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SITE ASSESSMENT
REMEDIATION &
REVITALIZATION

October 26, 2017

Reference No. 077150

Ms. Regan Rahn, Project Manager
South Carolina Department of Health and Environment Control
2600 Bull Street
Columbia, SC 29201

Dear Ms. Rahn:

Re: Soil Gas Sampling Addendum to Revised Remedial Site Investigation
Bluewater Thermal Solutions Site
File No. 305608
Fountain Inn, South Carolina

1. Introduction

GHD on behalf of Gibraltar Industries Inc. (Gibraltar), hereby submits to the South Carolina Department of Health and Environmental Control (SCDHEC) the following Soil Gas Sampling Addendum as requested by the August 25, 2017 SCDHEC letter. This document supplements the August 7, 2017 Revised Remedial Site Investigation Work Plan.

The purpose of this Addendum is to assess the potential for soil vapor intrusion around the outside of the buildings. Figure 1 presents the locations of the proposed soil gas points.

2. Soil Gas Sampling

Based on the results of the groundwater sampling, an evaluation of the vapor intrusion pathway is warranted. In order to evaluate the potential for vapor intrusion into the Site buildings, installation of four soil gas monitoring points is proposed outside of the buildings as shown on Figure 1. As access to the inside of the building has not been granted, the soil gas points will be installed within ten feet of the building's exterior. The soil gas points will be installed during the proposed groundwater monitoring well installation activities. All soil gas points will be installed as permanent probes in case additional monitoring is warranted. A utility survey will be completed prior to installation as well as an evaluation of any preferential pathways. The actual locations of the final soil gas points may be adjusted based on the results of the utility survey and pathway evaluation.

The vapor points will be installed following GHD's Standard Operating Procedures (SOP) (attached as Appendix A) and the USEPA Vapor Intrusion Guidance. The soil gas points will be installed to at least 5 feet below the lowest level of the building (i.e. below slab-on-grade concrete floor) and screened with a minimum 6-inch open interval at the bottom of the point. A typical soil gas point installation diagram is provided in Attachment A. The soil gas points will be allowed to equilibrate at least 24 hours following installation before sampling.

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Prior to sampling, a leak test will be performed to test the integrity of the soil gas monitoring points. The leak test instruction are provide in Appendix A. The soil gas points and associated tubing will be purged prior to sampling. A PID will used to monitor the points prior to purging and following sampling. A laboratory-provided evacuated, one-liter Summa canister will be used to collect a sample from each soil gas point. The canisters will be fitted with a laboratory-calibrated critical orifice flow regulation device to restrict flow to approximately 100 milliliters per minute. Therefore, each sample will be collected over a duration of approximately ten minutes. One field duplicate is proposed for quality assurance/quality control. Soil gas sampling will not be conducted if a significant precipitation event (e.g. > 0.5 inches of rainfall) occurs within 24 hours of the planned sampling.

The soil gas samples will be submitted to H&P Mobile Geochemistry Inc for analysis of VOCs via method TO-15. The analytical results of the soil gas sampling will be reported in micrograms per cubic meter and compared to the USEPA indoor air screening values as provided in the most recent regional screening level tables (June 2017). In order to develop an appropriate vapor intrusion screening level (VISL) for soil vapor, an attenuation factor (0.03) will be applied to the indoor air screening value to account for soil vapor to indoor attenuation. The data will be screened against a non-residential VISL to account for the current industrial/commercial use of the property.

Please contact the undersigned at (678) 280 2140 if you have any questions or require additional information.

Sincerely,

GHD

Terefe Mazengia, PG

TM/tb/1
Encl.

cc: Richard Scherer - Lippes Mathias Wexler Friedman, LLP
Lucas Berresford - SCDHEC

Figure

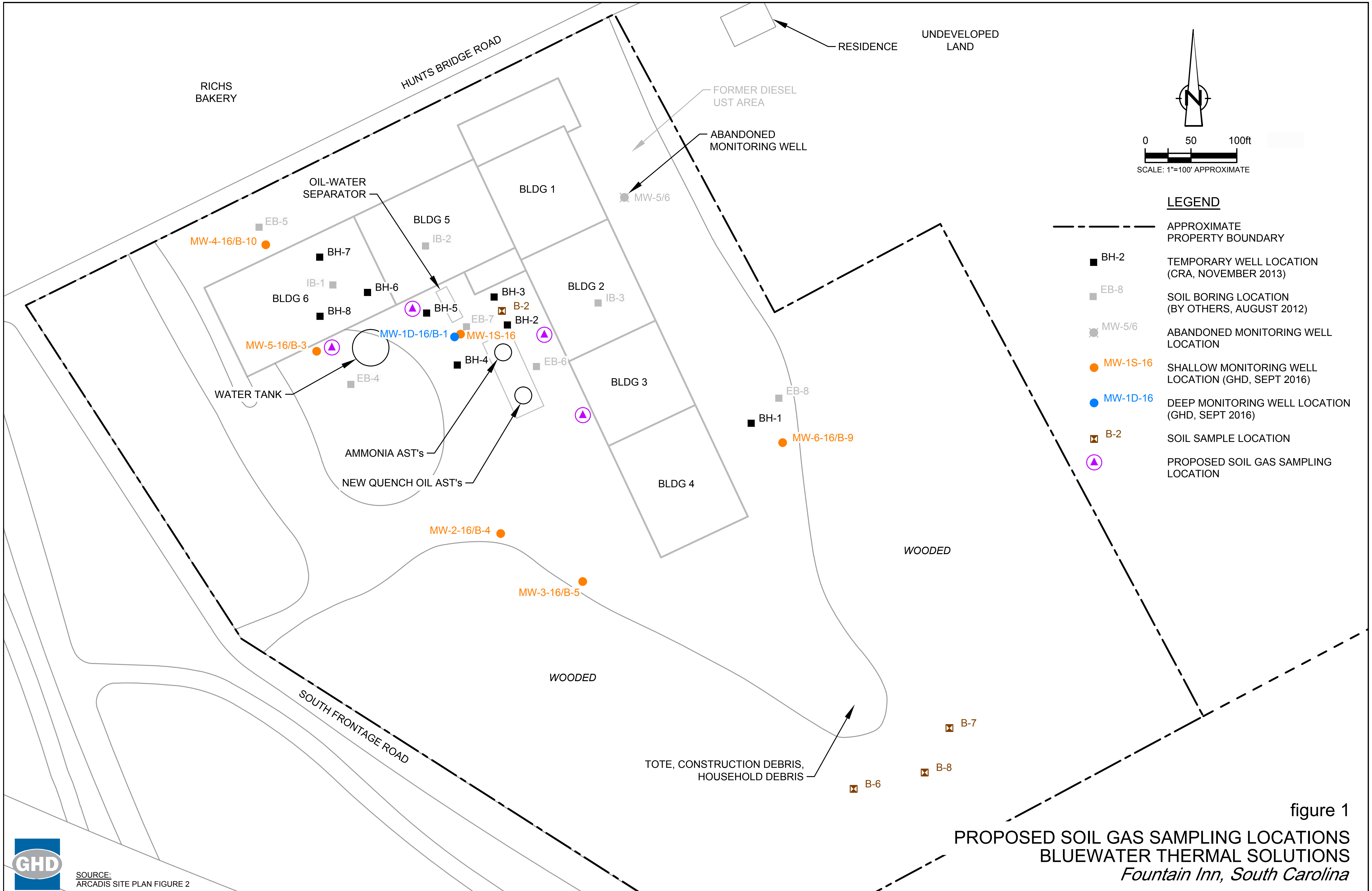

figure 1

PROPOSED SOIL GAS SAMPLING LOCATIONS
BLUEWATER THERMAL SOLUTIONS
Fountain Inn, South Carolina

77150-004(RAHN001)GN-WA001 SEP 19, 2017

Attachments

Attachment A
Soil Gas Sampling SOP

GHD Field Training Manual

Section 15.0
Soil Gas Sampling Standard Operating Procedures

(T113)

200010 (2) - Revision 1 – August 11, 2015

Please adhere to the following Quality System training requirements:

- Employees who are required to conduct a specific field activity must be properly certified to do the work.
- This involves reviewing the SOP and completing the online training course and exam.
- Employees must also conduct this field work under supervised conditions on at least three occasions, and must be certified by a qualified mentor. Only then can an employee conduct a specific field activity on their own. This is documented on a Field Method Training Record (QSF-021).
- Complete the QSF-021 and forward it to trainingrecords-northamerica@ghd.com.

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Figure Index

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15. Soil Gas Sampling Standard Operating Procedures

15.1 Introduction

The procedures described in this section pertain to the installation of temporary and permanent soil gas and sub-slab probes to assess the vapor intrusion pathway. Soil gas and sub-slab probes are both used to collect soil gas samples; however, soil gas probes are installed at a greater depth, often outside a building, and sub-slab probes are installed to collect soil gas samples from immediately below a slab on grade or a basement floor slab. Permanent probes are recommended when more than one sampling event is required or when assessing seasonal variations in soil gas concentrations. Temporary probes are suitable for conducting a screening level assessment of vapor intrusion where the results could assist in locating future, permanent soil gas probes. Temporary probes are also suitable for conducting a preliminary evaluation of the magnitude and extent of volatile organic compound (VOC) impacts to the subsurface (e.g., such as in the case of a soil gas survey).

15.2 Prior Planning and Preparation

When designing and constructing soil gas and sub-slab probes the following questions should be considered:

1. What is the purpose of the soil gas probes?
2. What are the potential health and safety hazards?
3. What type(s) of soil gas probe construction materials are to be used?
4. What kinds of analyses are required (e.g., VOCs, petroleum hydrocarbon fractions)?
5. What are the geologic/hydrogeologic conditions at the site?
6. What are the seasonally high water table levels?
7. Do perched conditions exist at the site?
8. What is the anticipated total depth of the probes?
9. Are nested soil gas probes required for vertical delineations?
10. Does a vapor barrier already exist under the slab, if so, sub-slab sampling might puncture the barrier, so the hole must be carefully resealed after monitoring is complete?
11. If a basement exists, could the primary entry point(s) for vapor intrusion be through the sidewalls rather than from below the floor slab? If so, sub-slab samples might need to be augmented with samples through the basement walls.
12. Although sample collection and analysis are analogous to those in other types of soil gas sampling, is an analytical method with lower detection limits required since risk-based screening levels for sub-slab samples are lower than those for deeper soil gas samples?

Note: If field staff are not aware of and able to answer all of the above noted questions before undertaking work in the field, the work plan must be reviewed in detail with the Project Coordinator/Manager.

15.3 Safety and Health

GHD is committed to conducting field activities with sound safety and health practices. GHD adheres to high safety standards to protect the safety and health of all employees, subcontractors, customers, and communities in which they work. The safety and health of our employees takes precedence over cost and schedule considerations.

Field personnel are required to implement the Safety Means Awareness Responsibility Teamwork (SMART) program as follows:

- Assure the Health and Safety Plan (HASP) is specific to the job and approved by a Regional Safety & Health Manager.
- Confirm that all HASP elements have been implemented for the job.
- A Job Safety Analysis (JSA) for each task has been reviewed, modified for the specific site conditions and communicated to all appropriate site personnel. The JSAs are a component of the HASP.
- Incorporate Stop Work Authority; Stop, Think, Act, Review (STAR) process; Safe Task Evaluation Process (STEP) Observations process; Near Loss and Incident Management process in the day-to-day operations of the job.
- Review and implement applicable sections of the GHD Safety & Health Policy Manual.
- Confirm that all site personnel have the required training and medical surveillance, as defined in the HASP.
- Be prepared for emergency situations, locating safety showers, fire protection equipment, evacuation route, rally point, and first aid equipment before you begin working, and make sure that the equipment is in good working order.
- Maintain all required Personal Protective Equipment (PPE), safety equipment, and instrumentation necessary to perform the work effectively, efficiently and safely.
- Be prepared to call the GHD Incident Hotline at 1-866-529-4886 for all incidents involving injury/illness, property damage, and vehicle incident and/or significant Near Loss.

It is the responsibility of the Project Manager to:

- Ensure that all GHD field personnel have received the appropriate health and safety and field training and are qualified to complete the work.
- Provide subcontractors with a Job Hazard Analysis to enable them to develop their own HASP.
- Ensure that all subcontractors meet GHD's (and the Client's) safety requirements.

15.4 Quality Assurance/Quality Control

Quality assurance and quality control procedures should be implemented in every step of the assessment process to ensure the collection of data of acceptable quality. A well-designed Quality Assurance/Quality Control (QA/QC) program will:

- Ensure that data of sufficient quality are obtained in order to facilitate an efficient site investigation.
- Allow for monitoring of staff and subcontractor performance.

- Verify the quality of the data for the regulatory agency.

The QA/QC program is developed on a site-specific basis.

15.5 Design Considerations

Diameter

Soil Gas Probes

The probe casing diameter should be kept to a minimum to reduce the volume of soil gas that must be purged from the probe during sampling. A maximum casing diameter of 3/4-inch (19 mm) to 1-inch (25 mm) will be used for solid piping casing material (e.g., polyvinyl chloride [PVC]), although casing diameters this large are not recommended for deep soil gas probes (e.g., greater than 15 feet [4.6 m]) since large purge volumes (e.g., milliliters) will result. Casing diameters of 1/4 inch (6.4 mm) to 3/8-inch (9.5 mm) are typical when flexible tubing is used for the casing material (e.g., Teflon® or nylon).

Sub-Slab Probes

A typical sub-slab probe is constructed from small-diameter (e.g., 01/8- or 1/4-inch outside diameter) stainless steel or another inert material and stainless steel compression fittings. The probes are cut at a length to either float in the slab or to extend to the base of the slab.

Screened Interval and Sand Pack Material

Soil Gas Probes

The length and depth of the perforated (screened) section should consider the desired monitoring interval as well as the geologic conditions encountered. A typical screened section would consist of a 6-inch (0.15 m) to 1-foot (0.3 m) perforated section. The use of prefabricated stainless steel screen implants is common. Alternatively, the screened interval can be created from casing material by hand-cutting slots, or hand-drilling holes, into the casing at a regular pattern. For hand-cut or hand-drilled screened intervals, the preferred sand pack material for soil gas probes is pea gravel. For prefabricated screens, the preferred sand pack material is inert 10/20 silica sand (#1 morie sand) or glass beads.

Sub-Slab Probes

A screen is not always used with sub-slab probes. When a screen is utilized, it is often pre-fabricated with a length of approximately 6 inches, due to the limited depth intervals sampled. When a screen is not utilized, the bottom of the probe is left open to facilitate sample collection. The perforated or open section should be consistent with the desired monitoring interval and sub-slab conditions encountered.

Monitoring Parts

For both soil gas and sub-slab probes, airtight stainless steel or brass compression fittings (e.g., Swagelok®) with valves should be installed at ground surface to allow for an airtight connection to sampling equipment. The valve is required to isolate the soil gas sampling assembly from the soil gas probe while sampling assembly airtightness tests are conducted prior to probe purging and sampling.

Casing Materials

Soil Gas Probes

The materials selected for soil gas probe casing construction must be compatible with the volatile chemicals anticipated to be present in soil gas. Experience has shown that PVC casing is suitable when VOCs are present. However, as described above, PVC is typically not available in small enough diameters to provide practical soil gas probe purge volumes. To minimize purge volumes, small diameter (e.g., 1/4-inch [6.4 mm] to 3/8-inch [9.5 mm]) flexible tubing (e.g., Teflon® or nylon) is more commonly applied as the soil gas probe casing. Where solid casing is used (i.e., PVC), threaded piping will be used to avoid any possible contamination from solvent cement.

Sub-Slab Probes

The materials selected for sub-slab casing construction must be compatible with the volatile chemicals anticipated to be present in soil gas. Often, 1/4-inch OD stainless steel tubing is utilized to collect sub-slab soil gas. The length of the stainless steel (or brass) tubing is cut to a desired length prior to installation.

15.6 Soil Gas and Sub-Slab Probe Installation

The information contained in this section has been compiled from existing manuals, various reference documents, and a broad range of colleagues with considerable practical and educational backgrounds. This SOP outlines the generic procedures necessary to install a soil gas/sub-slab probe. Site conditions, contaminants and geology may require modification of this procedure. Review applicable government procedures and informational documentation prior to installation.

This SOP is not intended to prohibit those conducting evaluations from using means other than those specified herein to measure soil gas concentrations; however, departures from this guidance will often need to include information for a more detailed review.

15.6.1 Installation Procedures - Soil Gas Probes

The soil gas probe is to be installed using Geoprobe® dual tube sampling system to advance a borehole to the target depth. The dual-tube sampling system consists of first advancing a 2 1/2-inch (6.4 cm) diameter inner sampling probe followed by advancing a 3 1/2-inch (8.9 cm) diameter outer casing. The outer casing should cut away disturbed soil immediately surrounding the borehole left by the inner probe. The outer casing should create a zone of reduced soil disturbance due to the inner probe having already been advanced. It is anticipated that using the dual tube system will result in a minimum amount of soil disturbance around the borehole annulus. The soil lithology should be logged during drilling activities and recorded on a field boring log along with any applicable observations. Permanent soil vapor probes can be installed with a conventional drill rig equipped with a hollow-steam auger, although increased formation disturbances would likely result. Rotosonic and mud or air rotary drilling methods are not recommended since they can influence soil vapor sample results and/or alter the physical properties of the subsurface adjacent to the borehole annulus.

The probes should be constructed with a 6-inch (15 cm) to 12-inch (30 cm) long screened interval. The screened interval can be hand-fabricated or prefabricated. The probe casing should be constructed using flexible tubing or solid casing. Flexible tubing (e.g., Teflon® or nylon) of small diameter (e.g., 1/4-inch [6.4 mm] to 3/8-inch [9.5 mm]) is most commonly used in combination with prefabricated screened intervals. Solid casing (e.g., PVC) of small diameter (e.g., 3/4-inch [19 mm] to 1-inch [25 mm]) is most commonly used with hand-fabricated screened intervals. After positioning the screened interval and casing into the borehole, the screen should be surrounded by the appropriate sand pack material (i.e., pea gravel for hand-fabricated screens and 10/20 silica sand for prefabricated screens). When placing the sand pack into the borehole, 1 inch (2.5 cm) of sand pack material should be placed under the bottom of the probe screen to provide a firm footing. The sand pack should extend to 6 inches (15 cm) above the screened interval. A bentonite pellet seal should then be installed to 1-foot (0.3 m) above the sand pack and should be hand-hydrated. The remaining annulus should be backfilled with pre-hydrated bentonite cement. The soil gas probe casing should extend to ground surface and should be fitted with airtight stainless steel or brass compression fittings (e.g., Swagelok®) with valves to allow for an airtight connection to soil gas sampling equipment. A flush-mount protective cover should be installed above the soil probe and cemented into place. Schematics of typical soil gas probe installation details are presented on Figures 15.1 and 15.2, respectively, where hand-fabricated and prefabricated screened intervals are applied.

15.6.2 Installation Procedures - Sub-Slab Soil Gas Probes

Sub-slab soil gas probes allow for collection of soil gas samples from directly beneath the slab of a building. Sub-slab soil gas probes are not recommended when groundwater is present directly below the slab, since the slab could allow groundwater to enter the building. Sub-slab soil gas probes can be installed using several different methods: (1) utilizing a small diameter hole, (2) a larger diameter hole w/ flushmount casing and (3) a Vapor Pin™. Summaries of the steps involved are presented below:

Small Diameter Sub-Slab Soil Gas Probe:

A schematic of a typical small diameter sub-slab soil gas probe installation detail is presented on Figure 15.3.

1. Prior to drilling holes in a foundation or slab, contact local utility companies to identify and mark utilities coming into the building from the outside (e.g., gas, water, sewer, refrigerant, and electrical lines). Consult with a local electrician and plumber to identify the location of utilities inside the building.
2. Prior to fabrication of the sub-slab vapor probes, use the rotary drill and the two inch diameter drill bit to create a shallow (e.g., 1/4 to 1/2 inch in depth) outer hole that partially penetrates the slab. This outer hole will allow the protective cap to be flush with the concrete surface (Figure 15.4).
3. Use a small portable vacuum cleaner to remove cuttings from the hole.
4. Use the rotary hammer drill and a one-inch drill bit to create a smaller diameter “inner” hole through the remainder of the slab to some depth (e.g., seven to eight centimeters or three inches) into the sub-slab material. Figure 15.5 illustrates the appearance of “inner” and “outer” holes. Drilling into the sub-slab material will create an open cavity, which will prevent the obstruction of any probes during sampling.
5. Use a small portable vacuum cleaner to remove cuttings from the hole.
6. Determine the thickness of the slab and record the measurement.

7. Assemble the vapor point using the basic design of a sub-slab vapor probe illustrated in Figure 15.3.

8. Place the assembled vapor point (Figure 15.6) into the hole and ensure the screen extends beyond the concrete and that the top of the probe is flush with the slab. Also apply the tamper resistant cap so as to not interfere with day-to-day use of the buildings. Cut tubing if necessary (Figure 15.7).

9. Confirm the fit of the rubber shaft plug to the sides of the boring. It should be snug with no gaps present. If additional thickness is necessary, plumbers putty can be added to the sides of the rubber.

10. Mix a quick-drying Portland cement to ensure a tight seal.

11. Inject the Portland cement with a 50 cc syringe or push into the annular space between the probe and outside of the “outer” hole (Figure 15.8).

12. Complete installed vapor point (Figure 15.9) with a tamper-resistant cap (Figure 15.10) or plug (Figure 15.11).

13. Allow cement to cure for at least 24 hours prior to sampling.

Sub-slab probes constructed in the aforementioned manner may be abandoned by removing any tubing and all surface protective covers. The boring annulus can then be backfilled with uncontaminated native material or grout. Inspect/clean the work area, and return site conditions to their original state.

If the tubing cannot be removed, the tubing should be cemented in place. All surface protective covers must be removed and returned to as close as possible to original site conditions.

Larger Diameter Hole w/ Flushmount Casing:

A schematic of a typical large diameter sub-slab soil gas probe installation detail is presented on Figure 15.12.

1. Prior to drilling holes into the building floor, the location of utilities coming into the building (e.g., gas, electrical, water, and sewer lines, etc.) must be identified. Avoid installing sub-slab soil gas probes near where utilities penetrate the slab as these may be entry points for downward ambient air migration through the slab during soil gas sampling.

2. A concrete corer is used to drill a hole through the concrete floor slab. The diameter of the hole should be sufficient to allow the installation of a protective casing within the hole. A sufficient space for placement of cement is required between the outer edge of the flush-mount casing and the hole in the concrete. Smaller diameter flush-mount protective casings are not recommended as they make accessing the probe within the casing difficult.

3. Once the hole in the concrete is cored and the center core removed, the flush-mount protective casing shroud should be cut to a suitable length. Ideally, the length of the shroud should allow the flush-mount casing to be flush with the surrounding floor while resting on the bedding material beneath the slab.

4. The probe assembly, including a valve at the top of the probe, should be placed so that the tip of the probe is within the bedding material beneath the concrete slab. Care should be taken to not force the probe into the bedding so that the open end of the probe doesn’t plug. Note: the probe assembly should be vacuum-tested on both sides of the valve prior to

installation. A piece of ¼ inch Teflon tubing should be attached at the top of the valve prior to installation. This tubing will allow easier access for the use of compression fittings to attach purging and sampling equipment to the probe.

5. The probe should be cemented into the flush-mount casing with hydraulic cement. The hydraulic cement should form a continuous seal from the bedding material to just below the top hex nut of the probe assembly.

Vapor Pin™

This SOP describes the procedure for installing a sub-slab soil probe using a Vapor Pin™. Borings should be done through the use of a rotary hammer drill. The specific drill utilized must be capable of utilizing the drill and coring bits identified by the SOP (see below) and be of sufficient size to penetrate the expected thickness of the concrete present.

General List of Materials

This installation SOP utilizes the following products, which are available from Cox-Colvin & Associates, Inc. Equipment:

1. Silicone sleeve.
2. Hammer drill.
3. 5/8 inch diameter hammer bit (Hilti™ TEYX 5/8" x 22" #00206514 or equivalent).
4. 1½ inch diameter hammer bit (Hilti™ TEYX 1½" x 23" #00293032 or equivalent) for flush mount applications.
5. 3/4 inch diameter bottle brush.
6. Wet/dry vacuum with HEPA filter (optional).
7. Vapor Pin™ installation/extraction tool.
8. Dead blow hammer.
9. Vapor Pin™ flush mount cover, as necessary.
10. Vapor Pin™ protective cap.
11. Equipment needed for abandonment.
12. Vapor Pin™ installation/extraction tool.
13. Dead blow hammer.
14. Volatile organic compound-free hole patching material (hydraulic cement) and putty knife or trowel.

Flushmount Vapor Pin™ Installation Protocol

1. Prior to drilling holes in a foundation or slab, contact local utility companies to identify and mark utilities coming into the building from the outside (e.g., gas, water, sewer, refrigerant, and electrical lines). Consult with a local electrician and plumber to identify the location of utilities inside the building.
2. Set up wet/dry vacuum to collect drill cuttings.
3. Drill a 1½ inch diameter hole at least 1¾ inches into the slab.

4. Remove the drill bit, brush the hole with the bottle brush, and remove the loose cuttings with the vacuum.
5. Drill a 5/8 inch diameter hole through the slab and at least six inches into the underlying soil to form a void.
6. Remove the drill bit, brush the hole with the bottle brush, and remove the loose cuttings with the vacuum.
7. Assemble the Vapor Pin™ assembly (Figure 15.13) by threading the Vapor Pin™ into the extraction/installation tool and placing the silicone sleeve over the barbed end.
8. Place the lower end of the Vapor Pin™ assembly into the drilled hole. Place the small hole located in the handle of the extraction/installation tool over the Vapor Pin™ to protect the barb fitting and cap, and tap the Vapor Pin™ into place using a dead blow hammer (Figure 15.14). Make sure the extraction/installation tool is aligned parallel to the Vapor Pin™ to avoid damaging the barb fitting.
9. Unscrew the threaded coupling from the installation/extraction handle and use the hole in the end of the tool to assist with the installation (Figure 15.15). During installation, the silicone sleeve will form a slight bulge between the slab and the Vapor Pin™ shoulder.
10. Place the protective cap on the Vapor Pin™ (Figure 15.16).
11. Cover the Vapor Pin™ with a flushmount cover.
12. Allow 20 minutes or more (consult applicable guidance for your situation) for the sub-slab soil gas conditions to equilibrate prior to sampling.
13. Remove protective cap and connect sample tubing to the barb fitting of the Vapor Pin™.

Temporary Soil Gas Probes

First, a core drill should be used to remove any surface cover, as needed. The temporary soil gas probes should consist of a decontaminated hollow sampling rod driven to the target depth below ground surface. The sampling rod should consist of a decontaminated 1-inch (2.5 cm) hollow stainless steel outer rod that is retracted to expose a 1-foot (0.3 m) long stainless steel screen. The rod should be advanced by a slide hammer to the target depth, and the outer rod retracted to expose the screen at the bottom of the rod. A surface seal comprised of hydrated bentonite cement should be placed around the base of the driven rod. The sampling rod should be completed at ground surface with airtight stainless steel or brass compression fittings (e.g., Swagelok®) with valves to allow for an airtight connection to soil gas sampling equipment. A schematic of a typical temporary soil gas probe installation detail is presented on Figure 15.17.

15.6.3 Installation Documentation

Details of each soil gas probe installation should be recorded on GHD's standard Stratigraphic Log Overburden (Form SP-14), or recorded within a standard GHD field book. The Well Instrumentation Log (Form SP-15) is provided for recording the overburden well instrumentation details, and can be used for soil gas probe installations. This figure must note:

- Borehole depth
- Probe perforation intervals
- Filter pack intervals

- Plug intervals
- Grout interval
- Surface cap detail
- Soil gas probe material
- Soil gas probe instrumentation (i.e., riser and screen length)
- Soil gas probe diameter
- Filter pack material
- Backfill material detail
- Stickup/flush-mount detail
- Date installed

The soil stratigraphy encountered at soil gas probes refusal must be recorded in accordance with GHD's standard borehole advancement methods (see Section 5.0).

Each soil gas probe should be accurately located on a site sketch. An accurate field tie to the center of the gas probe from three adjacent permanent features should be completed. The field ties should be located in a different direction from the installation.

Each soil gas probe must be permanently marked to identify the soil gas probe number designation.

15.6.4 Follow-Up Activities

Once the soil gas probe(s) have been completed, the following activities need to be done:

1. Conduct initial monitoring round of gas probes.
2. Submit all logs to the appropriate GHD hydrogeology department, who will be responsible for the generation of the final well log.
3. Survey accurate horizontal and vertical control of the soil gas borings and any pertinent structures needed to create a suitable site map.
4. Prepare an accurate soil gas probe/boring location map. Tabulate soil gas probe construction details.
5. Write-up all field activities including, but not necessarily limited to; drilling method(s), construction material, site geology.
6. Distribute all/any field book(s) to the appropriate GHD office.

15.7 Soil Gas and Sub-Slab Sampling Protocol

The following sampling protocols are for collecting a vapor sample through either a soil gas probe and/or sub-slab probe for the analysis of volatile organic compounds (VOCs) by the United States Environmental Protection Agency Method TO-15 (USEPA, 1999).

This SOP does not cover, nor is it intended to provide, a justification or rationale for where a sampling point is installed. It is assumed by using this SOP that site conditions have been fully evaluated and that the sampling location and depth meet the objectives outlined in the work plan or scope of work. Considerations must be given to the types of chemicals of concern, lithology encountered, and the depth of the vapor source. Samples collected deeper than any potential source of vapors may not fully characterize the potential risk and sampling points should never be installed or collected within the zone of saturation.

Most soil gas/sub-slab probes are installed at relatively shallow depths (less than ten feet below ground surface) so minimum purge volumes and low-volume samples must be performed to minimize potential breakthrough from the surface or between sampling intervals. Tracer/leak gas is necessary to ensure breakthrough does not occur and that a leak does not occur at any fitting above grade. Sampling should not occur during a significant rain event. A significant rain event is defined as 0.5 inches or greater of rainfall during a 24-hour period by Cal EPA (2012), or 1 centimeter or greater of rainfall during a 24-hour period by MOE (2013). A period of 1 day for coarse-grained soil conditions and several days for fine-grained soil conditions after a significant rain event should occur prior to collecting soil vapor samples. This time interval is required for drainage to occur and soil conditions to return to ambient moisture conditions.

Note: The sampling interval after a significant event should be verified based on the applicable jurisdictional regulatory vapor intrusion guidance.

Samples from wells with multiple points installed must not be collected simultaneously and approximately 30 minutes must elapse between each sampled interval. Sample times should be documented on the field log. Sample flow rates are not to exceed 200 milliliters per minute (ml/min) to minimize the potential for vacuum extraction of contaminants from the soil phase. A flow rate greater than 200 mL/min may be used when purging times are excessive, such as for deep wells with larger-diameter tubing. However, a vacuum of 100 inches of water (7.4 inches of mercury [Hg]) or less must be maintained during sampling whenever a higher flow rate is used. Volumes of various tubing sizes are provided in Table 1 in order to aid in calculating purge volumes.

Table 1 Volumes for Select Tubing Sizes

Tubing Size (inches ID)	Volume/ft (liters)
3/16	0.005
¼	0.010
½	0.039

Care must be used during all aspects of sample collection to ensure that sampling error is minimized and high quality data are obtained. Care must also be taken to avoid excessive purging prior to sample collection and prevent pressure build-up in the enclosure during introduction of the tracer gas. Inspection of the installed sample probe, specifically noting the integrity of the surface seal and the porosity of the soil in which the probe is installed, will help to determine the tracer gas setup. The sampling team must avoid actions (e.g., fueling vehicles, using permanent marking pens, and wearing freshly dry-cleaned clothing or personal fragrances) which could potentially cause sample interference in the field.

15.7.1 Soil Gas Collection General List of Materials

The equipment required for soil gas sample collection is as follows:

Flow Meters and Detectors

1. Flow regulator with vacuum gauge. Flow regulators provided by a qualified laboratory are pre-calibrated to a specified flow rate (e.g., 100 ml/min).
2. Photoionization detector (with appropriate lamp).
3. Helium detector (if helium is utilized as a tracer gas).
4. Methane meter for petroleum sites that is capable of also measuring percent of methane (CH4), carbon dioxide (CO2), and oxygen (O2).

Tooling and Supplies

1. Sampling canister (one per location).
2. Regulated flow meter assembly set to a maximum of 200 ml/min (one per location).
3. 1/4 inch tubing (Teflon®, polyethylene, or similar) and assorted fittings.
4. Plastic housing for using tracer gas.
5. 50 ml syringe (for purging).
6. Camera.
7. Adjustable crescent wrenches, small to medium size, and/or open end combo wrenches 9/16 to 1/2 inch.
8. Scissors/snips to cut tubing.
9. Ballpoint pens.
10. Nitrile gloves.
11. Compound to be used as tracer gas - lab grade helium or isopropyl alcohol (IPA).

15.7.2 Soil Gas Tracer Compounds

A leak in the sampling assembly may allow ambient air into the system and dilute the soil gas results (Benton and Shafer, 2007). Therefore, tracer gases must be utilized during the collection of soil gas samples to verify that the sample collected is from the installed sampling point. The presence of a tracer compound, whether liquid or gaseous, can confirm a leak in the sampling train assembly and whether the usability of the sample will need to undergo further evaluation.

Careful thought and consideration must be used when choosing a leak check compound as a tracer, since each compound can have specific benefits and drawbacks.

Helium used as a tracer gas beneath a shroud allows for the screening of the sampling train in the field. In conjunction with the use of a field meter capable of detecting helium, leaks within the sampling train could be detected prior to sampling. A retightening of all fittings prior to collecting the sample for analysis should be done. If a leak has been detected and is unable to be resolved, the sampling point may need to be decommissioned and a new one installed. Only lab-grade helium (UHP-Ultra High Purity) should be used as a tracer, since helium available at general merchandise stores may contain secondary contaminants, such as benzene.

Understanding the relationship between a leak and the concentration detected of the tracer gas used to check for leaks, the potential for absorption of the tracer gas (i.e., helium) onto sample train tubing, and the potential for interference by the tracer gas compound with VOCs is important in answering the data usability. An ambient air leak of up to five percent may be acceptable if quantitative tracer testing is performed. A soil gas vapor well should be decommissioned if the leak cannot be corrected. Any replacement vapor wells should be installed at least five feet from the location where the original vapor well was located

Note: The ambient air leak of up to five percent leak should be verified based on the applicable jurisdictional regulatory vapor intrusion guidance.

15.7.3 Soil Gas and Sub-Slab Probe Leak Testing

The use of leak testing is recommended as a quality control check to ensure ambient air has not leaked into the soil gas probe or sampling assembly, which may affect (i.e., dilute) the analytical results. Contaminants in ambient air can also enter the sampling system and be detected in a sample from a non-contaminated sampling probe resulting in a "false positive" result. The leak testing should be conducted as described in the following two steps:

- Step 1 - Vacuum Test: used to ensure that the tubing and fittings/valves that make up the sampling assembly are air-tight
- Step 2 - Tracer Test: used to ensure that ambient air during soil gas sample collection is not drawn down the soil gas probe annulus through an incomplete seal between the formation and the soil gas probe casing.

The vacuum test and tracer test are detailed below.

Step 1 - Vacuum Test

- The sampling assembly must be connected to the soil gas probe valve at the surface casing. Once connected, the sampling assembly will consist of the soil gas probe, the vacuum gauge supplied by the laboratory, personal sampling pump, and Summa™ canister, all connected in series (i.e., in the order of soil gas probe, vacuum gauge, pump, and canister), using tee-connectors or tee-valves.
- The personal sampling pump will be used to conduct the vacuum test. The vacuum test should consist of opening the valve to the personal sampling pump while leaving closed the valves to the Summa™ canister and the soil gas probe. The pump should then be operated to ensure that it draws no air from the sampling assembly (i.e., creates a negative pressure, or vacuum within the sampling assembly), thus establishing that all assembly connections are air-tight. The sampling pump low-flow detect switch will likely activate within 10 to 15 seconds, turning the pump off. A negative pressure, or vacuum, should be established within the sampling assembly, and should be sustained for at least 1 minute.
- If the pump is capable of drawing flow, or if the vacuum is not sustained for at least 1 minute, all fittings and tubing will be checked for tightness (or replaced) and the vacuum test will be repeated.
- The reading from the vacuum gauge pressure should be recorded in field logbook to demonstrate that the pump is able to create a vacuum within the sampling assembly (it will also be noted whether the low-flow detect switch on the pump was activated), and that the vacuum is sustained for at least 1 minute.

Step 2 - Tracer Test

A tracer compound is released at ground surface immediately around the soil gas probe surface casing and is used to test for ambient air leakage down the annulus of the soil gas probe and into the soil gas sample. Two options are described below for the tracer test where either isopropanol (Option A) or helium (Option B) is used as the tracer compound.

Option A - Isopropanol

- For Option A, isopropanol is used as the tracer compound. It is included as an analyte in U.S. EPA's TO-15 method, it is readily available (i.e., as isopropyl rubbing alcohol), and it is safe to use.
- Approximately 1 teaspoon (approximately 4 mL) of isopropanol (rubbing alcohol) should be mixed in 1 gallon of de-ionized water to create an approximate 1/1,000 solution.
- Paper towels soaked in a dilute solution of isopropanol should then be wrapped around the soil gas probe surface casing and ground surface immediately surrounding the surface casing. Soil gas probe surface casing then should be covered over, using clear plastic sheeting that will be sealed to the ground surface. As the ground surface finish permits, sealing the plastic sheeting to ground surface should be accomplished by using tape or by weighting the edges of the plastic sheeting with dry bentonite.
- Immediately before conducting the soil gas probe purging, remove the paper towels from the solution, wringing out the towels so they are very damp, but not dripping. Place them around the vapor probe and seal them in place using the plastic sheeting.
- The isopropanol solution should be kept fresh, with new solution being made every hour. The solution should be mixed at a central location away from the sampling activities. The isopropanol should be kept tightly capped and kept away from all sampling equipment. The solution should be kept away from the sampling assembly until immediately before sample collection begins. Sampling personnel must wear latex gloves while handling the solution and soaked paper towels, and will remove the gloves while working with the sampling assembly.
- Soil samples with laboratory analytical results for isopropanol that are greater than 10 percent of the starting concentration of isopropanol in the vapors emitted from dilute isopropanol solution should not be considered reliable and representative of soil gas concentrations within the formation (ITRC, 2007). The starting concentration should be calculated based on the concentration of isopropanol in the dilute solution, the vapor pressure of isopropanol, and Henry's law.
- A disadvantage in using isopropanol as the tracer compound is that it will not be known whether a significant leak occurred until after the cost of analyzing the sample has been spent. Elevated levels of isopropanol can also interfere with laboratory analytical method detection limits.

Option B - Helium

- The presence of helium within the sampling assembly should be monitored during purging and soil gas sample collection using a helium meter installed in-line with the sampling assembly. The meter should be positioned along the sampling line just before the personal sampling pump.
- Helium is readily available at a variety of retail businesses, is safe to use, and does not interfere with laboratory analytical method detection limits.

- A containment unit is constructed to cover the soil gas probe surface casing. The containment unit should consist of an overturned plastic pail set into a ring of dry bentonite to create a seal between the ground surface and the rim of the pail. The pail can be set directly on top of the sampling assembly tubing connected to the soil gas probe, which when pressed into the dry bentonite, should create a sufficient seal around the tubing. The pail will have two holes: one to allow for the introduction of helium; and the other to allow for air trapped inside the pail to escape while introducing the helium. The second hole will also allow insertion of the helium meter to measure the helium content within the pail.
- Prior to soil gas probe purging, helium will be introduced into the containment unit to obtain a minimum 50 percent helium content level. The helium content within the containment unit should be confirmed using the helium meter and recorded in the field logbook. Helium should continue to be introduced to the containment unit during soil gas probe purging and sampling and care should be taken not to increase the pressure within the containment unit beyond that of atmospheric pressure.
- During soil gas probe purging and sampling, the helium meter should be connected in-line with the sampling assembly. In the event that the helium meter measures a helium content with the sampling assembly of greater than 10 percent of the source concentration (i.e., 10 percent of the helium content measured within the containment unit), the soil gas probe will be judged to permit significant leakage such that the collected soil gas sample will not be considered reliable and representative of soil gas concentrations within the formation (ITRC, 2007).
- An advantage of using helium as the tracer compound is that a significant leak can be detected in the field and the cost of analyzing the Summa™ canister can be avoided.

Note: The 10 percent of the source concentration should be verified based on the applicable jurisdictional regulatory vapor intrusion guidance.

15.7.4 Sample Collection Procedure

1. Soil gas samples for assessing the vapor intrusion pathway must be collected using an acceptable canister, including certified clean Summa™ canisters. Only canisters certified clean at the 100 percent level can be used for soil gas sampling activities (i.e., pre-cleaned at the laboratory in accordance with U.S. EPA's TO-15 method and documentation of the cleaning activities will be provided by the laboratory). Summa™ canisters typically come in 1-, 1.7-, and 6-liter capacities, depending upon laboratory availability.
2. The canisters must be fitted with a laboratory-calibrated critical orifice flow regulation device sized to restrict the maximum soil gas sample collection flow rate to approximately 100 milliliters per minute (mL/min), which corresponds to the lower end of the maximum soil gas sampling flow rate recommended by Cal EPA (2012) of 100 to 200 mL/min. The 100 mL/min maximum flow rate is equivalent to sample collection times of 10, 17, or 60 minutes, respectively, for of 1, 1.7, or 6 liter canister capacities. A maximum flow rate of 100 mL/min is recommended to limit VOC stripping from soil, prevent the short-circuiting of ambient air from ground surface down the soil gas probe annulus that would dilute the soil gas sample. A maximum flow rate of 100 mL/min increases confidence that the soil gas sample is drawn from immediately surrounding the screened interval.
3. A vacuum gauge should be supplied by the laboratory and used during sample collection to measure the initial canister vacuum, canister vacuum during sample collection, and residual

canister vacuum at the end of sample collection. The vacuum gauge will be returned to the laboratory and used by the laboratory to measure the residual canister vacuum upon receipt of the canisters by the laboratory.

4. The canister should be connected to the soil gas probe valve at the surface casing using the sampling assembly (see Figure 15.18). The sampling assembly is connected using short lengths (e.g., 1-foot [0.3 m]) 1/4-inch (6.4 mm) or 3/8-inch (9.5 mm) diameter tubing (the tubing material will be Teflon® or nylon) and airtight stainless steel or brass tee-connectors and tee-valves (e.g., Swagelok® type). The canister should be connected to the soil gas probe along with a vacuum gauge and a personal sampling pump, all in series, using tee-connectors or tee-valves (in the order of soil gas probe, vacuum gauge, pump, and canister). A tee-valve should be used to connect the pump, which will allow the pump to be isolated from the sampling assembly during sample collection. Fresh tubing must be used for each sample.

5. Prior to collecting a soil gas sample, the stagnant air in the sampling assembly tubes and soil gas probe casing/sand pack must be removed. The soil gas probes should be purged prior to sampling using the personal sampling pump at a flow rate of less than 200 mL/min. A flow rate greater than 200 mL/min may be used when purging times are excessive, such as for deep wells with larger-diameter tubing. However, a vacuum of 100 inches of water (7.4 inches of Hg) or less must be maintained during sampling whenever a higher flow rate is used. This ensures that the collected soil gas sample is representative of actual soil gas concentrations within the formation. Measurements of the lengths and inner diameters of the above-ground sampling assembly and below-ground gas probe casing, screen, and sand pack should be used to calculate the "purge volume" (the purge volume will consider the pore volume of the sand pack assuming a 30 percent sand pack porosity). Prior to sample collection, two to three purge volumes should be drawn from the probe/sample assembly, unless otherwise required by the applicable regulatory guidance. The purge data (calculated purge volume, purging rate, and duration of purging) should be recorded in the field logbook.

6. Prior to purging, a vacuum, or tightness, test should be conducted on the sampling assembly as the first of two leak-testing steps, as described further in Section 15.7.3. Briefly, this first leak-testing step (the vacuum test) should consist of opening the valve to the personal sampling pump leaving the valves to the Summa™ canister and the soil gas probe closed. The pump should then be operated to ensure that it draws no air from the sampling assembly (i.e., creates a negative pressure, or vacuum within the sampling assembly), thus establishing that all assembly connections are airtight. Further details of the vacuum test are described in Section 15.7.3.

7. Prior to purging, and following the vacuum test, the set-up for the second of the two leak-testing steps should be conducted. The second leak-testing step is the tracer compound step. A tracer compound is released at ground surface immediately around the soil gas probe surface casing. The tracer test is used to test for ambient air leakage down the annulus of the soil gas probe and into the soil gas sample. The tracer compound is either monitored using a meter connected in-line to the sampling assembly (e.g., helium), or is included as an analyte in the laboratory analysis of the soil gas samples (e.g., isopropanol). The setup requirements of the tracer compound leak-testing step are described in Section 15.7.3.

8. Following the vacuum test, and the setup for the tracer compound leak-testing step, the soil gas probe purging should commence by opening the valve to the soil gas probe and activating the personal sampling pump (and leaving closed the valve to the Summa™

canister). At the start and the end of the purging period, the total concentration of volatile organic vapors of the personnel sampling pump exhaust gas should be monitored using a portable photoionization detector (PID) meter. The PID meter should be connected in series after the personal sampling pump. Since typical PID instrument flow rates vary from approximately 300 to 500 mL/min (depending on the manufacturer and model), drawing a sample into the PID meter through the personal sampling pump will likely increase the purging flow rate temporarily, until a reading from the PID meter is obtained. PID readings should be recorded and entered in the field logbook and chain of custody form. The PID readings should provide the laboratory with an indication of whether a sample could require dilution before analysis.

9. Following purging, the valve to the personal sampling pump should be closed, and the valves to the soil gas probe and Summa™ canister opened to draw the soil gas sample into the canister. This should be completed concurrent with continued application of the leak-testing tracer compound. The vacuum gauge reading must be recorded during sample collection. Should the vacuum gauge reading remain elevated above 10 inches Hg for more than 30 minutes, this will be taken to indicate that the initial vacuum in the canister has not sufficiently dissipated, and that the soil screened by the soil gas probe does not produce sufficient soil gas to permit sample collection due to low permeability soil. If low permeability conditions are encountered, the probe can be sampled using the techniques outlined in Appendix D (Soil Gas Sampling in Low Permeability Soil) of Cal EPA (2012).

10. To ensure some residual vacuum in each canister following sample collection, the canister vacuum should be recorded at approximately 80 percent through the expected sample collection duration. With a 100 mL/min maximum flow rate, the expected sample collection duration would be 10, 17, or 60 minutes, respectively, for canister capacities of 1, 1.7, or 6 liters. A maximum residual vacuum of 10-inches Hg is allowed. A canister residual vacuum above this value will require continued sampling until vacuum reading is below this threshold, unless the vacuum remains above 10-inches Hg for more than 30 minutes, as described above. A minimum 0.5 to 1-inch Hg residual vacuum will be required for the sample to be considered valid, or the sampling will be repeated using a fresh Summa™ canister. Once the vacuum is measured, the safety cap must be securely tightened on the inlet of the Summa™ canister prior to shipment to the laboratory under chain-of-custody procedures.

Note: The 0.5 to 1-inch Hg residual vacuum should be verified based on the applicable jurisdictional regulatory vapor intrusion guidance.

11. The vacuum gauge provided by laboratory must be returned with the canister samples to check residual vacuum in the laboratory prior to sample analysis and recorded on the analytical data report. This check will ensure sample integrity prior to laboratory analysis, and that the canister has not become compromised during shipment to the laboratory.

12. If the critical orifice flow regulation devices (provided by the laboratory) and sampling assembly fittings/valves are to be re-used during sampling, they must be cleaned in accordance with laboratory requirements by purging with zero air (provided by laboratory) for minimum 45 seconds at minimum 75 psi (153 inches of Hg).

13. The canisters should be labeled noting the unique sample designation number, date, time, and sampler's initials. A bound field logbook should be maintained to record all soil gas sampling data.

14. The canisters should be listed on the chain-of-custody in order of suspected highest to lowest impact, as evidenced by the recorded PID readings. Indicate on the chain-of-custody for the laboratory to analyze the canisters in order from the lowest to highest PID reading.

The soil gas samples should be analyzed for VOCs by the project laboratory using U.S. EPA's TO-15 gas chromatograph/mass spectrometer (GC/MS) methodology, with the mass spectrometer (MS) run in full scan mode. QA/QC measures implemented during the soil gas sampling event will include the two-step leak testing procedure (see Section 15.7.3), maintaining a minimum residual vacuum in the Summa™ canisters following sample collection, collection of one duplicate per sampling event or from at least 10 percent of the samples obtained, and collection of an ambient air sample (if needed). As an additional QA/QC measure, the laboratory should conduct a duplicate analysis of the sample collected in one of the canisters.

15.7.5 Follow-Up Activities

The following activities should be performed at the completion of the field work.

1. Review and compare newly obtained data with historic data and flag unusual or extreme readings for review.
2. Soil gas concentrations are reported in units of $\mu g/m^3$ or ppbv. Unlike concentration units for groundwater, these units are not directly interchangeable. The molecular weight of the compound in question is a factor in the conversion from units of mass per unit volume to parts per billion by volume.
3. Ensure site access keys are returned.
4. The equipment should be cleaned and returned to the Equipment Coordinator. All equipment should be cleaned at the site.
5. Monitoring forms and field notes should be sent to the file. The field book should be stored at the appropriate GHD office.

15.8 References

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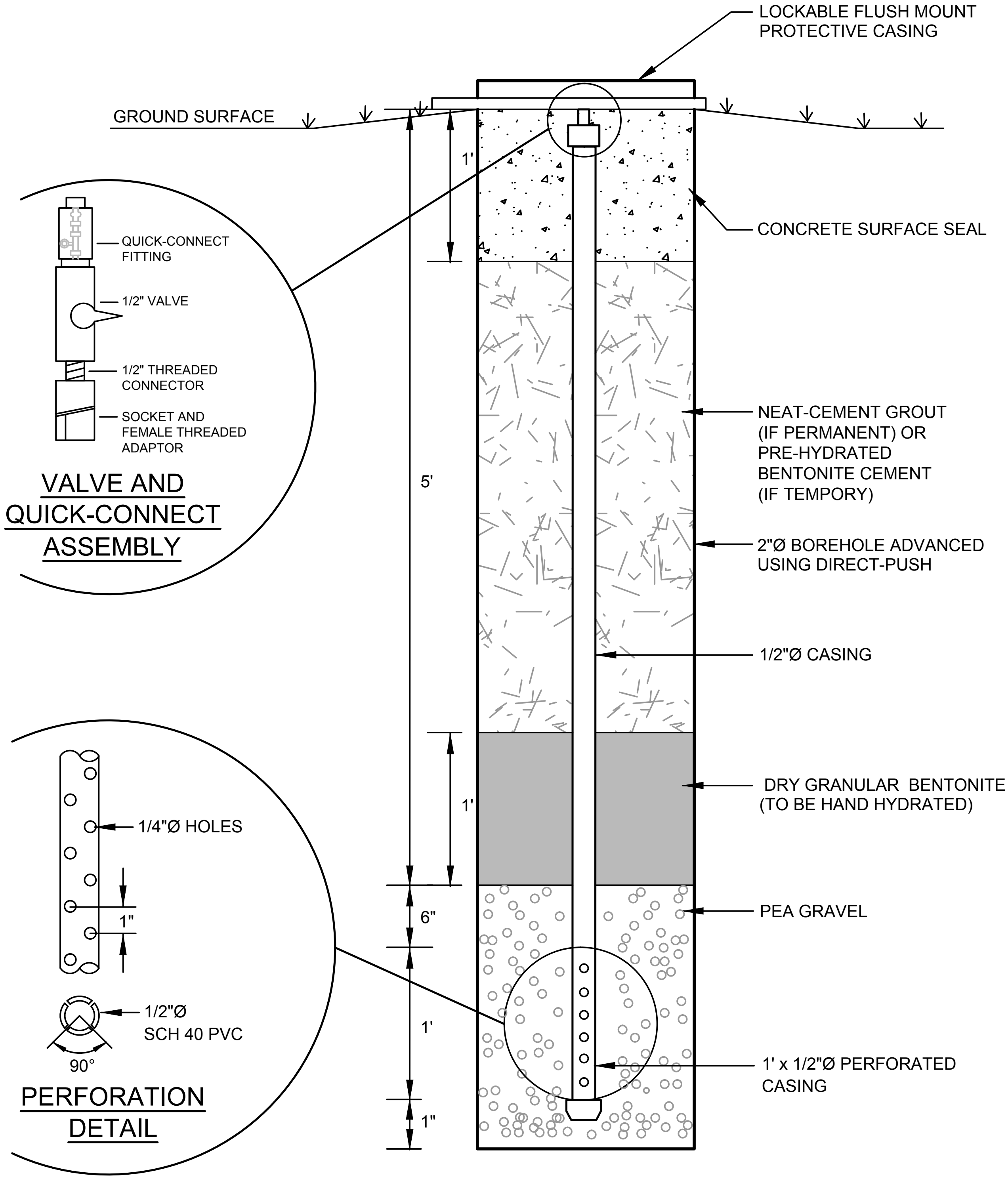

NOTE: CONNECTIONS AND ADAPTORS ARE
NOT TO BE GLUED

NOT TO SCALE
GENERALIZED CONSTRUCTION DIAGRAM

GHD

figure 15.1

TYPICAL SOIL GAS PROBE COMPLETION DETAIL