Direct Push Technology (DPT)

For

Leaking Aboveground and Underground Storage Tank Programs

PREPARED BY:
West Virginia Department of Environmental Protection
Division of Water and Waste Management
Environmental Enforcement/Tanks Corrective Action Unit
601 57th Street SE
Charleston, WV 25301

JULY 2018

Contents

1.0 INTRODUCTION 1
2.0 DIRECT PUSH TECHNOLOGY 2
3.0 SOIL SAMPLING 3
3.1 Types of Soil Samplers 3
3.1.1 Closed Barrel Sampler 3
3.1.2 Open Solid-Barrel Sampler 3
3.1.3 Split-Spoon Sampler 4
3.1.4 Thin-walled Tube Sampler 4
3.2 Soil Sampling Considerations 4
4.0 GROUND WATER SAMPLING 5
4.1 Groundwater Grab Samplers 5
4.1.1 Exposed-Screen Samplers 6
4.1.2 Sealed-Screen Samplers 6
4.2 DPT Installed Wells 7
4.2.1 Conventionally Screened and Packed Wells 7
4.2.2 Pre-Packed Screen Wells 7
4.2.3 Well Development of DPT Wells 8
4.3 DPT Groundwater Samples as a Screening Tool 8
4.4 Groundwater Sampling Considerations 9
4.5 Boreholes and Monitoring Well Abandonment 9
5.0 DPT SPECIALIZED MEASUREMENT TOOLS 10
5.1 Geotechnical 10
5.2 Geophysical 10
5.3 Analytical 11
6.0 REFERENCES 12

Acronyms

AST	Aboveground Storage Tank
ASTM	American Society for Testing and Materials
CPT	Cone Penetrometer Technology
DPT	Direct Push Technology
FATE	Field Analytic Technologies Encyclopedia
FFD	Fuel Fluorescence Detector
HPT	Hydraulic Profiling Tool
LAST	Leaking Aboveground Storage Tank
LUST	Leaking Underground Storage Tank
MIP	Membrane Interface Probe
NAPL	Non-aqueous Phase Liquids
OIP	Optical Image Profiler
PAH	Polycyclic Aromatic Hydrocarbons (also called polynuclear aromatic hydrocarbons or polyaromatic hydrocarbons)
TDS	Thermal Desorption Sampler
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VOC	Volatile Organic Compounds
WVDEP	West Virginia Department of Environmental Protection
XRF	X-ray Fluorescence

1.0 INTRODUCTION

This guidance is provided to aid the tank owners/operators and consultants in meeting requirements of the Aboveground Storage Tank (AST) and Underground Storage Tank (UST) Acts and associated Rules. The methods and practices described in this guidance are not intended to be the only methods and practices available for complying with the rules, but is intended to offer flexibility in meeting site characterization requirements of the Leaking AST (LAST) and Leaking UST (LUST) programs. The use of direct push technology (DPT) can be an efficient and cost-effective sampling method for both soil and groundwater. Additionally, DPT can be equipped with numerous other measurement tools for geophysical, geotechnical, and analytical data collection for site characterization. As with any method or procedure it has its limitations, advantages, and disadvantages some which are shown in the table below.

Advantages	Disadvantages
DPT systems allow for faster installation rates and quicker groundwater sampling after installation	Some well installations have no filter which can lead to groundwater samples with high turbidity
More accessible in remote locations than a drilling rig because the equipment is smaller	Can “drag down” contamination in some cases
Small well diameters allow for rapid purge volume removal	Sample volume limited by smaller well diameter
Wells can be sequentially sampled at successive depths for a complete aquifer profile	Depth for well installation or soil sampling is limited to depths of less than 100 feet
Facilitates more complete site characterization by increasing the number of points that can be sampled	Cannot be used to collect samples from consolidated aquifers
Creates very little soil or groundwater related investigation derived waste to handle in comparison with a drilling rig (green initiative)	Unless a DPT well is installed, you can’t resample the same location- it is a “one and done”
Significantly cheaper costs than using a drilling rig	The smaller well diameters limit the choices of purging and sampling equipment.
May be utilized when seeking site closure under the “standard” corrective action path	Generally, not accepted when seeking site closure by a “risk based” path

There has been some controversy on the utilization of DPT for groundwater monitoring purposes over concerns about reproducibility of data. While the DPT method of well installation and construction materials differs from traditional drilled wells, direct push wells have been shown to provide usable data. DPT can be an effective and cost-effective method for data collection for site characterization purposes. Comparison studies between direct push and hollow-stem auger drilled wells performed by British Petroleum Corporation North America Inc. and the UST Programs of the United States Environmental Protection Agency (USEPA) Regions 4 and 5 (2002) and Kram et al. (2001) found that water-level elevations and contaminant concentrations were statistically comparable between the two well types. Bartlett et al. (2004) and British Petroleum and USEPA (2002) did find that some types of direct push wells yielded slightly lower hydraulic conductivity values than drilled wells. However, they also found that the proper well development and variables other than well construction were of greater significance.

Since reproducibility is important to the proper collection of compliance monitoring samples, grab samples which are representative of a one-time sampling event cannot be reproduced over time and are thus not appropriate for use in compliance monitoring sampling. However, grab samples may be very useful in initial site characterization activities.
Samples from properly constructed DPT wells should be equivalent in accuracy to conventional ground water samples if they are properly constructed, sealed, developed, purged and sampled. Field-constructed DPT wells are not recommended for compliance monitoring sampling due to limited annular space surrounding the well screen, proper construction of the well cannot be assured. Pre-packed screened wells should be utilized when installing a DPT well as it aides in ensuring proper well construction. All monitoring wells must be installed in accordance with the West Virginia Department of Environmental Protection's (WVDEP) Monitoring Well Design Standards (47CSR60) and the installation must be performed by a WVDEP certified monitoring well installer. Furthermore, DPT wells are generally considered temporary wells which must be properly abandoned within one hundred twenty (120) days. Even though DPT wells or DPT grab samples may be utilized on a site for site characterization purposes, permanent conventional monitoring wells will be required if contamination above the action levels is detected.

2.0 DIRECT PUSH TECHNOLOGY

Direct push rigs are hydraulically powered and are generally mounted on a customized four-wheel drive vehicle. The base of the sampling device is positioned on the ground over the sampling location and the vehicle is hydraulically raised on the base. As the weight of the vehicle is transferred to the probe, the probe is pushed into the ground. A built-in hammer mechanism allows the probe to be driven through dense materials. Maximum depth penetration under favorable circumstances may be greater than 100 feet.

A DPT tool string includes the sample collection tool and extension rods. There are two types of rod systems: 1) single-tube and 2) dual-tube. Both allow for soil and ground water sampling. Single- and two-tube systems have overlapping applications and can be used in many of the same environments. However, strengths and limitations associated with each should be considered.

Soil samples can be collected using specially designed sample tubes. The sample tube is pushed and/or vibrated to a specified depth. In the simplest sampler, the piston-activated system, the interior plug of the sample tube is removed by inserting small diameter threaded rods. The sample tube is then driven an additional foot to collect the samples. The probe sections and sample tube are then removed, and the sample is extruded from the tube. Latch-activated systems are like those that use piston-activation mechanisms, but they can collect samples more rapidly. Sampling rates can also be increased by using dual-tube samplers.

The single-tube rod system is not recommended because the probe hole may collapse or slough without the stabilization of an outer casing rod. A second drawback of single-rod systems is the potential for formation or saturated zone cross-contamination during continuous sampling. Because the probe hole is uncased during rod retraction and reinsertion, the open probe hole can serve as a conduit for potentially contaminated soils or ground water from overlying zones that may slough or migrate to otherwise uncontaminated lower zones. Cross-contamination is of concern if NAPLs (non-aqueous phase liquids) are present since they could migrate down the probe hole.

The dual-tube sampling system is recommended for continuous sampling at LAST/LUST sites as the outer casing prevents sloughing and cross-contamination from other depths. Because the hole is cased, continuous sampling is simplified and expedited.

3.0 SOIL SAMPLING

3.1 Types of Soil Samplers

There are two types of soil samplers used with DPT: sealed and non-sealed. Sealed samplers remain closed until they reach the sampling depth. A common used sealed sampler is the closed barrel sampler. The non-sealed soil samplers remain open as they are pushed into the ground. Three possible non-sealed samplers are: open solid-barrel; split-spoon; and the thin walled tubes. However, split-spoons and thin walled tubes are not often used with DPT sampling. Many of these samplers allow for a liner to be inserted to contain the sample interval and allow for easy extraction from the sample barrel.

3.1.1 Closed Barrel Sampler

Closed-barrel samples are sometimes referred to as piston samplers or discrete-depth samplers. They are like open solid-barrel samplers, except the barrel opening is sealed with a rigid, pointed piston that displaces soil as it is advanced into the ground. These samplers are pushed to the desired depth (without the need to collect shallower soil cores), the piston is unlocked by releasing a retaining device, and subsequent pushing or driving forces soil into the sampler. The assembly can then be withdrawn from the ground and the soil extracted. Piston samplers are typically air and water tight; however, the O-ring seals may leak if not properly maintained.

3.1.2 Open Solid-Barrel Sampler

The open solid-barrel sampler consists of a drive head assembly, a non-sealed barrel, and a cutting shoe. The sampler is attached to the rods at the head assembly. A check valve is located within the head assembly. The purpose of the check valve is to allows air or water to escape as the barrel fills with soil which improves the amount of soil recovered in the tube. With the use of liners, samples can be easily removed for volatile organic compound (VOC) analysis or for observation of soil structure.

3.1.3 Split-Spoon Sampler

Split-barrel samplers are also often used with hollow-stem augers and are like open solid-barrel samplers except the non-sealed barrels are split lengthwise, so the sampler can be easily opened. The major advantage of split-barrel samplers is they allow direct observation of soil cores without the use of liners and without physically extruding the soil core which makes split-spoon samplers good for geologic logging; they may cause more soil compaction than open solid-barrel samplers because the tool wall thickness is often greater.

3.1.4 Thin-walled Tube Sampler

Thin-walled tube samplers are commonly referred to as Shelby tubes. Shelby tubes are used with both DPT and hollow-stem augers for collecting undisturbed samples. The non-sealed sampling tube is typically attached to the sampler head using recessed cap screws or rubber expanding bushings. The sampler walls, made of thin steel with a sharpened cutting edge, minimize soil compaction compared to other types of samplers; therefore, their use results in relatively undisturbed soil samples which are required for certain geotechnical analyses such as permeability.

3.2 Soil Sampling Considerations

DPT techniques are appropriate for soil sampling when:

- The use of DPT methodology is consistent with the data quality objectives of the sampling program.
- Unconsolidated soils are to be sampled.
- Materials to be sampled contain a low percentage of gravel and cobbles and are not dense or highly compacted.
- Materials to be sampled are less than 100 feet in depth.

If using DPT:

- Dual-tube sampling is recommended for use on LAST/LUST site and should be used whenever possible. This is especially important if there is a potential for sloughing to a lower zone. If a single-tube is used for vertical profilers, it is imperative sealed samplers are used. The use of single-tube samplers should be limited and its use over the dual-tube sampling needs to be justified.
- Closed-barrel samplers should be used for most applications. The only situation where non-sealed samplers would be acceptable is with single sample collection events above the saturated zone.

- If recovery of samples is low, then a different sampling technique will need to be utilized.
- If cave-in of the probe hole becomes an on-going issue, then a different sampling technique will need to be utilized.
- Contaminated soil cuttings may not be placed back into the ground. They must be properly disposed of an approved facility.
- Field screening methods can be utilized to supplement and guide traditional site characterization work; however, materials used for field screening cannot be retained for laboratory analysis.

4.0 GROUND WATER SAMPLING

There are two common types of ground water sampling equipment used in DPT methods: tools for obtaining one-time grab samples (i.e. groundwater grab samplers), and wells installed using DPT for short-term sampling. Most sampling devices used with DPT tools are composed of stainless steel or other inert metals. Well screen materials may be composed of stainless steel, polyvinyl chloride, polyethylene or polytetrafluoroethylene. DPT is a useful cost-effective method for groundwater delineation and can facilitate determining the need for and/or placement of permanent monitoring wells. When used for hydrogeological evaluation and plume mapping, a sufficient number of points must be sampled. An advantage of using DPT over installing a permanent monitoring well is that the ease of use and cost makes it practical to collect data from many sampling points thus providing a more complete site characterization at a cheaper cost that installing conventional wells.

4.1 Groundwater Grab Samplers

DPT grab sample collection may be utilized to delineate site-wide hydrogeology more quickly and efficiently than monitoring wells. Applications where grab samples make sense are: detecting the presence of ground water contaminants; assessing the relative concentrations of contaminants; delineating the contamination plume; and guiding the installation of monitoring wells.

Because they are easy to use and do not require well materials, grab samples typically have a significant advantage over traditional monitoring wells as site screening tools. With respect to site screening investigations in which ground water samples are not being collected for compliance purposes, grab samplers may provide quick, relatively inexpensive useable data about potential impacts to the groundwater. In addition, they often facilitate hydrogeological evaluation and plume mapping, and can be very helpful in optimizing the location and construction of permanent monitoring wells.

DPT grab ground water samplers can be grouped into two classes: sealed protected screens; and exposed screens. There are also two types of drive systems: single-rod and dual-rod. Single-tube systems have only one drive rod. Dual-tube systems have an inner and outer drive rod. The inner rods are removed to obtain a sample. Dual-tube systems allow for some protection of cross-contamination, therefore, are more advantageous if multiple level sampling is desired from a single boring.

4.1.1 Exposed-Screen Samplers

Exposed-screen samplers are also known as open screen samplers because they consist of a well screen to allow the influx of ground water and a riser pipe permitting the extraction of a water sample. Exposed-screen samplers are driven to the approximate sample depth below the ground surface and a sample is taken with either a bailer or tubing/pump combination. Purging and development must be conducted prior to sampling. An advantage of the exposed-screen sampler is it can be pushed to different depths so multi-level water samples can be taken without having to remove the tool string. This allows for collection of a vertical profile of the groundwater.

Exposed-screen samplers have significant disadvantages such as clogging of the well screen in silty or clay rich soils and because of the small screen diameter, development of the formation can be difficult when abundant fines are present in the screened interval. Additionally, whenever multiple depths are sampled, there is a possibility of drawing contamination to deeper depths, potentially biasing results. For these reasons, the use of exposed-screen samplers is not generally recommended for use for LAST/LUST sites unless conditions are such that these issues are not a concern. If utilized, this sampling method must be sufficient to meet data quality objectives.

4.1.2 Sealed-Screen Samplers

Sealed-screen samplers are also known as closed-screen sampler. These samplers are protected, sealed sampling devices consisting of a well screen housed within a protective sheath to which are attached an expendable drive point, drive rod(s) and drive head. Rubber O-rings keep the device water tight ensuring sample integrity. Once the desired depth is reached, the screen is held in place and the outer casing is retracted to expose the screen to formation water. After a sample is obtained, the expendable drive point is left in place and the sampling assembly is removed.

Since the screen is only exposed after the tool has been placed at the target depth, susceptibility of the screen to clogging is reduced and the O-ring seals reduces the possibility of cross contamination. Additionally, some closed-screen samplers have been designed to leave the outer casing and screen with an attached riser (usually polyvinyl chloride) in place as a temporary monitoring device. Vertical profiling can be accomplished with a single-tube closed-screen sampler or dual-tube inner rod screen by sampling from the shallowest to deepest intervals. Prior to sample collection at each interval, the sampler must be retracted, decontaminated, reassembled and redeployed to new target depth, and then purged to best obtain the formation water at the new sample interval.

Development of the formation can be difficult due to the small screen diameter when significant amounts of fines are present. A problem can also occur if extension rods aren’t used to hold the base of the screen on place, the screen may completely fail to deploy or only partially deploy. The use of seal-screen samplers is preferred over using exposed-screen samplers for LAST/LUST sites when grab sampling is performed to meet data quality objectives. However, DPT wells with a pre-packed screen is the preferred method for water sampling when DPT technology is utilized.

4.2 DPT Installed Wells

DPT used for advancing probe rods can be adapted to install temporary wells. The most common method is to push the probe rods or the drive casing to the desired depth with a sacrificial tip. The screen and well casing are usually inserted into the rods or drive casing to the total depth. This protects the screen from becoming plugged with soil and being exposed to any overlying zones of contamination. The annulus of the boring is sealed to prevent migration of contaminants into the ground water zone. DPT monitoring wells must be installed by a WV Certified Monitoring Well driller adhering to the requirements for well installation, development, and abandonment in 47CSR 60.

Since DPT wells are installed with a filter pack, they allow for more thorough well development and lower sample turbidity than grab samplers. DPT wells offer several advantages over wells installed with conventional methods. The speed and mobility of DPT sampling allows a more complete and accurate investigation than would be available with conventional wells.

DPT temporary wells can be conventionally screened or they can be constructed with a pre-packed screen. Due to the limited annular space surrounding a conventionally screened well it can be difficult to ensure the proper construction of the well. Use of pre-packed screens may make it possible to use finer grain filter pack sand than is used for conventional well filter pack, providing less turbid samples. For this reason, DPT wells constructed with a pre-packed screen is preferred.

4.2.1 Conventionally Screened and Packed Wells

The inside diameter of probe rods or temporary drive casings used for DPT well installations range from 1.5 to 4.5 inches. DPT wells can be installed using conventional well production casing with inside diameters up to two inches, provided the well can be properly packed and sealed. In general, filter pack material is placed around the outside of the screen by pouring it into the annular space between the production casing and the temporary drive casing as the temporary drive casing is pulled from the borehole, resulting in filter pack material between the annular space of the screened completion casing and borehole wall. The well is sealed by pouring granular bentonite into the annular space or pumping bentonite slurry through a tremie line ran downhole in the annular space to the top of the filter pack. The well is grouted from the bottom up by pumping bentonite slurry through the tremie line as the temporary drive casing is removed from the hole. This type of field-constructed DPT wells are not recommended for LAST/LUST sites due to limited annular space surrounding the well screen because proper construction of the well cannot be assured.

4.2.2 Pre-Packed Screen Wells

DPT wells can be installed using pre-packed well screens on the production casing. The use of pre-packed well screens helps to eliminate problems with small diameter wells in the placement of filter pack around the screen. A pre-packed screen is an assembly consisting of an inner slotted screen surrounded by a wire mesh sleeve which acts as a support for filter media. The pre-packed screen assemblies can either be shipped with filter media already packed within the mesh sleeve or can be shipped without filter media and packed with filter sand in the field. Refer to ASTM D5092-02 for appropriate sizing of filter pack material. The wells are sealed and grouted using same procedure described for conventionally completed wells. If a DPT well is to be installed, the pre-packed screen well is recommended for use at LAST/LUST sites.

4.2.3 Well Development of DPT Wells

Well development of DPT wells is needed to ensure representative samples. Development of the well helps repair damage done to the formation during the driving of DPT tools and increases the hydraulic communication between the well and the formation. Due to the small casing diameters of a DPT well, the equipment available to develop small diameter wells is limited to small capacity bailers, inertial pumps (inertial check valve and tubing systems), peristaltic pumps and small diameter bladder pumps.

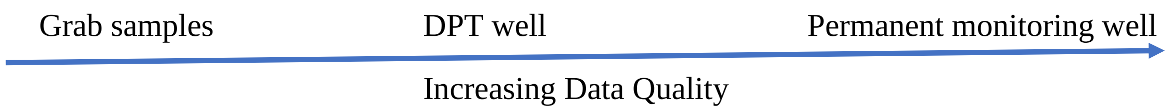
The time interval between well installation and development is a function of the well construction, type of grout, and conditions under which the grout is installed. Well development should not be performed until the seal has cured. Type 1 cement generally cures within 48 hours and bentonite based grouts tend to set within 24 to 48 hours. Prior to performing groundwater sampling, sufficient time must be allowed for equilibration within the formation after development of a new well or redevelopment of an existing well. A minimum of forty-eight (48) hours must be allowed for stabilization after well development (or redevelopment), prior to collecting groundwater samples.

The importance of well development in monitoring wells is extremely important and is frequently not performed correctly if at all. Like conventional wells, determining when development is complete is the stabilization of certain indicator parameters (that is, temperature, specific conductance, pH, redox potential, dissolved oxygen) that are easily measured in the field.

4.3 DPT Groundwater Samples as a Screening Tool

Groundwater samples collected from DPT can be used as part of the site investigation to determine the presence and the extent of contamination, and select sampling locations for permanent well installation, if necessary. Screening samples are not intended to meet the same data quality objectives as compliance samples, but still can satisfy the purpose of determining the presence of contamination, defining the extent of contamination, and selecting sampling locations for potential compliance sampling.

It is generally accepted that the data quality of a groundwater grab sample collected via DPT is lower than the data quality of a groundwater sample collected from a DPT well with pre-packed screen which in turn is of lower data quality than data from a conventional permanent monitoring well.



When performing site characterization to determine groundwater contamination, a minimum of three (3) permanent monitoring wells are frequently installed. More wells generally are not initially installed simply due to cost associated with installing this type of well. While the groundwater sample from this type of well is generally considered to be of high data quality, the overall quality of the site characterization may suffer because of the limited number of sample points. Because of the cost of and ease of collecting groundwater samples with DPT, more sampling locations can be installed. While the data quality from the groundwater sample from the DPT may not be as of high quality as a corresponding sample from the permanent conventionally installed well, the increased number of sampling locations can lead to confidence in the overall characterization for the site. Therefore, it is recommended that if DPT is used for initial groundwater characterization to determine the presence of contaminants that a minimum of six (6) DPT wells (pre-packed screens are preferred) be installed or a minimum of nine (9) grab samplers be used to collect groundwater. This number of sampling points may be decreased or increased based upon field conditions. However, failure to install a sufficient number of wells or sampling points may result in the Agency deeming the site characterization incomplete and requiring additional investigation. Even though DPT temporary wells may be utilized on a site for site characterization purposes, permanent conventional monitoring wells will be required if contamination above the action levels is detected.

4.4 Groundwater Sampling Considerations

DPT techniques are appropriate for groundwater sampling when:

- The use of DPT methodology is consistent with the data quality objectives of the sampling program.
- Only relatively small sample volumes of groundwater are needed.
- It is being used for screening for the presence of ground water contaminants; assessing the relative concentrations of contaminants; and guiding the installation of monitoring points.

4.5 Boreholes and Monitoring Well Abandonment

Inadequately or unsealed boreholes or monitoring wells can create a preferential pathway for the infiltration of contaminants to previously uncontaminated zones. All borings and monitoring wells shall be appropriately sealed and abandoned pursuant to the WVDEP's Monitoring Well Design Standards (47CSR60). DPT wells are generally considered temporary wells that must be properly abandoned within one hundred and twenty (120) days. Incomplete borings, destroyed wells, or decommissioned monitoring wells must be permanently abandoned in accordance with 47CSR60 to prevent any future conduit for contaminants to reach an aquifer. Copies of the monitoring well abandonment forms must be included in the site investigation report and documentation of any plugging activities should be included in the boring logs. Borings and monitoring wells must be properly abandoned in accordance with 47CSR60 prior to the issuance of a No Further Action (NFA) letter for a site. Contaminated soil cuttings may not be placed back into the ground. They must be properly disposed of at an approved facility.

5.0 DPT SPECIALIZED MEASUREMENT TOOLS

Specialized direct push probes may be used to collect *in-situ* geotechnical, geophysical and analytical measurements or soil gas samples. Several tools are available and may be appropriate for usage as part of a site characterization. Limited discussion is provided in the following sections, additional information about these technologies is presented in U.S. EPA (1997), *Direct Push Technologies, Expedited Site Assessment Tools for Underground Storage Tank Sites*; draft U.S. EPA guidance *Groundwater Sampling and Monitoring with Direct Push Technologies*; and the Field Analytic Technologies Encyclopedia (FATE). FATE is an online encyclopedia providing information about technologies for field sampling, sensing and analysis of contaminated media. The website is provided by the U.S. EPA Office of Superfund Remediation and Technology Innovation and may be accessed at ***http://clu-in.org/characterization/technologies/***.

5.1 Geotechnical

Cone penetrometer technology (CPT) may be used to quickly and efficiently evaluate soil stratigraphy. CPT characterizes the subsurface lithology by testing the response of the soil to the force of a penetrating cone. Sensors mounted in the tip of the rod send electronic signals to a computer at the ground surface, where the information is processed. CPT cones are pushed rather than vibrated into the subsurface. The most commonly used type of CPT cone is called a three-channel cone which contains sensors that measure soil resistance on both the end of the cone and the friction sleeve. The tip resistance to sleeve resistance ratio, called the friction ratio, can be used to estimate the soil type. The resistance data are recorded in real time at the surface to show relative density with depth. A continuous vertical profile of stratigraphy can be inferred from these data through comparison with existing drilling and soil sampling information.

5.2 Geophysical

Geophysical logging probes can be used with direct push rods to evaluate subsurface conditions. A limited amount of drilling and soil sampling information in the immediate vicinity of the geophysical logging locations are needed to correlate geophysical responses with known site stratigraphy and subsurface conditions. Examples of standard geophysical logging tools include the following:

- Electrical conductivity (or resistivity) probes are used to evaluate stratigraphy, locate ground water zones and identify the presence of ionic contaminants (e.g. brines) or injected remediation fluids such as high concentration sodium persulfate.

- Nuclear logging tools are used to evaluate stratigraphy, ground water conditions, and subsurface contaminant distribution.

- Piezocone is like a three-channel CPT cone with the addition of a pressure transducer mounted in the cone. Measurements of pore water pressure using a piezocone can determine the depth of the saturated zone and the relative permeability of the saturated sediments. A piezocone can also be useful for estimating (within an order of magnitude) hydraulic conductivity.

- Hydraulic Profiling Tool (HPT) allows the user to create a continuous profile of the soil hydraulic properties in both fine and coarse-grained material. While most soil profiling methods infer permeability from parameters like grain size or geotechnical properties, the HPT system can measure high resolution data on hydraulic permeability directly by injecting water into the formation. HPT can be used to:
  - Identify the ground water zones and confining units
  - Locate and define better migration pathways for contaminants
  - Target specific regions for injection of remediation material
  - Select well screen intervals

5.3 Analytical

Several chemical sensors can be used in combination with DPT methods to provide screening level analysis of contaminants at depth. A few examples of chemical sensors that may be useful in site characterization are as follows:

- Induced fluorescence systems use ultraviolet light to induce fluorescence of polynuclear hydrocarbons (PAHs). The fluorescence signal is then transmitted to the surface via a fiber-optic cable.

- Fuel fluorescence detector (FFD) uses a mercury lamp is used as the light source. FFD can be configured to target detection of several different hydrocarbon contaminants.

- Optical Image Profiler (OIP) system can be used for investigation of petroleum fuels and related hydrocarbons. The OIP uses an ultraviolet light emitting diode and down hole camera to log images of ultraviolet induced fluorescence.

- Membrane interface probe (MIP), also called a semipermeable membrane sensor, heats the soil to promote volatile constituents to diffuse across a thin permeable membrane on the probe's side. Once inside the probe, an inert carrier gas carries the chemicals to the surface where they can be analyzed by an in-line on-site gas chromatograph. The presence or absence of VOCs and their relative distribution can be estimated.

- Thermal desorption sampler (TDS) for VOCs works similarly to the MIP. The TDS system employs a special DPT probe for collecting a soil sample into a chamber at depth where it is then heated, causing VOCs in the sample to desorb from the soil. A pneumatic system then employs a carrier gas to transport the VOCs to the surface for qualitative analysis.

- XRF, or x-ray fluorescence, emits x-rays onto subsurface soils to induce fluorescence of the elements in the subsurface. The elements present in a sample are excited by the x-rays and emit fluorescent x-ray with a characteristic energy signature. The x-rays are then detected in the probe tip.

6.0 REFERENCES

American Society for Testing and Materials (ASTM), Standard Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers, ASTM-D6725-04, 2016.

American Society for Testing and Materials (ASTM), Standard Guide for Direct-Push Groundwater Sampling for Environmental Characterization, ASTM-D6001-05, 2012.

American Society for Testing and Materials (ASTM), Standard Guide for Direct-Push Groundwater Sampling for Environmental Characterization, ASTM-D6001-05, 2012.

American Society for Testing and Materials (ASTM), Standard Guide for Installation of Direct Push Ground Water Monitoring Wells, ASTM-D6724, 2010.

American Society for Testing and Materials (ASTM), Standard Guide for Direct-Push Soil Sampling for Environmental Site Characterizations, ASTM-D6282, 2005.

U.S. EPA, 2005. Groundwater Sampling and Monitoring with Direct Push Technologies. Solid Waste and Emergency Response OSWER No. 9200, 1-51 EPA 540/R-04/005, Washington, DC

U.S. EPA, 1997. Direct Push Technologies. In: Expedited Site Assessment Tools For Underground Storage Tank Sites. Solid Waste and Emergency Response, EPA 510-B-97-001, Washington, DC.

Geoprobe Systems, 2015. ***http://geoprobe.com***

Kram, M., D. Lorezana, J. Michaelsen, and E. Lory, 2001. Performance Comparison: Direct-push Wells Versus Drilled Wells, NFESC Technical Report TR-2120-ENV. NAVFAC, Washington, DC.