes. It is best to use a fine screen to remove clumps when mixing the cement into the water. This will help the grout to mix more evenly and without lumps that can clog the channels.

4. Move quickly to pumping the grout before it starts to thicken. Solinst provides a grout adaptor that connects the CMT tubing to the grout hose; this allows the six outer channels to fill simultaneously from the bottom of the well (Appendix A). Typically, grout is pumped using a diaphragm hand pump; however, other pumps can be used if needed.

5. Be sure the pressure relief valve (25 pounds per square inch) on the grout adaptor is unrestricted. In the event that the channel is blocked, it is possible to continue grouting by inserting 1/4-inch tubing down from the top via the vent hole (for this reason, it is advisable to have some 1/4-inch tubing and an adaptor available to connect it to the selected pump).

6. When a channel is full, grout will be expelled from the vent hole. Shut off the pump and plug the vent hole with bentonite and plastic plugs provided by Solinst. Grout may leak from the plug, so be sure that the screens are free of grout by covering or elevating the screens.

7. Repeat procedure for all outer channels (Channels 1 through 6). Once Channels 1 to 6 are pre-grouted, insert the expansion plugs into the bottom of the channels and tighten with the torque-driver.

8. Attach the well cap anchor to the bottom of the CMT tubing to complete Channel 7 and secure it with Oetiker and hose clamps.

2.4.2.5 Transporting the Well

If it is not possible to build the well on site, the well must be transported from the assembly location to the borehole location, which can be accomplished by coiling the well around a large spool. During transport to the site, it is possible that the pre-grouted channels may leak around the plugs and impact the sampling ports and associated screened sections. To minimize this potential, keep the screened sections covered and ensure the screens are clear before installation.

2.4.2.6 Installation

Lower the assembled CMT well into the borehole slowly. Backfill the annular space between the CMT and the borehole wall with filter sand pack (screened sections) and bentonite pellets (intervals between screened segments) as designated on the well design. Sand filter packs are 3 to 4 linear ft of 10/20 or 20/40 silica sand centered on each sampling port. Backfill with bentonite pellets between sand pack intervals. Coated bentonite pellets are the preferred annular seal material in order to delay dehydration of the bentonite and allow additional time to frequently check the height of the pellets in relation to the screens. The bentonite should be poured into the annulus at a rate no greater than 3 minutes per standard package of bentonite chips. Continuously measure the depth of materials in the annular space to ensure placement at the correct depth and to minimize the potential for bridging. Bentonite chips or pellets above the water table should be hydrated after placement.

As described in the conventional well installation section of this SAP, the well seal will extend to approximately 2 ft bgs followed by a surface completion. To minimize the curvature of the tubing at the top of the well, install a length of 2-inch PVC as a straightening sleeve at the top of the CMT that extends a maximum of 5 ft bgs. The top of the PVC should line up with the top of the well. Use a level to ensure that the straightening sleeve is even and cut the top of the CMT tubing to the final elevation. If the tubing is not level, each individual channel may need to be surveyed. A well cap with numbered channel identifiers should be installed to identify the channels corresponding to the individual sampling ports. Surface completion should be done using the same guidelines as described for conventional wells (Section 2.4.1.4).

2.5 Well Development

The purpose of development following installation is to improve the hydraulic connection between the well and the formation to facilitate collection of representative groundwater samples. The goals of well development include creating an effective filter pack around the screen, rectifying damage to the formation caused by drilling, removing fine particles (silt and clay) from the formation near the borehole, and assisting in restoring the natural water quality of the aquifer near the well. To accomplish these goals, well development stresses the formation around the screen and filter pack so that mobile silt and clay are drawn into the well and removed to facilitate the collection of samples at an acceptably low turbidity level. Additional well development is completed for injection wells to facilitate extracting groundwater and injecting bioremediation amendments with as little resistance to flow as possible. Well development procedures for conventional monitoring wells, multilevel wells, and injection wells are outlined below. All water removed from the wells during development will be contained and disposed of as described in Section 11.0.

Well development may begin no sooner than 24 hours after installation to allow bentonite seals to cure. The depth to water and total depth of the well will be measured before and after well development. The drilling contractor or LAI will perform the development. Well development performed by the drilling contractor, will be overseen by an LAI geologist. Well development and general well information will be documented on a well development log as described in Section 2.6.3. The groundwater depth should be recorded after the groundwater has had adequate time to recover. Depending on the diameter of the pump intake hose, it may not be possible to measure the groundwater depth during pumping. Development procedures for each type of well are listed below;

procedures may be modified in the field as conditions warrant and as approved by the project manager.

2.5.1 Conventional Monitoring Wells

1. Use a weighted 1.5-inch-diameter PVC or stainless steel bailer with a ceramic-ball check valve to remove sand and fines from the bottom of the well casing. Carefully lower the bailer to the bottom of the well and gently raise and lower it collect the fines. Withdraw the bailer from the well and pour out (rinse if necessary) the fines and purged water. Repeat until no more sediment is retrieved from the bottom of the well.
2. Surge the well screen interval with the bailer or a surge block several times.
3. Pump water from the well using a centrifugal pump or airlift. Raise the pump intake incrementally to remove turbidity through the entire screened interval. Periodically record the pumping rate and the turbidity of discharged water. Continue pumping water from the well until the turbidity is significantly reduced.
4. Again, surge the well with the bailer or a surge block.
5. Measure and record the total depth of the well. Evaluate whether fines are present in the bottom of the casing.
6. Pump again and continue pumping until the well yields water with a turbidity of 50 nephelometric turbidity units (NTUs) or until a minimum of 10 casing volumes have been pumped from the well. If water was added to the well during drilling, a minimum of 200 percent of the volume of water added to the well must be purged during development. Record the final turbidity of the well on the well development log.

2.5.2 Multi-level Monitoring Wells

1. Insert the dedicated 1/4-inch (outer diameter) Teflon® tubing into each channel. Due to the narrow nature of CMT wells, it is very difficult to remove tubing from a CMT well if it slips down below the top of the channel; thus, tubing should be longer than the full length of the well by no less than 5 ft.
2. Pump water from the well using a peristaltic pump. During the purge, lower the intake of the tubing incrementally throughout the screen section in a surging-like motion in order to maximize the mobilization and removal of fines. Periodically record the turbidity of discharged water.
3. Continue pumping until reaching a turbidity of 50 NTUs or until a minimum of 10 casing volumes have been pumped from each well channel. Record the final turbidity of the well on the well development log.
4. Measure and record the total depth of each individual well channel and the static water level. Due to the narrow nature of the CMT wells, the Solinst multi-level water-level indicator will be required. Evaluate whether fines are present in the bottom of the casing.

2.5.3 Injection Wells

The general goal for injection well development is to purge water at or above the planned injection/extraction rate for a given well with the final purge water having a NTU value of less than 50.

This is accomplished by alternating mechanical surging to mobilize fines followed by purging groundwater at a high flow rate. Due to geologic formation limitations, it is not always possible to develop an injection well to the point that the purge rate exceeds the planned injection rate.

1. Calculate the casing volume and estimated purge volume[1]. Final purge volumes will be performance based and communicated to the project manager.
2. Remove sand and fines from the bottom of the well casing using a weighted 1.5-inch-diameter PVC or stainless steel bailer with a ceramic-ball check valve. Carefully lower the bailer to the bottom of the well and gently raise and lower it to collect the fines. Withdraw the bailer from the well and pour out (rinse if necessary) the fines and purge water. Repeat until no more sediment is retrieved from the bottom of the well.
3. Surge the well screen interval with a surge block 10 to 15 times for each 5 ft length of screen. The surge block should be appropriately sized and fitted with a rubber gasket tight enough to the inside of the well screen to generate a pressure wave that loosens silt within the sand pack and screen slots. The surge block can be operated manually (by hand), or by specialized vehicles outfitted for well development.
4. Pump water from the well using a centrifugal pump capable of at least 290 gallons per minute (gpm) under zero head conditions[2]. The pump capacity should be scaled up as project conditions require. During the purge the intake of the hose should be lowered incrementally throughout the screen section and, on occasion, quickly raised and lowered in a surging-like motion in order to maximize the mobilization and removal of fines. Periodically record the pumping rate and the turbidity of discharged water. Continue pumping water from the well until the turbidity is significantly reduced, stabilized, or until the well goes dry, whichever comes first.
5. Repeat steps 4 and 5 above until the well yields water during pumping with a turbidity of less than 50 NTUs. If NTU values stabilize above this 50 NTU goal, contact the project manager.

2.6 Drilling and Well construction/Development Documentation

A field geologist will maintain detailed records of drilling and well installation and development activities. These records will consist of soil boring and well installation and development logs, information recorded in field notebooks, and driller's daily field reports. Field forms including examples of the field logs and development sheets are included in Appendix B.

2.6.1 Soil Boring Logs

A qualified geologist will log soil borings using the form provided in Appendix B, or an equivalent. Log entries will include the following:

- Boring location.
- Dates and times of drilling.

[1] Based on results of the summer 2015 Algona pilot test, the estimated purge volume for this project could range from 200 to 550 gallons.

[2] A 3-inch diameter, 8 horsepower trash pump is adequate for this purpose, as was used during the summer 2015 Algona pilot test, in which purge rates ranged from 20 to 40 gpm.

- Drilling equipment such as type of rig, size of bits, drill rod designations, and sampler types.
- Boring dimensions.
- Stratigraphy – descriptions of soil will be according to the Unified Soil Classification System. Descriptors will include soil composition, density, color, approximate percentages of grain sizes present, and a qualitative estimate of moisture content. Deep wells may include identification of the OM deposit.
- Sample depths.
- Depth to groundwater.
- Additional sample features such as odor, the presence of volatile organic compounds (VOCs) [based on screening with a photoionization detector (PID)], non-native debris, and the presence of free product if present.

2.6.2 Well Construction Logs

A graphic log (example in Appendix B) showing well construction details will accompany each boring log. Construction logs will include the following:

- Well location and designation (Water Table, Shallow, Intermediate, Deep, or Multi-level)
- Date completed
- Boring dimensions
- Ecology Well Tag ID Number
- Well screen and riser pipe material descriptions and lengths
- Composition and depths of filter pack materials, bentonite well seal, and surface concrete
- A description of the surface monument and protective mechanisms.

2.6.3 Well Development Logs

Well development logs will contain the following information:

- Well location and designation
- Screened interval and casing diameter
- Date and time of development
- Weather conditions
- Static water levels measured before and after development
- Total depth of well before and after well development
- Volume of water in the well casing
- Descriptions of development equipment (pumps, surge blocks, hose/tubing diameter, etc.)
- Descriptions of water quality measurement equipment
- Equipment calibration data

- A record showing water volumes purged from the well, purge rates, water quality parameter measurements (turbidity), and presence of fines in the bottom of the well.

2.6.4 Field Screening Documentation

As described in the health and safety plan (HASP), the onsite geologist will use a PID to monitor the field staff breathing zone for volatile organic gases. If action levels exceed the levels listed in the HASP, drilling will be discontinued. Drilling will proceed only when volatile organic gas concentrations have returned to an acceptable level.

Headspace analysis, if required by the work plan, will be conducted on a sample from each soil core at each boring location. Headspace analysis is performed by collecting a small amount of soil in a clean Ziploc® bag, sealing the bag, breaking up the soil and letting it sit for 2 to 5 minutes, and then screening the headspace in the bag for VOCs using a PID. All field screening results will be entered in the comments section of the soil boring logs.

2.6.5 Daily Driller's Report

The driller will prepare and maintain a field drilling report on a daily basis. The drilling report will specify the amount of hours worked, material used, unusual problems, and other special comments and observations. The driller will provide a copy of the log for approval to the onsite geologist at the end of each day.

3.0 GROUNDWATER SAMPLING

LAI will conduct groundwater sampling described in the current site-wide groundwater monitoring plan. Samples will be collected from all new monitoring wells. The first round of samples will be collected no sooner than 5 days after development of the new conventional wells; the first round of samples will be collected no sooner than 14 days after development of new multi-level wells, where drilling water was added.

3.1 Well Depth and Static Water Level Measurement

Before sampling begins, the static water level of each well, or well channel (for multi-level wells), will be measured with a water level indicator. The static water level in multi-level well channels will be measured with a specialized water level indicator. The probe and attached tape for all water level indicators will be thoroughly rinsed with de-ionized (DI) water and wiped with a clean towel before use in each well or individual well channel. The water level indicator will be constructed of chemically inert materials to prevent damage of the equipment and cross-contamination between wells.

After the well cap is removed (but prior to removal or significant disturbance of down-hole sample tubing or passive sampling devices), the depth to water will be measured by slowly inserting the water level indicator probe into the well casing. As the probe enters the water, a buzzer and indicator light will be activated. The probe will be gently inserted into and retracted from the water surface so that the water surface can be determined accurately. The depth at which the water level buzzer and light activate represents the groundwater surface. The graduation mark on the water level tape adjacent to the reference mark on the rim of the PVC well casing represents the depth to water. After initially determining the depth to water, the probe will be re-inserted to re-check the measurement. This measurement will be recorded on the groundwater sampling form to a precision of 0.01 ft.

3.2 Passive Diffusion Bag Sampling

Conventional 2-inch, PVC groundwater monitoring wells can be sampled for VOCs using a passive diffusion bag (PDB). The PDBs typically arrive from the laboratory pre-filled with DI water. Once the PDB is submerged in groundwater within the well screen, molecules diffuse through the semi-permeable membrane of the PDB until equilibrium with the surrounding groundwater is reached. Water in the PDB reaches equilibrium with the surrounding groundwater within approximately 2 weeks, depending on flow conditions.

The depth to groundwater should be measured before removing the PDB from the well. The PDB should then be removed slowly from the well to avoid excessive disturbance of the water column in the well. Once the PDB is removed from the well, it is sampled by using a sharp plastic straw to puncture the PDB, and then pouring the water into the sample containers. Water that remains in the PDB after sample containers are filled is drained into a bucket, and, as a part of standard Boeing protocol, is disposed of in accordance with Boeing's current groundwater waste profile. Unlike conventional sampling methods, the well is not purged, and field parameters are not collected. The empty PDB can be discarded as municipal solid waste, and a new PDB can be installed at this time if the well is scheduled to be sampled again within approximately 1 year.

3.3 Low-Flow Purging

Low-flow sampling minimizes disturbance to the aquifer during groundwater sample collection. The low pumping rate induces laminar flow in the immediate vicinity of the sampling pump intake; thus, drawing groundwater horizontally from the aquifer and into the sampling device.

Purging and sampling will be performed using a peristaltic pump with dedicated polyethylene or Teflon tubing. Conventional wells will have dedicated tubing that is stored in the well. Multi-level wells will have dedicated 1/4-inch tubing that may be stored in labeled Ziploc bags between sampling events. Tubing cannot be stored in some multi-level well channels because it would prohibit closing the well cap or inserting the water level indicator probe. To avoid cross contamination, when removing or inserting the dedicated tubing, it is important that the tubing does not touch the ground surface or other objects. The downhole end of the tubing will be cut at an angle to distinguish it from the sampling end.

The end of the sample tubing will be positioned at 2 to 3 ft above the bottom of the well or within the well screen for CMT wells. For wells screened across the water table, the end of the sample tubing will be positioned approximately 1 ft below the surface of the water table. Care will be taken to gently insert the tubing to minimize disturbance of any sediment that may have accumulated in the well. Purging will proceed by pumping groundwater from the well at a rate of approximately 0.5 liters per minute (L/min). The flow rate will be measured by filling a 1-liter (L) container and measuring the rate of filling using a stopwatch. Some wells may need to be pumped at slower rates to avoid drawdown of the water column within the well.

Specific conductance, temperature, dissolved oxygen (DO), oxygen reduction potential (ORP), pH, and turbidity will be measured during purging using field meters. In-field measurements will utilize a flow-through cell. The field meters will be calibrated each morning before sampling in accordance with the manufacturer's instructions. All in-field measurements made during purging will be recorded on a groundwater sampling sheet at intervals of approximately 3 minutes. When readings have stabilized over three measurements, purging may cease and samples may be collected. Stabilization is reached when three successive readings are within ±0.2 standard units for pH, + 1 degree Celsius (°C) for temperature, and +10 percent for other parameters. If one or more of the readings have not stabilized within 30 minutes, samples will be collected and the unstable readings will be noted on the sampling form. Purge water will be contained in 5-gallon buckets dedicated to the site and transported back to the drum storage area.

3.4 Sample Collection and Analyses

Groundwater samples will be collected after water quality parameters have stabilized during low-flow purging. The pump will not be turned off for an extended period of time nor will the pumping rate be changed between the purging and sampling process. Samples that do not require filtering will be collected into the laboratory-provided sample container directly from the end of the sample tubing. Sample bottles for volatiles analyses will be filled with no headspace, while avoiding overfilling that would dilute the preservative.

Samples collected for dissolved metals analysis will be field-filtered. An in-line, nitrocellulose, 0.45-micron cartridge filter (Cole-Parmer Model 29600-00 or equivalent) will be attached to the sample discharge line. Groundwater will be passed through the filter for approximately 1 minute prior to filling the sample bottle. The bottle will then be filled directly from the discharge outlet on the filter. The bottle will be filled to just below the neck to prevent overfilling and loss of the sample preservative.

All samples will be stored in coolers with ice and transported using proper COC procedures to Boeing's contracted laboratory [Lancaster Laboratories, Inc. (LLI) in Lancaster, Pennsylvania at the time of this report]. Additional information regarding proper COC procedures is included in Section 10.5 of this report.

4.0 SOIL SAMPLING

Occasionally, releases of hazardous materials or petroleum products may occur at the facility or historical releases may be encountered during construction. These releases often comprise oils, cutting fluid, or metals used in the machining process and are typically limited to shallow soil. Upon Boeing's request, LAI will be on site to oversee soil sampling and removal as necessary.

If soil excavation is required, field screening (headspace analysis, sheen testing, visual observation of color and staining, and/or observation of odor) will be used to guide the extent of excavation. Headspace analysis is performed by collecting a small amount of soil in a Ziploc bag, sealing the bag, breaking up the soil, and letting it sit for 2 to 5 minutes. The tubing from a PID is then inserted into the Ziploc bag, the bag is resealed around the tube, and the highest reading for each compound measured by the PID is recorded. Sheen testing is performed by agitating a small volume of soil in a stainless steel bowl with clean water to see if a sheen is generated.

Soil samples will be selected from the most impacted zone as indicated by field screening or from directly above the water table when drilling when there is no evidence of contamination. Samples will be collected from the excavation base and side walls or from soil in an excavator bucket using the jar and clean, stainless steel sampling spoons. Sampling spoons will be cleaned between samples using an Alconox® wash, tap water rinse, and final DI water rinse. All samples will be collected in laboratory-provided containers appropriate for the analyses.

Soil samples for volatile constituents will be collected using U.S. Environmental Protection Agency (EPA) Method 5035A procedures. The procedures involve using a small coring device or open-ended syringe to collect an undisturbed soil sample of a specified weight, which is then placed in a pre-preserved VOA vial. This method minimizes loss of VOCs to volatilization during the sampling process. The contracted analytical laboratory will provide specific sampling equipment and instructions on how to collect the samples (e.g., sample quantity to for each VOA vial). EPA Method 5035A will not be used to collect samples of disturbed soil (such as drill cuttings) for waste disposal characterization because the method is intended to be used for relatively undisturbed soil.

Soil samples for non-volatile constituents including, but not limited to, metals, diesel-range petroleum hydrocarbons, polychlorinated biphenyls (PCBs), and semi-volatile organic compounds will be collected in laboratory provided jars of an appropriate size for the number of analyses being conducted. Care will be taken to collect an appropriately representative sample. Larger samples may be mixed in stainless steel bowls to homogenize the sample before collecting into sample jars. Sampling spoons and bowls will be cleaned between samples using an Alconox wash, tap water rinse, and final DI water rinse. Soil analyses will depend on the nature of the release.

All samples will be stored in coolers with ice and transported using proper COC procedures to Boeing's contracted analytical laboratory.

5.0 AIR SAMPLING

Air sampling procedures presented in this section are applicable to aboveground samples collected from, indoor air, crawlspaces, ambient air, and other indoor and outdoor locations where air sampling is desired. Current applicable air sampling guidance for Washington State[3] will be used to supplement these procedures and for determining procedures, such as the sample duration, locations, and procedures specific to the particular building being sampled. Air samples may be collected in various methods and sample containers such as Summa canisters, passive diffusive samplers, Tedlar® bags, and sorbent tubes. The two most commonly used methods of sample collection at this site (Summa canister and passive diffusive sampling) are discussed in the following sections.

For all air sampling methods, atmospheric conditions during the sampling period will be collected. Conditions including temperature, barometric pressure, wind direction, wind speed, and precipitation totals, will be recorded using a combination of publicly available meteorological data from the nearest weather station, and information collected from the specific buildings (if applicable) regarding average indoor temperatures.

5.1 Summa Canister Sampling

Summa canisters are evacuated stainless steel canisters that use vacuum pressure and a flow controller to collect air over a specified time or at a specified rate. The canisters are reused, cleaned, and certified by the laboratory after each sampling event. Summa canisters can be used to collect many types of air samples including indoor air samples and ambient air samples.

The procedure for indoor air also applies to crawl space and basement air sampling. Indoor air sample locations will be 8-hour, 10-hour, or 24-hour (dependent on exposure scenario) time-weighted average (TWA) samples. The TWA samples will be collected using 1-L or 6-L laboratory-certified evacuated Summa canister depending on the desired reporting limits. Each laboratory is certified for different reporting limits depending on the analytical method, the size of the canister, and the residual vacuum in the canister after sampling. Required certification (batch or individual) of each canister is also dependent on the analytical method. Always communicate the desired reporting limits for each constituent and discuss appropriate analytical methods, sample containers, and certification with the laboratory prior to placing a canister order. Each Summa canister will be equipped with a pressure gauge that indicates the vacuum pressure inside the canister and a flow controller that regulates the air collection rate. Duplicate samples require a co-locator attachment from the laboratory. Canisters will be clearly labeled with signs indicating the purpose of the canisters and that the canisters are not to be interfered with or moved.

Indoor air canister intakes will be set-up in accordance with the typical activities and breathing height of the receptors in the area being sampled. For example, in a home, the canister may be placed at the

[3] Guidance in effect at the time this report was prepared was draft guidance from Ecology (Ecology 2009).

level of a sitting receptor if the area is primarily used as a sitting room or at the height of the bed in a bedroom.

Ambient air samples will be set-up outside the building either at the air intake for a heating, ventilation, and air conditioning system (if the system only takes air in) or upwind of the building as high as reasonably possible to represent air quality at heights representative of building intake locations. If ambient air samples are placed upwind of the building of interest, the final location will be selected at time of sampling and the canister inlet valve will be placed at a height greater than or equal to 5 ft aboveground.

The TWA Summa canisters will be evacuated to a vacuum pressure of 25 to 30 inches of mercury (in.Hg.) by the laboratory. Record the initial pressure on the vacuum gauge before opening. A final vacuum pressure reading greater than ambient (i.e., 0 in.Hg.) indicates a valid sample; however, canister closure will be targeted for a vacuum pressure of 5 in.Hg. to provide a margin of safety. Canister pressures will be checked within 1 to 2 hours after beginning sampling to evaluate whether airflow controllers are functioning properly. Any canisters observed to have a faulty flow controller will be replaced with a backup canister and flow controller.

Summa canisters will be shipped using the original shipping packaging under COC procedures to Boeing's contracted air laboratory [Eurofins Air Toxics, Inc. in Folsom, California at the time of this report]; air COCs include initial and residual vacuum pressures, Summa canisters and flow controller IDs, analytical methods, and other applicable information.

5.2 Passive Diffusive Sampling

Passive diffusive samplers provide a TWA sample over a longer time period such as 21 days. The most common sampler type for trichloroethene is the Radiello® sampler; specifically model 130 (R130). A Radiello sampler consists of a diffusive protective body made of porous polypropylene in which a cartridge of adsorbent media is inserted. Due to the narrow and cylindrical (radial) design of the adsorbent cartridge, the uptake rate is at least three times that of axial diffusive sampling designs. The type of adsorbent is selected based on analytic needs.

Sample collection will use the following protocol:

- Immediately prior to placement at the planned sample location, the adsorbing cartridge will be removed from its protective packaging and placed in the previously assembled Radiello supporting plate/diffusive body. The identification label associated with each adsorbing cartridge will be attached to the supporting plate and the ID information will be recorded on the sample collection form. During assembly, nitrile gloves will be worn to minimize any potential contamination of the adsorbing cartridge.
- After the sample period is complete, samplers will be retrieved from the sample locations. At the time of removal, the adsorbing cartridges will be placed back in the original protective

tube and the adsorbing tube ID label will be placed on the protective tube; such that the barcode is parallel to the axis of the tube.

The sample stop date and time, to the nearest minute, will be recorded on the sample collection form. Samples will be kept cool, but do not need to be chilled on ice. Completed sample containers will be shipped under COC procedures to Boeing’s contracted air laboratory.

6.0 SOIL GAS SAMPLING

Soil gas samples may be collected from borings outside of a building footprint or directly below building slabs (i.e., sub-slab). These sampling methods are described below.

6.1 Soil Gas Sampling from Borings

Soil gas sampling can be conducted from shallow borings at discrete depths. Borings can be advanced using a mechanized drill rig (DP probe or other) or hand tools.

6.1.1 Direct Push Post-Run Tubing Setup

If using a DP drill probe to conduct soil gas sampling, specialized tooling called post-run tubing (PRT) can be used for soil gas sample collections. The PRT setup comprises probe rods, an expendable drive point and point holder, PRT tubing adapter (connects sample tubing to holder), and either Teflon or Nylaflow® sample tubing. After the probe rod (with expendable drive point and point holder) has been driven to depth, the PRT tubing adapter is attached to the sample tubing and is fed into the probe rod. Once the bottom of the PRT tubing adapter reaches the bottom, it is connected to the point holder, which seals off the sample tubing from the air in the annulus of the probe rods. At the ground surface, the sample tubing can then be directly connected to the purge and sampling devices. The PRT tooling setup does not allow for a soil characterization sample to be collected; however, some soil cuttings may be generated. If the soil cuttings do not allow for adequate soil characterization, a second borehole may be driven adjacent to the soil gas sample boring to allow for additional soil characterization and evaluation of the depth of the groundwater table if needed. The detailed sampling procedures are listed below:

- The probe rod fitted with an expendable drive point and point holder will be driven to the targeted depth above the measured groundwater elevation.
- Dedicated soil gas sampling tubing and a PRT tubing adapter will be inserted into the drilling rod and connected to the expendable drive point holder.
- The rod will be pulled back 1 ft, leaving the expendable point at the bottom of the borehole. This will leave approximately 1 ft of borehole exposed from which the soil gas sample will be collected.
- A surface seal of hydrated bentonite or clay will be placed around the drill rod at the surface and leak checked to prevent intrusion of atmospheric air. Once the seal is constructed, a closed ball valve will be placed on the end of the sample tubing to allow the soil vapor to equilibrate without exposure to ambient air.

Once the seal is constructed, the sample location should be left undisturbed for a minimum of 30 minutes to allow for the soil vapor to equilibrate. A helium leak test, shut-in test, and purge should be conducted prior to sample collection. Appendix C presents detailed procedures for the helium leak test, shut-in test, purge, and sample collection.

Sample containers will be shipped using the original shipping packaging under COC procedures to Boeing's contracted air analysis laboratory of other appropriate air laboratory[4].

6.1.2 Vapor Implant Setup

The vapor implant setup can be used with any of method of borehole construction (mechanical or hand tool) and may be used either for soil gas or sub-slab sampling; instructions provided here are primarily for use as a soil gas sampling point. The vapor implant setup comprises a porous vapor implant, sand, dry granular bentonite, hydrated bentonite or cement, and either Teflon or Nylaflow sample tubing. After the borehole has been completed to the desired depth, any excess soil is removed and approximately 2 inches of sand is installed in the bottom of the hole. The vapor implant is attached to a length of sample tubing and installed at the bottom of the hole. Additional sand is used to create a filter pack around the implant, extending approximately 2 inches above the top of the vapor implant screen if space allows. A layer of dry granular bentonite is installed above the filter pack; ideally, this layer should be at least 2 inches thick if using hydrated grout to seal the remainder of the borehole. Hydrated bentonite grout or other annular seal material is placed above the top of the dry granular bentonite to the surface. At the ground surface, the sample tubing can then be directly connected to the purge and sampling devices with minimal potential for leakage and reduction of the dead volume that must be purged prior to sampling. The detailed vapor implant construction procedure is as follows:

- The borehole will be completed to the targeted depth above the measured groundwater elevation and the soil core removed.
- Two inches of sand will be installed at the bottom of the boring (less may be used if constructing the implant for a sub-slab vapor point). A dedicated vapor implant and sampling tubing (Teflon or Nylaflow) will be inserted into the boring.
- Sand will be installed around the vapor implant to approximately 2 inches above the top of the vapor implant. Two inches of dry granular bentonite will be installed above the filter pack. Hydrated bentonite grout will be installed to the surface.
- Once the seal is constructed, a closed ball valve will be placed on the end of the sample tubing to allow the soil vapor to equilibrate without exposure to ambient air.

Once the seal is constructed, the sample location should be left undisturbed for a minimum of 30 minutes to allow for equilibration. Following this equilibration period, a helium leak test, shut-in test, and purge should occur prior to sample collection. Appendix C presents the detailed procedures for the helium leak test, shut-in test, purge, and sample collection. Boreholes will be abandoned and sealed appropriately at the surface.

[4] H&P Mobile Geochemistry in Carlsbad, California was used during 2015 soil gas sampling.

Summa canisters will be shipped using the original shipping packaging under COC procedures to Boeing's contracted air laboratory; air COCs include initial and residual vacuum pressures, Summa canisters, flow controller IDs, analytical methods, and other applicable information.

6.2 Sub-Slab Sampling

Sub-slab soil vapor sampling is accomplished by drilling a hole through the slab, inserting a sample collection device, and sealing the hole around the sample collection device so that ambient air cannot enter the subsurface. Sample points may be constructed two ways, either by inserting a Cox-Colvin Vapor Pin™ (Vapor Pin) of approximately 3 inches in length into each core or by placing a vapor implant and sealing the hole with hydrated bentonite. The sections below describe the installation process for both the Vapor Pin and the vapor implant.

Once the seal is constructed, the sample location should be left undisturbed for a minimum of 2 hours to allow for equilibration. Following this equilibration period, a helium leak test, shut-in test, and purge should occur prior to sample collection. The detailed procedure for the helium leak test, shut-in test, purge, and sample collection is presented in Appendix C. Sample points will be abandoned and sealed appropriately at the surface.

Summa canisters will be shipped using the original shipping packaging under COC procedures to Boeing's contracted air laboratory; air COCs include initial and residual vacuum pressures, Summa canisters, flow controller IDs, analytical methods, and other applicable information.

6.2.1 Cox-Colvin Vapor Pin Setup

Vapor Pins are comprised of a barbed, stainless steel sample point fitted with an inert, compressible, silicon sleeve. Each Vapor Pin will be installed using a hammer and specialized installation tool to drive the Vapor Pin into a 5/8-inch-diameter vertical core within the slab. Driving the Vapor Pin into the core compresses the sleeve, creating a seal between the sample point and slab surface. Typically, slabs are thicker than 3 inches, so the bottom of the Vapor Pin will rest within the slab core, above underlying soil. After the Vapor Pin is installed, the end with a hose barb is exposed at the ground surface. A fitted cap will be attached to the barb to allow the sub-slab soil vapor to equilibrate without exposure to ambient air.

6.2.2 Vapor Implant Setup

Vapor implants are typically installed in a 1-inch-diameter vertical core within the slab; larger cores may be used, but are not anticipated for this sampling event. Vapor implants comprise a porous sampling tip and sample tubing placed in the core. Teflon or Nylaflow tubing may be used as sample tubing. The porous sampling tip should extend 1 to 2 inches below the slab. The void space around the sampling tip will be backfilled with drilling grade silica sand up to the bottom of the slab.

Granular bentonite will be used to seal the annular space between the sample tubing and the slab within the core. Two to three inches of dry bentonite will be placed on top of the silica sand. Tap water will be used to hydrate the top 1 inch of bentonite. Care will be taken to avoid getting water into the silica sand layer. Once the top layer of bentonite is hydrated, additional bentonite will be added and hydrated in 1 to 2 inch lifts until the bentonite is within 1/2 inch from the top of the slab.

7.0 SURFACE WATER SAMPLING

Surface water sampling will occur only after a period of no measureable precipitation over a 48-hour period. These criteria will minimize stormwater runoff contribution at sampling locations. If prolonged rainfall occurs during the sampling window, it may not be practical to wait 48 hours prior to sampling. If this is the case, Ecology will be consulted about sample time and sampling may occur within 48 hours of a rainfall event with permission from Ecology.

Sampling may be conducted using a composite liquid waste sampler (COLIWASA), dedicated tubing with a peristaltic pump, or dipper. The sample collection method will depend on water depth, accessibility, and availability of an electrical source. Samples will be collected no more than 4 inches above the bottom of the water column and at least 2 inches below the water surface, if possible. If less than 4 inches of water is present, the sample will be collected from the approximate mid-point of the water column. The approximate water column thickness will be recorded on the sample collection form for each sample. If adequate water is available, field parameters will be measured at the time of sampling and recorded on the surface water sample collection form (Appendix B). A multi-parameter probe (YSI 556 MPS) will be used to monitor the following field parameters: pH, temperature, and conductivity. Field parameters will be measured by submerging the instrument probe directly into the surface water or by pumping water through a flow through cell if using the peristaltic pump.

The COLIWASA is a rigid, hollow tube (i.e., bailer) with a stopper on one end and an open/close mechanism on the other. The COLIWASA is known as a depth discrete sampling method (EPA 2013, Byrnes 2009). A description of the COLIWASA sampler is presented in ASTM International (ASTM) Standard D5495. The COLIWASA is constructed of polypropylene, which will not react with VOCs. Additionally, each sampler is dedicated and will be disposed of after one use. Sampling procedures for the COLIWASA are as follows:

- With the stopper closed, lower the stopper end to the desired sampling depth; the stopper is then released and water from the desired depth fills the tube
- The stopper is then closed and the sampler is removed from the water
- An appropriate sample volume is collected from the COLIWASA and placed in the designated sample container
- The sampling process will be repeated until all sample bottles are filled for a particular location
- Once the sample is collected, any remaining water in the sampler will be discarded.

Where the water column thickness is less than about 4 inches, a stainless steel ladle will be used to collect the water quality sample. The ladle is known as a dipper sampling method (EPA 2013, Byrnes 2009). Sampling procedures for the ladle are as follows:

- The ladle will be dipped into surface water being careful not to stir up sediment.
- The ladle will then be decanted into the sampling container. This process will be repeated until all sample bottles are full.

- The ladle will be decontaminated (Section 9.5) and then reused at the next sample location.

Where sampling access is limited or water depth prevents use of the COLIWASA or dipper methods, a peristaltic pump and dedicated tubing will be used to collect the surface water sample. Sampling procedures for the pump and tubing are as follows:

- Dedicated sample tubing will be attached to a rigid pole to allow control of the sampling location and depth. The tubing intake will be placed 4 inches above the bottom of the water column.
- At the time of sampling, a field meter will be used to monitor field parameters using a flow-through cell.
- Field parameters will be allowed to stabilize. Once stabilized, replicate readings will be recorded on the sample collection form.
- Sample containers will be filled directly from the sample tubing.

All samples will be placed in laboratory-provided sampling containers. All samples will be stored in coolers with ice and transported using proper COC procedures to Boeing's contracted laboratory. S

8.0 SEDIMENT PORE WATER SAMPLING

A sediment pore water sample can be collected from a surface water body using an EON Sediment Diffusion Sampler canister (canister) placed directly into the sediment below the water column. The canister is approximately 20-inches long, 2 inches in diameter, and constructed of slotted PVC well casing with a riveted pointed tip and screw-top lid. A pre-filled PDB is inserted into the canister, and the entire assembly is placed directly into the sediment. The filled canister will be placed so the canister will remain fully submerged during the sampling. After the assembly has equilibrated for a sufficient period (minimum 2 weeks), the canister is removed from the sediment, the PDB is extracted from the canister and a sample is collected in accordance with the PDB sampling procedures (Section 3.2).

9.0 SUPPORT ACTIVITIES

This section describes various support and preparation activities related to well installation and groundwater sampling. Support activities for other types of environmental fieldwork will be described in work plans.

9.1 Utility Locates

No more than 2 weeks before any drilling or coring program begins, utility locates will be conducted. Each location will be marked in the field with white paint or a stake with flagging. A One-Call Utility Locate form will be filled out for each location (Appendix B) and the One-Call Utility Locate Service[5]. For locations within the facility or for other access-restricted areas, a meet time will be requested. The on-site Boeing representative will need to be present to escort the public utility locator on site. All utilities listed by the One-Call service will be contacted if specific markings are not visible within the requested locate radius around each boring. An additional private utility locator will be hired to clear each location.

9.2 Permits and Access Agreements

Right-of-way permits and property access agreements will need to be acquired from the appropriate municipalities and property owners before the drilling program can begin. Boeing and LAI will work collaboratively to facilitate such agreements.

9.3 Traffic Control

Traffic control procedures will be used at all locations where drilling activities will impact a roadway or walking path. Traffic control plans will be prepared, as needed.

9.4 Well Surveying

A licensed land surveying subcontractor will survey the horizontal and vertical coordinates of monitoring well locations. The vertical coordinates will be measured at the lip of the PVC well casing at the notched point that will be used for future groundwater measurements. Horizontal coordinates (x, y) will be measured to the nearest 0.1 ft and vertical (z) elevations will be measured to the nearest 0.01 ft. Horizontal coordinates will be measured in Washington State Plane south zone coordinates referencing the North American Datum 1983 (NAD83). Vertical elevations will be measured in National Geodetic Datum of 1929 (NGVD 29). Geographic coordinates of borings will be collected in the field using a handheld global positioning system unit. The accuracy of the global positioning unit is typically better than +/- 1 ft.

[5] Contact information for One-Call Utility Locate Service is the website: www.callbeforeyoudig.org/washington/ or call 1-800-424-5555.

9.5 Decontamination Procedures

Non-dedicated sampling equipment will be decontaminated between sample locations. Sampling equipment includes all devices that used to collect or contain a sample prior to placement into a laboratory-provided sample container, or used downhole in a well (e.g., water level indicator and depth sounding tape). Before initial use, sampling equipment that may contribute to the contamination of a sample must be thoroughly decontaminated, unless specific documentation exists to show that the sampling equipment has already been decontaminated. Pre-cleaned equipment and sample jars in factory-sealed containers do not require decontamination.

Decontamination will be performed according to the following procedure:

- Scrub equipment thoroughly with phosphate-free detergent (Alconox) and potable water using a brush to remove any particulate matter or surface film
- Rinse with potable water
- Final rinse with DI water
- Keep decontaminated equipment in a clean location to prevent recontamination.

10.0 SAMPLE HANDLING AND DOCUMENTATION

This section describes sample handling and documentation procedures. The procedures described are designed to provide a thorough record of events surrounding the collection of each sample and ensure that data collected in the field are usable.

10.1 Sample Labeling

Gummed paper labels which adhere strongly to glass or plastic will be used. Labels will be prepared with waterproof indelible ink and will include the following information:

- Project number
- Sample ID number
- Date and time of sampling
- Name(s) of sampling personnel
- Analysis and type of preservatives added.

To ensure a consistent sample tracking mechanism, each sample collected will be given a unique sample ID number using a consecutive numbering system or an alphanumeric system. The consecutive numbering system consists of five primary types: groundwater monitoring wells, surface water samples, borings, air samples, and test pits. The sample ID numbers derived from the consecutive numbering system will share the following general structure. In general, the sample ID number will include the Boeing Auburn site code (A), a location type (either GW for groundwater monitoring well, SB for soil boring, TP for test pit, SW for surface water), a consecutive number provided by Boeing, and a date or a depth (borings). For multi-level well water samples, the date will be preceded by the multilevel well channel and channel depth. For borehole water samples, the date will be preceded by the sample depth. Additional details and examples are provided in the following sections.

Field duplicate samples will share the following general structure. Field duplicate samples will be given fictitious sample ID numbers beginning with a 9 (900 series numbers for monitoring wells and surface water and 9000 series numbers for borings and test pits). No indication that the sample is a duplicate will be provided on the sample label or the COC form. A cross-reference of sample ID numbers for duplicates will be clearly recorded on the water sampling form or borehole log.

The following sections below describe the creation of the sample ID number, which will be used for samples collected throughout the project.

10.1.1 Groundwater - Conventional Wells

The sample ID for conventional wells will be created as follows:

- Site code for Boeing Auburn Plant (A)
- Location type: Groundwater monitoring well (GW)

- Well number (a three-digit consecutive number, assigned by Boeing)
- Date of sample collection by year, month, and day (20110603).

Thus, a groundwater sample collected from the Boeing Auburn Plant at groundwater monitoring well 125 on June 3, 2011, would be assigned the following sample ID number:

AGW125-20110603

A	GW	125	20110603
Boeing Auburn Plant	Location type (groundwater monitoring well)	Well number	Date: yyyymmdd

Additional example sample ID numbers for the Boeing Auburn Plant are as follows:

- AGW055R-20110918 represents a water sample collected from monitoring well 055R on September 18, 2011
- AGW900-20110918 represents a field duplicate collected at the same time as the above monitoring well sample.

10.1.2 Groundwater - Multi-level Wells

The sample ID for multilevel wells will be created as follows:

- Site code for Boeing Auburn Plant (A)
- Location type: Groundwater monitoring well (GW)
- Well number (a three-digit consecutive number, assigned by Boeing)
- Channel number (1-7)
- Screen depth (ft bgs)
- Date of sample collection by year, month, and day (20110603).

Thus, a sample collected from the Boeing Auburn Plant at multi-level groundwater monitoring well 201, from channel 2, from a depth of 30 ft, on June 3, 2011, would be assigned the following sample ID number:

AGW201-1-30-20110603

A	GW	201	2	30	20110603
Boeing Auburn Plant	Location type (groundwater monitoring well)	Well number	Channel number	Depth of screen (ft bgs)	Date: yyyymmdd

10.1.3 Groundwater – Injection Wells

The sample ID for injection wells will be created as follows:

- Location type: Injection well (IW)
- Well number (a two-digit consecutive number, assigned by Boeing)

- Date of sample collection by year, month, and day (20150603).

Thus, a groundwater sample collected from the Boeing Auburn Plant at injection well 37 on June 3, 2015, would be assigned the following sample ID number:

IW37-20150603

IW	37	20150603
Location type (injection well)	Well number	Date: yyyymmdd

10.1.4 Groundwater – Well Borehole Sample

Collect borehole groundwater samples from a boring during construction of a monitoring well. Borehole samples will have the bottom depth of the screen added between the well number and the date. For example, AGW183-30-20110505 is a borehole sample collected from the boring during construction of well 183. The sample ID indicates bottom of the screen at 30 ft bgs and sample collection on May 5, 2011.

10.1.5 Soil/Solid – Well Borehole Sample

This section describes the creation of the sample ID number used for soil samples collected during the installation of a monitoring well. The sample matrix could be asphalt, concrete, soil or other solid material, and will not be included in the sample ID number. The sample ID number will be created as follows:

- Site code for Boeing Auburn Plant (A)
- Location type: Groundwater monitoring well (GW)
- Well number (a three-digit consecutive number, assigned by Boeing)
- Sample collection depth in ft bgs.

Thus, a sample collected from the Boeing Auburn Plant during construction of groundwater monitoring well 183 at a depth of 6 ft bgs on August 5, 2011, would be assigned the following sample ID number:

AGW183-6

A	GW	183	6
Boeing Auburn Plant	Location type (groundwater monitoring well)	Well number	Depth (ft bgs)

Additional example sample ID numbers for the Boeing Auburn Plant are as follows:

- AGW081-5 represents a soil sample collected during construction of monitoring well 081 at a depth of 5 ft bgs
- AGW900-5 represents a field duplicate collected at the same time as the sample listed above
- AGW081-0.5 represents a sample of concrete from the surface to 0.5 ft bgs.

10.1.6 Surface Water and Pore Water Samples

The sample ID for surface water samples will be created as follows:

- Location type: Surface Water (SW), Pore Water (PW)
- Water Type (if necessary), for example, RD for roadside ditch; YP for yard pond
- Location number (for pore water samples this number would be the same as the co-located surface water sample)
- Date of sample collection by year, month, and day (20110603).

Thus, a surface water sample collected from the Boeing Auburn Plant at surface water location 19 on June 3, 2011, would be assigned the following sample ID number:

SW-19-20110603

SW	19	20110603
Location type (surface water)	Location number	Date: yyyymmdd

Additional example sample ID numbers for the Boeing Auburn Plant are as follows:

- SW-15-20110918 represents a surface water sample collected from location 15 on September 18, 2011
- PW-15-20110918 represents a pore water sample collected from co-located surface water sample location 15 on September 18, 2011
- SWRD-12-20130501 indicates a roadside ditch surface water sample collected in the project area from location SWRD-12 on May 1, 2013
- SW900-20110918 represents a field duplicate collected at the same time as the above surface water sample.

10.1.7 Borings

This section describes the creation of the sample ID number used for samples collected from a boring not completed as a monitoring well. Borings also do not include samples, which are hand augured. The sample matrix will not be included in the sample ID number, but will be recorded in the field logbook. Groundwater samples will include the date to distinguish them from soil/solids samples. The sample ID will be created as follows:

- Site code for Boeing Auburn Plant (A)
- Location type: Boring (SB)
- The boring number will be a four digit consecutive number, assigned by Boeing
- Sample collection depth in ft bgs.
- For water samples, the date of sample collection by year, month, and day (20110603).

Thus, a soil sample collected from the Boeing Auburn Plant at boring number 0827 at a depth of 12 ft bgs would be assigned the following sample ID number:

ASB0827-12

A	SB	0827	12
Boeing Auburn Plant	Location type (boring)	Boring number	Depth (ft bgs)

Additional example sample ID numbers for the Boeing Auburn Plant are as follows:

- ASB0273-0.2 represents a sample (e.g., concrete, asphalt, soil, etc.) collected from boring 0273, from a depth of 0.2 ft bgs
- ASB0273-15 represents a sample (e.g., concrete, asphalt, soil, etc.) collected from boring 0273, from a depth of 15 ft bgs
- ASB9000 represents a field duplicate collected at the same time as the sample listed above
- ASB9273-30-20110505 is a borehole groundwater sample collected with the bottom of the temporary screen at 30 ft bgs and sample collection on May 5, 2011.

10.1.8 Air Samples

This section describes the creation of the sample ID number which will be used for soil gas (collected outside of a building footprint), sub-slab soil vapor, indoor air (inclusive of crawl space/basement air), and ambient air samples. Sample identification will be as follows:

- Location type: soil gas (SG), sub-slab soil vapor (SSV), indoor air (IA), or ambient air (AA)
- The sample number will be a three digit consecutive number
- R for Radiello, if applicable
- Date of sample collection by year, month, and day (20110603).

Thus, a sub-slab soil vapor sample collected at sample location 003 June 3, 2011, would be assigned the following sample ID number:

SSV003-20110603

SSV	003	20110603
Location type (sub-slab soil vapor)	Sample number	Date: yyyymmdd

Additional example sample ID numbers are as follows:

- IA045-20120123 would represent an indoor air sample collected on January 23, 2012
- AA046-20120123 would represent an ambient air sample collected on the same day as the above sample
- IA046-R-20120123 would represent an indoor air sample collected using a Radiello sampler on the same day as the above sample.

10.1.9 Test Pits

This section describes the creation of the sample ID number used for test pits. Sample identification will be as follows:

- Location information

- Location type: Test pit (TP)
- Test pit number
- Date of sample collection by year, month, and day (20110603).

Thus, a test pit sample collected from the Boeing Auburn Plant Waste Water Plant number 4 collected on January 14, 2010 would be assigned the following sample ID number:

WWPTP-4-20100114

WWP	TP	4	20100114
Location information (wastewater plant)	Location type (test pit)	Test pit number	Date: yyyymmdd

Additional example sample ID numbers are as follows:

- WWPTP-1-20100114 would represent a test pit sample collected at the Waste Water Plant from test pit 1 on January 14, 2010
- WWPTP-2-20100115 would represent a test pit sample collected at the Waste Water Plant from test pit 2 on January 15, 2010.

10.1.10 Other Samples

This section describes the creation of the sample ID number, which will be used for samples not associated with borings, monitoring wells, test pits, or air sample locations (such as composites, drums, and stockpiles). The sample ID number will be determined in the field for specific quick response events. All samples not falling under the criteria listed above (groundwater monitoring wells, borings, test pits, or air sample) will begin with "AGR", followed by a building or solid waste management unit (SWMU) number, if applicable. The sample ID number will be created as follows:

- Site code for Boeing Auburn Plant (A)
- Location type other (GR)
- Building number with the 17 removed or SWMU number, if applicable
- Other descriptive information, if applicable
- Sample collection depth in ft bgs, if applicable.

Thus, a sample collected from the Boeing Auburn Plant at Building 17-07, from location B at a stockpile 1, from a depth of 3 ft bgs would be assigned the following sample ID number:

AGR07-SP-B-3

A	GR	07	SP01	B	3
Boeing Auburn Plant	Location type (all other samples)	Building no.	Stockpile	Location B at the stockpile	Depth (ft bgs)

Additional example sample ID numbers for the Boeing Auburn Plant are as follows:

- AGR34-SP01-A-0.5 represents a composite soil sample collected from location A, at stockpile 1 near Building 17-34, at a depth of 0.5 ft bgs

- AGR34-SP99-A-0.5 represents a field duplicate collected at the same time as the above sample.

The designated "SP" is for stockpile in this example. Other designations or words may be used as appropriate, for example, AGR34-DrumA or AGR34-PaintA.

When composite samples are collected, the Consultant Field Team Leader will ensure that the locations of sub-samples composited to form the project sample are clearly identified in the project field notebook.

10.2 Field Logbooks

Permanently bound field logbooks with waterproof paper will be used in the field because of their compact size, durability, and secure page binding. The pages of the logbook will be numbered consecutively and will not be removed for any reason. Entries will be made in waterproof indelible ink.

Logbooks will document the procedures performed by field personnel. Each entry will be dated, legible, and contain accurate and complete documentation of the individual's activities. Documentation in the field logbook will be at a level of detail sufficient to explain and reconstruct field activities without relying on recollection by the field team members. Because the logbook is a complete documentation of field procedures, it will contain only facts and observations. Language will be objective, clear, concise, and free of personal interpretation or terminology that might be misconstrued.

No erasures are allowed. If an incorrect entry is made, the information will be crossed out with a single strike mark and the change initialed and dated by the team member making the change.

Both electronic and paper copies of the field logbooks will be made and stored with the project files.

10.3 Sample Preservation and Handling

This section describes the preservation, handling, and storage requirements of sample containers.

10.3.1 Sample Containers

Water and soil samples [primary as well as quality assurance/quality control (QA/QC)] will be collected in glass or plastic containers supplied by the contract analytical laboratories. The containers will have screw-type lids to ensure the bottles are adequately sealed. Teflon inserts located inside the lids of the containers will prevent sample reaction with the lid and improve the quality of the seal. The sample containers will be pre-cleaned and certified under COC procedures. Commercially available, pre-cleaned containers are acceptable. The contract laboratories' sample container shipment documentation will record batch numbers for the containers. With this documentation, containers can be traced and wash analyses can be reviewed. The sample container wash analysis certificates will be retained in the project file.

Soil vapor and air samples may be collected in Summa canisters[6]. Canisters will be certified clean for the corresponding analysis and reporting limits.

10.3.2 Sample Preservation

Before shipping sample bottles to the field, LLI will add the required preservatives to the sample bottles that will be used for groundwater. LLI will provide or affix waterproof labels to the bottles, on which the type of analysis and the type and amount of preservative will be written.

Sample preservation procedures are used to maintain the original character of analytes during storage and shipment. Regardless of the nature of the sample, absolute stability for all constituents cannot be achieved. Preservation techniques, such as pH control and refrigeration, may retard physiochemical and biochemical changes. Generally, analyzing the sample as soon as possible is the best way to minimize physicochemical and biochemical changes.

Samples will be placed in the appropriate laboratory-supplied sample container and chilled (on ice in a cooler) immediately upon sample collection. The samples will be transferred to LLI by no later than the second day after the groundwater sampling events. LLI will meet all specified holding times and should make every effort to prepare and analyze the samples immediately after they are received.

10.3.3 Storage Requirements

Samples will be placed in secure, on-site storage or remain in the possession of the sampling personnel until they are shipped or delivered to LLI. Immediately after collection and during shipment to LLI, samples will be stored in Ziploc bags (or equivalent) in coolers on ice at approximately 4°C. Ice packaged in Ziploc bags will be used to maintain the temperature in the shipping containers at approximately 4°C. Ice will be replenished as needed to ensure adequate cooling of samples during storage and shipping.

10.4 Sample Documentation

Entries into the field logbook or other relevant sampling forms for sampling events may include, but not necessarily be limited to, the following:

- Project name, location, and number
- Name of person maintaining the field logbook
- Rationale for collecting the sample
- Date and time of sampling

[6] Other types of sample containers may be used such as sorbent tubes or Tedlar bags.

- Sample numbers
- Cross-reference of numbers for split and blank samples
- Media sampled
- Field observations
- Geographical location of the sampling point in reference to site facilities
- Physical location of the sampling point
- Method of sampling, including procedures, equipment, and any departure from the procedures specified in the RI Work Plan or the SAP
- Results of field measurements and calibration record (e.g., water quality readings)
- Sample preservation
- Type and quantity of container used for each sample
- Weather conditions at the time of sampling and previous events that may influence the representative nature of a sample – at a minimum, include temperature and sky cover
- Photographic information, when appropriate, to briefly describe what was photographed and why, the date and time, the compass direction of the picture, number of picture in file
- Sketches, when appropriate, with locations referenced to existing structures in the area (i.e., trees, existing monitoring wells)
- Analyses requested
- Disposition of the sample (i.e., laboratory to where it is being shipped) and point of contact
- Shipping confirmation number of sample shipment, when applicable
- Other pertinent observations, such as the presence of other persons on the site (those associated with the job or members of the press, special interest groups, or passersby), and actions by others that may affect performance of site tasks
- Type of personal protective equipment (PPE) used if other than Level D
- Name(s) of sampling personnel
- Name of Field Team Leader and site Health and Safety Officer
- Names and time of arrival/departure of visitors and equipment to the site
- Summary of site safety meetings and levels of protection
- For air samples, other information such as the canister ID, flow controller ID, sample collection times (start and stop), pressure readings (start and stop), flow controller flow rates, and types of samples collected (SSV, IA, and AA) will be recorded on field sample collection forms to be kept in the project files. The sample location and height must also be recorded.

10.5 Chain-of-Custody Procedures

Verifiable sample custody is an integral part of all field and laboratory operations associated with this site investigation. The primary purpose of the COC procedures is to document the possession of the samples from collection through storage and analysis to reporting. COC forms will become the permanent record of sample handling and shipment. The Field Investigation Manager or his/her designee will be responsible to the Project Manager for monitoring compliance with COC procedures.

Field sampling personnel are responsible for the care and security of samples from the time the samples are collected until they have been turned over to the shipping agent or laboratories. A sample is considered to be in one's custody if it is in plain view at all times, in the physical possession of the sampler, or stored in a locked place where tampering is prevented.

Empty coolers containing ice will be available at the study area for use each day in the field. Samples collected during the day will be stored in shipping coolers beginning at the time of collection. The coolers will be locked inside the field vehicle when sampling personnel are not present.

A COC form will be filled out for each cooler that is shipped. Only samples in that cooler will be listed on the COC. An example of the COC records that will be used is shown in Appendix A. Each COC form will contain the following information:

- Site name and contract number
- Company name
- Project number
- Sample ID numbers
- Date and time of sampling
- Type of sample and number of sample containers associated with each sampling point
- List of analyses requested
- Metals analyses will be separated into dissolved or total categories under analyses requested columns; the list of metals for analysis will be specified in the comments section of the form along with information about field filtering and/or preservation of groundwater samples
- Number of containers for each sample
- Name and signature of sampling personnel
- Shipping confirmation number, when applicable
- Comments regarding matrix spike/matrix spike duplicate (MS/MSD) samples, or any other information that is necessary for the lab
- Spaces for transfer of custody acknowledgment.

When the COC form is complete, field team members will crosscheck the form for possible errors. Any corrections made to each record will be with a single strike mark that is dated and initialed. The person who initials corrections will be the same person who relinquishes custody of the samples.

10.5.1 Transfer to Project Laboratories

Samples will be shipped to LLI by overnight delivery service or picked up by a courier for overnight delivery. LLI will provide return shipping labels as well as packing supplies, bubble wrap, secondary containment bags, absorbent pads, etc., to secure samples during transit. The COC form that has accompanied a cooler from the time of sample collection will be signed, dated, placed in a Ziploc bag, and taped to the inside lid of the cooler.

When VOCs are being analyzed in groundwater, a trip blank provided by the laboratories will be placed in each cooler. The trip blank will consist of two labeled vials filled with laboratory-provided DI water; two vials constitute one trip blank. The trip blank must be included on the COC form. This sample will be analyzed for possible contamination from outside sources.

A temperature blank (provided by the lab) must also be included in each cooler.

11.0 INVESTIGATION-DERIVED WASTE HANDLING AND DISPOSITION

IDW generated during the RI will be stored, handled, and disposed of according to guidelines described in this section. According to the EPA guidelines, the most important elements of managing IDW include:

- Leaving the site in no worse condition than existed before the investigation
- Removing wastes that present an immediate threat to the human health or the environment
- Complying with federal and state applicable or relevant and appropriate regulations to the extent practicable
- Planning and coordination of IDW management
- Minimizing the quantity of generated wastes.

11.1 Expected Types of Investigation-Derived Waste

The methods for handling and disposing of IDW were developed under the assumption that it is unlikely that any of the IDW generated during this project will require special handling or disposal. The following sections discuss the different types of IDW that will be generated during this project.

11.1.1 Drill Cuttings

Drill cuttings resulting from soil boring activities will be placed in 55-gallon drums, lined tub skids, or roll off containers. Disposal will be in accordance with appropriate regulations and Boeing disposal practices.

11.1.2 Development and Purge Water

As a part of standard Boeing protocol, development and purge water is disposed of in accordance with Boeing's current groundwater waste profile[7]. During development of the monitoring wells, field personnel will observe the water for visual and olfactory evidence of contamination. Water generated during development of the wells will be contained in 55-gallon drums or other transportable liquid containers. The drums will be labeled and stored on site in a specified containment area. The water will be stored until laboratory analysis of groundwater samples is complete and IDW disposal options are evaluated. Disposal will be in accordance with appropriate regulations and Boeing disposal practices.

Use of low-flow, minimal drawdown or passive sampling procedures greatly reduces the volume of water produced during monitoring well purging. It is anticipated that a maximum of approximately 2

[7] Boeing disposes of development and purge water as hazardous waste at the time of this report; changes may occur in the future that update this designation.

(low-flow sampling) or 0.25 (passive sampling) gallons of groundwater will be purged from each well (per sampling round) during the sampling process.

11.1.3 Decontamination Solutions

Decontamination solutions will consist of a 1 percent solution of non-phosphatic laboratory detergent (Alconox) and distilled water. Alconox is nontoxic, nonhazardous, and biodegradable. Decontamination solutions will be stored along with other decontamination water in 55-gallon drums pending laboratory analytical results.

11.1.4 Personal Protective Equipment

Level D PPE will be used while performing sampling tasks for this project, unless additional PPE is required by the applicable health and safety plan. The only PPE that will need disposal will be nitrile gloves. The nitrile gloves will be bagged and disposed of with other inert solid wastes. When working in PCB-contaminated soil, protective booties (or rubber boots to be decontaminated), and Tyvek® suits may be needed to protect clothing from becoming contaminated.

11.1.5 Solid Wastes

Non-hazardous solid wastes such as used paper towels, used gloves, and used sampling hoses will be placed in plastic refuse sacks and discarded into a receptacle identified by the on-site geologist.

11.1.6 Drum Sampling for Disposal

All development purge water will be sampled for constituents determined by Boeing. Boeing will provide the sample containers, coolers, COCs, and labels. Samples will be returned to the Wastewater Pre-Treatment Plant located on the facility.

11.1.7 Drum Handling

All drums with soil or water will be returned to the facility at the end of each day and placed in the pre-determined drum storage area. All drums will have labels provided by Boeing. Soil, decontamination rinse water, and concrete slurry drums will have a green non-hazardous waste label. All purge water drums will have a white hazardous waste label. These labels can be acquired from the on-site Boeing field representative. Drums will be stored according to the following procedures:

- The bolt must be over the label and facing down
- The bolt and label must be facing the side of the pallet the forks slide into so that when a forklift operator picks up the pallet, they can see the labels easily
- The drums must be wiped clean of soil clumps and the labels easy to read
- No more than four drums will be placed on a pallet
- Only drums of like material will be placed on the same pallet
- Only like materials will be stored in each drum.

12.0 FIELD CORRECTIVE ACTIONS

The ultimate responsibility for maintaining quality throughout the site investigation rests with the contractor Project Manager. The day-to-day responsibility for ensuring the quality of field and laboratory data rests with the Field Investigation Manager and field staff.

Any nonconformance with the established QA/QC procedures will be expeditiously identified and controlled. If procedures are not in compliance with the established protocol, corrective actions will be taken immediately. Subsequent work that depends on the non-conforming activity will not be performed until the identified non-conformance is corrected.

The Field Investigation Manager will review the procedures being implemented in the field for consistency with the established protocols. Sample collection, preservation, labeling, and other procedures will be checked for completeness. Where procedures are not strictly in compliance with the established protocol, the deviations will be field documented and reported to the Project Manager. Corrective actions will be defined by the Field Investigation Manager and Project Manager and documented as appropriate. Upon implementation of the corrective action, the Field Investigation Manager will provide the Project Manager with a written memo documenting field implementation. The memo will become part of the project file.

13.0 CONTACT INFORMATION

Contact information for Boeing personnel, subcontractors, and relevant off-site property contacts are listed below:

Company	Contact/Title	Phone	Email	Comments
Boeing	Jim Bet/ Project Manager	(206) 679-0422	James.n.bet@boeing.com	Provides IDW and Auburn facility employee communication support
Boeing	Jim Swortz/ Auburn Facility contact	(360) 790-1767	James.p.swortz@boeing.com	Notify when scheduling relevant field work
Boeing	Lindsey Mahrt/ Field Engineer	(206) 327-0404	Lindsey.e.mahrt@boeing.com	Notify when scheduling relevant field work
Boeing	Jennifer Parsons/ Field Engineer	(206) 715-7981	Jennifer.p.parsons@boeing.com	Notify when scheduling relevant field work
APS	Bill Phillips/ Manager	(206) 517-1857		Private utility locates
One-Call Utility Locate		(800) 424-5555		Public utility locates
The Outlet Collection	Security	(253) 833-2155		Notify when sampling or drilling at The Outlet Collection
Prologis/ Starbucks	Eleanor Romero/ Prologis Property Manager; Rishi Nair/ Starbucks (tenant)		eromero@prologis.com rinair@starbucks.com	Email 2 weeks prior to accessing indoor Prologis wells
City of Algona	Diana Quinn		Dianaq@algonawa.gov	Email prior to any field work on City of Algona right-of-way
General Services Administration (GSA)	Richard Hall	(206) 220-4836	Richard.hall@gsa.gov	Email 2 weeks prior to accessing GSA wells
Primus	Nathan Malik		snmalik@pccearo.com	Email 2 weeks prior to accessing Primus wells
DCT Industrial	Eileen Galarza and Ben Brodsky		egalarza@dctindustrial.com bbrodsky@dctindustrial.com	Email 2 weeks prior to accessing DCT Industrial well
Commercial Crating & Box Packaging, Inc.	Catherine Liao	(253) 804-8616 (206) 369-6156		Call to get access code to well AGW216
Landau Associates	Jennifer Wynkoop/ Project Manager	(253) 926-2493	jwynkoop@landauinc.com	
Lancaster Laboratory (analytical laboratory)	Kay Hower/ Project Manager	(510) 232-8894	khower@lancasterlabs.com	Submit bottle orders to Kay and confirm sample logins with Kay
Cascade Concrete Sawing & Drilling		(253) 872-7578		
Cascade Drilling, LP		(253) 883-5200		Subsurface drilling
K&D Services		(425) 252-0906	wadispatch@kndservices.net	Traffic control

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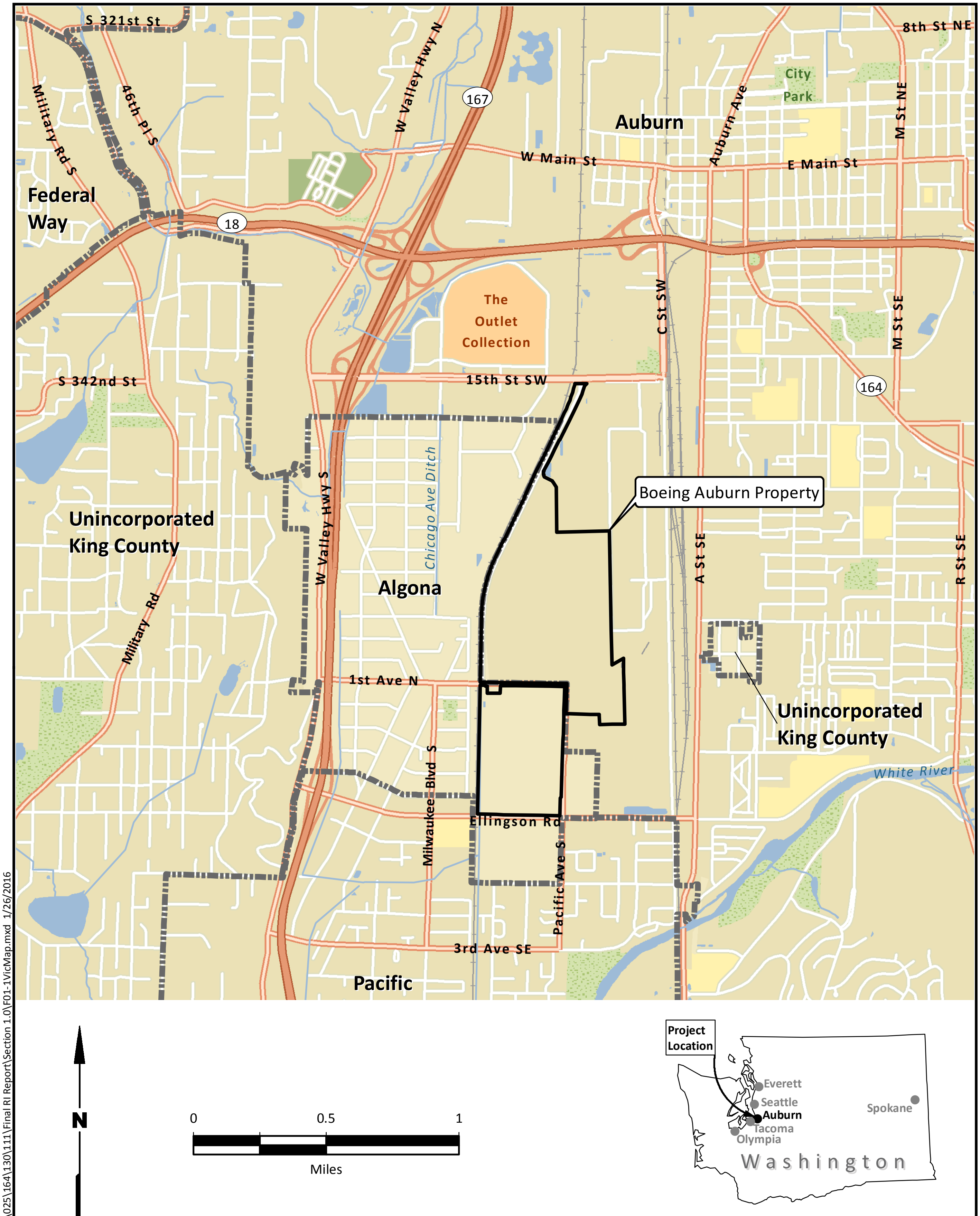

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LANDAU ASSOCIATES

Boeing Auburn Auburn, Washington	**Vicinity Map**	Figure D-1

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APPENDIX A

CMT Manuals

CMT Multilevel System Assembly Manual

Printed in Canada
11/2004

Solinst®

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CMT Multilevel System Pre-installation Requirements

Please complete this form to verify that proper consideration has been given to design and borehole specifications for each CMT Multilevel System to be installed. (CMT tubing 1.7" OD, Guide Point Port 1.75" OD, Guide Point Port with Anchor 3.75" OD).

1/ **Minimum information required for effective design of the CMT Multilevel System:**

Accurate borehole depth _______________ Borehole Angle ____________________

Depth to which CMT System is to be installed ______________________

Borehole geology _________________

Drilling Method _____________________

Casing size (minimum ID) ________________

Depth to base of well casing ____________________

Number of Monitoring Zones _______________________

Approximate Depth to Static Water Level ____________________

Expected Maximum Pressure Heads at each Port location ______________________

Site Conditions (eg. dry field, bush, swamp, paved, etc.) __________________________

Any special surface requirements for completion __________________________________
of installation (eg. flush mounted, angled, etc)

Solinst can assist the client in the design and component selection for the CMT Multilevel System based on the above requested information, but final design and installation details remain the responsibility of the purchaser.

2/ **Ensure that these additional items are available on site during installation:**

- CMT Installation Toolkit (as shown at right)
- Measuring tape
- Hacksaw
- Marking pen or wax pencil
- Model 103 Tag line for checking backfill depths
- Model 101M or 102 Water Level Meters
- At least two client representatives to supervise and assist with installation. Solinst can provide a technician to assist with the installation upon request.
- Support stand (if purchased separately)
- Adjustable wrench

Tip: Practice making one or two ports in a short section of CMT before starting out on the real thing.

Introduction

The Solinst Model 403 CMT Multilevel monitoring well system represents a revolution in multilevel groundwater monitoring. The CMT System provides the simplicity of a bundle type installation with the benefits of backfilling or sealing around a single tube.

This manual describes the above-ground assembly of CMT wells. This consists of creating intake ports in the various channels at the desired depths, installing water-tight plugs below each intake port, adding mesh screens, sealing the bottom of the tubing, and attaching low-profile borehole centralizers to the tubing. For installations in bedrock or cased 2” wells, inflatable packers can be attached to the CMT tubing to seal the borehole between the various intake ports.

Assembling CMT wells is straightforward and can be performed by either drilling contractors or environmental consultants. The wells can be assembled on site after the borehole is being drilled or off site and then transported to the job location. While the assembly of CMT wells is not difficult, it is important to follow all of the steps described in this manual. It is especially important when creating the monitoring ports to avoid cutting into one of the adjacent channels. Doing so creates a hydraulic connection between the two channels that cannot be repaired. Please read this manual carefully before assembling your first CMT well. In addition we suggest that you practice making one or two ports in a short section of CMT tubing before starting out on the real thing.

Preparation

Before making any ports in the CMT tubing, make a sketch of the desired well design. Show the depths of the desired monitoring zones and centralizers (if used) in feet/meters below ground surface. Also, show the depths of the desired lifts of sand and bentonite graphically on the figure. This will come in handy when you are measuring the depths of the backfill materials when you are building the well. If you are building a CMT well where alternating layers of sand and bentonite backfill are added from the surface, try to allow for two feet or more of sand above and below the monitoring ports to ensure that the bentonite does not cover the monitoring ports.

Remember to allow sufficient wellhead access when you install the protective cover over the well. Plan on using a large well cover (greater than 4” diameter is recommended) to allow plenty of room to access the wellhead. A diagram showing suggested dimensions of the wellhead and protective cover is shown in Figure 1 for flushmount and above ground completions.

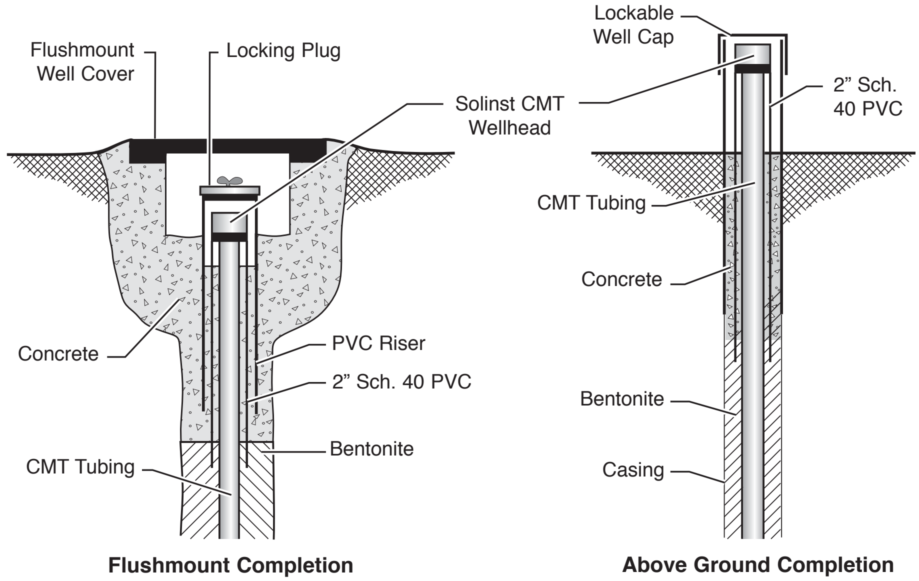

Figure 1

Example 1: Assembling Standard CMT Multilevel Systems

Table 1 shows the design of a hypothetical CMT Multilevel System designated well "ML-1." Each channel in this well can be used for both collecting a groundwater sample (with either a peristaltic pump, inertial pump or micro double valve pump) and measuring the depth to water. Each channel therefore functions both as a sampling port and an observation port.

Table 1
Hypothetical Design for a Standard CMT Well (Well ML-1)

Example

Monitored Zone	Channel Number	Depth to Center of Port (from ground surface)
1	1	23
2	2	34
3	3	48
4	4	55
5	5	69
6	6	77
7	7	92

Note: Newly uncoiled CMT tubing has a memory which can make it difficult to lay out straight. Sand bags help to hold down the ends of the tubing. The "memory" goes away relatively quickly, especially in warm weather. Placing the tubing on black plastic sheeting can warm the tubing, helping it straighten out more quickly.

Note: The channel identifier on the CMT tubing is intentionally subtle to avoid being a conduit for vertical leakage.

Note: The Channel 1 identifier is a low profile repetitive marking “<< CMT >>”.

Marking the CMT Tubing with the Locations of the Monitoring Ports and Cutting the Tubing to the Proper Length

Uncoil the CMT tubing on the ground or other flat surface. Stretch out a measuring tape at least as long as the depth of the well, next to the CMT tubing.

Allowing for your desired wellhead stick up (2-3 feet above ground surface), place the end of the measuring tape below the length of tubing you want above ground. This is your measuring point which represents ground surface and all depths below this point use depths below ground surface.

3) The next step is to make marks on the CMT tubing at the depths corresponding to the midpoint of the desired monitoring ports. Before you do this, you will note that there is a faint channel identifier, a low profile repetitive marking “<< CMT >>” that runs along the entire length of the CMT tubing opposite one of the outer channels. This channel identifier facilitates identification of the various internal channels anywhere along the length of the tubing. The channel that has the identifier is always Channel 1. By convention, Channel 1 corresponds to the shallowest monitoring zone. The other five outer channels are numbered clockwise from 2 through 6 as you are looking down on the completed well from above. The center channel is Channel 7 and is always the deepest monitoring zone.

4) Make a mark across Channel 1 on the exterior of the CMT tubing at the depth corresponding to the center of the uppermost monitored port (23 feet below ground surface in our hypothetical example; Figure 2). A permanent marker or a "China marker" wax pencil works well for this. Write "Port 1" on the CMT tubing about 6 inches above the mark.

Figure 2

5) Next, draw a line along the Channel 1 identifier (i.e., parallel with the tubing) extending approximately 6" above and 6" below the depth mark (Figure 3). You will use this line (and other similar lines drawn at the other port depths) to index the Port Cutting Guide. This ensures that you cut holes only in the intended channels corresponding to the desired monitoring zones (as shown in Table 1).

Figure 3

6) Make similar marks at the depths corresponding to the next five monitoring zones (i.e., 34, 48, 55, 69, and 77 feet below ground surface). Make the marks identical to the ones you drew at Port 1. That is, draw the depth mark across Channel 1 and draw the longitudinal line along the Channel 1 identifier. The Port Cutting Guide has been indexed so that it always references the Channel 1 identifier when it is used to cut holes in the five other outer channels. Label these depth marks as Port 2, Port 3, etc..... about 6 inches above each mark. Finally, make a mark at the depth of the deepest monitoring port (i.e., the internal channel, Port 7), which is also the bottom of the well, at 92 feet. Cut the CMT tubing at this mark using a hacksaw, sharp knife, or PVC cutter.

Figure 4

7) The design of the well has now been transferred to the CMT tubing.

Note: When using the Port Cutting Guide, ensure that the cutting bolts are located below the number 1 on the front of the Guide. The locking bolts go below the number 4 on the back of the Port Cutting Guide.

Cutting the Outer Ports and Vent Holes

8) Slide the Port Cutting Guide over the CMT tubing down to Port 1. Align the notch stamped "1" on the Port Cutting Guide with the line you drew along the Channel 1 identifier. Position the Port Cutting Guide so that the depth mark "+" (indicating the centre of the Port) is visible in the window in the center of the Port Cutting Guide (Figure 5). Secure the Port Cutting Guide to the CMT tubing by tightening the knurled Locking Bolts on the underside of the guide (Figure 6). Tighten the bolts, **by hand only**, to prevent the Port Cutting Guide from moving.

Figure 5

Figure 6

9) Next, cut three holes, as described below into Channel 1 using the cutting bolts screwed into the Port Cutting Guide.

Start by threading a cutting bolt into one of the holes located on the same side as the window. Use the hex wrench to tighten the Cutting Bolt. Tighten the bolt a few revolutions, then loosen it one revolution. Continue doing this until the Cutting Bolt "bottoms out" (Figure 7). Remove the Cutting Bolt. There should be a plastic disk inside of the cutting bolt. If there isn't, re-insert the cutting bolt and repeat the cutting process (make sure that the knurled Locking Bolts are tight). Push out the piece of plastic from the inside of the Cutting Bolt by inserting an Allen wrench through the small hole drilled in the head of the Cutting Bolt (Figure 8). Repeat this process to cut all three holes. The two upper holes will provide the port plug access and the lowest hole is the vent hole (Figure 9).

Figure 7

Figure 8

Figure 9

Note: The two upper holes allow you to use snips to cut away a panel of plastic between the two holes, creating a 3-inch-long port in Channel 1. The bottom hole is a vent hole. A vent hole is needed to allow air to escape from the channel beneath the monitoring port when the CMT tubing is inserted into the water-filled borehole during well installation.

Note: The vent hole does not allow cross connection with other monitoring zones because the bottom of the channel is sealed with a water-tight plug.

10) Loosen the cutting tool and move it "down" the CMT and out of the way. Next, use the snips as shown in Figure 10 to cut out the panel of plastic between the upper two port holes. **Do this carefully and keep the snips parallel to the channel side wall to avoid cutting into the walls separating Channel 1 from Channels 2 and 6**. Make the opening as large as possible to facilitate the insertion of the expansion plug as described in the next step.

Figure 10

11) Insert an expansion plug through the opening (Figure 11) so that it seals Channel 1 below the monitoring port and above the vent hole. If necessary, use the torque driver to gently push the plug into place (Figure 12). Use the snips to trim the port opening if you have difficulty inserting the plug. Tighten the plug to a torque of 10 inch-pounds using the supplied torque driver.

Figure 11

Figure 12

Note: To avoid installing ports in the wrong channels start by positioning the Port Cutting Guide so that the depth mark is visible in the window, then rotate the guide so that the appropriate number (corresponding to the port number) is indexed against the line you drew earlier along the longitudinal Channel 1 identifier. This step is very important

Note: At some sites, you may decide that it is not necessary to monitor every channel. In that case, only cut ports in the desired channels.

When constructing the bottom assembly, only insert the expandable plugs into the monitored channels, leaving the other channels open so that they can fill with water as the CMT tubing is inserted into the borehole (e.g. If only three channels are monitored, only those channels should have plugs inserted at the base.) This reduces buoyancy during well installation.

12) The last step in making the Channel 1 port consists of wrapping the stainless steel mesh around the port, forming a well screen over the opening. Center the mesh over the port opening and wrap it tightly around the CMT tubing (Figure 13). Use the low profile Oetiker clamps and pliers to firmly secure the mesh to the tubing. Use two clamps for each monitoring port (Figure 14). Construction of Port 1 is now finished. You are now ready to make Port number 2.

Figure 13

Figure 14

13) Slide the Port Cutting Guide down to Port 2. Position the Port Cutting Guide exactly as you did for Port 1. The depth mark should be visible in the window of the Port Cutting Guide and the longitudinal Channel 1 identifier should be indexed to the number "1" stamped on the guide (Figure 15). Now, rotate the Port Cutting Guide (without moving its position along the CMT tubing) so that the longitudinal line is now indexed to the number "2" stamped on the guide (Figure 16). This positions the Port Cutting Guide so that the cutting bolts will cut holes only into Channel 2. Secure the Port Cutting Guide using the knurled Locking Bolts as before. Cut the two port holes and one vent hole into Channel 2. Next, loosen the cutting tool and slide it down the tubing out of the way.

Figure 15

Figure 16

14) Snip away the panel of plastic between the upper two holes, creating an opening for Port 2.

15) Next, insert an expansion plug though the opening, positioning it below the monitoring port, and tighten it to 10 inch-pounds as before. Finally, wrap a piece of stainless steel mesh around the opening and secure it with two stainless steel clamps. You have now finished constructing Port 2.

16) Continue the steps described above for Ports 3 through 6.

Configuring the Bottom of the CMT Tubing (Zone 7)

17) Insert an expansion plug into each of the six channels. (Figure 17) Tighten each to a torque of 10 inch-pounds using the torque driver.

18) Slide the Guide Point Port Assembly (Figure 18) over the end of the CMT tubing and secure it to the tubing with two stainless steel clamps (Figure 19). The end of the Guide Point Port Assembly is tapered to prevent the bottom of the CMT tubing from getting snagged on a rock ledge or casing joints as it is being inserted into a borehole.

Figure 17

Figure 18

Figure 19

19) If desired, an anchor (3.75” diameter) can be attached to the Guide Point Port using a hex bolt (Figure 20). An anchor is used during installations where it is helpful to secure the bottom of the CMT to keep it from moving during well construction. Once the tubing has been inserted, use sand placed on top of the anchor to secure the well. This will prevent it from being pulled up as drive casing or augers are withdrawn from the borehole. Holes have been drilled in the anchor to allow water in the borehole to pass through the anchor when the CMT well is inserted.

Figure 20

Note: Solinst has developed special tubing centralizers that ensure that the tubing is centered in the borehole during well construction. The fins on the centralizers are low-profile to prevent them from obstructing the tremie tube, or sand and bentonite pellets poured from the surface.

Attaching Tubing Centralizers

20) Place the centralizers over the CMT tubing at the desired depths. Centralizers are generally placed along the CMT tubing at intervals ranging from every 5 to every 15 feet. Attach the centralizers securely to the CMT tubing using two stainless steel clamps (Figure 21).

The CMT well is now ready to be inserted into the borehole.

Figure 21

Note: The Solinst Tag Line, (Model 103), is recommended for accurate sand and bentonite placement.

Note: On the underside of the wellhead is a groove to fit 2" dia. PVC riser pipe.

Figure 22

CMT Placement

21) Lower the assembled CMT System into the borehole slowly.

If buoyancy is a problem, wait, as the channels below water level will slowly fill and allow the system to be lowered further. To speed this process along, pour or pump clean water into the vent holes.

When the required depth is reached, suspend the system with the System Support Clamp to prevent it from moving during well construction (Figure 22).

22) Complete the installation by carefully pouring or using a tremie to place sand and bentonite at appropriate levels to seal the borehole annulus

Attaching the Standard Wellhead (after the well has been installed)
23) After the well has been built, cut the CMT tubing to the final elevation. You may choose to finish your CMT installation off above ground surface. If so, you can leave the CMT stick-up as is and install the standard wellhead or "house" the CMT inside a cut length of 2" dia. PVC riser pipe (not supplied). On the underside of the wellhead cap is a groove which is designed to allow a 2" dia PVC riser pipe to "key" into the wellhead. Locate Channel 1 and slide the Standard Wellhead over the tubing (Figure 22). Remember, Channel 1 has the identifier on the outside of the tubing. Secure the wellhead to the CMT tubing by tightening the hex screw on the side of the wellhead.

Optional Flow Control Monitoring Assembly
Under flowing artesian conditions or for vapor sampling, the CMT can be fitted with a special flow control monitoring assembly to allow the user to collect a sample, measure hydraulic or pneumatic pressure, and prevent uncontrolled flow from the well.

Well Completion

Model 103 Tag Line

The Model 103 Tagline is ideal to aid accurate placement of sand and bentonite during borehole completion.

Model 403 Well Head Seal Assembly

For flowing conditions or vapor monitoring, Solinst offers a monitoring assembly, which applies a pressure seal to the individual CMT channel. This facilitates sampling through the well head at the surface.

Monitoring Options

Water levels and samples can be accurately obtained using the following high quality Solinst instruments:

Water Level Measurement

Model 102 Water Level Meter

A narrow coaxial cable Model 102 Water Level Meter with a 1/4" dia probe can be used to monitor water levels in any CMT Channel.

Sampling Methods

Depending on your site's depth to water and your sampling protocol, Solinst offers various sampling options.

Model 410 Peristalitic Pump

Ideal for sample retrieval from shallow water levels less than 30ft (9m).

Mini Inertial Pump

Mechanical pump used inside 1/4" LDPE tubing. Typical flow rates of 50 to 250mL/min. If your site's water level is deeper than 50ft (15m), Teflon tubing is recommended

Model 408M 3/8" Dia. Flexible Micro Double Valve Pump

Small and flexible design makes this gas drive pump ideal for delivering high quality samples, in combination with the Model 466 Electronic Control Unit. Flow rates of 20 to 150mL/min make the 408M suitable for low flow sampling applications. Constructed of Stainless Steel and LDPE for lengths less than 50ft (15m) and Teflon tubing for any depths up to 200ft (60m) applications. This is the only viable option in wells with depth to water over 150 ft.

408 Accessories

Multi-purge Manifold

A multi-purge manifold can be considered for purging multiple CMT channels simultaneously using 408M Micro Double Valve Pumps

Model 466 Electronic Control Unit

The 408M is durable and easy to operate using the presets and fine tuning capabilities built into the Solinst Model 466 Electronic Control Unit.

CMT Decommissioning

Introduction

The CMT® (Continuous Multichannel Tubing) System is a multilevel groundwater monitoring system constructed from a single extruded polyethylene tube, 1.1” (28 mm) or 1.7” (43 mm), that has either three or seven isolated channels running internally along its length, respectively (Figure 1). Each channel, approximately 3/8” (9.5 mm) diameter, can be used to monitor groundwater heads/levels and quality at separate specific depths in a borehole. Ports are constructed on site at desired depths along the CMT tubing, using plugs to seal off the unused channels below each port and at its base.

Sand packs and bentonite seals are placed in the annular space between the CMT tubing and the borehole wall. This is done by backfilling from the surface, or with the sand and bentonite cartridges developed for the 3-channel CMT System. It is necessary to ensure that the unused portion of each channel, below the constructed port, is sealed to prevent groundwater from deeper zones migrating up the tubing causing cross-zone contamination. This can be achieved by inserting a plug at the bottom end of the channel and a second plug just below the port. This allows the lower unused portion of the channel to fill with water from the monitored zone through a vent hole placed just below the port plug, as the System is lowered into the borehole. Although many regulators are comfortable with this method of installation and the decommissioning methods described herein, some local regulators require that, in preparation for decommissioning, this unused portion of each channel be filled with grout prior to installation. If this is required in your area, please see page 3 for pre-installation instructions.

Thousands of CMT multilevel monitoring wells have been installed at contaminated sites in North America and around the world. Many of these sites have been cleaned up and the CMT wells are no longer needed. Thus, there is a need to decommission the wells in accordance with industry and local standards.

Figure 1
CMT Tubing (3 and 7 Channel) with wellhead identifying channels.

Options for Decommissioning CMT Wells

Several methods for decommissioning CMT wells have been tried in the last few years.

Over-drilling and grouting the borehole has been performed successfully at many sites. However, in soft materials the drill bit has a tendency to deviate from the original borehole. In some cases, this has resulted in partial system removal, leaving some doubt as to whether the multilevel wells have been fully decommissioned.

Removal of the CMT system by pulling should NOT be attempted as the low tensile strength of the polyethylene tube causes it to stretch and break before the entire length can be removed. Experience has shown that even a shallow 50 ft. (15 m) System may not be possible to completely remove in this manner.

Grouting the CMT wells in place is the easiest and most reliable option for decommissioning the wells. Tremie grouting is a simple, reliable way to decommission CMT wells. The grouting is done routinely in the geotechnical industry and a wide variety of grout compounds and mixtures are readily available. Further, tremie grouting of wells and other earth structures is an accepted sealing method throughout North America and Europe.

At a minimum, the channels should be completely filled with grout to prevent them from conveying water vertically in the multilevel. In addition, it may be desirable in some cases to inject grout into the sand pack adjacent to the various ports in the CMT wells. However, this is often unnecessary since the sand-packed intervals of CMT wells are often relatively short and are already hydraulically isolated in the boreholes by bentonite seals placed between the sand-packed intervals when the wells were constructed.

For best results, grouting of CMT wells should be performed “from the bottom up” using a tremie tube that is inserted into the CMT channel being sealed. The grout is then pumped through the tremie tube and into the CMT channel. The tremie tube is either left behind or removed incrementally as the grout is added, leaving a continuous column of grout within the CMT channel. The channels can be grouted sequentially or all at once using several tremie tubes (one in each channel). Because of the relatively small inside diameter (ID) of the CMT channels, however, it is necessary to use a tremie tube that has an outside diameter (OD) no larger than approximately 1/4" (6 mm). Adding grout through such a small diameter tremie tube requires the use of a low-viscosity grout that flows easily.

In order to provide guidance to it’s CMT customers on decommissioning CMT wells by tremie grouting, Solinst undertook a research and testing project in spring 2005 to identify and test various methods and products for decommissioning CMT wells by in-place grouting. This Technical Bulletin presents the results of Solinst’s research and testing.

Testing of Grouting Products & Procedures

The first step in developing a successful grouting technique for decommissioning CMT wells is to find an appropriate grout with the following characteristics:

1. Environmentally friendly, does not introduce any contaminants of concern into the subsurface.
2. Low viscosity, to allow injection through 1/4" (6 mm) polyethylene tremie tube.
3. Appropriate composition to allow rapid setting and reliable long-term seal.

In order to source the grout, Solinst contacted a local grouting company. Multiurethanes (MU) has operated since 1988 offering a range of grouting materials, equipment, accessories and services (see web-site at www.multiurethanes.com).

Bench scale testing was conducted July 2005 at the Multiurethanes facility in Mississauga, Ontario, Canada by both Solinst and Multiurethanes personnel. A model CMT well was first constructed using a 5 ft. (6 mm) length of straight 7-channel CMT tubing, built with one port and two centralizers. This assembly was placed within a 4.75" (12 cm) ID clear acrylic cylinder (Figure 2). The annulus between the CMT tubing, and the cylinder was filled with dry #0 (16-35 mesh) filter sand. Six of the seven channels were plugged at the wellhead using mechanical plugs, and grout was injected into Channel 1. The recipe selected for the test was 55 lbs (25 kg) of Ultrafine Cement, 2.2 lbs (1 kg) of Superplasticizer (4% by weight of cement) and 110 lbs (50 kg) of water.

The Superplasticizer turns the otherwise viscous cement mixture into an easy-to-pump fluid for a short period (typically 15-30 minutes) before the cement grout starts to set. In the bench scale grouting test, "Spinor A12 Microfine Cement" was choosen which is an ultrafine blast furnace slag cement. Its composition is chemically similar to ordinary "Portland Cement". Microfine or ultrafine cement is typically used in the geotechnical industry for permeation grouting, construction of curtain walls and subsoil water barriers in soils where conventional cement grouts (ie Portland) cannot penetrate.

The grout mixture was pumped into Channel 1 of the CMT tube at a rate of 0.50 US gpm (2 L/min.). Due to the small size of the CMT model and the lack of water to displace, grout was injected directly into channel 1. Grout was quickly observed exiting the port screen and soaking through the sand at the Port 1 location (Figure 3). Approximately four minutes from the beginning of the injection, grout reached within 3" (76 mm) of the top of the sand in the test cylinder and grouting was stopped. Pressure at the wellhead while injecting reached a maximum of 25 psi. The total volume of the grout used was 3.5L in 13L of sand (about a 1 to 4 ratio, corresponding to a sand porosity of about 0.27). The preferential flow of grout during pumping was upward in the sand pack. Below the port in the sand pack, the flow was gravitational and fingered its way through the sand. A 2:1 water to cement ratio in this specific test was very successful in permeating out into the filter pack. Examination of the column weeks later provided evidence that all the grout had entered the column sand and solidified. However, higher water to cement ratios may be necessary for deeper applications with lower porosity values.

Figure 2
CMT model assembly in 4.75" (12 cm) acrylic cylinder, later filled with sand and used in grout testing.

One important issue that was examined was the ability of this low viscosity mixture to be transmitted through the narrow 1/4" (6 mm) tube (i.e., tremie tube) that is inserted in the CMT channels. The low viscosity grout used in the test described above was pumped through 172 ft (52 m) length of 1/4" OD (6 mm) x 0.17" ID (4 mm) LDPE tube at a pressure of 90 psi, considerably higher than the pressure needed in the shorter test cylinder. A discharge rate of 0.9L/min (0.24 US gpm) was achieved through the end of the tubing.

Further testing of different grout mixtures indicated that a somewhat higher ratio than 2:1 of water to cement may be preferable when tremie grouting through long 1/4" (6 mm) lines.

Figure 3
CMT model showing grout seeping into the sand annulus through the the screen of the constructed port and trial batches of grout in pails.

Recommended Grouting Procedures

The most crucial aspect of grouting is to formulate the right recipe for the grout, whether using bentonite or cement and plasticizer with water. Every application is unique, due to factors such as length of monitoring interval, depth of port, hydraulic conductivity of the formation, and the static level in the channel.

A reasonable starting point is somewhere between a 2:1 and 3:1 water to cement ratio, with an addition of plasticizer at approximately 4% by weight of cement. It is prudent to mix a variety of grout compositions prior to the actual field decommissioning to determine how well they set and how easily they can be pumped through small diameter tubing.

The other items to have on site for the grout injection is the 1/4" (6 mm) tubing and a grout pump. The pump used by some grout experts is an electric airless paint sprayer, that can provide a flow rate of 0.5 US gpm or about 2 L/min with pressures of 0 to 2000 psi. This style is preferred over a standard grout pump because it has a lower piston stroke and therefore allows for a more controlled injection rate. They can generally be rented from local equipment rental outlets.

In addition to the equipment listed in the previous paragraph, remember to bring the following:

- A supply of clean water is needed to test circulation and clean equipment on-site.
- Containers to both mix (large pail or tub) and feed (a graduated bucket) the grout into the pump and through the tubing.
- A mechanical mixer (drill style mixer works well) to mix the cement, water, and plasticizer in small easy to handle batches.
- A mesh screen to place over the graduated bucket, when pouring from the mixing tank, to prevent any coarse clumps from entering the grout tube and blocking it (Figure 4).

Figure 4
Screening of clumps in grout mix using mesh over mixing bucket. Mixture of cement and plasticizer is being stirred using a drill mixer prior to being pumped into CMT Channel in the model.

Pre-Installation Grouting

The option exists to grout the lower (below port) section of tubing prior to installing a CMT system. With this approach the plugs would still be used but rather than having portions of the tubing filled with water (depending on your regulations) a low viscosity grout bentonite/cement would fill the space. It would then be possible, when or if decommissioning is required, to seal all CMT channels from top to bottom.

When considering the use of cement to seal CMT systems both prior to installation and then as a final decommissioning procedure, one concern that has been raised is the heat of hydration of cement and its possible effect on the CMT tubing. The approximate melting point of CMT tubing, a medium density polyethylene, is estimated in the literature at approximately 150°C or 300°F. Different types of cement, the volume of fluid or water inside the CMT to dissipate heat and the volume of cement used are all important factors in how much heat is released during hydration. However, most cements (typically Type I Portland) used to complete environmental installations are required in low volumes (typically a 2" annulus, or less in the channels) and are not injected as a large mass. Temperature increases in the order of 10-15°C (50-60°F) could be anticipated for a completion with a 2" annulus. The risk therefore of a CMT system melting due to the heat produced from cement hydrating is low and has never been reported by a client or contractor. Actual field applications where the lower segments of the CMT channels were sealed, during well construction, are discussed in detail in the following section.

Pre-grouting the lower CMT channels below the intake ports has been done successfully by certified CMT installers on several projects. In some cases, a cement grout was pumped simultaneously into all the outer channels through the bottom end of the CMT tubing prior to insertion into the borehole. The injection was performed using a boot device that was pushed on the end of the system and secured with hose clamps (Figure 5). Grout was pumped simultaneously into all outer channels until it flowed out of the vent holes (Figure 6). After all of the channels below the ports were full of grout, standard explansion plugs were inserted into the base of each outer channel and tightened. A bottom guide tip and port assembly was attached to the bottom of the CMT tubing and the system was lowered to the desired depth in the borehole. A slightly different approach was taken on a 50-foot CMT installation by another certified CMT installer. On this project, the contractor used a standard peristaltic pump to to inject low viscosity cement grout through the bottom of each of the outer channels up to the vent hole. The contractor used 1/4" (6mm) OD polyethylene tubing to convey the grout from the grout reservoir into the various CMT channels (Figure 7). An advantage of filling the lower sections of the CMT with grout prior to installing the tubing is that it is possible to visually confirm that each section is completely filled with grout from the bottom of the well right up to the vent hole, leaving no void spaces.

Figure 5
Pre-installation grouting of CMT by injection using a grout boot device.

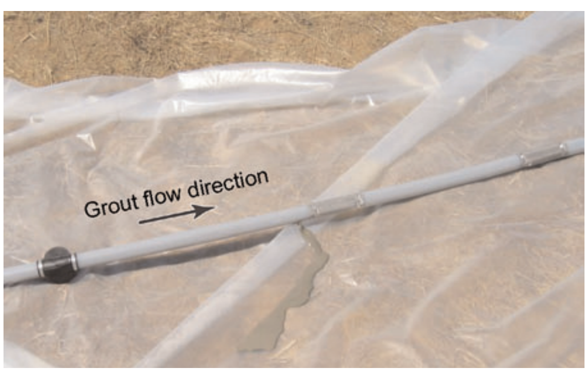

Figure 6
Grout exiting vent hole during pre-installation grouting.

Figure 7
Pre-installation grouting of CMT by injection of grout through 1/4" (6 mm) tubing using a peristaltic pump.

Another option, that has not yet been field tested, is to inject grout into the open CMT channels below each intake port via the vent holes as the tubing is lowered into the borehole. The CMT would be constructed, as usual, at the ground surface with plugs inserted in all outer channels at the bottom end of the CMT tubing. The contractor then would proceed to insert the CMT tubing into the borehole until the first (i.e., deepest) vent hole is easily accessible (e.g., a few feet above the ground surface). Then, a 1/4" (6mm) OD polyethylene tremie tube is inserted into the vent hole and pushed to the bottom of the channel (i.e., to the bottom end of the CMT tubing). Grout is then pumped down through the tremie tube, filling the lower, unused portion of the channel below the intake port. The tremie tube is incrementally retracted as the grout is pumped into the channel. This procedure is then repeated to fill each of the channels as the CMT tubing is being inserted into the borehole. An advantage of this method of pre-grouting the lower portions of the CMT channels is that this procedure can be performed at sites where it is not possible or desirable to lay the tubing on the ground. This type of pre-installation grouting procedure is very similar to the grouting technique that is described below for complete decommissioning of a CMT well when it is no longer needed.

Further field testing and discussion is planned in order to select the preferred methods and the optimal grout bentonite/cement mix to effectively seal lower sections of the CMT. See Solinst's website for updates and reports as they become available.

Grouting for Final Well Decommissioning

Using a tremie technique, a 1/4" (6 mm) tube is placed in each channel down to the depth of the port. Grout is injected, using a pump, through the tubing. Volumes of grout used during this process should be monitored and recorded to ensure that grout has completely filled the channel. For calculations, the volume in the outer 6 channels of a 7-channel CMT is 40 ml/ft. The volume of the central channel of the 7-channel CMT system and each channel of the 3-channel system, is 30 ml/ft. To simplify this procedure, leaving the grout tube in place for each channel may be preferable, rather than trying to remove the tube and potentially creating void space and also to minimize concerns with disposal. It may be necessary to top up the channel with additional grout, after allowing 24 hrs for setting.

Although the bench scale testing (described above) was conducted using a pressure grouting technique, in an actual field application tremie grouting would likely be the preferred option. This is due to the depth that grout would be placed and displacement issues (air and water) in the channels.

Remember that although the Superplasticizer makes the grout more fluid and easier to pump, its effect lasts for only about 15 to 30 minutes, depending on how much is added. After that brief period of time, it is consumed or "used up" by the cement and its viscosity lowering ability is greatly reduced.

As with any grouting project there are three steps that are recommended, to minimize the chance of this procedure failing due to a blockage:

1. Always experiment with the grout composition in advance of the actual field application so that a consistency is reached that can be injected to the deepest port depth and will still provide an effective seal.
2. Before injecting grout to the port location using a tremie tube, always test the pumping system with water first to be sure that flow is consistent through the pump and tubing. Only after flow is confirmed should the pump be switched to injecting grout.
3. In the event that there are no "grout returns,", i.e., the grout is not pumped back to the ground surface after a volume equal to the volume of the sand pack voids and the volume of the channel has been pumped, it may be the case the grout is being lost to the formation surrounding of the sand pack. In this case, it may be advisable to increase the viscosity of the grout mixture by reducing the amount of water added to cement.
4. Once grout injection has begun, the flow must not be stopped until the channel has been completely filled. If the flow is halted even for a matter of minutes it is very likely that further injection through the same tube will not be feasible. To continue the procedure, lower a second clean tube down into the channels after the initial tube is removed. In order to get this tube down it is advisable to flush water through as it is lowered, to prevent clogging. Then continue with the grouting procedure until the channel is full.

Summary

A review of your local well decommissioning guidelines or regulations should be performed prior to deciding the best approach for installation or decommissioning of any CMT well. The decommissioning procedure outlined above is believed to be the best option currently available to decommission existing and future CMT installations. It is deemed to be the most reliable method to seal the installation with minimal risk verses some of the other options discussed on page 1. Tremie and other forms of pressure grouting have been performed on geotechnical, environmental, and water supply projects for decades around the world. Also, there are many low-viscosity, environment-friendly grouts suitable for tremie grouting CMT wells. To grout a CMT system experienced professionals could obtain the equipment themselves to seal the installation by following the procedure outline in this document, or contact Certified CMT Installers or grouting experts (eg. Multiurethanes) for field assistance and guidance.

Depending on the type of sand pack, depth of the ports and water within the installation it may be necessary to vary the percentages of water, cement/bentonite grout and plasticizer used to seal the system for each decommissioning project. This document should be used as a guide and provides a starting point for optimizing the sealing of CMT installations in various environments. Should you have further questions or concerns please do not hesitate to contact either Solinst, Multiurethanes, or a certified CMT installer.

For further information contact: Solinst Canada Ltd.
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35 Todd Road, Georgetown, Ontario, Canada L7G 4R8
Web Site: www.solinst.com E-mail: instruments@solinst.com

Grouting Option

Model 403 7-Channel

Tools and Materials Needed for Grouting

1. 7-Channel CMT Purge/Grout Adaptor Assembly (#108130) Includes:
   - Purge/Grout Adaptor
   - 1 x Gear Clamp (#107095)
   - 2 x Internal (#V130) O-rings (one extra) (#103807)
   - 12 x Grout Plugs (#104027)
   - 1 x Hex Plug (#107096)
2. Tools from the 7-Channel Standard Installation Tool Kit (#106223)
   - 7-Channel Torque Driver (#106715)

Note: 2" = 50 mm, 1" = 25 mm, 1/4" = 6 mm, 1/8" = 3 mm

Grout Adaptor Operating Principles

Once the ports are completed in the CMT, and prior to installation, the vent holes, located below each of the port openings, are fitted with Grout Plugs. This helps reduce the amount of excess grout flowing from the vent holes during the grouting process.

The Purge/Grout Adaptor is then attached to the bottom of the CMT. The Grout Adaptor allows the connection of a 1" diameter NPTM grout line. The unused CMT channels below each port opening can be filled with grout from the bottom port up. A pressure relief valve (25 psi) is built-in to the adaptor to avoid over-pressurizing the CMT channels.

Grout Adaptor Setup Instructions

1. With the ports completed, lay the CMT on the ground and use the torque driver to install and torque the Hex Plug into the bottom/base of the CMT (in middle Channel 7).
2. Insert the Grout Plugs to restrict flow into each vent hole.
3. With the top-mounted 1/4" compression fitting still attached, unscrew and remove the upper black Delrin® fitting from the top of the Grout Adaptor. This will allow access forthreading the 1" diameter grout line.
4. Be sure to keep the O-ring inside the base of the Adaptor. This will ensure a seal between the Adaptor and the CMT tubing.
5. Place the Adaptor onto the base of the CMT tubing and slide up by about 2". Tighten the Gear Clamp at the base of the Adaptor to secure it to the CMT.
6. Plug the Side-mounted Discharge with a grout bypass line.

Grouting Instructions

1. With the CMT assembly still lying on the ground, thread the 1" diameter grout line directly onto the top of the Grout Adaptor.
2. Proceed to grout until the grout reaches and exits the Grout Plugs, in each of the vent holes.
3. Remove the Grout Adaptor and clean. Wipe the end of the CMT clean.
4. Install and torque the Base Plugs into each of the outer CMT channels.
5. Remove the centre Hex Plug and install the guide point port.

Decontamination Suggestions

Follow your usual cleaning protocols and procedures. Washing the Adaptor can be easily accomplished with a small brush and suitable cleaning solution.

1" diameter Grout Line connected to Grout Adaptor, attached to bottom of CMT.

Grout exiting the Grout Plug, below the Port Screen.

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(#109095)

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Solinst®

APPENDIX B

Field Sampling Forms

Boeing Lab Transition/Chain of Custody

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For Lancaster Laboratories use only
Acct. # ____________ Group # ____________ Sample # ____________
Please print. Instructions on reverse side correspond.

1 Client Information

Site Location: ____________
Site Project: ____________
Site Program/#: ____________
Boeing PM: ____________
Consultant Contact: ____________
Report To: ____________
Invoice To: ☐ Boeing EHS ☐ Other (specify): ____________
Samplers: ____________ # of Coolers: ____________

5 Analyses Requested

6 Comments/Remarks

2 Sample Identification	Collected: Date	Collected: Time	4 Matrix	No. of Containers	5 Analyses Requested												6 Comments/Remarks

Additional Comments:

7 Turnaround Time Requested (circle)

Standard 5 day 4 day

72 hour 48 hour 24 hour

Other (Specify):

Temperature upon Receipt: ________ °C

Custody Seals Intact?: Yes No

Relinquished by:	Date/Time	Received by:	Date/Time (9)
Relinquished by:	Date/Time	Received by:	Date/Time
Relinquished by:	Date/Time	Received by:	Date/Time
Relinquished by commercial carrier (circle): UPS FedEx Other: ________		Received by:	Date/Time

LANDAU ASSOCIATES

- ☐ **Seattle/Edmonds** (425) 778-0907
- ☐ **Tacoma** (253) 926-2493
- ☐ **Spokane** (509) 327-9737
- ☐ **Portland** (503) 542-1080
- ☐ ____________

Date ____________

Page ______ of ______

Chain-of-Custody Record

Project Name ____________ Project No. ____________

Project Location/Event ____________

Sampler's Name ____________

Project Contact ____________

Send Results To ____________

Testing Parameters

Turnaround Time
- ☐ Standard
- ☐ Accelerated
- ☐ ____________

Sample I.D.	Date	Time	Matrix	No. of Containers												

Observations/Comments

_X_ Allow water samples to settle, collect aliquot from clear portion

_X_ NWTPH-Dx - run acid wash/silica gel cleanup

____

___ run samples standardized to ____________ product

___ Analyze for EPH if no specific product identified

VOC/BTEX/VPH (soil):
- ___ non-preserved
- ___ preserved w/methanol
- ___ preserved w/sodium bisulfate
- ___ Freeze upon receipt

___ Dissolved metal water samples field filtered

Other ____________

Special Shipment/Handling or Storage Requirements

Method of Shipment

Relinquished by	**Received by**	**Relinquished by**	**Received by**
Signature	Signature	Signature	Signature
Printed Name	Printed Name	Printed Name	Printed Name
Company	Company	Company	Company
Date ______ Time ______	Date ______ Time ______	Date ______ Time ______	Date ______ Time ______

WHITE COPY - Project File **YELLOW COPY - Laboratory** **PINK COPY - Client Representative**

Rev 8/09

H&P Mobile Geochemistry Inc.

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& Field Office - Signal Hill, CA
W handpmg.com E info@handpmg.com
P 760.804.9678 F 760.804.9159

VAPOR / AIR Chain of Custody

DATE:___________
Page ____ **of** _____

Lab Client and Project Information	
Lab Client/Consultant:	Project Name / #:
Lab Client Project Manager:	Project Location:
Lab Client Address:	Report E-Mail(s):
Lab Client City, State, Zip:	
Phone Number:	

Sample Receipt (Lab Use Only)	
Date Rec'd:	Control #:
H&P Project #	
Lab Work Order #	
Sample Intact: ☐ Yes ☐ No ☐ See Notes Below	
Receipt Gauge ID:	Temp:
Outside Lab:	
Receipt Notes/Tracking #:	
Lab PM Initials:	

Reporting Requirements	Turnaround Time	Sampler Information
☐ Standard Report ☐ Level III ☐ Level IV	☐ 5-7 day Stnd ☐ 24-Hr Rush	Sampler(s):
☐ Excel EDD ☐ Other EDD:_________________	☐ 3-day Rush ☐ Mobile Lab	Signature:
☐ CA Geotracker Global ID:__________________	☐ 48-Hr Rush ☐ Other:_____	Date:

Additional Instructions to Laboratory:

☐ Check if Project Analyte List is Attached

**** Preferred VOC units (please choose one):***

☐ µg/L ☐ µg/m³ ☐ ppbv ☐ ppmv

SAMPLE NAME	FIELD POINT NAME (if applicable)	DATE mm/dd/yy	TIME 24hr clock	SAMPLE TYPE Indoor Air (IA), Ambient Air (AA), Subslab (SS), Soil Vapor (SV)	CONTAINER SIZE & TYPE 400mL/1L/6L Summa or Tedlar or Tube	CONTAINER ID (###)	Lab use only: Receipt Vac	VOCs Standard Full List ☐ 8260SV ☐ TO-15	VOCs Short List / Project List ☐ 8260SV ☐ TO-15	Oxygenates ☐ 8260SV ☐ TO-15	Naphthalene ☐ 8260SV ☐ TO-15 ☐ TO-17m	TPHv as Gas ☐ 8260SV/m ☐ TO-15m	TPHv as Diesel (sorbent tube) ☐ TO-17m	Aromatic/Aliphatic Fractions ☐ 8260SV/m ☐ TO-15m	Leak Check Compound ☐ DFA ☐ IPA ☐ He	Methane by EPA 8015m	Fixed Gases by ASTM D1945 ☐ CO2 ☐ O2 ☐ N2			

Approved/Relinquished by:	Company:	Date:	Time:	Received by:	Company:	Date:	Time:
Approved/Relinquished by:	Company:	Date:	Time:	Received by:	Company:	Date:	Time:
Approved/Relinquished by:	Company:	Date:	Time:	Received by:	Company:	Date:	Time:

**Approval constitutes as authorization to proceed with analysis and acceptance of conditions on back*

Rev 12/31/2013

Summa Canister Field Test Data/Chain of Custody

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For Lancaster Laboratories use only
Acct. # ______________ Group # ______________ Sample # ______________
Instructions on reverse side correspond with circled numbers.

(1) Client Information		(3) Turnaround Time Requested (TAT) (circle one)
Client	Account #	Standard
Project Name/#		Rush (specify) ______________
Project Manager	P.O. #	(4) Data Package Required? Yes No
Sampler	Quote #	(5) EDD Required? Yes No
Name of state where samples were collected		

(6) Analyses Requested

(2) Sample Identification	Sample Collection Date	Time Start (24 hr clock)	Time Stop (24 hr clock)	Canister Pressure In Field ("Hg) (Start)	Canister Pressure in Field ("Hg) (Stop)	Interior Temp. (F) (Start)	Interior Temp. (F) (Stop)	Flow Reg. ID	Can ID	Can Size (L)	Controller Flowrate (ml/min)	EPA TO - 15	EPA 18 ☐ BTEX ☐ MTBE	EPA 25 (select range below)	Helium as tracer	O2/CO2	Library Search	

(7) Instructions/QC Requirements & Comments

EPA 25 (check one)
☐ C1 - C4 ☐ C2 - C10
☐ C1 - C10 ☐ C4 - C10 (GRO)
☐ C2 - C4

			(8)
Canisters Shipped by:	Date/Time:	Canisters Received by:	Date/Time
Relinquished by:	Date/Time:	Received by:	Date/Time:
Relinquished by:	Date/Time:	Received by:	Date/Time:

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As-Built Well Completion Form

Exploration No.: ____________

Well No. (If different than Expl. No.): ______

Client/Owner: ____________ Project No.: ____________

Project Name: ____________

Drilling Co.: ____________

LAI Rep(s): ____________

Installation Start Date: ____________ Hour: ______

Installation Finish Date: ____________ Hour: ______

Well Type: ☐ Single ☐ Nested ☐ Clustered

BORING AND WELL DIMENSIONS AND INSTALLATION DETAILS

DOE Unique Well No.: ____________

Number of Pipes in Boring: ____________

Boring Diameter at Top of Hole: ____________

Does Diameter of Hole Change? ____________

Boring Diameter at First Step Down: ____________

Depth of First Step Down: ____________

Boring Diameter at Second Step Down: ____________

Depth of Second Step Down: ____________

Well Completion Date: ____________

Elevation of Well Cover: ____________

Elevation of Top of Well Pipe: ____________

Depth to Water: ____________

Date: ____________ Time: ____________

MATERIALS USED

______ Sacks of ____________ Sand

______ Sacks of ____________ Concrete/Cement

______ Sacks of ____________ Grout Mix Used

______ Sacks of Bentonite Chips

______ Feet of ______-inch PVC Blank Casing

______ Feet of ______-inch PVC Slotted Screen

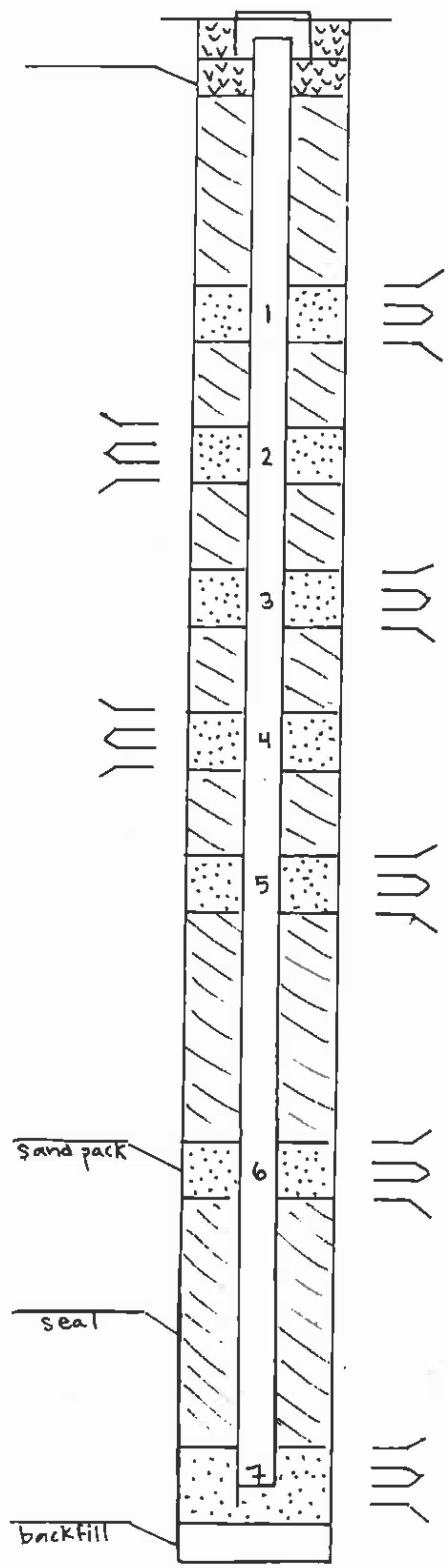
______ Threaded End Cap

______ Waterproof Well Seal/Slip Cap

______ Flush Mount/Aboveground Protective Monument

______ Protective Posts

\\Edmdata\wproc\000MasterForms\Field\Well As-Built Form.cdr



LANDAU ASSOCIATES

Drum/Tank Inventory

Project Name ______________________________ Project Number ______________________________

Location ______________________________ Date ______________________________

Client ______________________________ Landau Representative ______________________________

Drum/Tank Number	Date Generated	Contents	Estimated Quantity	Suspected Contaminants	Generation Source	Disposal Method / Date Disposed	Sketch of Site and Drum/Tank Location

LANDAU ASSOCIATES

Field Report

Project No.: ______________________ Report No.: ________

Client: ______________________ Date: ________

Project Name: ______________________ DPD Permit No.: ________

Location: ______________________

Weather Conditions: ______________________

Prepared By: ______________________

Visitors: ______________________

Unsatisfactory Conditions & Recommended Correction: ______________________

____

Attachments: None______________________

Signed:______________________

130 2nd Avenue South • Edmonds, WA 98020 • (425) 778-0907 • fax (425) 778-6409 • www.landauinc.com

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Surface Water Sample Collection Form

PROJECT ____________ PROJ. NO. ____________
EVENT ____________

SAMPLE NO. ____________
DATE COLLECTED ____________ TIME ____________

WEATHER ____________ COLLECTOR ____________

WATER LEVEL/WELL/PURGE DATA

Sample Type: ☐ Groundwater ☒ Surface Water ☐ Other

Depth of Water Column: ____________ Location of Sample Within Water Column: ____________

Precipitation Info: ____________

Sample Location: ____________

Begin Purge: Date/Time ____________ **End Purge: Date/Time** ____________

Purge Water Disposal to: ☐ 55-gal drum ☐ Storage Tank ☒ Ground ☐ Other ____________

Time	Temp. (°F/°C)	Cond. (uS/cm)	DO (mg/L)	pH	ORP (mV)	Comments/Observations
Purge Goals: Stabilization of parameters for 3 consecutive readings within the following limits						
	+/-1 deg	+/-10%	+/-10%	+/-0.2 units	+/-10 %	
Average:						

SAMPLE COLLECTION DATA

Sample Collected With: ☐ Coliwassa ☐ Ladel ☐ Pump/Type ____________

Made of: ☐ Stainless Steel ☐ PVC ☐ Teflon ☐ Polyethylene ☐ Other ☐ Dedicated

Decon Procedure: ☐ Alconox Wash ☐ Tap Rinse ☐ DI Water ☐ Dedicated ☐ Other

Sample Description (color, turbidity, odor, sheen, etc.): ____________

pH Meter: YSI Cond Meter: YSI ORP Meter: YSI Calibration Date: ____________

QUANTITY	Analysis
3-40 mL VOA	Boeing 38 VOC's
2-40 mL VOA	SIM for vinyl chloride

Duplicate Sample No(s): ____________

Comments: ____________

Signature: ____________ Date ____________

LANDAU ASSOCIATES

Groundwater Low-Flow Sample Collection Form

Projec.: ____________________ Project Number ____________________

Event: ____________________ Weather: ____________________

Sample Number: ____________________ Date: ____________ Time: ____________

Well Name: ____________________ Landau Representative: ____________________

WATER LEVEL/WELL/PURGE DATA

Well Condition: Secure (YES or NO) Damged (YES or NO) Describe: ____________________

DTW Before Purging (ft) ________ Time: ________ GW Meter No.(s) ____________________

Begin Purge: Date/Time: ____________ End Purge: Date/Time: ____________ Gallons Purged: ________

Purge water disposed to: ☐ 55-gal Drum ☐ Storage Tank ☐ Ground ☐ Other ____________

Time	Temp (°F/°C)	Cond. (uS/cm)	D.O. (mg/L)	pH	ORP (mV)	Turbidity (NTU)	Purge Volume (gal)	Comments/Observations
	Purge Goals: Stabilization of Parameters for 3 consecutive readings within the following limits							
	+/-1 deg	+/-10%	+/-10%	+/-0.2 units	+/-10 %	+/-10%		

SAMPLE COLLECTION DATA

Sample Collected With: ☐ Bailer ☐ Pump/Pump Type peristaltic pump

Made of: ☐ Stainless Steel ☐ PVC ☐ Teflon ☐ Polyethylene ☐ Other ☐ Dedicated

Decon Procedure: ☐ Alconox Wash ☐ Tap Rinse ☐ DI Water ☐ Dedicated

(By Numerical Order) ☐ Other ____________________

Sample Description (color, turbidity, odor, sheen, etc.): ____________________

Replicate	Temp (°F/°C)	Cond. (uS/cm)	D.O. (mg/L)	pH	ORP (mV)			Comments/Observations
1								
2								
3								
4								
Average:								

QUANTITY	ANALYSIS
	Iron (mg/L)

Duplicate Sample No(s): ____________________

Sample Location: ____________________

Comments: ____________________

Signature: ____________________ Date: ____________

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Client: Boeing Project: 025164.080.085
Sample: ______________________________
Date:______ Time:_____ Sampler: KMH, JCS
Analysis: VOC's Site: Boeing Auburn

Exploration No. ____________
Page ________ of ________
Date ________ Hour ________

Log of Exploration - RotoSonic

LANDAU ASSOCIATES
ENVIRONMENTAL | GEOTECHNICAL | NATURAL RESOURCES

Project Name ____________ Project No. ____________

Client/owner ____________ Exploration Operator ____________

Exploration Method ____________

Logged by ____________ Exploration Completed ____________

Ground Surface Conditions ____________

Location Sketch (show dimensions to mapped features)

North Arrow

Coordinates: "x" (East)________ "y"(North) ________ Method ________ Elevations ________ Datum ________

Weather Conditions ____________

Sampler and Hammer Information

a = 3.25-in. O.D. – D&M	1 = 300-lb./30-in. Drop
b = 2.0-in. O.D. – SPT	2 = 140-lb./30-in. Drop
c = Shelby Tube	3 = Pushed
d = Grab Sample	4 = Vibrocore
g = 2.5-in. O.D.– WSDOT	5 = ________
h = 3.0-in. O.D. – M.Calif.	
i = ________	

Water Level Information

Date						
Time						
Depth to Water						
Hole Depth						
Casing Depth						

Run Depth (top) (ft.)	Run Length (ft.)	Recovery Length (ft.)	Retained Depth (top) (ft.)	Retained Length (ft.)	Run Number	Sample Number	Date/Time	Other Test Data: ____	USCS Symbol / Unit Contact	Graphic Log	Depth Scale (ft)	Sample Description Color, secondary soil type, PRIMARY SOIL TYPE with modifiers and minor components (density/consistency, moisture)(geologic unit)	Comments on Heave, Water Conditions, & Drilling Action
											0		
											1		
											2		
											3		
											4		
											5		
											6		
											7		
											8		
											9		

Total Depth ________ Finish Date ________ Hour ________ Continued

Exploration No. ____________
Page ________ of ________

Log of Exploration - RotoSonic

Rn Dpth	Rn Len	Rec Length	Rt.Depth	Rt.Lngth	Run #	Sample #	Date/ Time	Other	USCS	Graphic	Depth	Sample Description	Comments
											0		
											1		
											2		
											3		
											4		
											5		
											6		
											7		
											8		
											9		
											0		
											1		
											2		
											3		
											4		
											5		
											6		
											7		
											8		
											9		

Exploration No. ________________
Page ____________ of _________

Log of Exploration - RotoSonic

LANDAU ASSOCIATES

Exploration No. ___________________
Date __________ Hour _____________

Log of Exploration

Project Name ______ Project No. _____

Client/Owner ______ Exploration Operator ____________

Exploration Method _ ____________________________

____

Logged by _ ____ Exploration Completed ______________

Ground Surface Conditions ____

Weather Conditions ____

Location Sketch (show dimensions to mapped features)

North Arrow

(East) (North)

Coordinates: "x" __________ "y" __________ Method __________

Elevations ______________________ Datum _________________

Sampler and Hammer Information

a = 3.25-in. O.D. – D&M	1 = 300-lb./30-in. Drop
b = 2.0-in. O.D. – SPT	2 = 140-lb./30-in. Drop
c = Shelby Tube	3 = Pushed
d = Grab Sample	4 = Vibrocore
g = 2.5-in. O.D.– WSDOT	5 = _____________
h = 3.0-in. O.D. – M.Calif.	
i = ______________	

Water Level Information

Date		
Time		
Depth to Water		
Hole Depth		
Casing Depth		

Sample Depth (top) (ft.)	Sample Length (ft.)	Recovery Length (ft.)	Retained Depth (top) (ft.)	Retained Length (ft.)	Sample Number	Sampler/Hammer Codes	Blow Counts	Other Test Data) ____	USCS Symbol / Unit Contact	Depth Scale (ft)	Sample Description Color, secondary soil type, PRIMARY SOIL TYPE with modifiers and minor components (density/consistency, moisture)(geologic unit)	Comments on Heave, Water Conditions, & Drilling Action
										0		
										1		
										2		
										3		
										4		
										5		
										6		
										7		
										8		
										9		
										0		
										1		
										2		
										3		
										4		
										5		
										6		
										7		
										8		
										9		
										0		

Total Depth _____________ Finish Date ________________ Hour _____________ Continued

Photograph Log

Roll No./Phone No.	Comments

LANDAU ASSOCIATES

Sub-Slab Vapor and Soil Gas Sample Collection Form

Project Name ______________________ Project Number ______________________

Client ______________________ Sample Number ______________________

Landau Representative ______________________ Date/Time Collected ______________________

Location ______________________

____

Weather ______________________

WELL AND PURGE DATA

Sample Type: ☐ Sub-slab ☐ Ambient Air ☐ Soil Gas

Sample Location: ______________________

Sample Port Type: ☐ Cox Colvin Stainless Steel ☐ Other: ______________________

Tubing: ☐ Teflon ☐ Other: ____________

Sampling tip: ☐ Stainless Steel ☐ Nylon or Polyethylene ☐ Other: ________

Hole Diameter: ____________ (inches) Depth of Hole (inches): ______________________

Purge Volume Calculation: ______________________

Hole Diameter x Depth of Hole

Volume Purged (in^3): ______________________

Purge Equipment: Mity Vac hand pump where 1 stroke = 1 cubic inch (e.g. purge Vol = 6.3in^3 = 7 strokes)

Vol. Purged (in3)	Temp. (°F/°C)	PID (ppm)	He Detector	Comments/Observations

SAMPLE COLLECTION DATA

Sample Container: ☐ Summa Canister, Size (liters) ____________ ☐ Tedlar Bag, Size (liters): ____________ ☐ Other: ____________

Canister number: ____________

Flow regultor number: ____________

Sample Type: ☐ Grab ☐ Integrated (composite sample over time)

Sample Collection/Purge Pump (if used): ______________________ Pressure: ____________

Summa Canister, Pre-Sampling and Post-Sampling

Initial Vacuum (inches of mercury): ______________ Vacuum After Sample Collection (specify units): ____________________

LABORATORY ANALYSES:

____

____

____

____

Duplicate Sample Number(s): ______________________

Comments: ______________________

concrete slab thickness =

PID =

____

____

Signature: ______________________ Date: ______________________

Utility Locate Checklist

Project Name ______________________ Project No. ______________________

Location ______________________ Date ______________________

Client ______________________ Landau Rep. ______________________

Exploration Number (White)	TV & Telep. (Orange)	Lighting & Elect. (Red)	Fuel & Gas (Yellow)	Water (Blue)	Drains & Sewer (Green)	Access / Restriction	O.K. To Drill/Exc.	Remarks

Vapor Intrusion Assessment Building Survey

LANDAU ASSOCIATES

Project No.: ____________________

Client: ____________________ Date/Time: __________

Project Name: ____________________

Location: ____________________

Weather Conditions (note wind direction/intensity): ____________________

Prepared By: ____________________

1. OCCUPANT:

   Interviewed: Y / N

   Last Name:__________________________First Name:____________________________

   Contact Info:____

   Number of Occupants/persons at this location:______________________________

   Age of Occupants:____

2. OWNER OR LANDLORD: (Check if same as occupant____)

   Interviewed: Y / N

   Last Name:__________________________ First Name:____________________________

   Address:____

   Contact Info:____

3. BUILDING CHARACTERISTICS:

   a. Type of Building: (Circle appropriate response)

Residential	School	Commercial/Multi-use
Industrial	Church	Other:

   b. If the property is residential, type? (Circle appropriate response)

Ranch	Split Level	Colonial
Raised Ranch	Contemporary	Mobile Home
Cape Cod	Apartment House	Townhouse/Condos

Duplex Log Home Modular

Other:

c. If multiple units, how many?

d. If the property is commercial, what type?

Business Type(s):

Does it include residences (i.e., multi-use)? Y / N If yes, how many?

4. OCCUPANT/OWNER QUESTIONAIRE

a. Typical hours home and rooms most occupied:

b. Building age:

c. Type of heating used in the building: (circle all that apply – note primary)

Hot air circulation	Heat pump	Hot water baseboard
Space heaters	Steam radiation	Radiant floor
Electric baseboard	Wood stove	Outdoor wood boiler
Other stove:		

d. Primary type of fuel used in the building:

Natural gas	Fuel oil	Kerosene
Electric	Propane	Solar
Wood	Coal	

e. Boiler/furnace located in:

Basement Outdoors Main floor Other:

f. Ventilation:

Central air   Window units   Open window   Heat pump   Ceiling fan

None

g. Is there a radon mitigation system for the building/structure?   Y / N

Date of Installation:

Is the system active or passive?   Active / Passive

h. If it is a non-residential building, do they know if the building is under positive or negative pressure?

i. Water Supply:

Public water   Drilled well   Driven well   Dug well   Other:

j. Sewage Disposal:

Public sewer   Septic tank   Leach field   Dry well   Other:

k. How is roof runoff/storm drainage routed?

Downspouts directly to surface

Directed to the surface away from the building

Infiltrated

Collected and reused

l. Is the basement/lowest level occupied?

Full-time   Occasionally   Seldom   Almost Never

m. Does the garage have a separate heating unit?   Y / N

n. Has the building ever had a fire?   Y / N   When:

o. Is a kerosene or unvented gas space heater present?   Y / N
Where & Type?

p. Is there a workshop or hobby/craft area?   Y / N
Where & Type?

q. Is there smoking in the building? Y / N Frequency?

r. Have cleaning products been used recently? Y / N
When & Type?

s. Have cosmetic products been used recently? Y / N
When & Type?

t. Has painting/staining been done in the last 6 months? Y / N
Where & When?

u. Is there new carpet, drapes or other textiles? Y / N
Where & When?

v. Have air fresheners been used recently? Y / N
When & Type?

w. Is there a clothes dryer? Y / N If yes, is it vented outside? Y / N

x. Has there been a pesticide/herbicide application? Y / N
When, type, & location?

y. Do any of the building occupants use solvents or volatile chemicals at work? (e.g., chemical manufacturing or laboratory, auto mechanic or auto body shop, painting, fuel oil delivery, boiler mechanic, pesticide applicator, cosmetologist, carpet installer) Y / N

If yes, what type of solvents are used?

If yes, are their work clothes stored at or washed at home? Y / N

z. Do any of the building occupants regularly use or work at a **dry-cleaning** service? (circle appropriate response below)

Yes, use dry-cleaning regularly (weekly)

Yes, use dry-cleaning infrequently (monthly or less)

Yes, work at a dry-cleaning service

No

Unknown

aa. Ask them to review the Common Household Chemicals List (page 13) and to point out locations where these items are stored.

List specific locations/items that need further inspection based on responses to these questions:

5. BUILDING TOUR/INSPECTION
    a. General
        i. Review the Occupant/Owner Questionnaire and inspect associated locations of interest (e.g., heaters, HVAC unit, hobby area, etc.)
        ii. Above grade construction:

            Wood frame   Concrete   Stone   Masonry/bricks

        iii. Are there air distribution ducts present? Y / N
        iv. Describe the supply and cold air return ductwork; its condition where visible; whether there is a cold air return and tightness of duct joints. Indicate the locations on the floor plan diagram.
        v. General use of each floor: (e.g., family room, bedroom, laundry, workshop, storage)

            Basement:

            1st Floor:

            2nd Floor:

            3rd Floor:

            4th Floor:

        vi. Please describe any odors in the building:
        vii. Use air current tubes or tracer smoke to evaluate airflow patterns and qualitatively describe:

            Airflow between floors:

            Airflow near a potential preferential pathway:

            Outdoor air infiltration:

            Infiltration into air ducts:

b. Basement (Circle all that apply)

Basement type:	full	slab	crawlspace	other:
Basement floor:	concrete	dirt	stone	other:
Basement floor:	unsealed	sealed	covered with:	
Foundation walls:	poured block	stone	other:	
Foundation walls:	unsealed	sealed	sealed with:	
The basement is:	wet	damp dry	moldy	
The basement is:	finished	unfinished	partially finished	

Is a sump present? Y / N

Is there water in the sump? Y / N

Basement/Lowest level depth below grade: (in feet)

Identify potential soil vapor entry points and approximate size: (e.g., cracks, utility ports, drains)

Note the general condition of the basement/crawlspace floor:

c. Kitchen

i. Is there an exhaust fan? Y / N If yes, where is it vented?

d. Bathroom(s)

i. Is there an exhaust fan? Y / N If yes, where is it vented?

e. Garage

i. Is the garage attached? Y / N

ii. Are petroleum-powered machines or vehicles stored in the garage? (e.g., lawnmower, ATV, car) Y / N Please specify:

f. Floor plans:

Draw a plan view sketches of the basement & upper floor(s) of the building (**use consistent orientation per plan)**.

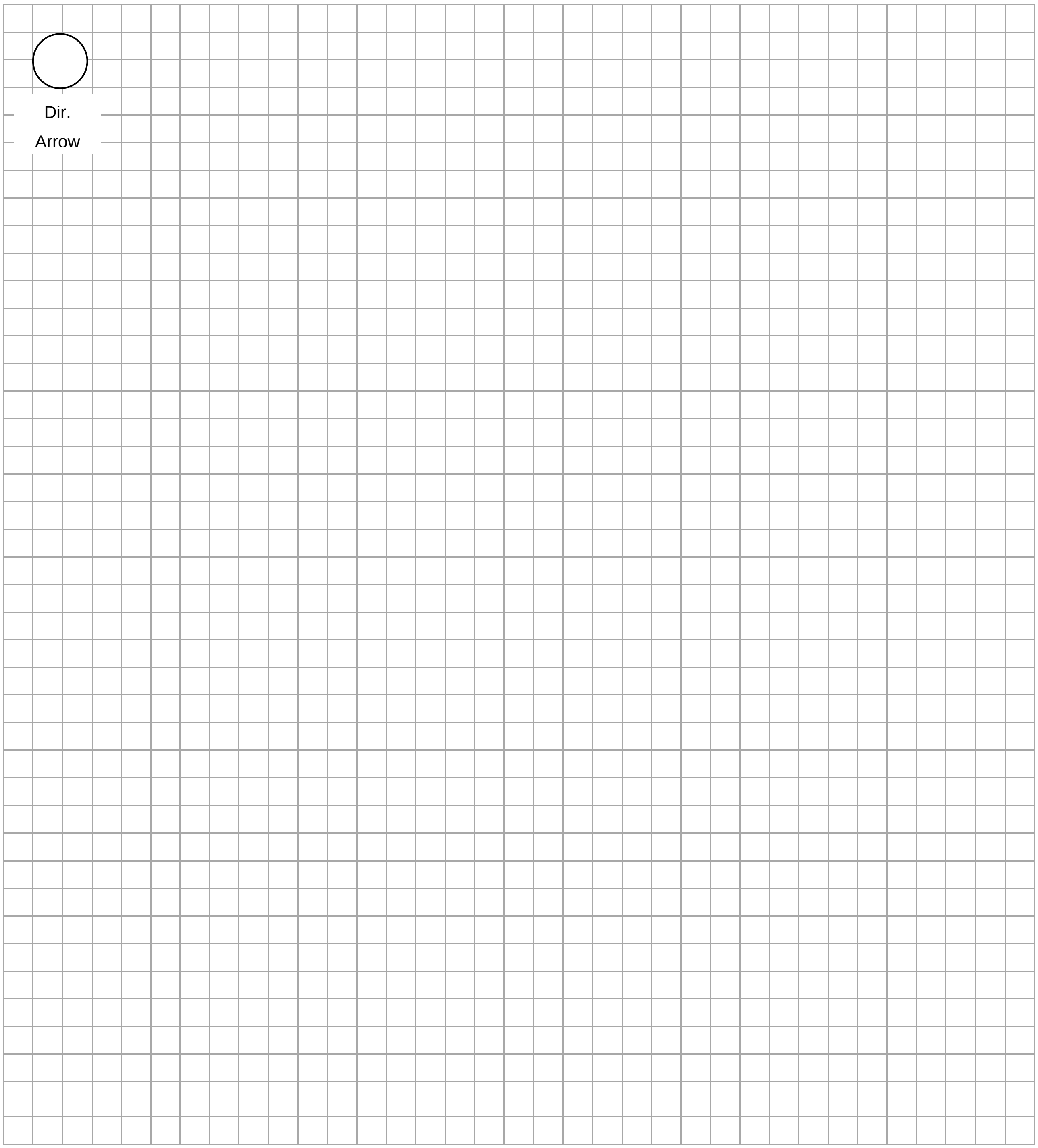
Note any potential air sampling locations, preferential pathways, household chemicals, heating and ventilations elements, plumbing, doors, windows, and other items of interest.

i. Basement:

Dir.
Arrow

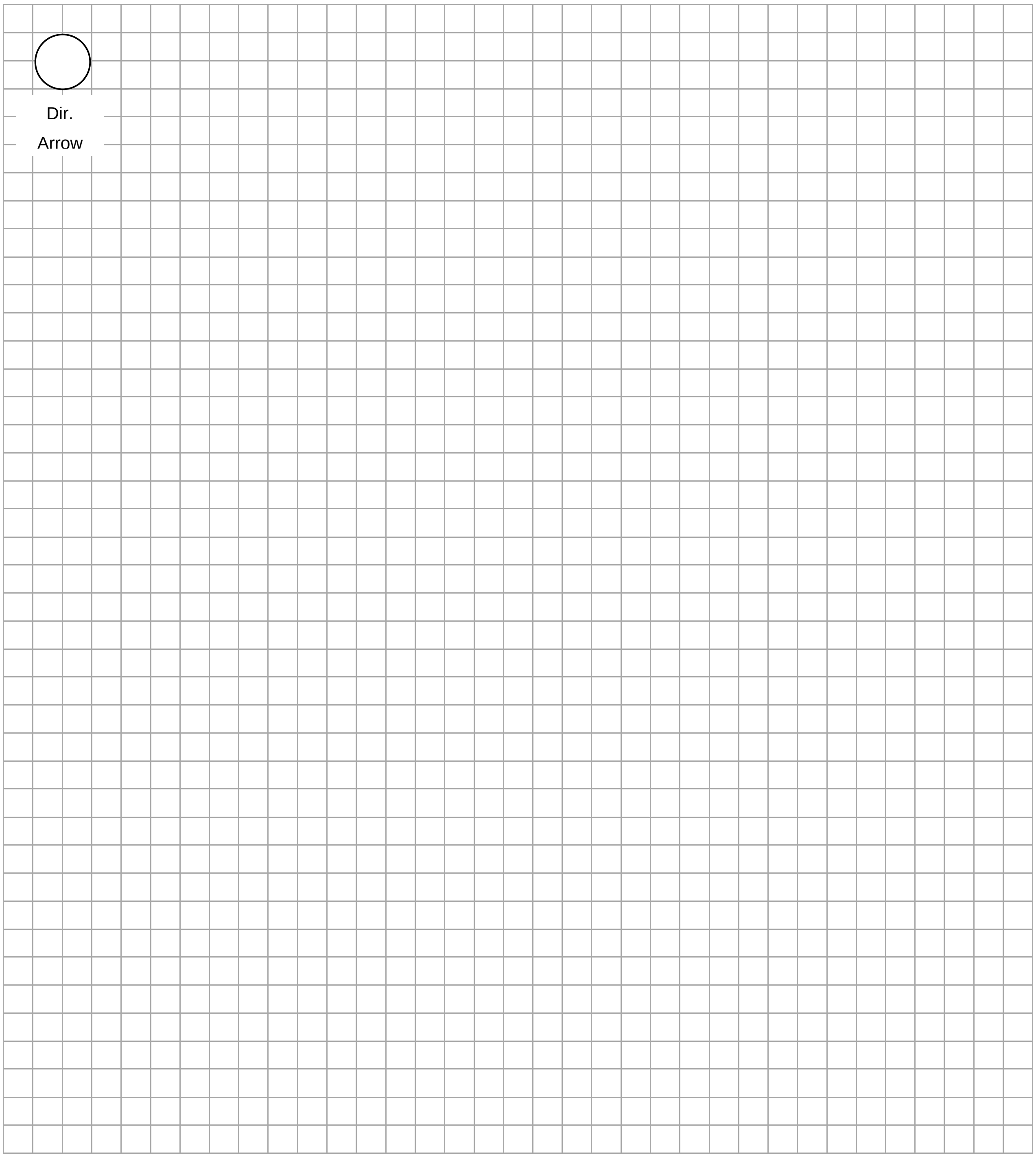
ii. First Floor:

Note any potential air sampling locations, preferential pathways, household chemicals, heating and ventilations elements, plumbing, doors, windows, and other items of interest.



iii. Second Floor:

Note any potential air sampling locations, preferential pathways, household chemicals, heating and ventilations elements, plumbing, doors, windows, and other items of interest.



iv. Outdoor Plot

Draw a sketch of the area surrounding the building being sampled. If applicable, provide information on spill locations; potential air contamination sources (industries, gas stations, repair shops, landfills, etc); outdoor air sampling location(s). Also indicate the locations of the well, septic, and drainage systems, if applicable; any known utilities; and a qualifying statement to help locate the site on a topographic map. **Note any standing water within the yard.**

Dir. Arrow

g. Product inventory log

Describe the condition of the product containers as **Unopened (UO)**, **Used (U)**, or **Deteriorated (D)**. Photographs of the front and back of the product containers can replace the hand written list of chemical ingredients; however, the photographs must be of good quality & ingredient labels must be legible.

Location	Product Description	Size (units)	Condition (UO, U, D)	Chemical Ingredients	Field Instrument Reading (units)	Photo Y / N

Additional Notes/Comments:

Attachments: ____________________

Signed: ____________________

Common Household Chemicals

- Adhesives (automotive, household, craft, plumbing)
- Household cleaners
- Lubricants
- Bonders
- Adhesive removers
- Antistatic aerosols
- Automotive parts cleaners
- Paint strippers
- “Spot removers” for fabrics
- Jewelry polish
- Water repellants
- Spray paints
- Dry-cleaned materials (e.g., clothes)
- Caulks and sealants
- Cosmetics including hair spray, nail polish, nail polish remover, and perfume/cologne
- Air fresheners and odor eliminators
- Inset repellants

Photograph Log

Roll No./Phone No.	Comments

As-Built Well Completion Form

Exploration No.: ______________

Well No. (If different than Expl. No.): ______

Client/Owner: ______________ Project No.: ______________

Project Name: ______________

Drilling Co.: ______________

LAI Rep(s): ______________

Installation Start Date: ______________ Hour: ________

Installation Finish Date: ______________ Hour: ________

Well Type: ☐ Single ☐ Nested ☐ Clustered

BORING AND WELL DIMENSIONS AND INSTALLATION DETAILS

DOE Unique Well No.: ______________

Number of Pipes in Boring: ______________

Boring Diameter at Top of Hole: ______________

Does Diameter of Hole Change? ______________

Boring Diameter at First Step Down: ______________

Depth of First Step Down: ______________

Boring Diameter at Second Step Down: ______________

Depth of Second Step Down: ______________

Well Completion Date: ______________

Elevation of Well Cover: ______________

Elevation of Top of Well Pipe: ______________

Depth to Water: ______________

Date: ______________ Time: ______________

____

____

MATERIALS USED

________ Sacks of ______________ Sand

________ Sacks of ______________ Concrete/Cement

________ Sacks of ______________ Grout Mix Used

________ Sacks of Bentonite Chips

________ Feet of ______-inch PVC Blank Casing

________ Feet of ______-inch PVC Slotted Screen

________ Threaded End Cap

________ Waterproof Well Seal/Slip Cap

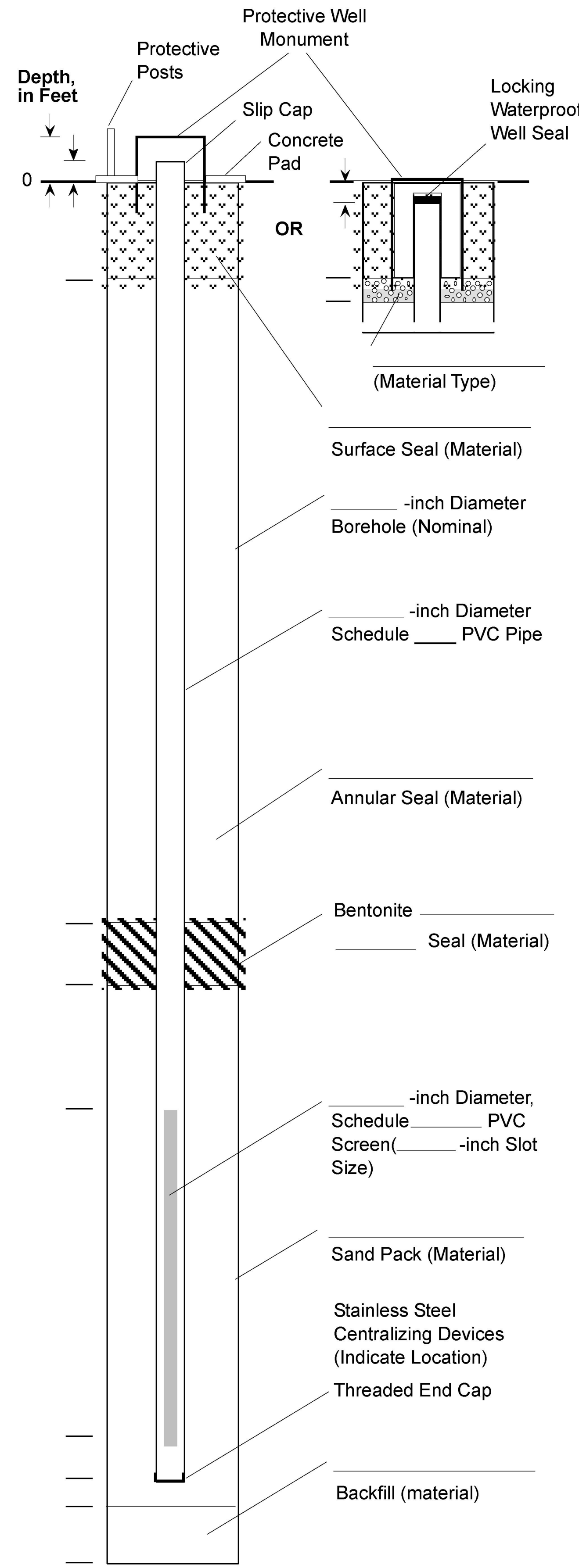
________ Flush Mount/Aboveground Protective Monument

________ Protective Posts

____

____

____



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LANDAU ASSOCIATES

Well Development Record

Project Name: ______________________
Location: ______________________
Client: ______________________

Project No. ______________________
Date: ______________________
Landau Representative: ______________________

Well Number: ______________________

Time: ______________________

Depth to Water: ______________________
Well Depth: ______________________
Casing Diameter: ______________________
Casing Volume: ______________________

Volume of Schedule 40 PVC Pipe

Diameter (inch)	O.D. (inch)	I.D. (inch)	Volume (gal/ln ft)	Wt. Water (lbs/ln ft)
1.25	1.660	1.380	0.08	0.64
2	2.375	2.067	0.17	1.45
4	4.500	4.026	0.66	5.51
6			1.47	12.24

Est. Purge Volume: ______________________

Method of Development: ______________________

Surge Block: Yes ______ No ______

Begin Development: Time:
Finish Development: Time:

Final Volume Purged: ______________________
Water Disposal: ☐ 55-gal drum ☐ Storage Tank ☐ Ground ☐ Other __________

Initial Water Quality: (Turbidity, Color, Odor, Other) ______________________ Initial Yield: ______
pH: ________ Temp: ________ Conductivity: ________ Turbidity: ___
Notes: ______________________

Water Quality Notes: ______________________

Gallons	pH	Temperature	Conductivity	Turbidity	Comments

Final Water Quality: (Turbidity, Color, Odor, Other) ______________________
Final Yield: ______________________
pH: ________ Temperature: ________ Conductivity: ________ Turbidity: ________

Depth to Water After Development: ______________ Well Depth After Development: ______________

APPENDIX C

Soil Gas Sampling

Appendix C – Soil Vapor Sample Collection

Sub-Slab Soil Gas Sampling Procedure

After sample port installation, the sample point will be left undisturbed for a minimum of 2 hours to allow for the soil vapor to equilibrate. To prevent the sample point from being tampered with or damaged, a small safety cone will be placed over the sampling assembly during the equilibration period.

Each sub-slab sample will be collected in a 1-liter (L) Summa (vacuum) canister fitted with a flow controller. The flow controller will be calibrated by the laboratory to a flow rate not to exceed 200 milliliters per minute.

After the equilibration period is complete:

- Turn on the helium detector and zero-out the instrument to read a helium concentration of 0 parts per million (ppm).
- Attach sample tubing to the Summa canister. Teflon or Nylaflow tubing is acceptable. If using a vapor pin, install new connection tubing (Masterflex® or other acceptable connection tubing) on the barb of the Vapor Pin and connect it to the sample tubing. If using the vapor implant, the sample tubing connected to the porous implant should be long enough to connect it directly to the Summa canister.
- Place the shroud over the sample point, tubing, and Summa canister.
- Connect the helium tank to the shroud from the exterior of the shroud and ensure that all connections are tight. Place the helium detector inside the shroud. Only ultra-pure helium should be used. Balloon grade helium can contain other contaminants and is not acceptable for use in sampling.
- Attach the shroud lid to the shroud. Release one burst of helium into the shroud.
- Concentrations should be at least two orders of magnitude above the lower detection limit of the helium detector (for example: if the lower detection limit is 25 ppm, the concentration in the shroud should be at least 2500 ppm). It is expected that helium concentrations will peak and begin to fall. Maintain concentrations inside the shroud at least two orders of magnitude above the lower detection limit. If concentrations fall near or below that concentration, add another short-burst of helium to maintain the minimum concentration.
- Using the attached gloves, open the Summa canister valve to begin collecting the sample.
- Record helium concentration and time at the start of sampling and at the end of sampling. If the sampling period is longer than 5 minutes, record one additional reading approximately halfway through the sample period. Record the lowest concentration of helium during sample period.
- Once the vacuum gauge on the Summa canister reaches 0 inches of mercury (in. Hg), remove the shroud lid and close the valve on the Summa canister itself. Ensure the Summa canister valve is closed prior to disconnecting it from the well to prevent accidental entrance of remnant low-level helium from the shroud into the Summa canister.

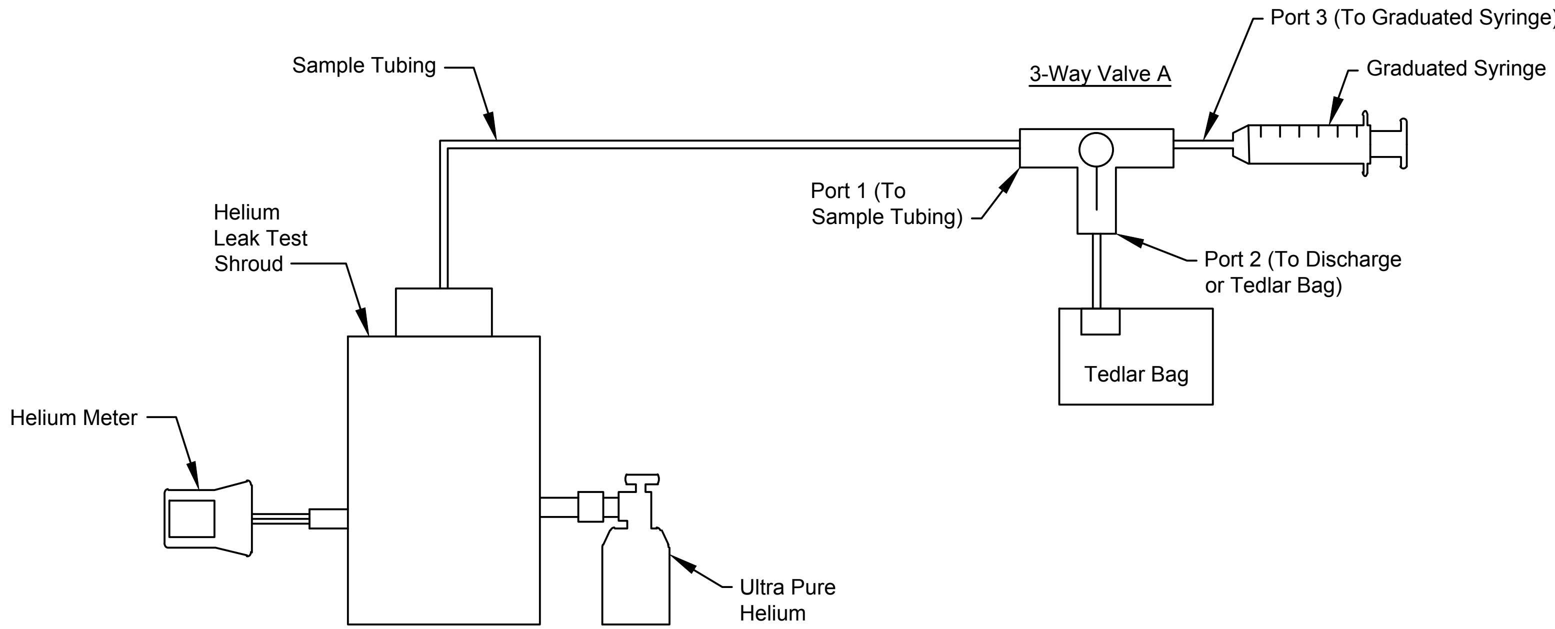
- After collecting the required samples at each location, the sample point assembly will be removed and the core hole patched with quick-set concrete to reseal the concrete slab.

Borehole Soil Gas Sampling Procedure

Figures C-3 and C-4 present helium leak test (Figure C-3) and shut-in test, purge and sample collection set-up (Figure C-4) diagrams specific to soil gas sampling:

- Select the appropriate height shroud to fully encapsulate the aboveground portion of the sample port and tooling to complete a helium leak test. Teflon® or Nylaflow tubing should be used throughout the sample train; avoid use of polyethylene tubing. Place the shroud over the sample port and extend the sample tubing through the outlet at the top of the shroud.
- Hydrated bentonite or bentonite clay can be used around the base of the shroud if an uneven ground surface is present. Though this is usually not necessary in order to maintain adequate helium levels inside the shroud. sub
- Connect the helium tank to the shroud from the exterior of the shroud, and ensure that all connections are tight.
- Turn on the helium detector and zero-out the instrument in ambient air to read a helium concentration of 0 percent and/or 0 parts per million (ppm). Insert the probe of the meter inside the shroud.
- Release helium into the shroud until the helium detector indicates the air inside the shroud contains at least 70 percent helium. Record the highest concentration of helium in ppm.
- Purge the sample train: Connect to the end of the sample tubing to port 1 of a laboratory-provided 3-way valve (3-way valve A) and connect a large graduated syringe to port 3 of the 3-way valve A (port 2 is left open for discharge). Purge 1volume of air from the sample train by placing the valve so that port 2 (discharge) is closed and extracting the required volume of air with the graduated syringe; turn the valve so port 1 (sample tubing is closed and push the extracted air out of the syringe through port 2.
- Collect soil gas for leak testing: Connect a Tedlar bag to port 2 of the 3-way valve A. Turn the valve so port 2 is closed. Collect a sample of air from the tubing using the graduated syringe. Turn the valve so port 1 is closed and empty the syringe into a Tedlar bag. Repeat the process until approximately 400 mL of soil gas has been purged into the Tedlar bag. Turn the valve so port 1 is closed. Leave the valve in this position until the shut-in test has been completed and the sample is ready to be collected. Close the Tedlar bag and remove it from the valve. Remove the syringe from Port 3 of the 3-way valve A. Leave the sample tubing connected to the 3-way valve A.
- Remove the helium detector from the sample shroud. Zero-out the instrument to read helium concentration of 0 ppm and 0 percent.
- Insert the helium detector into the Tedlar bag to measure the helium concentration in the extracted soil gas. Concentrations of helium in the sample should be zero.
- If concentrations of helium are detected in the Tedlar bag sample, a leak is present in the surface seal, allowing ambient air to enter the well and then the sample. Double-check surface seal, tightness of fittings and other possibilities for leaks and repeat the test.

- Attach the Summa canister portion of the sample train to port 2 of the 3-way valve A. The Summa canister portion of the sample train consists of the Summa canister, a vacuum gauge, and inline flow controller. To port 3 of the 3-way valve A, attach an inline vacuum gauge, a second 3-Way Valve (3-way valve B) and a large graduated syringe; on 3-way valve B, connect port 1 to the syringe, port 2 to the inline vacuum gauge and 3-way valve A, and leave port 3 open for discharge of purge air. The same syringe may be used for the helium leak test and shut in test unless there are concerns about helium contamination in the syringe.
- Turn 3-way valve A so that port 1 (sample tubing) is closed. Turn 3-way valve B so that port 3 (discharge) is closed. At this point the sample train between the Summa canister and the syringe will be open. Use the syringe to pull a vacuum on the sample train. Both vacuum gauges should indicate a vacuum has been applied. Record the shut in test starting vacuum pressure. Hold the vacuum for two minutes. Record the shut-in test ending vacuum. If the vacuum holds steady, this indicates there are no leaks in the sample train between the sample tubing and the summa canister. At this point the entire sample train has been tested for leaks.
- If the vacuum pressure drops during the shut-in test period, a leak is present. Double-check tightness of fittings, examine tubing and other equipment for defects or other possible leaks and repeat the test.
- Turn valve B so that port 3 (discharge) is closed. Turn 3-way valve A so that port 2 (Summa canister) is closed. At this point the sample train will be open between the sample tubing and the syringe. Use the syringe to purge 3 volumes from the sample train (approximately 6 mL per ft of ¼- inch sample tubing) by filling the syringe, turning 3-way valve B so port 2 is closed, and discharge the air from the syringe through port 3. Repeat the process if the required purge volume is greater than the capacity of the syringe. Record the purge volume.
- Once purging is complete, turn 3-way valve A so that port 1 (syringe) is closed. The sample train will then be open between the Summa canister and the sample tubing.
- Insert the helium detector probe back into the helium shroud. Maintain concentrations of helium in the shroud exceeding 70 percent throughout sample collection.
- Open the Summa canister valve to begin collecting the sample. The 400 mL evacuated canister and 200 mL per minute flow regulator will allow for the collection of a sample in 2-3 minutes. Allow the canister to fill completely [0 inches of mercury (in. Hg)]. Collecting a full 400 mL sample will allow the laboratory to reach the projected limits of quantitation (LOQs). The LOQs are presented in the attached Table 1.
- Once the vacuum gauge on the Summa canister reads 0 in. Hg, close the valve on the Summa canister itself. Ensure the Summa canister valve is closed prior to disconnecting if from the well to prevent entrance of ambient air.
- Prepare the sample for transport. Analyze the sample for the chemicals of concern and helium (ASTM International D-1945).



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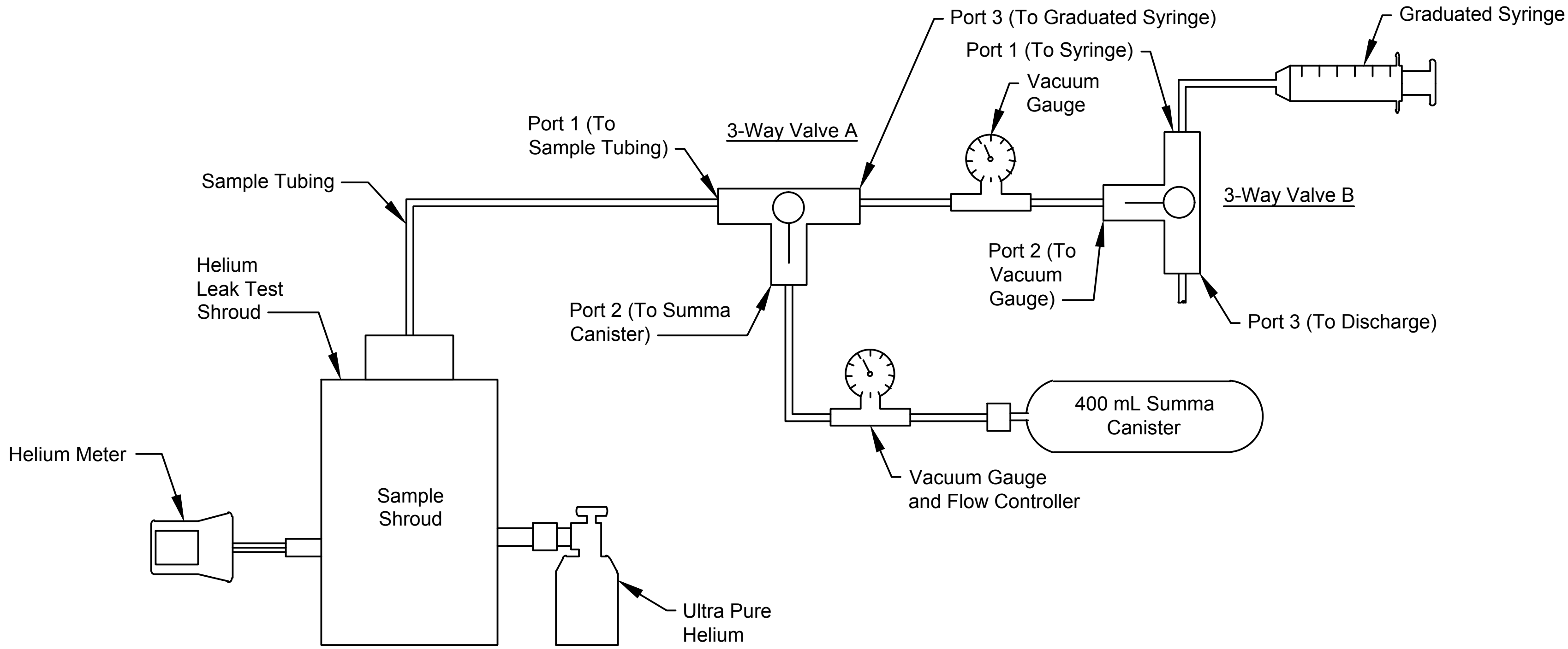
Helium Leak Test

Figure
C-3



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Shut-in Test, Purge and Sample Collection Set-up

Figure C-4